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Global and regional impacts of the Fukushima nuclear disaster

Introduction
After the Fukushima nuclear incident, several countries have expressed their concerns about the further use of nuclear energy and have envisaged the re-evaluation and also the reverse of their nuclear policies. Most countries, which have decided to phase-out their nuclear capacities or abandon their expansion plans, are in Europe. This means that the Fukushima incident will cause the biggest market turmoil on the European electricity, gas and energy markets. The purpose of this paper is to analyze the potential impacts of the Fukushima nuclear incident on the nuclear industry and on the global and regional energy markets.

Competitiveness of the nuclear industry
In the following, we are examining how the nuclear industry might react on the Fukushima catastrophe from a purely economic point of view. In order to assess the effects and possible reactions, the situation and the competitiveness of the nuclear power generation has to be analyzed and described.

The competitiveness of different power plants can be evaluated by the price of the generated electricity, as the most important factor. As Figure 1 shows the LCOE (levelized cost of electricity [1,2]) which represents basically the cost of the generated electricity, differs technology by technology. Currently producing one unit of electricity with a nuclear power plant (NPP) is one of the most competitive technologies, in terms of LCOE. Numerous studies and analysis of different companies and institutions are trying to measure and model the cost of electricity generation which generally concentrate on the examined country or region with its own specifications. We have chosen an IEA-OECD study [1] because it collects data from different countries around the world. Furthermore the data used for the analysis is provided by the responsible bodies of the different countries, thus presumed as the most reliable source.

According to the already announced and planned safety measures, the Fukushima incident may affect the competitiveness of NPPs due to increased safety expenditures. Analyzing the cost breakdown of different source of energies, it can be concluded that NPPs are one of the most CAPEX-intensive production capacities. Compared to other technologies, operational expenditures represent a significantly lower proportion in nuclear energy generation. Figure 2 shows this phenomenon in case of the different technologies.

Abstract
World nuclear industry developed at a rapid pace until notable disasters compelled authorities to rethink nuclear policies. It is uncertain whether the most recent Fukushima disaster can be another turning point in the industry’s history. Worldwide, besides stricter standards – hence increasing costs – it may have a slighter impact. In Europe, notably in Germany, however, it is a point of reference for accelerated technology abandonment. Based on our cost-based calculations, we consider that this alone can bear a 34-49% upward LCOE (~base-load electricity production price) risk by 2020 that might affect Hungary as well, along with rising safety design costs.

Összefoglalás
A fukushimai nukleáris katasztrófa globális és regionális hatásai

A világ atomipara jelentős űtemben fejlődött, amíg egyes jelentős katasztrófák a nukleáris politikák újragondolására ösztönözték. Még bizonytalan, hogy a fukushimai baleset trendfordító hatású lesz-e az iparág történetében. Globálisan tekintve az emelkedő biztonsági költségektől eltérővé kisebb hatással lehet, ugyanakkor Európában, különösen Németországban erre az eseményre hivatkoza gyorsították fel a nukleáris technológia kivezetését. Költségalapú számításaink szerint egyedül ennek 34-49% LCOE (belső adám áram termelői ár) felhajtó hatása lehet 2020-ig, amely Magyarországot is érintheti a nukleáris biztonsági költségek emelkedésén túl.

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1Yoshihiko Noda, Japan’s new prime minister has slightly shifted away from his predecessor’s statement to phase out nuclear technology in Japan, claiming that nuclear energy is indispensable in Japan’s future economic growth.
the CAPEX of NPPs can increase to an unexpectedly great extent. Currently, the global average LCOE of coal-fired power plants is approx. 30% higher and the LCOE of gas-fired power plants is approx. 50% higher, than that of the nuclear ones. To match the competitiveness margin between these three types of generation considering only the CAPEX as a variable, the CAPEX of the nuclear power plants should increase by 40% and 68.5%, respectively, on average.

It also should be realized that the LCOEs of the fossil technologies are calculated with assumptions of current CO2 allowance prices. According to IEA and EU projections, the CO2 allowance prices are to increase in the forthcoming decades. If NPP CAPEX increases due to new safety measures and nuclear technology starts to lose its relative competitiveness to other conventional technologies, it can be offset by increasing CO2 prices on the other hand.

Furthermore, the relatively low ratio of maintenance and fuel costs in the LCOE during the lifespan of a nuclear power plant (ca. 25-35%) means that the competitiveness of nuclear generation reacts less elastic to a marginal change of the fuel price. The uranium price elasticity of the nuclear fuel cost is approx.: 

In order to maintain the competitiveness, the fuel price has to be examined on a case-by-case basis.

### The world after Fukushima

**NUCLEAR POWER GENERATION IN THE WORLD**

Nuclear power generation represents a significant share in the world’s electricity generation with its 13.4%, as it can be seen on Figure 3. As the 4th biggest source of electricity, it is quite important to analyze the possible effects of the Fukushima disaster on this sector, as the possible future changes in the policies can highly affect the world’s energy mix in the mid- and long-term.

This means, that – despite the potentially rising safety-related OPEX – the low ratio of OPEX in the total cost makes the nuclear power plants resistant to increases in O&M (operation and maintenance) and fuel costs, whereas the competitiveness of conventional technologies are highly exposed to the volatile and increasing fuel prices.

On Figure 1 we can see that the LCOEs of the different methods disperse. This dispersion can be mostly explained by the location and the technology applied. Based on the given sample, the dispersion of the nuclear technologies are the smallest compared to the other solutions, and nuclear technologies show the smallest average LCOE among the different technologies.

Depending on individual projects, however, and as it can be seen on Figure 4, almost 75% of the total built in generation capacities are concentrated in the 6 largest producer countries. The 5 largest, namely the USA, France, Japan, Russia and South Korea are also present in the value chain as technology producers and exporters, which also conserve their leading position on the market.

Besides the above mentioned ranking, countries with generation capacities can be grouped along several other factors, such as the share of nuclear power in the specified amount of produced electricity.

Currently the countries with low production and low share of nuclear power in the first group are less exposed to the possible future changes in their nuclear power generation capacities, as we can see on Figure 5. The second group includes the countries with bigger capacities and medium share of nuclear energy in their energy mix, such as Russia and Germany. Typically the countries with high share of nuclear power in their energy mix are part of the third group of countries, such as Hungary or Ukraine. There are three countries: the USA, Japan and France, which represent more than half of the world’s nuclear capacity. Although France is the 2nd largest generator in the world, its role is special, as the share of nuclear power in the country is outstandingly high being more than 75%.

Regarding Japan, currently only 11 reactors are operating out of 54 available. This has not quantified any possible effect of a possible Japan phase-out, since no policy or road map has been laid out so far.

**PROJECTED CHANGES IN THE WORLD AFTER FUKUSHIMA**

Before the Fukushima disaster, numerous nuclear accidents occurred throughout the world. By analyzing the nature and the impact of these, it can be concluded that the Three Mile Island (TMI) (1979) and Chernobyl (1986) disasters had a major impact on the global nuclear landscape. Figures 6 and 7 show the impact of the individual incidents on the development of nuclear capacities.
industry, however, competing fuel prices did not play a significant role (see relatively stable fuel prices before the oil crises).

The Fukushima disaster in Japan not only turned the nuclear industry’s attention but also highlighted the importance of decommissioning, which can be slowed down by Fukushima’s aftermath. Nuclear incidents can have a notable effect on energy mixes, as it was e.g. in Italy after Chernoby.

In the 2000s, a new nuclear upswing took place, which can be slowed down by Fukushima’s aftermath. Nuclear incidents can have a notable effect on energy mixes, as it was e.g. in Italy after Chernobyl.

After the Fukushima disaster in Japan, many countries and international organisations started to rethink and reassess the role of nuclear power generation and the level of risk that it means. Countries launched stress tests and programmes to assess risks and define the future role of nuclear power in their countries’ long-term energy policy.

The projected commissioning in South Korea will significantly increase the share of nuclear power in the energy mix of the country.

Europe after Fukushima

Despite the Fukushima disaster, only a few countries decided to reverse their nuclear policy, and these countries are mainly in Europe. They include Germany, France, Spain and Italy. This does not seem, however, pivotal to the global nuclear landscape. So far three European countries: Germany, Switzerland and Italy announced major changes.

Germany phases out its capacities at an increased pace until 2022. Switzerland neither builds new facilities nor prolongs the lifetime of its already existing NPPs. Italy has again refused the usage of nuclear power. Although these changes are relatively important regionally, they will not have major effect on the world’s current nuclear power supply, as we have seen before.

France, the UK, Germany and Sweden are the major players in the European nuclear supply structure – as we can see on Figure 9 –, since they represent approx. 75% of the total installed capacities in Europe.

Germany’s capacity divestment represents a 15% decrease in Europe’s current nuclear capacities. On one hand this is a remarkable capacity decrease; on the other hand the effects are not so dramatic, if we have a look on the planned new capacities across the continent. With current NPPs, and the planned projects, European capacities are expected to peak around 2030. The most notable new entrant will be Turkey and significant developments are forecasted around the Baltic Sea area (Lithuania, Finland and Russian Kaliningrad).

As Figure 11 shows, EEX electricity prices sharply increased after Germany announced the forthcoming closure of its nuclear capacities. Since April 2011 European power markets seem to have stabilized again, yet at a higher price level.

The effects of significantly higher electricity prices resulted in the announcement of many German companies such as BASF, Siemens, E.ON and RWE that they may consider to relocate parts of their businesses outside Germany in the near future.

Challenges

Using the basic assumptions for capacity development scenarios of the base study for the German energy strategy [8], we have created a model to forecast the possible weighted average German LCOE of electricity generating capacities and prices. As input, we have used the German LCOEs of [1]. This means that our model inherited the assumptions and barriers of the above study.

On the other hand, as input we have used the installed capacity and the gas scenarios of the above study as constant, we had to create assumptions for the future load factor of the German power plants, since this factor was the only variable.

Regarding the merit order of the German capacities, we assume compulsory takeover of the renewable energy, meaning that the conventional, base load technologies are to be less loaded, whereas renewable electricity is always taken over, resulting in an ‘upside-down’ merit order.

8 In Italy, the 30 bcm annual gas consumption in 1985 grew by further 50 bcm by 2010.

9 As reported in [8], Germany’s capacity divestment represents a 15% decrease in Europe’s current nuclear capacities. On one hand this is a remarkable capacity decrease; on the other hand the effects are not so dramatic, if we have a look on the planned new capacities across the continent. With current NPPs, and the planned projects, European capacities are expected to peak around 2030. The most notable new entrant will be Turkey and significant developments are forecasted around the Baltic Sea area (Lithuania, Finland and Russian Kaliningrad).

10 According to the German government, 10 GW capacities will be replaced by fossil fuels which roughly correspond to the total capacity phased out in 2011.
The basic assumptions and the barriers of the model are as follows:

**Merit order assumptions:**
1. Wind, PV are loaded when technically / based on weather possible - as in LCOE model
2. Biomass produces in base load with 85% load factor - as in LCOE model
3. Pumped-storage power plants load increases with renewable (wind) share
4. Natural Gas power plants are responsible for covering peakloads
5. Other conventional power plants are loaded less as renewable production increases
6. Technological phenomenon of power plant load factors is not included. If decreased load factor is not possible economically / technologically for coal/gas power plants, capacities will stop operating until reaching the economically / technologically optimal levels, thus average load factors for conventional might increase, but the sum of produced electricity stays stable, according to [6].

Due to the LCOE model of [6]:
1. Assuming the certainty of production costs and stability of electricity prices throughout the horizon, until 2022. All output is sold at the stable price right away
2. Return of capital with no market or technology risks
   a. Closer to regulated markets with monopolistic electricity markets, loan guarantees
   b. Then to the real costs of investments in a competitive market, with variable prices
3. Discount rate stable and equals 5%
4. Variables are net of inflation - costs and cash flows are discounted with the discount rate
5. Baseload like production because of fixed load factors for the entire horizon
   a. Nuclear, coal, gas, biomass load factor is 85% in the LCOE model, however variable in our model
   b. Wind onshore / offshore, biomass, photovoltaic, etc. load factors are acquired through national data supply and reflect technical and weather related potentials
   c. No system costs - Effect of a single power plant on the whole system is not calculated
6. Variables are net of all governmental interventions. Thus model highlights only social resources necessary for the operation of a power plant.

Limitations of the model:
1. Assuming the certainty of production costs and stability of electricity prices throughout the time horizon, until 2022
2. Cost based evaluation instead of marginal analysis. Marginal analysis determines more the competitive side of the electricity markets
3. Where possible, same load factors used in our model, as in the LCOE model of [6], however the load factors of coal, oil and gas had to be modified to achieve the constant gross production values of [6].
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Due to the LCOE model of [6]:
1. Assuming the certainty of production costs and stability of electricity prices throughout the horizon (until 2022). All output is sold at the stable price right away
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   c. No system costs - Effect of a single power plant on the whole system is not calculated
6. Variables are net of all governmental interventions. Thus model highlights only social resources necessary for the operation of a power plant.

According to the different scenarios, the net installed power generating capacity in Germany will increase by 16% to 44%. Since nuclear capacities are to be replaced (with an average plant load of ca. 80% in 2010) by renewable generating capacities in long-term, the net installed renewable capacities have to be increased.12

The different scenarios also differ in the assumed net German annual electricity demand.13 Figure 13 highlights the different German electricity demand scenarios, and also presents how the electricity mix will develop with the onshore wind energy growth. If this will be realized, the wind output will be capable of offsetting the disappearing nuclear energy generation.

Currently, the LCOE of producing one unit of electricity in Germany with an onshore or offshore wind power plant is approx. 210% to 275% more expensive than that of an average German PWR (pressurized water reactor) [1].

Considering the LCOEs of the different technologies as a fixed value until 2022, we calculated the sum LCOE for the total amount of electricity produced in 2022 in the different scenarios. We have also calculated the weighted average LCOE of the whole electricity mix in 2022.13

The results of the calculations are highlighted on Figure 14, with the weighted average LCOE in the different scenarios, compared to the Reference scenario.

Scenario C represents the most expensive scenario, with the highest ratio of alternative energy sources. The amount of the produced electricity is the same, but the unit price of the electricity produced by the C mix is more expensive because of the higher ratio of the wind production (~36% in C, compared to ~24% in B). The B unit cost is cheaper because of the relatively higher ratio of the natural gas based electricity production (~12% in C compared to ~19% in B).

Scenario A is the cheapest in terms of unit price because the ratio of the conventional technologies (coal, natural gas, oil) is the highest among the three scenarios. It lies approx. at 58%, compared to 53% and 43%, respectively.

Figure 15 shows the sum LCOE for the total amount of electricity produced in the alternative scenarios.
in case of the weighted average of the LCOEs. The reason for that is the different plant load assumptions in the different scenarios, due to the different net installed capacities, with high electrical consumptions in scenarios B and C and decreasing consumption in scenario A. Nevertheless what we can state is that there is a fundamental cost-side pressure, on the baseload German electricity price during the time horizon. However, the above model has its limitations to predict the final customer price of electricity in Germany, since numerous other factors are influencing it (e.g., the peak price).

We have seen that the [1] model does not take into consideration the anticipatory alteration in the load factor by the end of the horizon; nevertheless it would affect the LCOE. In our model however, we have calculated with a modified load factor. As mentioned above, the load factor of the conventional power plants is expected to decrease. According to [1] with the decrease of the load factor, the LCOE is increasing. This function is highlighted on the below graph (Figure 16).

The phenomenon is salient: with the decrease of the load factor, the LCOE of the conventional plants are growing. Without predicting any numerical data (how much this effect would influence the actual cost of generating electricity) we note that this phenomenon also has a fundamental price pressure on the baseload electricity product.

From a strategic point of view, it is not surprising that Germany exits the nuclear industry. The supportive study for the German energy policy listed this option as the first alternative scenario that was published as early as the end of 2010. Germany has a comparative disadvantage as it possesses of advanced nuclear know-how but it has not been a global nuclear technology leader (as it is in the renewable sector) and does not have the whole value chain of the nuclear industry as the US, Russia and France do. Focusing and concentrating resources on the renewable sector has already been a lucrative business for German companies as well as the whole economy (e.g., through exports and rapidly growing number of employees in the sector). Thus the Fukushima disaster has rather been a pretext that accelerated the German nuclear phase-out and a new green leap.

From a security of supply point of view, replacement scenarios seem to strengthen Germany’s independence from foreign energy sources and gas transit countries in CE/SEE region. According to latest news, Germany electricity transmission system operators plan to construct a ‘supergrid’ within the country that will function as the main physical electricity link between different European regions boosting trade via Germany.

As a conclusion, we can say that according to the model, the baseload production price (LCOE) of the German electricity will increase by 34% to 49% depending on the replacement scenario including the power plant replacement programmes and energy efficiency measures from 2010 to 2022. As the major point of reference for regionally traded electricity markets is the EEX, this upward momentum could appear in regional electricity prices.

The CE/SEE region’s own nuclear schedule itself (besides the development of the German market) is another source of upward electricity price factor due to high frontload CAPEX and unpredictable economic growth. In case of CE-SEE projects are not realized, the regional electricity prices could remain higher in the long-term and security of supply may weaken while economic competiveness could decrease beyond the energy sector.

Conclusions

Nuclear energy counts as one of the most competitive technologies but high CAPEX threshold and in some cases public aversion and politics make it highly concentrated throughout the world. Furthermore, major nuclear accidents such as the TMI and Chernobyl drastically shaped the global nuclear industry. The March 2011 Fukushima disaster compares to those mentioned in its magnitude both in damages caused and public reaction triggered. Thus far it is uncertain whether it will reverse any trend in the global nuclear industry, however locally it already had served as a point of reference. Stress tests are currently under way that has an upward safety cost risk globally. Focusing on Europe, the German nuclear exit will likely generate an increase in regional electricity prices on top of extra safety expenses. It is certain, however, that the abandonment of nuclear capacities is a long process that will require – if only temporarily – the increase of fossil fuels in the energy mix.

References

[1] Projected costs of generating electricity 2010, IEA, NEA and OECD
[3] Powering the Nation Update 2010, Parsons Brinkerhoff

Keywords: nuclear industry, Fukushima disaster impacts, electricity price, Germany, power generation

On the other hand, it shall be mentioned that the alternative cost of NPP construction is extremely high as these resources could be spent on alternative energy source development. The comparison of the two possible policies is not the purpose of this essay.
Downstream renewable energy projects – In harmony with sustainable development

Abstract

Global warming and climate change issues are perhaps the greatest threat to the planet nowadays. Scientists predict that if the planet’s temperature raises more than 2 °C above the pre-industrial level, there will be more extreme weather phenomena and rising sea levels, threatening coastal areas. Drought, desertification, and the burning of fossil fuels are greatly blamed for the warming effect, Deforestation and the burning of fossil fuels are the main reasons behind the warming effect. The burning of fossil fuels causes the concentration of carbon dioxide in the atmosphere to increase, which leads to the greenhouse effect. The greenhouse effect is a natural process that keeps the planet warm. However, when too much carbon dioxide is released into the atmosphere, it can lead to global warming. Scientists are concerned about the impact of global warming on the planet’s ecosystems and human societies. They are working on developing renewable energy sources to reduce our dependence on fossil fuels. In this paper, we will discuss the downstream renewable energy projects and their role in promoting sustainable development.

Regulation background

As a part of the climate and energy package, the Renewable Energy Directive (RED 2009/28/EC) is a legal framework that aims to increase the amount of renewable energy to 20% of the bloc’s energy mix by 2020. The Directive sets targets to reduce the life-cycle GHG emission of fuels and it places the responsibility of the emission reduction on fuel suppliers who are bound to report annually to Member States on the life cycle emissions per unit of fuel supplied. One of the most important points of the Directive is the fuel suppliers’ 6% GHG emission reduction requirement by 2020. The rate of this reduction is compared to the EU-average level of life cycle greenhouse gas emission per unit of energy supplied. Only biofuels met these requirements. As for the GHG emission, biofuels must deliver savings of at least 35% compared to fossil fuels, rising to 50% in 2017 and to 60% for biofuels from new plants in 2018.

At the same time, an EU directive (2009/30/EC) amending the Fuel Quality Directive (FQD 98/70/EC) as regards the specification of fuels and introducing a mechanism to monitor and reduce GHG emissions has also been adopted with the aim of reducing the emission of different key air pollutants released during the production and combustion of different fuels. The Directive sets targets to reduce the life-cycle GHG emission of fuels and it places the responsibility of the emission reduction on fuel suppliers. The Directive requires EU Member States to report annually to Member States on the life cycle emissions per unit of fuel supplied. One of the most important points of the Directive is the fuel suppliers’ 6% GHG emission reduction requirement by 2020. The rate of this reduction is compared to the EU-average level of life cycle greenhouse gas emission per unit of energy supplied. Only biofuels met these requirements. As for the GHG emission, biofuels must deliver savings of at least 35% compared to fossil fuels, rising to 50% in 2017 and to 60% for biofuels from new plants in 2018.

Greenhouse gas emission of biofuels

Biofuels are a renewable energy source that can be used as an alternative to fossil fuels. They are produced from organic matter, such as plants, or waste products. Biofuels can be used in a variety of ways, including as transportation fuel, energy source, and medicine. Biofuels are produced through various processes, such as fermentation, pyrolysis, and gasification. The production of biofuels results in lower greenhouse gas emissions compared to fossil fuels. Biofuels, such as biodiesel and bioethanol, have been used as a way to reduce transport-related GHG emissions. In case of biofuels such as biodiesel and bioethanol, the

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life cycle analysis of the climate impact includes all GHG emissions associated with the following life cycle stages: planting and harvesting of crops, processing the feedstock into biofuel, transporting the feedstock and the final fuel (including storing, distributing and retailing the fuel) and finally the exhaust emissions from combustion. Biofuels are known to be carbon neutral over their life cycle, namely they emit only as much CO₂ as the feedstock absorbs. Outside the combustion-related emission, the primary sources of life cycle GHGs can be attributed to their production.

From the emission point of view, not all biofuels perform equally (Figure 1), because their GHG saving efficiencies depend on several factors such as the type of feedstock crop, the type of cultivated land and farming practices and therefore, they have a different impact on the state of the environment.

At the cultivation stage, the level of fertilizer and pesticide use, the fuels utilized to drive farm machinery, the means of irrigation and treatment of the soil are all important parts which have to be considered during the life cycle analysis of biofuels. Fertilizers and pesticides also represent a significant factor in terms of climate impact. Nitrogen fertilizers emit N₂O which is released directly from the soil. Gases such as N₂O and CH₄ have larger global warming potential than carbon-dioxide thus life cycle calculations are always given in CO₂ equivalent. Feedstock selection is also a critical part, because there are differences in the energy yields per unit of land and the amount of necessary fertilizers uses (e.g. 2,500 litres of ethanol per hectare from European wheat or 1,200 litres of biodiesel per hectare from European rapeseed). The emission, released during the feedstock processing into biofuels, depends on the conversion efficiency of the refining process or facility, source of process energy and the emissions attributed to co-products as well. The efficiency of feedstock conversion is important, because it determines the amount of feedstock required for a given volume of biofuel affecting the amount of land

biogas burning to reduce the life cycle emissions of the biofuels. As for the transport-related emissions, biomass and biofuels are carried by trucks, however, rail or pipeline transportation can significantly reduce the emissions. In the future, GHG emission reduction can be further increased with the improvement of existing crop yields, process efficiency, new energy crops and new technologies.

Biocomponent blending

The European Union started to take actions on biofuels in 2003 by adopting the Directive (2003/30/EC) on the promotion of the use of biofuels or other renewable fuels for transport. Indicative values (2% for 2005 and 5.75% by 2010) were given for the energy content share (% of biofuels and other renewable fuels placed on the market. According to the renewable-related EU directives, biofuels are defined as liquid or gaseous fuels for transport produced from biomass. According to the European Commission’s Joint Research Centre, EU CAR and ConWAVE joint statement (6 July 2010) biofuels can be defined by feedstock utilization and technology maturity. First generation biofuels such as ethanol (from sugar cane, grains, sugar beets, etc.) and fatty acid methyl ester (FAME) from vegetable oils and animal, waste oils are produced through widely available commercial technologies (like fermentation, esterification, esterification). Second generation biofuels are ethanol from biomass, di-methyl ether (DME) from black liquor, and biomass to liquids, hydrogenated oils as well as FAME from non-edible seeds (jatropha, karanja) and new seed oils (cuphea, crambe, cotton seed). Their processing technologies (gasification / synthesis, hydrotreatment, hydrogenation, lignocelluloses processes) are being implemented or are at pilot plant stage. Third generation biofuels are represented by biogas from waste, biobutanol and biodiesel from algae and can be produced by processes at research stage (like pyrolysis, hydrothermal upgrade).

BIOETHANOL

Ethanol, also known as ethyl alcohol and grain alcohol, can be produced from a variety of feedstocks, but only corn and sugarcane are used for large-scale production. Ethanol production is based on a fermentation process where sugars are converted to ethyl alcohol and carbon-dioxide by yeast. Feedstocks such as sugarcane and sugar beet are naturally high in fermentable sugars (monosaccharides), but corn, wheat and potato contain sugar polymers such as starch or cellulose. Starch is the chief storage form of carbohydrate in plants consisting of glucose molecules linked together by covalent bonds. To form free sugar molecules for the fermentation process, glucose polymer chains of starch are broken down by an enzyme called amylase. Today sugar cane is the main feedstock for ethanol production in Brazil, but ethanol is mainly produced from corn in Europe and in the USA.

There are two basic types of corn ethanol production, the ‘wet mill’ and the ‘dry mill’ technology. The main difference is in the initial treatment of the grain. The ‘wet mill’ process soaks the grain in an acidic solution until it is able to be broken down into its components. Corn germ is removed from the slurry to produce corn oil while the remaining slurry contains starch, bran and gluten. After separation, the remaining starch is taken for ethanol fermentation. The ‘dry mill’ technology which is the most common type of ethanol production, grinds or mills the corn into flour by using hammer mills. This flour then goes through the fermentation process where the starch is converted to ethanol and the reminder is dried and sold as DDGS (dried distillers grains with solubles). There is a greater range of valuable products that can be produced by the ‘wet mill’ process, however, the cost of building a wet mill facility is far greater than that of a ‘dry mill’ plant. In both cases, distillation is needed to purify aqueous ethanol produced by the fermentation of simple sugars. This involves the separation of water and other components from ethanol to yield approximately 95% purity ethanol. However, alcohol and water form azeotrope thus further separation by distillation cannot be performed directly. In most cases molecular sieves are used to remove the remaining water from the ethanol.

The first step towards the introduction of renewable fuels into our fuel portfolio was the revamp of the existing methyl tert-butyl ether (MTBE) unit into bio-ethyl tert-butyl ether (ETBE) production in 2005. The successful project was executed without external license partners and finally the MTBE unit of MOL Duna (Százhalombatta) and Slovnaft (Bratislava) refineries started the production of renewable gasoline octane booster fuel additive. After a fuel test period on bioethanol blends, E5 fuel grade (max. 5 v/v% ethanol

Fig. 1. Greenhouse gas emissions (g CO₂ eq/ MJ) of different types of fuels.

(1) process fuel not specified, (2) lignite as process fuel in CHP plant, (3) natural gas as process fuel in conventional boiler, (4) natural gas as process fuel in CHP plant, (5) straw as process fuel in CHP plant, (6) process not specified, (7) process with methane capture at oil mill, (8) waste vegetable or animal oil of biodiesel. GHG saving values, set by the Directive, are also presented.
content) was introduced into MOL markets in 2007.

As for transportation, pipelines are considered to be the fastest and the most economical mode of transporting liquid fuels, however, wider use of pipelines for transporting ethanol is problematic for several reasons. Ethanol absorbs water and impurities appear in pipelines. Water can cause separation of the ethanol-gasoline blends, which can reduce the engine performance. Another challenge of transporting ethanol by pipeline is the corrosion. To avoid these potential problems, ethanol is usually blended to gasoline at distribution and storage terminals instead of refinery blending. However, due to the successful ethanol blending project, MOL is able to blend ethanol to gasoline directly in the refinery and the blend can be transported via pipeline. The refinery blending and pipeline transportation is an outstanding industrial solution saving significant investment cost for the company.

Further biofuel production technologies on the edge of commercial-scale feasibility

Second generation ethanol production consists of a sugar fermentation step like first generation methods described above, however, it is more difficult to break down cellulose into fermentable sugars because of its more complex structure. Cellulose is the most common organic compound on Earth which is the major component in the rigid cell walls of plants. Cellulose exists within a matrix of other polymers, primarily hemicellulose and lignin. Cellulose is a linear chain of several hundred to over ten thousand linked glucose units connecting to each other by chemical bonds much stronger than in starch. Cellulose is enveloped by lignin which is a complex compound and part of the cell walls. Lignin inhibits enzyme access to polysaccharides representing a significant barrier in biomass conversion to biofuels. Therefore, a pretreatment step with heat, acids or enzymes is needed to remove lignin and hemicellulose and to make the enzymes accessible to the cellulose polymer chains. The separated lignin, as a residue of the biomass conversion, can be burned to produce heat or electricity consumed by the ethanol production process. The economic competitiveness of the cellulose ethanol production is highly depends on the feedstock cost consisting of the collection, storage and transportation of the biomass. The primary challenge of the production technology is breaking down (hydrolyzing) cellulose into its sugar components in a cost effective way. The cost competitive enzyme production is still a technological challenge and research is being carried out worldwide to reduce enzyme cost and make the production commercial. Technologies using genetically modified microorganisms are being investigated to convert cellulosic feedstock to sugar and produce alcohol in one step without the addition of enzymes. The production is expected to commence in 2013 in Michigan, USA on the basis of an agreement between Mascoma Corp. and Valero Energy Corp.

Main ethanol production technologies can be seen on Figure 2.

As another promising gasoline substitute, biobutanol has advantages over traditional fuel ethanol in terms of energy density and vapour pressure. It is also produced by fermentation from the same agricultural feedstocks as ethanol and it can be blended with gasoline at higher concentrations than ethanol in standard vehicle engines. Biobutanol does not absorb water like ethanol so there is no corrosion or water contamination problems during transportation. Butanol tolerance of a bacterium used in the fermentation is one of the important aspects affecting the economics of the production. Despite the problems and challenges to overcome, the first commercial scale biobutanol facility is expected to begin operation in 2013 in Hull, UK in the frame of a Joint Venture between BP and DuPont.

The use of cellulose biomass feedstocks has the potential to dramatically expand the resource base for biofuel production, however, the production cost of cellulose originated biofuels has not been competitive with petroleum-derived fuels yet.

The so called biomass-to-liquid (BTL) technologies mean thermo-chemical conversion of biomass to produce a wide range of products such as synthetic diesel and gasoline, aviation fuel or alcohols. Gasification is usually used to obtain diesel from coal (coal-to-liquid, CTL) when coal is gasified to synthesis gas (or syngas), a mixture of carbon monoxide and hydrogen. During gasification, steam is used to provide needed hydrogen. Typical operating temperature is 1,330-1,500 °C with a residence time of a few seconds. To avoid poisoning of the Fisher-Tropsch (FT) catalyst, syngas is cleaned and then it is sent to an FT synthesis reactor. Reaction is carried out at the temperature range of 210-300 °C and at high pressures (1.5-4.0 MPa). The products are mainly straight-chain hydrocarbons including light hydrocarbons, propane, butane, gasoline, diesel and waxes. The relative distribution of the products depends on the catalyst and the process conditions (temperature, pressure, and residence time). Pyrolysis is the thermal decomposition of biomass, which occurs in the absence of oxygen or when significantly less oxygen is supplied than needed for complete combustion. Depending on the measurement conditions (e.g. temperature, speed of heating, residence time), pyrolysis can convert biomass into more useful fuels such as hydrocarbon-rich gas mixture, an oil-like liquid (‘bio-oil’) and a carbon-rich solid residue. Biomass pyrolysis is typically carried out in the temperature range of 400-700 °C and at near-ambient pressure. The main aim of pyrolysis is the production of ‘bio-oil’ which is a viscous, corrosive and unstable mixture of oxygenated molecules. This oil needs to be upgraded before use as a liquid fuel by e.g. hydrotreating or catalytic cracking.

The thermo-chemical conversion technologies of biomass into fuel are still too expensive to become economical, and additional development is needed for overcoming the barriers (e.g. clean-up requirements of syngas for removing the possible poisons for FT catalyst). Although the processes for production of BTL are well known and have been applied using fossil-feedstocks, such as methane (gas-to-liquid, GTL) or coal (CTL), commercial biofuels based on these technologies are not currently available on the market.

**Biodiesel**

Conventional biodiesel is produced from vegetable oils or animal fats by a process called catalyzed transesterification (Figure 3).
Biodiesel production from municipal waste

By considering emission and land-use change issues, the European Union supports biocomponent production from residues, non-food cellular materials and wastes such as used cooking oil (UCO) or animal fats. According to RED, these waste-derived biocomponents are counted twice towards the national biofuel quota because, from restaurants (e.g. from restaurants controlled by law in Hungary and oil is collected by several oil pick-up service companies such as Biofilter. A part of the municipal waste cooking oil, however, is poured into the drains causing damage to the environment. In a frame of a pilot project, started in May, 2011, more than a hundred filling stations were equipped to handle and store the waste oil. As it is hard to estimate the amount of the collectible oil at the beginning, depending on the results the project will be expanded countrywide not only at the filling stations but supermarkets as well. Currently the oil is collected and pre-treated by Biofilter specialized in collection and purification, and the oil is handed over to Rossi Biofuel for biodiesel production.

Second generation biodiesel

Hydroprocessing uses hydrogen to break C-C double-bounds and to remove oxygen from the triglyceride molecules to produce renewable diesel. Oxygen is easily removed via two competing reactions: decarboxylation and hydrogenolysis (Figure 4). The extent for each reaction depends on the catalyst and process condition. The three-carbon backbone produces propane which can be easily recovered and can be a valuable renewable LPG product. Oxygen contained in the carbon is rejected either as carbon monoxide, carbon-dioxide or water. In addition, all olefinic bonds are saturated forming a consistent, pure paraffin product.

Hydroprocessing can be carried out either by co-processing the feedstock in an existing distillate hydroprocessing plant of the petroleum refinery or in a standalone unit. Hydrotreating is a process traditionally used by petroleum refineries to remove sulphur impurities from diesel fuel. Co-processing method has a lower implementation cost, however, vegetable oils contain trace metal contaminants such as phosphorous, sodium, potassium and calcium which have to be removed because of catalyst poisoning and the cold flow properties of the combined diesel product may limit the quantity of vegetable oil that can be processed. As the deoxygenation reactions have a tendency to compete with the primary desulphurization, co-processing can present high risk of producing the required ultra-low-sulphur diesel fuel. Main biodiesel production technologies can be seen on Figure 5.

Renewable diesel can also be produced by using hydrotreating technology in a standalone unit that uses only vegetable oils or animal fats as feedstock. The Finnish Neste Oil has already developed a standalone process that produces non-ester renewable diesel through a thermal/hydrotreating process, called NExBTL technology. Nowadays, this is the only existing commercial scale technology in the field of renewable diesel production made by hydrotreating in the following operating plants: Parvoor, Finland 170,000 m³/year capacity, Singapore and Rotterdam, the Netherlands 800,000 m³/year capacity (Source: www.nesteoil.com). This process uses vegetable oils and / or animal fats and produces a mixture of hydrocarbons similar to petroleum diesel fuel.

The European Union’s climate-related requirements pose a huge challenge for every fuel supplier worldwide. Due to the differences in the chemical structure, current diesel fuel standards (EN 590) set a 7 v/v% blending limit for first generation biodiesel (FAME). According to back-of-the-envelope calculations, maximum biocomponent blending on both gasoline (E10)
Biogas production as a useful way of waste utilization

Converting biomass into biogas is another way of sustainable energy production. Biogas is a mixture of mainly CH\(_4\) and CO\(_2\) formed by the anaerobic digestion of waste materials with methanogenic bacterial species. Anaerobic digestion consists of a series of biochemical reactions involving distinct types of bacteria. Hydrolytic and fermentative bacteria first break down carbohydrates, proteins and fats present in biomass feedstock into fatty acids, alcohol, carbon-dioxide, hydrogen, ammonia and sulphides. This stage is called "hydrolysis" (or "liquefaction"). Acetogenic (acid-forming) bacteria further digest the products of hydrolysis into acetic acid, hydrogen and carbon-dioxide. Methanogenic (methane-forming) bacteria then convert these products into biogas. For the first 3 days, methane yield is near 0% and carbon-dioxide generation is almost 100%. From the day 11, the methane/carbon-dioxide production ratio changes to approx. 50-50%. Around 80-85% of the biogas forms in the first 15-18 days, thus the optimal digester retention time is approx. 15-18 day as well. The temperature of the reaction has a very strong influence on the anaerobic activity and there are two temperature zones which are optimal for the microbial activity and the biogas production rate. In the mesophilic zone (25-35 °C) temperature must be kept constant with 2-3 °C drift, however, only 1 °C drift can be accepted in the thermophilic temperature zone (45 °C or higher). Operation at thermophilic temperatures allows for shorter retention time in the fermentor and higher biogas production rate, however, maintaining the high temperature generally requires an outside heat source, because anaerobic bacteria do not generate sufficient heat. For the proper operation and multiplication of the methanogen microorganisms, the humidity of the feedstock must be at least 50% and oxygen- and light-free environment with neutral pH value (approx. close to 7.5) must be provided.

Depending on the type and nature of the biological components, different methane yields can be obtained from different biodegradable wastes (e.g. biogas yield/t feedstock is 202 m\(^3\) for maize silage, 163 m\(^3\) for grass silage and 70-60 m\(^3\) for pork/pig manure). Biogas yield can be further improved by mixing substrates with different gas yields. Due to the relative low methane content (typically 60-70%) and high concentration of contaminants, biogas is not suitable for direct use in vehicles. It can be utilized to produce both electricity and heat in systems called combined heat and power (CHP or cogeneration) equipped with heat exchangers. The purified gas can be burnt for steam production in boilers, and electricity can be produced directly in fuel cells. After appropriate gas cleanup (receiving 97% CH\(_4\) without H\(_2\)S and any impurities), the utilization of biogas can be the same as for fossil natural gas e.g. feeding into the natural gas grid, CNG production and different technologies for producing fuels such as biomethanol.

Considering the valuable by-products of the biogas production, investigations have been initiated to work out a concept for biogas production. Our experiments have proved that the soapy water and glycerine-rich waste material are excellent feedstocks for biogas production by using a special recipe. By feeding the calculated amount of biomethane into the refinery heating system, significant cost saving can be reached (10% of Duna refinery's annual natural gas need for heating).

Algae as a new source of third generation biofuels

Among alternative feedstocks, algae holds enormous potential to provide a non-food, high-yield, non-arable land-use source of biodiesel, bioethanol and biogas. Algae are organisms using photosynthesis to convert solar energy into chemical energy stored in the form of oils, carbohydrates, and proteins. In some algae, up to 50% of their mass is oil which makes them attractive feedstocks for e.g. biofuel production. Algae-based technologies can provide a key tool for reducing greenhouse gas emissions from coal-fired power plants and other intensive industrial processes as well, because they absorb CO\(_2\) as a nutrient as they grow offering cleaner and sustainable alternative to replace the currently used fossil fuels. When sources of carbon, light, nutrients and warm water are mixed in the right quantities and grown under the right conditions, certain algae
have the potential to produce large quantities of oil. This oil production process can be combined with wastewater treatment and nutrient recycling where polluted water (cleaned by algae) acts as a nutrient for their growth. As for their land-use, algae cannot require agricultural land as they can be grown in the open sea, open ponds (open cultivation systems) or on industrial land in photobioreactors (closed cultivation systems). Depending on the algae strains, algae farms can produce approx. 10 to 100 times of oil as compared to any other source of oil in closed systems, controlled research experiments for maximum oil production can be carried out where measurements parameters such as gas levels, temperature, pH, mixing, media concentration, and light can be optimized. In spite of the fact that open cultivation systems have lower capital costs and easy operation, they have several drawbacks such as different contaminations from the surrounding area, low light penetration, high rate of evaporation, dilution caused by rainfalls, destruction of algae strains by too much direct sunlight and not steady temperature. Light penetration is a common problem for both open and closed systems, because light is able to penetrate only the top of the water and during algae grow and reproduction the culture media becomes denser. As an innovative approach for the equal light distribution, so called light rods are being developed worldwide which can be immersed deep into the algae culture to light below the surface layer. After the growth phase, algae must be harvested by centrifugation, flocculation, or froth flotation. Harvesting process includes the separation of the algae from the growing medium followed by a drying process. Unfortunately, harvesting and oil extraction costs may contribute to a significant extent of the total cost of algal biomass and that is why the whole technology has not reached the commercial scale yet. Many research projects are being carried on worldwide to make the technology feasible, because algae based biofuel is said to be the best potential answer for the sustainable aviation fuel in the future.

By recognizing the possibilities in both the reduction of greenhouse gas emissions in the refinery and the suitable feedstock production for biodiesel or biogas, MOL Downstream has started its own algae research project in Székhalmombatta. Based on the laboratory-scale photobioreactor experiments, achieved together with the University of Pannonia, we have carried out and installed an open-air pilot reactor to continue our research towards the CO2 capture from refinery flue gases and the profitable algae utilization in renewable fuel production. Our current oil yield is about 20 l oil/day which may make the algae cultivation technology profitable. However, this requires further improvements of the harvesting process or biomass separation and oil recovery. Besides the several unsolved problems, algae biomass utilization as biogas feedstock seems to be more profitable than biodiesel production, because the expensive thickening up to 80% of dry solids after harvesting phase can be omitted by concentrating the algae suspension only to 5-10% (dry solid content).

Production of synthetic crude oil by waste plastic cracking

Cracking is one of the best technologies to manage the huge amount of polluting waste plastics formed annually worldwide. During plastic cracking, a preparation step (including size reduction and removal of most non-plastics components) is followed by feeding the feedstock directly into a heated reactor which operates in the absence of air. There are two main types of plastic cracking: the thermal and the catalyzed cracking process. In the latter case, the structure of the final product can be significantly influenced by the catalyst applied. However, there are several drawbacks of the catalyst utilization such as maintaining its activity and separation. Under optimized conditions, the plastics crack thermally to hydrocarbons which vaporize and finally the gas and vapour are cooled to condense most of the hydrocarbons into the feedstock. The proper set of the reaction temperature has an important effect on the product quality. To obtain paraffin-olefin mixture, temperature must be kept at approx. 400 °C. The composition of the feedstocks is especially important, because it affects the quality of the final product. The optimal feedstocks for the technology are plastics containing no heteroatom. In the case of PVC processing, solid impurities, including metals from stabilizers and some coke can pollute the catalyst. The decompositio of PVC leads to the formation of HCl as well, which must be neutralized by bringing the hot gas into contact with a solid absorbent. According to the sustainable development strategy of MOL, beside biofuels synthetic crude oil, originated from plastic waste, can be an alternative source of fuels. With our research, R&D partner, the University of Pannonia, our aim is to develop an environmentally-friendly technology for converting polyolefin-type waste plastics into fractions that can be directly utilized in refineries or petrochemical industry. During this project, MOL will test synthetic crude and survey processing routes in the refinery to maximize fuel production.

Conclusions

Considering the gradually growing biofuel demand, required by the European Union legislation by 2020, non-edible feedstocks such as algae and other waste materials will have a more and more significant role in the near future. With special emphasis on efficiency improvement in our existing facilities and cutting edge renewable development trends, our biofuel strategy is continuously revised and improved. As the main steps have already been taken towards both the implementation of the second generation biodiesel plastics formed annually worldwide, and the début of the refinery integrated biogas production concept, it can be concluded that MOL is on the right track of becoming a more sustainable company in the region.

Keywords: biofuels, bioethanol, biodiesel, bioethanol, biogas, algae
‘Freshhh’ on-line recruitment competition program of MOL Group

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Abstract
‘Freshhh’ on-line, recruitment and Employer Branding oriented competition was established in 2007 to address changing external and internal labour market trends. It is one of the first and most visible and popular but not the only tools to meet external and internal strategic HR needs. MOL Group strategic human resources concept addressing university and secondary school relations involves a coherent set of other inter-modular activities that are discussed in the following article.

Since the introduction in 2007 ‘Freshhh’ competition database records 6,186 students representing 67 countries, setting up total of 2,062 teams. The international oil and gas industry competition starts with the registration of 3-member teams. The participants are asked to prepare for solving oil and gas industry related tasks for valuable prizes. During the competition’s history, we incrementally led to increasingly structured HR efforts focused on strategic human resources.

Introduction
‘Freshhh’ on-line, recruitment and Employer Branding oriented competition was established in 2007 to address changing external and internal labour market trends. External factors include the increasingly widespread and popular use of on-line and alternative forms of job search among students, and the ‘war’ for (outstandingly) talented students. Key internal triggers included long-term (min. 3 year) corporate succession needs: unfavourable workforce age structure, the expected number of retirements and the lack of professionals aged between 30 and 40 – that collectively led to increasingly structured HR efforts focused on strategic human resources.

‘Freshhh’ competition is probably the most visible and popular but not the only tool to meet external and internal strategic HR needs at MOL Group. The strategic human resources concept addressing university and secondary school relations involves a coherent set of other inter-modular activities that are discussed in more detail below.

Let’s see ‘Freshhh’ competition details first.

What does ‘Freshhh’ stand for?
The competition is designed to provide several key features. It should be known, available and open to any student on international level. The design, structure and content should ensure a fair but demanding competition. The process is expected to select the best teams into the final round and provide some useful ideas / inputs to MOL Group as a result of the students’ efforts.

The international oil and gas industry competition starts with the registration of 3-member teams. The participants are asked to be prepared for solving oil and gas industry related tasks for valuable prizes. Since the introduction in 2007 ‘Freshhh’ competition database records 6,186 students representing 67 countries (see Figure 1), setting up total of 2,062 teams [1].

Fig. 1. Participants’ countries in 2011 (62)

The competition’s target group is university and college students pursuing studies mainly in engineering and natural sciences that are of utmost importance for MOL Group. Based on MOL’s strategic objectives and daily operations, ‘Freshhh’ is organised as an international competition right from the start. Advertisement campaigns and the competitions themselves are conducted in English through all the three (On-line, Creative and Live Final) rounds.

Besides the Euro 20,000 prize another valuable − or even more valuable − prize offered to participants is the professional carrier opportunity with MOL Group. As a result of the last 5 years, MOL Group has employed almost half (over 60) of the members of top 10 teams (about 150 participants in total) in various forms.

Összefoglalás
A MOL-csoport toborzású célú szakmai vetélkedője: a ‘Freshhh’

A ‘Freshhh’ online toborzású vetélkedő 2007-ben a változó külső és belső munkaerőpiaci trendek hívták létre. A ‘Freshhh’ vetélkedő mellett az egyetemi és középiskolai kapcsolatokat is felölelő stratégiai utánpótlást biztosító koncepcióban számos más, egymásra épülő tevékenység is szerepel, amelyekre részletesen kitérünk a cikk folytatásában.

A ‘Freshhh’ nemzetközi olaj- és gázipari vetélkedőben a versenyzők háromfős csapatokat alkotva mérkőznek meg olaj- és gázipari szakmai feladatok megoldásán keresztül az értékés növekményekért. 2007 óta összesen 6 186 diák versenyzett, 2 062 csapatot alkotva, 67 országból. A műszaki, és természettudományos hallgatók aránya az összes résztvevő közül már 70% felett volt az elmúlt 3 évben. A 20 000 EUR-os összijövedelmesztett értékés, ha nem értékesebb, növekmények számít a versenyzőknek az az előrelépési lehetőség is, amit egy szakmai gyakorlat, diplomairás vagy álláslehetőség jelent a vállalatszpolet valamelyik tagjánál. Az elmúlt 5 évben a mindenkori legjobb 10 csapattól (körülbelül 150 fő) versenyzők közé felét, hozzáférétségesen 60 fő, valamilyen formában foglalkoztatott a MOL-csoport.
of the last 5 years, MOL Group has employed almost half (over 60) of the members of top 10 teams (about 150 participants in total) in various forms. Since it is not required to be a graduate to participate, and students just starting or being in the middle of their studies are increasingly successful, the number of those who work for MOL Group is expected to increase. So the competition’s recruitment role works well.

The first round of ‘Freshhh’ is always an on-line competition that involves a number of professional tasks becoming increasingly complex over the years, such as quiz questions, technology-focused riddles covering the entire oil value chain, refinery simulation tasks, and in 2011, operation of a virtual oil company within the framework of a strategic game.

The most important part of the competition every year is the technology-focused on-line game. The basis for the game is developed by MOL Group experts in a form of professional case studies. This content is then adapted for the students’ level and presented in an attractive and exciting form of an on-line game. Over the years the on-line part has gradually becoming more and more complex.

The first, on-line round is followed by the second, so-called ‘Creative Round’ open for the selected 40 teams. It is usually an essay-writing task focusing on a specific MOL Group activity or an issue to be solved (e.g. the ‘Junior Freshhh’ Concept in 2010) or an industry-related topic concerning the society as a whole (e.g. consequences of Fukushima catastrophe in 2011).

Winning this competition takes more than lexical knowledge. The number of participants decreases throughout the rounds significantly. Therefore during the Live Final attended by the 10 best teams (50 participants) the so-called ‘soft skills’ – such as presentation techniques, problem-solving, stress tolerance and teamwork – play an increasingly important role. In the final the most successful participants can prove their abilities in the presence of MOL Group top executives and experts (in practical terms it is like an Assessment Centre). After the on-line technology skills and knowledge oriented rounds the ‘soft skills’ come to the front completing the set of evaluation criteria for the participants.

It clearly shows that it requires thorough preparation every year to ensure that technical competence of the participants is thoroughly tested through the tasks presented. During the last 5 years, we incrementally managed to access the target group: the mix of participants originally involving more students pursuing economics studies is gradually shifting towards students pursuing studies in engineering. Some testimonies from 2011 participants prove this as follows: “The competition was exciting and difficult. I have never yet met such a complex problem-solving, stress tolerance and practical knowledge-intensive game. We’re chemists, but we could learn a lot about the upstream area and the economic calculations as well. Sometimes the technical issues seemed as if it would go beyond our knowledge but then after a lot of research and learning we were able to solve them. To be honest the competition was worth a semester. Unfortunately we did not score the final level, but we really enjoyed the game. We will be back next year.”

Especially in the last 3 years, the rate of students pursuing studies in engineering and natural sciences increased to 75% compared to students involved in economics / other studies [2]. It is a significant achievement – and a recognized feature of ‘Freshhh’ –, since similar competitions are usually designed / announced for students pursuing economics and management studies. Further details are discussed below.

This approach is well received by the student communities and the feedbacks confirm both the high professional quality and the ‘fun factor’ of the competition as well.

‘Freshhh’ is spurred by the labour market undergoing transformation

After getting more familiar with ‘Freshhh’ itself, let’s see the business environment it fits in. In the introduction to the essay ‘Nurturing talent in a tough environment’, Igal Brightman, Deloitte Global managing partner says about labour market transformations that: ‘Companies around the world are starting to feel the early effects of a global talent shortage that is expected to last for decades. Against this backdrop, businesses of every shape and size must find new ways to attract, develop and retain qualified employees...’ The problem is particularly severe in developed countries where decades of declining birth rates and shifting education patterns are producing chronic talent shortages in science, technology, engineering and healthcare’ [3]. This clearly shows that every developed country struggles with talent shortage in science, technology and engineering. As for the oil industry, it can be clearly concluded that there is a worldwide war for talented professionals.

In general, experts also predict (radical) changes in key HR areas. According to a study published by Boston Consulting Group the HR area facing three main challenges: “Three trends are pushing Western companies to alter their HR strategy: globalization, ageing workforce, and decreasing loyalty employees have to their employers” [4]. By using the ‘EGG Model’ (see Figure 2), the study discusses the combined effect of challenges facing companies: vanishing borders (Globalization), changing employee attitudes and expectations (Ego) and ageing workforce (Generation).

When applying this metaphor to MOL Group, we got a different picture. All three effects can be observed in CEE countries: less available talent and shifting education patterns as well. Some success stories from MOL Group can at least partially mitigate these changes from CEE countries (it operates in: for example, from Pakistan, where the lack of university faculties most important for the oil industry and European ageing problems are almost unknown and the graduates’ motivation is well above the average).

How ‘Freshhh’ responds to challenges of the labour market undergoing transformation?

The ‘Freshhh’ competition concept attempts to influence all three pillars of the above EGG model.

1. Globalization. It is an international competition for university and college students. It has been announced in 15 countries/regions (e.g. China, India, Korea, Malaysia, Vietnam, Italy, France, etc.) and in 3 languages (English, Russian, Chinese).

2. Ego. By using the ‘Junior Freshhh’ Concept in 2010 or an industry-related activity or an issue to be solved (e.g. the ‘Junior Freshhh’ Concept in 2010). This approach is well received by the student communities and the feedbacks confirm both the high professional quality and the ‘fun factor’ of the competition as well.

3. Generation. Winning this competition takes more than lexical knowledge. The number of participants decreases throughout the rounds significantly. Therefore during the Live Final attended by the 10 best teams (50 participants) the so-called ‘soft skills’ – such as presentation techniques, problem-solving, stress tolerance and teamwork – play an increasingly important role. In the final the most successful participants can prove their abilities in the presence of MOL Group top executives and experts (in practical terms it is like an Assessment Centre). After the on-line technology skills and knowledge oriented rounds the ‘soft skills’ come to the front completing the set of evaluation criteria for the participants. The competition’s recruitment role works well.
students. Therefore it ensures that any student living outside MOL Group countries and inclined to submit an application may participate, and it also offers a larger pool of candidates to select from. Entering the competition by joining 3-member teams makes it possible to experience teamwork and offers the opportunity for students of various nationalities pursuing studies in geographically remote areas to submit joint applications. There are an increasing number of examples of such co-operation: in the 2011 Final there was a Hungarian-Romanian-Canadian trio from the University of the Alberta.

2. Generation / ageing workforce. It promotes long-term commitment of young people who will, on the basis of number of years of experience in the year of competition, become potential employees after entering the competition as graduates or some semesters later, after completing their studies. Of the 150 finalists between 2007 and 2011, more than 30 participants have already joined MOL Group member companies and 30 more still pursuing their studies were offered other forms of co-operation. The ratio where MOL Group has significant operation, e.g.: Croatia, Hungary, Slovakia.

3. Ego. ‘Freshhh’ attracts young people and it is almost conceived as an independent brand among students. Since 2007, in spring each year young people pursuing relevant studies look forward participating in upcoming ‘Freshhh’ competitions. It shows that members of Generation Y can be accessed by such competions. Computer-aided, simulation-based riddles presenting challenges attract them from round the world. Young people seeking challenges in work, alternative solutions and ‘entertaining’ satisfying experience, who more and more frequently start their career building in a structured way are inclined to participate in talent search competitions. As for retention, another version of Freshhh is designed for employees ‘FRESHHH FOR PROFESSIONALS’ is organised since 2010 to ensure that talents already employed can also test their skills through such games. Almost 500 employees have taken the challenge since 2010 in 156 3-member teams from 10 MOL Group countries. On the whole these achievements may increase their and other colleagues’ loyalty and engagement level.

MOL’s general response to challenges

Besides ‘Freshhh’, there are plenty of other ways to recruit young talents and ensure strategic succession (see Figure 3). The University and Secondary School Concept that is designed to provide for long-term succession includes a number of other program components as well. Key elements of the University Concept:

- Strategic university relations
- Council of University Relations (EKT) ¹
- Co-operation with student organisations (e.g. BEST/AIESSEC) ¹ and other higher educational student organisations
- Traineeships
- Student fellowships
- Professorships
- Growww Fresh Graduate Programme.

Due to the characteristics of public education, the Secondary School Concept is focused on local solutions. However, there are international aspects, such as the:

- MesterM / Naj Mentor Award
- ‘Junior Freshhh’ competition ¹¹
- ‘Freshhh’ EDU (Educational Framework System) ¹²
- Scientific competitions foundation ¹²
- Refinery visits ¹³
- Dialogue Teacher’s Conference ¹⁴
- Together for Future Engineers Association ¹⁵

Why is the student competition an outstanding role?

Student competitions were not unknown in the past. In Hungary, such competitions gained popularity in the nineties and today it has since become a ‘separate industry’ encompassing both conventional talent management (student competitions) and recruitment. In Hungary, about 8,000 students joined such competitions, including ‘Freshhh’ since 1996. Most of them (55-65%) entered these competitions near the financial sector (K&H Bank, Big Four) through IT firms (Microsoft) to producers (Dreher Breweries Ltd.) and energy and industrial (MOL Plc., E.O. Hungary companies) [8].

In 2007, MOL decided to launch its own oil and gas industrial competition with two objectives: it is designed to improve the effectiveness of MOL recruitment / succession processes and raise awareness / popularity of oil industrial knowledge. As a result of the brand, the main objective was to raise the awareness of to-be professionals of opportunities offered by the industry. Year over year, this form of communication is found increasingly effective in accessing the relevant target group. This trend is also true in terms of addressing foreign students: in 2011, the number of participants who broke all records with the involvement of 62 nations. To a significant extent it is attributable to the radical transformation of advertisement forms, as Facebook, Twitter and LinkedIn play a pivotal role. The media and social media coverage of ‘Freshhh’ has never been so widespread before in these new ways: the games official website www.freshhh.net has doubled to over 23 600 individual visitors in 2011 compared to the over 12 500 individual visitors in 2007. Additionally, via Facebook ‘Freshhh’ gained almost 1’000 friends which means more than 248,600 visitors who clicked either intentionally or accidentally on the competions’ Facebook page.

Last, but certainly not least, ‘Freshhh’ is a household name for students without any particular direct relation, it has been established and it has actually become an independent brand. It was well demonstrated in 2011 by the questionnaire of Ecosim Ltd.: it was completed by 11% of the 1,800 participants (204 students), indicating that 40% of them learnt about ‘Freshhh’ from friends. It is followed by email-based advertisements

¹ Mostowfi / Naj Mentor: Hungarian and Croatian students pursuing studies in engineering and natural sciences can acknowledge the contribution of their former secondary school teachers to their professional career. The awards are given by MOL / INA based onual career. The awards are given by MOL / INA based on nominations.

² ‘Freshhh’ is first launched in 2010 as a pilot limited to Hungary, but its regional level roll-out is already in progress. In the first year 900 teams of three students competed with each another.

³ ‘Junior Freshhh’ is the ‘little brother’ of ‘Freshhh’, offers interesting on-line challenges to secondary school students in the areas of physics, chemistry, mathematics and biology. Similarly to ‘Freshhh’, this competition is designed to make studies in engineering and natural sciences – considered as basic sciences required for oil industry – more attractive to students involved in public education. ‘Junior Freshhh’ was first launched in 2010 as a pilot limited to Hungary, but its regional level roll-out is already in progress. In the first year 900 teams of three students competed with each another.

⁴ ‘Freshhh’ EDU in parallel to ‘Junior Freshhh’ was also developed. It is an Internet-enabled application facilitating training and examination of secondary school level natural science knowledge of students, making it possible for teachers to get statistical details during and after individual phases of problem-solving and on achieved results by using a built-in statistical module. Thus they can get more direct feedback of secondary school level natural science knowledge of students, making it possible for teachers to get statistical details during and after individual phases of problem-solving and on achieved results by using a built-in statistical module. Thus they can get more direct feedback from the performance of students (e.g. about their strengths and difficulties in the task solving) and also about the performance of students (e.g. about their strengths and difficulties in the task solving) and also statistical analysis of the database via an on-line interface.

⁵ MOL Core supports a number of country-level scientific competitions, typically in Hungary (Dániel Arany Mathematics Competition, National László Solymár Competition in Physics) and Slovakia (e.g. Chemical Olympic, Summer School of Chemistry).

⁶ There are many companies that offer such competitions or separately, where experts promote technology-focused competitions and guided tours to production units (e.g. refinery) for groups of students.

⁷ There are company visits organized as part of such competitions or separately, where experts promote technology-focused competitions and guided tours to production units (e.g. refinery) for groups of students.

⁸ Students regularly participate in science competition based on regular competition – e.g. ‘Junior Freshhh’ – and also to industry participation in education, science and technology – e.g. ‘Freshhh’ – and also to industry participation in education, science and technology – e.g. ‘Freshhh’ – and also to industry participation in education, science and technology – e.g. ‘Freshhh’ – and also to industry participation in education, science and technology – e.g. ‘Freshhh’ – and also to industry participation in education, science and technology – e.g. ‘Freshhh’.

⁹ The competition attracted the interest of the student organizations in the form of student conferences, presentations and guided tours to production units (e.g. refinery) for groups of students.

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(22%) and teacher recommendations (15%). Thus it is clearly visible that together with other elements of the strategic succession concept, this competition successfully contributes to the promotion of MOL Group and its subsidiaries as attractive employers both in Hungary and neighbouring countries.

Conclusions and future possibilities
On the whole we can conclude that it made a good sense to launch the competition, especially because it established an overall concept which fully covers the key stakeholders’ recruitment issues. Moreover, it is a cost effective way to recruit young talents since this a structured and fine-tuned recruitment for the most needed professions e.g. chemical, oil and gas engineers, or geologists. Most of those who have joined via ‘Freshhh’ are still working for MOL with great success, which may be derived from two factors: they have been selected thoroughly by the three rounds and the trust and engagement towards the company might have been created in an early stage, even earlier than they joined. Many of them fulfil responsible positions or even have been appointed to be managers or expatriates. The competition itself can be considered as a CSR activity since it addresses not only the students and their institutions but also many kinds of industrial and non-industrial competitors and the society / parents in a way that awareness of workforce shortage has been raised. Providing jobs, traineeships and various kinds of supports to students in those societies where MOL Group is operating is also part of CSR. The competition strengthens the co-operation in MOL’s everyday life because it mobilizes significant internal resources to support the student relation / recruitment activities on Group level since it is always being organised in close co-operation with the subsidiaries involved.

What can we expect from 2012? The framework of the game enables us to further develop the competition in which new, even more demanding challenges will be introduced. Simultaneous professional and financial management of the integrated (upstream and downstream) virtual company will be the core task with high focus on the technical issues. Besides the business advantages (e.g. strategic decision making, cost and law recruitment, employer branding) this system also aims to be a teaching tool for universities in the long-run. In other words ‘Freshhh’ is a small but efficient contribution to putting MOL Group on the map of growing and well managed international enterprises.

References
[1] MOL Plc. Internal Data
[2] MOL Plc. Internal Data
[6] Ecosim Ltd. Internal Data

Keywords: strategic recruitment, online professional competition, Freshhh, Growww, labour shortage

Reviewed by Gábor Varjasi and Róbert Tóth

MOL GROUP WINS EUROPEAN HUMAN RESOURCES AWARD

MOL Group has won an HCM Excellence Award in the Recruitment category, given for the first time. MOL was recognised for its unique, integrated talent attraction strategy which includes online games – Junior Freshhh for secondary school pupils, Freshhh for university students and for its fresh graduate programme – Growww. The Awards were first launched to recognise and reward European organisations that demonstrate excellence in their Human Capital Management practices. Prizes were presented on 25 October 2011 at Budapest during the Human Asset 2011 conference. 65 nominations from 14 different countries were entered and the final decision was made by a prestigious international jury headed by Professor Dave Ulrich. For the sixth consecutive year, Dave Ulrich was named as Most Influential International Thinker by HR Magazine. The head of the jury Professor Ulrich commented: “MOL has done an incredible job in demonstrating what we consider the future of HR to be, which is to understand and adapt to one’s particular business context. The company has created awards and games and established excellent relationships both with students and teachers significantly increasing its pool of talent in the process. The number of applications grew from 1,000 in 2007 to 7,897 in 2011. Its investment has resulted in an increased pool of talent, retention of key talent and created a strong employer brand. MOL Group has developed a model of future HR by mastering and knowing the business context within which it finds itself and then shaping it to meet its objectives.”

MOL Sándor Galambos joined MOL Group in November 2001. First he worked as Knowledge Management Expert at IS and from 2007 at the Human Resources. At the same time he started to organise the online, oil-industry related, recruitment purpose ‘Freshhh’ competitions. Organising them annually together with other tasks derived from MOL Group’s secondary school concept (e.g. Junior Freshhh scientific competition of natural sciences) is his main activities today. His original profession is chemical engineer from University of Pannonia, Veszprém, Hungary.

Andrea Kóródi started working for MOL Group in 2008. Firstly she took part in the Round Table, Employee Engagement Survey 2008 project. From 2009 she was responsible for learning and development related tasks at HR and from 2010 she is fulfilling her current position at the Strategic Human Resources team where she is working on the ‘Freshhh’ competition and ‘Growww’ Fresh Graduate Program. Her original profession is sociologist from Eötvös Loránd Science University, Budapest.

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MOL Group

2011/3
Enterprise-wide risk management at MOL Group

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Abstract

Setting the Enterprise Risk Management (ERM) system as the integrated risk management practice of MOL Group is in the focus of our analysis: MOL has committed itself to use ERM in order to enhance risk awareness and mitigation programs on a company-wide basis. Amongst others, ERM is used to complement strategic decision-making, a robust insurance program, regular in-depth financial risk analysis and management, and an ‘ERM’ basis for business continuity management.

A strong correlation exists between the application of ERM framework and quality of the strategic decision-making: ERM supports more reliable and accurate risk-adjusted forecasts at any decision-making point. Incorporating lessons learnt from the regular ERM exercises in operational risk management offers opportunities for insurance and business continuity management as the company will be able to capture a wider range of risks and will also be able to exploit synergies of the different systems.

Enterprise Risk Management: scope and context

Every business faces the challenge to maximize earnings and to manage risks related to the strategic goals and objectives (incl. key operations) that generate those earnings. Risk is an everyday part of any business – establishing a culture that inherently finds the right balance between growth and risk taking is an elementary role of the risk management process. This way risk management becomes an important contributor to shareholder value.

By not taking enough risk, a company may underutilize its capital – excessive risk taking, however, can push the company towards negative returns. The balancing act is the point of optimal risk taking. To find this equilibrium, the company must have up-to-date information on its risk exposure and should develop an integrated approach to identify and measure all of its risks, set specific tolerance levels and treat these risks as integral part of its regular business processes.

Risk is assessed by estimating its two parameters: likelihood of occurrence (probability) and impact – the higher the probability and impact, the higher the risk is.

In many cases management may decide to accept risks: typically those that have low impact, or have relatively high upside potentials. In other situations risks may be appropriately controlled (e.g. compliance) or transferred to third parties (partnership outsourcing, etc.). Risks can also be completely avoided by stopping the activity that contains the specific risks (e.g. cancellation of a project). As it is seen there are various mitigation approaches available to keep exposures at an agreed level of risk tolerance. Nevertheless, even the best risk management shall not keep up the illusion that future can be always foreseen. Just remember the so called ‘Black Swan’ events (very low probability, but very high impact events), think of the Hungarian red sludge events or the Japanese tsunami with nuclear accident. These are not more frequent nowadays that they were in earlier days, but public scrutiny has dramatically increased in how media and firm’s managements handle such incidents and their consequences.

We should rather underline that effects can be limited with conscious, proactive risk management. Recognizing these tendencies, MOL Group took the decision in 2005 to extend its risk mitigation practices and charged Group Risk Management to move on from financial risk and insurance management towards the development of an Enterprise Risk Management (ERM) model. The main objective of ERM is to identify, assess and control the risks faced by the company. The ERM model of MOL Group has since continuously improved through benchmarking, performance measures, trend analyses, external / internal audit reports, results of previous risk surveys: these are crucial information sources to the successful operation of ERM.

Enterprise Risk Management framework at MOL Group

Integration of risk management into other regular business processes of the company is of key importance to successful identification and treatment of risks and threats associated with company operations.

Incorporation of the broadest variety of risks into a long-term, comprehensive and dynamic system is arranged by Enterprise Risk Management (ERM) on group level for all divisions. ERM is a consolidated, top-down, cross-functional risk management framework covering all business units and risk factors.

MOL’s ERM utilizes Monte Carlo simulation in quantifying the riskiness of its activities by statistically measuring the deviations of their net present values (NPV). These deviations in NPV emerge from the uncertain outcomes of different underlying risk drivers. It would be a mistake if the focus was only on potential losses, because risks are not necessarily linked to negative events, but also to attainable gains. Therefore it is essential to analyze overall distribution including downsides and upsides, instead of concentrating only on unfavourable outcomes.

ERM integrates financial, compliance, and operational risks along with a wide range of strategic risks:

• Financial risks incorporate market related risks such as commodity price, FX (foreign exchange) risk, interest rate risk and credit risk.
• Compliance risks are related to the regulations and rules that a company has to face. We should not think about compliance in terms of avoiding penalties, but rather in terms of how to enhance the business through for example developing a strong internal control system.
• Operational risks are risks that are related to the company’s operations, including process modification risks, reduction of human error, and other management failures.

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ERM integrates financial, compliance, and operational risks along with a wide range of strategic risks:
exchange market), interest rate risks or even the evolution of the financial markets in the future (external business environment)
• Compliance risks stem from regulatory non-compliance or a breach of internal policies and procedures, fraud or ethical misconduct
• Operational risks bind together risk drivers such as equipment or IT system breakdown, or possible environmental accidents caused by a potential large-scale facility disruption
• Strategic risks contain all key challenges that are crucial for the organisation to deliver its strategy and ensure long-term sustainability and development.

All of these risk types are relevant for each business unit, although differences exist in their priorities, attributes and resource needs division-by-division.

The risks are reassessed on a yearly basis as a joint effort between experts of Group Risk Management and responsibilities of line managements, supporting the decision-making process by providing analysis regarding risk profile evolution of the Group and the divisions. The yearly update process consists of the following five steps:

• **Qualitative assessment**. During the qualitative assessment Group Risk Management interviews business unit managers to identify all material risk drivers and to select the quantification paths. This phase represents the validation of risk trees (or risk pyramids), which show all risks faced by the business units on a 10 year strategic horizon

• **Quantitative assessment**. The quantitative assessment incorporates estimation of probabilities of risk events and their possible impacts. During this phase Group Risk Management team transforms the real risks into probability distributions which can be used during the modelling phase. Estimation of probabilities and impacts are provided by business units’ experts or external data providers based on historical experience or professional judgment. The assessment is also linked to definition of correlations between different risk drivers in order to take into account the interdependent structure of risk events

• **Modelling**. The aim of the modelling process is to forecast distribution of free cash flow to firm (FCFF) of all divisions by simulating future risk-adjusted cash flows. The baseline data are provided by the Group’s Planning and Controlling and Strategy departments, which data is based on business plans. To create risk-adjusted cash flows, relevant rows in the cash flow are shocked by the embedded uncertainties of the risk drivers. By discounting simulated FCFF’s, the distribution of net present values (both divisional and group levels) becomes available.

• **Mitigation actions**. Line management is responsible to address risks identified and set individual actions which have significant impact on the NPV of the division. Group Risk Management co-ordinates the formulation of these mitigation actions and monitors their execution over time.

• **Reporting and communication**. Results of the annual validation are shared with Executive Board of MOL and the Finance and Risk Management Committee of the Board of Directors. Also, at mid-year, a status report on mitigation steps is provided to the above bodies. Moreover, shareholders and stakeholders receive a high-level overview as part of the Annual Report.

By managing the ERM process, Group Risk Management improves profitability of the businesses and contributes to sustainable growth.

**EXAMPLE: ANALYSIS OF A RISK DRIVER IN ERM**

The practical example below presents how ERM assesses those risks which are above the risk tolerance level, thus inevitable for the company to deal with. The evaluation process is fully integrated into risk management because it directly influences final results, which determine the necessity and content of the mitigation action plans.

Building up key competencies and to retain them on the longer term is an area where the energy industry, including the oil and gas sector, is facing difficulties to keep it in line with the expansion strategies [1]. In this respect this is a complex risk driver that possibly has several layers on future EBITDA (earnings before interest, taxes, depreciation and amortization) generation; therefore it must be mitigated with different tools at the same time.

MOL’s Upstream Division operates in an international environment, aiming the best technology and knowledge available in order to remain competitive. The global shortage of professional experts in the upstream activity has an unfavourable effect on MOL, as well. In Hungary the supply of graduated experts has become increasingly tight. In the international arena the brain-drain of experienced drilling experts is a common practice with the participation of the oil majors. In the meantime Russia, which was one of the earliest labour exporters of upstream business, has become an importer of qualified workforce recently, further highlighting the seriousness of the situation. In light of these, it is highly required to build up, improve and retain key competencies; reasons and explanations are detailed below.

**Profit loss from competence shortage**

We have defined the possible losses on upstream projects separately for the exploration and the production phase according to their features. We have had to determine the sum of the competences that could be at risk. Then the probabilities and potential impacts of the following losses were specified:

- Decrease of drilling success
- Over/underestimation of reserves
- Increase of project CAPEX/OPEX
- Increase of relevant (employee-dependent) operational risks
- Delay of projects
- Decrease of produced volume (due to employee failure).

The results of the modelling proved that the shortage of internal competences would have major effect on the value of the actual and future Upstream portfolio, which may force MOL to resort to alternative recruitment practices such as the use of contractors, consultants, and outside vendors. In case these solutions solve the problem in the short-term it is not sustainable on the long run.

**Strategic opportunity cost**

This risk is estimated as the possible decrease of acquisition success (due to uncompetitive evaluation and negotiation processes).

The upstream oil and gas sector has unique challenges that may only be understood by someone with substantial experiences in resolving them. The negotiation techniques are not comparable with other industrial segments due to its unique features, such as the life-time of the projects and the involvement of special stakeholders (e.g. governments). Additionally, to manage the growing geopolitical risks and the uncertainty of future supply and demand, adequate, practical and international experience and knowledge over a sufficiently long period are required.

To ensure the continuous growth and competitiveness in Upstream, MOL decided that the specific, sufficient skills must be available within the company and the processes would not be outsourced.

**Mitigation strategies**

In general, risks can be mitigated internally by the divisions or by the functional experts. In this special example, as a main mitigation tool, MOL Upstream Division has introduced competency based development programme and has set up an internal academy to train MOL employees. On the other hand, HR has adjusted its priorities in light of the above risk analysis to support the expansion strategy of Upstream Division.

Additionally, in order to secure the future need of professionals MOL decided to sponsor a faculty at University of Miskolc (Hungary), where key competences required by the oil and gas sector are in the focus of education.

**Synergies between the ERM and the long-term strategic decision-making process**

There are plenty of evidences in the international corporate governance literature that there is a linear correlation between the level of Enterprise Risk Management and the quality of strategic decision-making. In fact, development of Enterprise Risk Management partially emerged from the incentive to provide more reliable and more accurate risk-adjusted forecasts for possible outcomes at any key decision-making point.

From historical point of view it is worth mentioning the period when inorganic growth possibilities, i.e. the start of global mergers and acquisitions (M&A) at a large scale were the primary source of growth for enterprises by exploiting synergies between business activities of the acquirer and the potential target. In this period huge risks were undertaken in hope for extra benefits in
return, but a series of these acquisitions were not always justified by long-term scenario analyses.

Due to this uncertain situation, shareholder and also stakeholder expectations forced senior executives of organisations to place more emphasis on raising the correlation between strategy and risk management processes in the frame of a coherent enterprise-wide structure. Although ordinary assessment tools were available for project / M&A evaluations providing relatively reliable inputs for decisions on financial and operational risks, the management of strategic risks was out of scope for senior executives at most enterprises at that time.

In case of financial risks, long history of available market data provided a basis for estimation of volatilities, expected values, dependency structures between different markets and products. This risk type was usually managed well by transferring risk to third parties by using derivative transactions or by establishment of naturally balanced positions within the production cycle of the company.

In case of operational risks, estimations were also available based on professional judgments and historical experiences. The emergence of different insurance types also contributed more effectively for the proper management of these risks.

The lack of proper assessment for strategic risks however was caused by the difficulty in precise predictability. Estimation of possible impacts and their probabilities were dependent on a professional judgment basis and by top management only. Corporate culture and management philosophy at that time was not supportive to collective participation and involvement of wide range of employees in setting and executing strategy. There was no transparent database available, which would provide industry-wide, consolidated estimations. With ERM in place at all, reliance on third parties by using derivative transactions or by establishment of naturally balanced positions within the production cycle of the company.

The illustrative example below (see Figure 1) shows the NPV distribution of R&M Division with and without a hydrocrack investment. It can be seen that without hydrocrack the NPV distribution had a larger spread and probabilities of extreme outcomes were higher than zero. On the other hand, implementation of hydrocrack was expected to result narrower distribution in discounted future cash flow and reduced the probabilities of extreme realizations to zero. From risk/return point of view this project was evaluated as a strategic risk mitigation project.

Possible projects can be analyzed not only separately, but also by taking into consideration portfolio effects. Simplest solution for this is the mean / variance analysis [2], which represents comparison of the given project’s risk / return profile with existing risk / return profile of the corporation (see Figure 2). By elaboration of such analysis it is possible to analyze whether a given project improves the risk / return profile of the corporation, or contrary to this, the project deteriorates it. Another point of view of such analysis is whether implementation of the new investment supports the current portfolio to get closer to the target portfolio set in the long-term strategy of the enterprise.

The process of project evaluation represents another application of ERM for strategic decision-making. By the utilization of the ERM capabilities (historical database, skills and competencies, tools, etc.), strategic, financial and operational risks of any new proposed investment can be assessed and measured.

This means that ERM contributes to the decision-making process by determining distribution of the net present value of the project, which encompasses not only the risk-adjusted expected net present value, but also the spread of the distribution. Risk-adjusted NPV provides more accurate and more reliable estimation compared to ordinary measures, in which only limited risk factors are captured or riskiness of the investment is not captured at all and decision makers can only rely on estimations for the expected value or, in better case, one or two alternatives. The spread and the shape of the distribution provides additional information for senior management regarding probability of a given NPV outcome, as well as minimum and maximum possible profit levels for the most pessimistic and most optimistic realizations.

Another possibility is to analyze different baskets (smaller portfolios) of projects and make specific decisions about the basket that has the highest contribution to expected return and the lowest incremental risk at the same time.

The fast changing environment forces operational risk management towards new efforts that attempt to hit multiple moving targets. In the same time, businesses have stretched their limits to grow internationally, increase efficiency and reduce costs. Reliance on IT systems and automated controls has become part of normal course of business. This implies emerging new threats and more imminent risk to control activities: need for higher resilience of the business moved high up on boardroom agendas.

These tendencies have increased high level attention to business continuity management and insurance. Beyond any perception that the world is an increasingly dangerous place
to make business, various external evidences influence heightened focus on operational risk management: extremely complex network of partners are being dealt with, with higher reliance on their performances. Regulators and shareholders are also requiring companies to reassure continuity of business and well planned measures in place to deal with business interruptions and risk mitigation actions to reduce negative consequences.

BUSINESS CONTINUITY MANAGEMENT (BCM)

In the past few years, business continuity management has emerged as one of the key tools besides insurance that companies use to manage operational risks. A number of low probability but high impact events have alerted executives that more cautious preparations for damaging incidents are necessary: beginning with the Y2K threat, followed by 11th September attacks, pandemic bird flu, then the BP oil catastrophe have shed light on vulnerability of businesses to ‘Black Swan’ events.

The successful management of operational risks requires companies to conduct a broader assessment of risks and threats and try to establish proactive controls early in time. The solution has evolved as the integrated approach by incorporating lessons learnt from the ERM exercise into business continuity management (BCM) that can enhance capturing a wider range of risks, extending risk mitigation activities and risk awareness through the company both horizontally (line-by-line) and vertically (through the chain of command from the top to all employees).

Business continuity management shall be developed to be a natural addition to the network of management systems in companies, by completing risk management with a more tactical view on processes and value creation chains, as compared to the strategic, long-term approach of ERM.

A BCM-led approach prioritises key processes, resources and services delivered by the business on the basis of their contribution to business survival: furthermore, it requires the risk management system to identify interdependencies, and assesses impacts of disruption. Business continuity plans ensure the business is able to recover from such disruptions.

BCM captures also such risks that may be omitted by ERM due to low aggregated effect from a strategic point of view. Also, by BCM, the quantification of impacts may be more precise being identified lower down in the organisation – compared to ERM, where specific risks may be considered less important being within the tolerance level at the aggregated level of the company.

As recommended by Marsh Risk Consulting [3], an integrated approach to ERM and BCM eliminates gaps and overlaps whilst still recognising desire for the two disciplines to achieve separate objectives but a common goal – to achieve an optimal balance between organisational performance and risk governance, thereby allowing a more efficient allocation of capital and risk-adjusted decision-making.

INSURANCE

Insurance is often considered to be one of the most effective ways of managing operational risks. However, in fact, insurance is rather the final tool to manage certain risks: if you consider that you have made all reasonable preventive steps to eliminate or mitigate operational risk and still you think that a potential event creates an exposure that is in excess of your risk tolerance, then you may want to transfer a part of this risk to third parties and protect yourself by way of procuring insurances.

It is important to understand which risks are insurable and which are not. Overall, frequent events with low impact are usually not part of insurance cover – rather those ‘Black Swan’-type patterns referred already in this article. Generally speaking, the most frequent risks include damages to property damage insurance) and the consequences of such damage on the continuation of the company’s business activity (business interruption insurance). In addition, unforeseen adverse events could cause harm to people’s health e.g. bodily injury or loss of life damage to property of third parties or the environment. Liability insurance is a typical tool to cover such risk exposure.

Financial risks, market risks and business counterparty risks are typically not possible to be covered by classic insurances. There are, however special products which may partially reduce counterparty risks (credit insurance, political risk insurance).

INSURANCE AND ERM

Revision of risk quality was always associated with providing insurance [4]. In its modern form in the energy industry, engineers of the insurers and insurance brokers are being regular visitors to main sites of the insured, rating the risk quality and giving risk improvement recommendations based on their experiences gained through having looked at similar sites worldwide, also having looked at losses incurred to peers. By accomplishing such recommendations the risk of a loss is already reduced to a certain extent. The level of management response to such recommendations is an important factor in insurers’ risk assessment and affects the pricing of insurance.

Non-commercial insurers, e.g. mutual insurers like OIL Limited also establish some criteria to measure the risk quality of their insured’s (i.e. their members). As the information to be provided by members is fairly limited (only audited gross asset values need to be reported broken down by business sectors), OIL’s distinction is made through allowing only investment grade energy companies to gain membership.

In the context of ERM, the financial impact of a facility disruption event is reduced through the application of insurance coverage. Therefore, management is able to focus and allocate resources on other risk exposures where such tools to mitigate or transfer risks are not available.

INSURANCE AND BCM

Recent studies point out that existence of BCM is gradually becoming a pre-requisite for insurers to underwrite energy risk [5]. This is again a sign that insurers expect that their client is aware of the risk and the potential loss it transfers to insurers, and has appropriate plans to minimise that loss, particularly on the business interruption side.

Also, the probability of loss is reduced in case the company has a trusted BCM programme, which ensures reliable strategies for coverage of less extreme events, too. It also makes sense to take all reasonable measures to avoid considering insurance as the only one risk management tool, as BCM is to protect market share and brand through retaining the organisation (or its unit and function) back to normal business as soon as possible, while risk transfer (to insurers) will complement this strategy by helping to provide cash flow following an incident until the end of the insured period (indemnity).

BCM can also be used to protect against losses incurred through traditionally non-insurable perils, such as supplier insolvency or pandemic flu [6].

Mitigation of risks by BCM programmes may also lead to reduce indemnity periods by faster recovery – having effect on insurance premium paid. In this respect, detailed scenarios can make insurance settlement (loss reimbursement) easier, by estimating e.g. how much financial support is required in the sequence of recovery actions. Insurance procedures should therefore be included in business continuity plans and insurers shall be kept up to date with BCM arrangements of the insured.

The three elements (ERM, Insurance and BCM) are in close co-operation and may be further developed in the future by new relationships to be created, synergies to be used, also with other strategic areas as well.

Conclusions

As mentioned earlier, integrated risk management supports enhanced management decision-making on different levels.

Leading corporations of the world are using risk management methodologies to achieve better results by taking advantage of long-term opportunities consciously: enterprise-wide risk management enables them to achieve goals within set levels of values, rules and parameters. There are also serious improvements in processes, strategies and tools to manage risks: companies are facing serious challenges in implementing their business strategies – one way of enabling fulfilment of targets is through effective risk management.

Rating agencies and investors are also looking more carefully at risk and compliance, and there is a growing consensus that effective management in this area is not just hygiene for business, but a barometer of good management overall [7]. To underline this fact, we shall be aware that MOL Group’s performance is also evaluated globally: a proud example is MOL Group's membership in the Dow Jones Sustainability Index (DJSI), the most prestigious sustainability index globally [8]. According to the assessment, MOL
is among the top 12 out of the 112 analysed oil and gas companies.

Amongst other reviewed elements, risk management of MOL (with the score of 88 points) is well above both the industrial average (60) and MOL’s total (75): another motive to ensure better focus and stronger integration of risk management tools for an enhanced global performance of MOL Group.

As a conclusion, enterprise risk management is a relatively new discipline, constantly changing, that has become more and more important as recognized by MOL Group: the aim is to embed risk management into other regular business processes of the daily operations. To achieve this target, ERM of MOL Group shall be further improved and innovative ways of exploiting results shall be applied.

Glossary

Enterprise Risk Management (ERM): “Enterprise Risk Management: is a process effected by an entity’s board of directors, management and other personnel applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objects” [9].

Monte Carlo methods: a problem solving technique used to approximate the probability of certain outcomes by running multiple trial runs, called simulations, using random variables.

Risk tree: network of risk drivers, which visually illustrates the relationship between risk driver categories and subcategories.

Net Present Value (NPV): the difference between the present value of future cash inflows and future cash outflows. NPV is used in capital budgeting to analyze the value creation capability of an investment or project.

Free Cash Flow to the Firm (FCFF): a measure of financial performance that expresses the net amount of cash that is generated for the firm, including expenses, taxes and changes in net working capital and investments.

Business Continuity Management (BCM): “An holistic management process that identifies potential impacts that threaten an organisation, and provides a framework for building resilience and the capability for an effective response which safeguards the interests of its key stakeholders, reputation, brand and value-creating activities” [10].

OIL Limited: mutual insurer for energy sector companies, only for property insurance with 51 members (incl. Chevron, ConocoPhillips, Eni, OMV, TOTAL, Repsol, Statoil) currently.

Indemnity period: the period beginning with the occurrence of the Damage and ending not later than the number of months specified in the Schedule thereafter during which the results of the Business shall be affected in consequence of the Damage.

References


[8] Dow Jones Sustainability Index Results of the 2010 Review, 9 September 2010


Keywords: Enterprise Risk Management, management practices, risk awareness, risk mitigation, insurance, business continuity

Reviewed by Dénes Doszpod

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Efficiency improvement (‘Eiffel’) programme at MOL Refining

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Abstract
Efficiency improvement is an operational requirement at MOL Group. Compared to the former instances, Eiffel programme is a unique one, because it has a bottom-up framework that allows and encourages people to contribute to the refinery efficiency improvement. On the other hand, it meets requirements of the employees as well, since they would have the opportunity to influence operation of a specific area.

A framework adjusted to the organisational culture was elaborated at MOL Refining to coordinate and maintain efficiency improvement processes. Possibility to generate an idea is a motive. Evaluation is based on a well-defined criteria system, and supported by experts teams composed from members from different areas of Refining.

What is Eiffel programme?
Eiffel programme at Refining was launched in 2008, in order to collect, analyze, evaluate and coordinate the implementation process of the efficiency improvement ideas. The basic assumption was that everyone would have real effect on the refining costs, and a huge amount can be saved by human knowledge, attention and creativity. Its launch was supported by two simultaneous facts.

Fig. 1. Cumulated number of submitted ideas, shown quarterly

Fig. 2. Distribution of idea generators by scope of activity

Efficiency improvement at Refining
The first step of launching the Programme was idea collection in each unit. It has been continuously gathering the new ideas since then. In 2008 a forum was held by the managers of Refining for the production managers and Colleagues started to start up and run Eiffel programme and got a lot of useful recommendations that contributed to the successful start-up of the programme.

As an impact of the forum number of ideas has increased. Keeping up idea generation is one of the most important tasks. As it can be seen on Figure 1 we have nowadays almost 1,000 ideas in the system.

Efficiency improvement ideas can be basically divided into two groups. They want to eliminate a formerly evolved bad practice or to improve efficiency of the operational systems. The second group represents the real scope of Eiffel programme and EIF.

We must not leave out of consideration recommendations that are beyond the daily operation of a specific area.

Összefoglalás
Hatékonyság javítási (Eiffel) programme a MOL Finomításnál

A mindenki menedztszent elvárasa a hatékonyság működtetését, a MOL Csoport minden működési területén, melyre számíthat példát lehet mondani. Az Eiffel Programme annyiban tör el a korábbi kezdeményezésektől, hogy olyan alulról építkező keretprogramme, amely mindenki számára lehetővé teszi, sőt bátótlja, hogy a finomítói hatékonyság növeléséhez saját ólóttével hozzájáruljon. Másrészt, a munkavállalók igénylik is, hogy lehessen ráhatásuk az adott terület működtetésére.

A MOL Finomításban a szervezeti kultúrához igazodó keretrendszer dolgoztunk ki a hatékonyság növelésére folyamatok és fenntartására, alapján alapoztunk az, hogy ötletet bárki beadj, a kiértékelést szakmai team támogatja. A felállított kritériumrendszer alapján kivitelezhetnek ílétt ötletek megvalósításra kerülnek. Az alvó hibás vagy gazdaságilag olvadt ötletekünket a hatékonysággal kapcsolatos idézetek megvalósítására kerülünk. Az alvó hibás vagy gazdaságilag olvadt ötletek kiértékelését az ólótt fölötti terület megismeri, így a rendszer a tudásmegosztásban fontos szerepet játszik. Azt akarjuk, hogy ötletet bárki beadj. Az Eiffel programme, being developed by each organisation of the Division, based on their own organisational culture.
routine and obligation on different levels of the organisational hierarchy. It has significance in motivation and will be mentioned later.

The evaluation process

The incoming idea is registered in the database then evaluated according to the methodology, shown on Figure 3.

Description of the idea, status of evaluation, type and amount of savings both in kind and in HUF, cost of implementation, and the date of implementation or reason of refusing are registered in the database.

A notable ratio, two thirds of proposals tend to save energy, what is not amazing, if we consider structure of operating costs. Beside energy savings, the most frequently received recommendations relate to reductions of maintenance costs, chemical consumption, lab costs, and slop production-reprocessing.

Responsibility of administration, managing of evaluation, and initiating implementation belongs to the Eiffel coordinator.

Part of idea evaluation is searching for other solution. Sometimes, we can find simpler way of implementation. In other cases, the recommended solution is not implementable, but it is obvious, that it is worth and we have to deal with the problem recognized by the idea generator. In these cases, we try to find the good solution with the help of colleagues taking part in the evaluation team.

If implementation is not refused on technical and HSE point of view, economic calculation has to be done. The experts assess whether the execution is profitable. It means that we have to calculate profit, and on the other hand, cost evaluation based on technical description shall be done.

Although the primary task is to find and realize ideas having clearly demonstrable profit, in case of a less scaling idea, it is not always possible to see the results because of the size of the system. Depending on the available data, we draw the conclusion and make calculation from measured data or from (partly) estimated data if we can not assign a measuring point in the examined area. When the result can not be proved, technical or model calculations are made, based on the available data.

Afterwards, based on other facts (annual operating hours, run times, etc.) and on the official prices, the yearly profit can be calculated. This has to be compared to the implementation cost and the simplified return rate is defined roughly. If this rate is under the expected value, idea is being put into the list of ideas to be realized. This mentioned value always depends on the actual economic environment, and on the return period of the parallel ideas to be realized.

Financing

Worked out ideas are ranked by the return rate and realized depending on the amount of the available CAPEX. Since both idea generation and idea evaluation are done continuously, it can happen that a recommendation coming in the good moment, can be immediately implemented, and others are postponed to a certain time (e.g. if realization is connected to a plant shutdown).

Idea generator is informed about the result of evaluation, and in case of refusal, its cause has to be explained. This is clue of the process, since he/she can easily accept a well-justified expert report without being discouraged. On the other hand, for those who read the database, it’s a good occasion for knowledge-sharing.

Follow up

Aim of follow up is to compare the planned and actual data. On the other hand, the conclusions make possible to improve the process itself. Last, but not least, basis of rewarding is the actual benefit.

Follow up period is basically one year, but the frequency depends on the action. It makes sense to check results month by month only at the starting of the action, because the initial difficulties can be corrected. When a process is in steady state, such a tight control is not necessary.

If results can be demonstrated as it is required in EIF, idea is registered as an action in the system, and follow up is done according to its rules.
If the implemented proposal is proved to be working on unit level (where idea comes from), we check over the whole Refining, if it is possible to achieve further savings by enlarging or adapting the idea. Eiffel is a good possibility to take over good solutions from each other. We have to ask ourselves, if it is really the best practice as we are doing now?

Motivation

One of the biggest challenges is to maintain the idea generating mind, what can be achieved by using different motivation devices.

Tickets can be won periodically to different programmes; a poster competition was launched to popularize Eiffel programme; related articles are published in internal press regularly; forums are organised connected with the rewarding ceremony; but first of all, premium is given. Reward is given only for an idea which is beyond obligation in scope of activities. Premium is given according to regulation, based on the actual results of one year, corrected with implementation cost. We have to mention, that 12 months follow up is not reasonable in all cases. In some cases, annual results are concluded on the basis of 3-6 months’ benefit, and premium can be given.

We can never say that we have done the best, on continuous changes of possibilities and demands in our internal and external environment. We can do it well, but it can be done better.

Reviewed by László Lázár

Keywords: efficiency improvement, idea generating, idea implementation, benefit, motivation, follow up, Refining

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The changing customer loyalty

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Abstract
The article describes the recent market developments which shaped the relationship between customers and retailers. It explains the rationale behind MOL’s decision to revitalize Multipoint loyalty programme by establishing a new multi-partner (coalition) based loyalty scheme together with OTP Bank.

Összefoglalás
A változó vásárlói lojalitás

Introduction
Customer loyalty is a convenient subject to talk about, because everybody is somebody’s customer hence everybody is affected or at least has an opinion on it. At the same time, it is also a difficult subject for the very same reason. It is like football, politics or raising a child – there is no need to be an expert to comment.

Despite such a public exposure for the subject matter, the author attempts to summarise in this article the major findings of a recent customer loyalty initiative at MOL Plc. and draw up the future intentions insomuch as it makes sense before going public. There was an article titled “How to win loyal customers” in issue 2008/2 of MOL Scientific Magazine from three Retail colleagues (A. Éber, A. Balásfalvi-Kiss and G. Dolezsai) who summarised the basic principles and practices around customer loyalty, which might serve well for the reader to refresh related theories. The current article builds upon the previous one in this subject from 2008 and updates the reader what hectic changes influenced customer behaviour and what changes applied in MOL’s approach to it [1].

Loyalty, as it matters for both parties

Whilst the above mentioned article defines customer loyalty, in simple words loyalty means very different things to customers and businesses. Customers exercise their loyalty by purchasing the same products and services and by going back to the same places, not questioning why they do so repeatedly. By doing so, customers enjoy the certainty that they get what they got used to, they know the price and quality and they can expect consistency in how they get treated. For the businesses this repeatability is the actual benefit of fostering customer loyalty. They can count on a solid customer base and calculate with expected volume and turnover. This all sounds nice so far, but something happened along the way! Walking down the street – say in the UK – proudly with the precious Marks & Spencer’s, Selfridges, John Lewis bags, along the way! Walking down the street – say in the UK – proudly with the precious Marks & Spencer’s, Selfridges, John Lewis bags, projecting to the neighbours that we shop at those fancy places is not enough any more. Customers are now demanding more than prestige, consistency and reliability. They want tangible benefits and they want it there and then, on the spot when they purchase. Also, businesses want somehow to secure the desired repeatability and preferably tie customers to themselves. Ultimately, both parties want real benefits that are expressed in money terms, so we can hardly call this loyalty any more rather we consider it financial interest. The crisis enhanced this effect and in deed, MOL experienced that customers redeemed more intensively in the past years than before.

MOL commissioned a research from a professional service provider, who conducted a large-scale survey [2] re. people’s perspective on “loyalty programmes”. Their technique is to dig down to the very bottom of the respondents’ mind and reveal the fundamental thought (meme) about the matter. In our instance, over 1,400 individual thought items were processed, and based on their filtering/categorisation, four significant dimensions were identified. The wide diversity of opinions is indicated by the fact that only 62.3% of all responses had substantial weight of opinions is indicated by the fact that only 62.3% of all responses had substantial weight.

The dimensions are best characterized by the extreme opinions pro and con, however, none of the identified significant dimensions reveal any loyalty aspect in the customer-retailer relationship. This is particularly true if we consider the underlying meaning of loyalty, i.e. faithfulness or devotion. As one of the survey respondents summed it up: “I have to be loyal to my own pocket not to an alien brand”. Nevertheless, for the sake of tradition and simplicity let us use the word ‘loyalty’ for any programme that aims to maintain the repeatability we discussed earlier.

Table 1. Attitude dimensions to loyalty programmes

<table>
<thead>
<tr>
<th>Name of dimension</th>
<th>Extreme negative</th>
<th>Extreme positive</th>
<th>Weight of dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit</td>
<td>“I’ll get nothing for it”</td>
<td>“It’s a good deal”</td>
<td>27.2%</td>
</tr>
<tr>
<td>Prestige</td>
<td>“Embarassing”</td>
<td>“Trendy”</td>
<td>17%</td>
</tr>
<tr>
<td>Accessibility</td>
<td>“Complex, unclear”</td>
<td>“Simple, transparent”</td>
<td>9.6%</td>
</tr>
<tr>
<td>Game</td>
<td>“Serious, rational”</td>
<td>“Playful, emotional”</td>
<td>8.5%</td>
</tr>
</tbody>
</table>

Table 1. Attitude dimensions to loyalty programmes

The MOL perspective

The ‘customer loyalty journey’ started at MOL in 1998 when MOL ‘Törzsvásárlói Program’ – ‘Regular customer programme’ was first implemented. The basic principle was that after registration, customers could collect (earn) points on their spending written up to a plastic card, equipped with a data storage chip. They could also redeem (burn) the points when bought either fuel or shop items at MOL

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filling stations. This meant that both account and transactional information was stored at the card and the central card processing system was responsible to reconcile data between the card systems and a central database. This method was selected at the time due to low data network bandwidth and availability across the filling station network. This system enabled an offline operation, i.e. earning and burning was possible even though there was no online connection between the card terminals at the filling station and the central card authorisation system.

This scheme was limited to MOL network and the points people could earn could also burn within the same filling station network. MOL achieved little over 600,000 registered customers but the active users – who interacted at least once in the past year – are just half of this number.

MOL is also a founder and member of the ‘MultiPoint’ loyalty programme operated by OTP Bank. This enables customers to earn and burn points (one point is equivalent to one Hungarian Forint) to/from their OTP and burn points (one point is equivalent to OTP Bank. This enables customers to earn ‘Multipoint’ loyalty programme operated by MOL is also a founder and member of the programme as a result of the merger of all Deutsche Telekom interest companies.

A DECISION TO BE MADE

In the meantime, several retailers started their own loyalty schemes more or less under similar principles, occasionally with a more sophisticated IT infrastructure. By 2005, a commercially agile customer could easily be a proud owner of several dozens of loyalty programmes and thickened his/her purse. Little we know about the origin of coalition schemes but the first ones were certainly using convenience as an argument for having these programmes. The customers might not have a high perception of their products and service as ‘an object of desire’ when redeeming the earned points. By joining forces, these companies provide benefits for themselves and for their customers. The companies can extend their reach to each others’ customer base, hence achieving a much larger scale than they used to have individually. The customers will have also a much wider opportunity to collect their points and an equally wide choice to harvest the points for something that suits their needs when they need it. Large coalition schemes are usually owned by one or more of the participating parties. It can be also run by them or by their co-owned service provider, but an independent party can also be contracted for the operations. There are a few large schemes that are owned and run by professionals and not retail market players. The most prominent ones are Nectar in the UK, Smiles in France.

Fig. 1. Loyalty schemes

- Intimacy
- Village
- TESCO
- TESCO - Nectar
- Coalition
- Multipoint

The third founder, MATÁV withdrew from the programme as a result of the merger of all the Deutsche Telekom interest companies.

The answer is simple. Yes! Both assumptions are true. In fact, it appears to be a self-generated spiral. The first one (i) is true because customers wanted benefits for returning and they increasingly become conscious about their spending. They are more conscious about what they buy, where they buy it they consider several factors (price, quality, origin, bio, supporting local business, sundry benefits, etc.) before they actually spend their money. The latter assumption (ii) is also true, because competition is the foundation of market economy where all players want to be differentiated and attract more customers. Every retail business is interested to provide higher Customer Value Proposition (CVP) with the products/services that project enhanced Customer Perceived Value (CPV) relative to competition. At the same time, technology has become accessible at a reasonable price to serve all those customer and company needs like access anywhere (good network penetration), quick service (megabit network speed, ever increasing processing power), confidentiality (identification and secure data handling technologies), large/increasing customer numbers (wide range of system scalability), and specific offers (segmentation based on history).

Depending on the route one decides to take, at least four options are open to proceed towards a sensible loyalty programme. It is mainly determined by two major parameters; what customer base is reachable by the company and who else are the potential partners to work together in the programme (see Figure 1).

1. Intimacy

The company with a limited number of customers in reach can decide (or can find itself in a situation) where it is best to create a scheme on its own. To make such a scheme work, it has to find a differentiator that makes it worth to customers to return. These can be centred on a deep knowledge of the customers, having a close relationship with them, treating them like part of the family in a local shop, essentially creating and maintaining a very close, intimate relationship.

2. Village

A natural progression from the previous stage is when several smaller players get together and broaden their proposition to essentially the same customer base. The partners know each other well, they probably have even ownership relations, too, and they cherish their customers like shopkeepers to do with their regulars along the high street at the village.

3. TESCO

There are few players who have such a scale that justifies a standalone scheme. The name of this class probably best describes it. There are on average 3.7 million transactions executed at TESCO in one calendar week in Hungary. No one can beat such a number of customer interactions, and it is well harvested by the company’s own Clubcard scheme across Europe. The major principle in Hungary is that every HUF 200 is rewarded back one point, which is an opportunity to spend only when an eventually accumulated 400 points get converted to a HUF 400 voucher. We consider a 0.5% discount of the previous purchase when redeeming a voucher, which is actually earned at a consecutive purchase.

Based on the immense success in the UK, TESCO established its financial service line as well as its travel agent activities in the Central European countries. The latest retail type service penetration from TESCO is mobile telephone that has been running successfully in the UK and Ireland. After Slovakia, Hungarian shoppers will have a choice to join the TESCO/Vodafone offer in 2012. This might question the single customer loyalty scheme, but it is very obvious that these businesses belong to one company.

4. Coalition

There are few players who can match up to TESCO. However, there are market leaders at certain segments who already have a relatively large pool of customers. Their dilemma is if they were running a standalone scheme, the customers might not have a high perception of their products and service as ‘an object of desire’ when redeeming the earned points. By joining forces, these companies can extend their reach to each others’ customer base, hence achieving a much larger scale than they used to have individually. The customers will have...
offers, all kinds of creative ways to promote goods and services, customers become fatigued; they often get tired of all the hassle involved with selecting what they really want or need. However, if they bump into something that is really close to their actual needs, that is exactly what they wanted for quite some time or something that matches exactly their desire then they are far more willing to spend on it. If this happens, then both the customer and the company are satisfied and such transitions shall enhance the relationship between them. This transaction certainly involved a relevant offer. Relevant for the customer because the offer has an exact match with the needs and relevant for the company because it is part of its service / product portfolio. The only trouble with it for the companies is to identify / create that something, that relevant offer for the several million customers.

Despite all the complexity of customer-company relationship, there is no other way but to get to know the customers, learn about their buying habits, their preferences.

The customer ‘process’

Some of the more experienced readers might recall the times when a small grocery shop served only the nearby community, the shopkeepers knew each and every customer, they greeted them by name, they knew about their problems and they had time to chat about things. That kind of relationship remains today only at smaller, local communities, but at the scale of nation wide companies, with several million members, we need a different solution to find the relevant offer.

In order to create relevant offer in a large scheme, the following steps are necessary:  
1. Acquiring members  
2. Collecting data on customers’ spending  
3. Analysis of data and understanding customer behaviour  
4. Segmentation of customers  
5. Developing the relevant offers  
6. Targeting customer segments with relevant offers.

Figure 2 is a highly simplified visualisation of what a coalition scheme needs to process in order to assure that their offer will not be more than an endless point gathering program for a vague catalogue item.

Figure 3 is a good indication of how much more a coalition scheme can contribute to both (1) acquiring members and (2) data collection on their spending. A single retailer can grow membership only within its own network, but more retailers have a larger pool of customers to join in. Similarly, the coalition partners’ outlets provide more data on existing members’ spending, hence there is a statistically bigger certainty to identify trends and behaviour. Moreover, banks and telecommunication companies actually have customers’ spending related data even from outside the coalition; after all, people use their bank cards everywhere and interact with their mobile phones increasingly. With necessary attention on personal data protection, aggregated information can be fed back to the scheme from these partners, too, that will enhance the picture of the identified customer segments within the coalition scheme.

The art of a large loyalty scheme is a thorough (3) analysis of data related to individual customers’ spending and establishing a sound conclusion of their behaviour. A tangible proof of how important is this step these days is the result of a survey conducted amongst 104 executives who are directly responsible for customer relationships. As Figure 4 indicates, over three quarter of the respondents consider in-depth customer knowledge as number one challenge. Moreover, understanding customer behaviour is number two.

The next step in the process is a proper (4) segmentation of customers based on the typical behaviour they possess. These two steps require an in-depth knowledge of the market, its social, economic, as well as regulatory environment and largely require human intelligence. However, with the recent development of software solutions and hardware processing power, a purpose built IT package is employed to do this. Ideally, it is part of the loyalty package that administers the earning and burning process but transactional data is often exported into a separate system (or professional service provider) that will identify the trends, customer habits and recommends segmentation. Sophisticated segmentation methods go well beyond social demographic data and take advantage of the historic spending of individual customers. The more precise the analysis, the narrower the segments can be, yet, there should be only as many segments as the responsible staff can administer. The right segmentation shall enable the desired differentiation in the service / product offers (4).

Once the segments established, the partners (ideally together) shall find the appropriate product / service portfolio in certain situations and (5) develop their relevant offers as well as configure that to the loyalty IT solution. This shall ensure that each Member will have relevant offer(s) because they are members of a defined customer segment.

The final step is (6) targeting customer segments with relevant offers. The impact on the customer can be achieved by active sales process, by promotion via appropriate channel. With all the promotional effort, there are customers who are not affected by the upfront work, which makes the second phase of targeting even more important; the actual interaction with the customer. Staff has to be properly trained to recognise what to offer to which customer (segment) and bridge the gap between uninformed customers and available relevant offers.

When a member interacts with a partner and the shop attendant (with the help of the system) presents the relevant offer, chances are that the member will take up the offer.

Repeat business

All so called loyalty schemes’ objective is to make people somehow attached to the company, hence make them come back with their purchase intentions again and again. MOL has also found that in its current loyalty programme the average customer basket size is twice as large, than an
average customer’s basket who is not a loyalty card holder. Taking into consideration the customer lifetime value (LTV) of active loyalty customers vs. ordinary customers, the difference grows to threefold over a five year horizon. This presents a large monetary difference that no retailer can neglect these days.

In a well founded coalition scheme, there are several partners (service providers, product sellers) who together cover a typical customer basket (food, clothing, telecommunication, banking, transport, etc.). The likelihood that a high CPV item for a customer exists in a coalition scheme is proportional to the participating partners’ product/service portfolio. Retailers are often criticized for their loyalty programme that they make people collect few points on their high value purchases yet give peanuts when it comes to redeem the points. This is particularly true for fuel retailers for an obvious reason; the margin content on fuel is far less than it is for clothing, white goods or on the majority of grocery store merchandise. Therefore a coalition scheme is twice beneficial for a fuel retailer; customers collect points on a wide retail scope as well as have the opportunity to redeem points for ‘an object of desire’. MOL also expects benefits from the future ‘Multipoint’ loyalty scheme as a result of partnering with OTP a grocery chain, a telecommunication company, a fast food network and several other retailers complimenting each others portfolio.

Collecting the vignettes – best customer management (BCM)

One of the recent years’ top sales phenomena is the so called best customer management (BCM) type promotion. The essence of BCM is also to achieve customers’ regular return. By returning regularly to the retailers over the promotional period, customers earn the right to buy a high CPV item for an attractive price. The supplier of the high CPV item is assured for high volume sales, but over the years it also turned out that the positive effect of such promotion is strictly limited to its defined period. Once the collection is complete the temporary nature they are not suitable to support the desired long-term / permanent customer-retailer (loyalty) relationship. Therefore, MOL concentrates on the coalition based ‘Multipoint’ loyalty scheme.

Benefits delivered by technology

The role of technology was discussed as part of the customer process, but it is important to highlight, what is made available in a sophisticated loyalty IT package and with the integration of mobile and internet technologies. The following items are far from a complete list of advanced functionalities, but they indicate the journey ahead:

- The customer identification can be now achieved not only with plastic cards but with barcode that is placed either on a keychain or even displayed on a mobile screen. Radio frequency driven stripe cards, a radio frequency operated (RFID) keychain or even a barcode on the mobile phone enable smooth interaction with the customers.

- Competent systems are also required for running a joint promotion in a coalition scheme, where two or more partners agree on providing benefits for customers based on defined buying criteria.

Figure 5 below is an indication of those medium that will serve as customer identification under the new ‘Multipoint’ loyalty scheme, where they can collect points together onto the same account and set the rights of redemption. All family members have their own cards, they all earn the points onto the family account but only the mother can burn the points.

Conclusions

MOL embarked on the road of customer loyalty in 1998 and achieved similar success to its peer group. However, recent market developments took us to a tipping point when MOL had to decide which way to proceed in order to improve the loyalty aspect of our customer relationship. The revitalisation of ‘Multipoint’ loyalty programme has been decided as a joint effort together with OTP Bank and the creation of a multi-partner coalition scheme is now under implementation.

The intention is to achieve long-term, lasting customer relationship by getting to know the customer community much deeper, by segmenting them according to their behaviour and by proposing them relevant offers that they are most likely to take up.

The expectations include good understanding of that part of the market which operates in cash, better customer engagement and ultimately increased results in both fuel and non-fuel sales.

References

[1] Internal project work, MOL Group Retail Loyalty Programme – Hungary, Retail Division, 2009-2010

Keywords: Retail, customer, loyalty, relationship, CVP, CPV, BCM, behaviour, Multipoint

Reviewed by László Piry

Gábor Farkas first got involved with MOL in the MARS project as consultant from Accenture in 1997. His process oriented consulting experience was well utilised in the outsourcing focused part of his career. After then being responsible for shaping new outsourcing engagements he became Commercial Director for the European finance and accounting outsourcing engagements. He was responsible for the Bratislava delivery centre when MOL offered him to join a major corporate project in 2007. Since then Gábor held senior advisor and regional management positions at the Corporate Centre, Information Services and recently at Retail. Gábor graduated as a Mechanical Engineer at Miskolc University. He earned his MBA degree at Ashridge Management School in the UK.
The role of microbiology in oil industry, from the laboratory research to the pilot MEOR test

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Abstract

One-half to two-thirds of the oil ever found is still in the reservoir even after primary and secondary production. Microbial enhanced oil recovery (MEOR) is one of the tertiary methods applied to increase oil recovery. This technique exploits the ability of microorganisms either indigenous or injected to produce useful products such as gases, biosurfactants, biopolymers, etc. to improve oil recovery. Since 1946 more than 400 patents have been issued on MEOR, but none of them could gain widespread acceptance by the oil industry. This paper reviews the progress, achieved over the past years in enhanced oil recovery with Pseudomonas aeruginosa bacteria and their metabolic products, and the MEOR technology development in Hungary.

Introduction

Oil industry has to face the increasing crude oil demand of the world nowadays. Conventional technologies only recover about one-third to one-half of the oil initially in place (OIH). The recovery of the remaining and trapped oil in the reservoir requires more and more sophisticated and expensive tertiary technologies, called enhanced oil recovery (EOR). Globally, about 1 trillion barrels (0.16 Tm) of oil have been recovered until today and about 2 to 4 trillion barrels (0.3 to 0.6 Tm) still remain in oil reservoirs being a target for EOR technologies [1]. The most effective techniques for tertiary oil recovery are the chemical enhanced oil recovery (CEOR), heat enhanced oil recovery (HEOR) and miscible displacement oil recovery (MDOR) [2]. However, all these technologies have shortcomings that constrain their implementation. These include shortage of gas such as carbon dioxide for MDOR, premature water breakthrough, problems of exorbitant fluidity in MDOR; high cost and unsuitability of surfactant enhanced oil recovery; the degradation of polymers by mechanical damage or microbial action; demetnution blockage in polymer enhanced oil recovery (PEOR); damage to the equipment in the well or crude oil coking for oil caking under the formation in HEOR; and the low efficiency of heat utilization in steam-enhanced oil recovery (SEOR) [2]. Clearly, additional technologies are needed to enhance oil recovery.

The microbial enhanced oil recovery (MEOR) was first tested by Beckmann et al. in 1926 [3]. Since then numerous studies demonstrated the effectiveness of this technology. MEOR is a collection of techniques that utilize microorganisms and their metabolic products to improve the recovery of crude oil from reservoir rock. MEOR technologies involve stimulating indigenous reservoir microbes, injecting single species, consortia of naturally occurring bacteria into the reservoir, produce specific metabolic products or perform specific activities to improved oil recovery [4]. MEOR can also involve injection of microbiologically-made agents produced ex situ by traditional fermentation approaches. Microbial methods are new and experimental area of EOR research. Generally, there are two ways to apply MEOR.

Cyclical microbial recovery is a single-well technique, similar to cyclic steam and cyclic CO2, simulation method [5]. The first step is a short (few hours) injection period when microorganisms and nutrients are injected into the production wells. Next, the wells are shut-in for a period long enough to allow microbial growth and product formation. The wells incubation period may last days or weeks. Finally, the oil production phase begins and extends over a period of weeks or months. When oil production declines, another injection phase is started. The goal of cyclical microbial recovery is to alter the drainage patterns and rock wetability near the well to improve oil production rates. Cyclical microbial recovery may not increase the ultimate amount of oil recovered from a reservoir, but can increase cash flow and thus and a positive benefit to the producer.

In microbial flooding nutrients are injected into the formation to stimulate the growth and activity of microorganisms indigenous to the formation. If the requisite microbial activity is not present, microorganisms can be bioaugmented into the formation along with the nutrients. The goal of microbial flooding is to alter crude oil properties and/or reservoir flow patterns within the reservoir to mobilize entrapped oil and increase the ultimate amount of oil recovered from the reservoir [5]. From this point of view a plugging effect of the biomass or the extracellular matrix of bacterial biomass can be very important. Due to reduction of the permeability, fluid and surfactants (naturally occurred or synthetic) are redirected into the unwept regions of the formation, which gains additional oil recovery [6,7].

Several field tests of microbial selective plugging have been carried out in the past decades. Gray et al. (2008) [8] suggest that reservoirs with less than 6% of the pore volume in high-permeability layers would be the best prospects for microbial selective plugging. Results of basic research and field studies show that MEOR is broadly applicable to many different kinds of oilfields, since it is simple to implement, needs low capital investment, can give a quick response, it is more flexible than other EOR approaches, and uses biodegradable and renewable resources. Maudgalya et al. (2005) [9] reported a survey in which they concluded that 96% (388 out of 403) of the reported MEOR field trials worldwide were considered successful.

Although MEOR technology is a more or less accepted tertiary industry, only a few studies are known in Hungary. In most cases the application of cyclic microbial recovery had been occurred when nutrients and glucose were injected into the reservoir. There were some trials to bio-augment exogenous fermented bacteria to the wells also. Although both approaches have been resulted in
increased oil recovery, the microbial enhanced oil recoveries are still out of practice in Hungary until yet. Already three years have passed and the well is still producing similar results.

In recent study we have investigated the possibility of the application of exogenous biopolymer synthesized by Gram-negative Pseudomonas aeruginosa strain in MEOR technology. In the project the production, characterization and the optimization of the biopolymer for MEOR process had to be solved.

Materials and methods

ISOLATION OF BACTERIA ABLE TO SYNTHESIZE BIOSOLYMER

The samples of the investigated wells (more than 100) were inoculated first onto Bouillon medium (10 g pepton, 3 g Beef extract, 4 g Na₂HPO₄·12H₂O, 3 g NaCl and 25 g agar in 1,000 ml distilled water, pH adjusted to 7) and incubated for 48 hours aerobically at 37 °C. The ability of bacteria to utilize or mobilize crude oil was tested in the surface of DSM-457 (2.44 g Na₂HPO₄, 1.52 g KH₂PO₄, 0.5 g (NH₄)₂SO₄, 0.2 g MgSO₄·7H₂O, 0.05 g CaCl₂·2H₂O, 10 ml SL-4 in 1,000 ml H₂O) agar plate covered with crude oil (500 μl oil, solubilised by 10% hexane), aerobically at 37 °C for 168 hours. The bacteria were capable of degrading or mobilizing crude oil were picked up and were inoculated into modified Bouillon medium where biopolymer synthesis took place at 37 °C for 5 days aerobically. From those bacteria (20 isolates) that were able to synthesize structured bacterial biopolymer the characteristic data were tested in emulsification experiment at 37 °C on these data we calculated the total (ER) recovery during the primary production phase. Steam, tensides and/or polymers are injected into the reservoir, than the well is shut in. After a sufficient time, generally a week or two, the injection wells are placed back in production. This cycle may be repeated until the response becomes marginal.

IDENTIFICATION OF ISOLATED BACTERIA

Bacterial genomic deoxyribonucleic acid (DNA) was prepared by conventional phenol extraction technique [10]. The 16S rDNA sequence was amplified by polymerase chain reaction (PCR) method, using the primers EubA (5' - AAGGAGGTGATCCANCRCRA-3') and EubB (27F: 5' - AAGGTTGATCMTGTCAGC-3') [11]. The reactions were carried out in 30 μl volume, 0.5 μl genomic DNA preparation served as template. Samples were subjected to PCR using the highly accurate KOD DNA polymerase (Novagen) in a Peltier thermocycler (MJ Research) with the following program: denaturation at 94 °C for 2.5 min, 30 cycles at 95 °C for 20 sec, 55 °C for 20 sec, 70 °C for 25 sec and final extension at 70 °C for 20 sec. The PCR fragments were analyzed by agarose gel (%) electrophoresis and made visible by ethidium bromide staining and UV transillumination. The PCR products were purified using the QIAquick Gel Extraction Kit (Qiagen), and sequenced at the DNA sequencing laboratory of BayGen Institute (Szeged, Hungary). For sequence homology search, we used the SEQUALMATCH tool at the Ribosomal Database Project (RDP; [12]) server.

RHEOLOGICAL MEASUREMENTS

For the determination of the rheological properties of crude oil and biopolymer samples, programmable Brookfield DV-I+ rotational viscometer was applied. The flow ability of crude oil samples was determined according to plastic viscosity calculated by the software of the instrument automatically, while in case of bacterial polymer the characteristic data was visualized at shear stress (N/m²) and shear rate (1/s) (apparent viscosity). Due to the inhomogeneous structure of the polymers (viscoelastic gel or liquid depending on the concentration) apparent viscosity had to be calculated.

STUDY OF THE EFFECT OF BIOTENSIDE, OIL EMULSIFICATION

The biotenside content of the biopolymer and the ability to generate emulsion with crude oil was tested in emulsification experiment at 37 °C for 168 hours aerobically. The 5 days old biopolymers synthesized by Pseudomonas aeruginosa ‘785’ and ‘1604’ strains were completed with reservoir water and crude oil in the ratio shown in Table 1. Proceed to mechanical homogenisation of the different solutions the volume of oil-water emulsion was determined after 4, 12 and 24 hours.

MEOR: LABORATORY MEASUREMENTS

The microbial enhanced oil recovery was examined in a self-made laboratory model system (Figure 1). The simulation of the pressure (p), temperature (T) and the flow rate of the reservoir water characteristic for the reservoir can be set using this instrument. During the determination the MEOR effect of the biopolymers on 125-250 μm fraction of original cores and the original crude oils of the given wells were observed. The treatment of the core was the following:

- Determination of pore volume (PV) and the water permeability
- Determination of initial oil (Sₚ) and water saturation (Sₚₗ)
- Determination of residual oil saturation (Sₙ)
- Oil recovery with 1 PV bacterial biopolymer (P. aeruginosa 785 and 1604) double diluted with synthetic reservoir water
- 2 PV flooding with synthetic reservoir water.

Results

Pseudomonas aeruginosa strains were isolated from oil well product as a part of the natural flora on oil covered medium. The selected bacterial strains called 785 and 1604 are proved to be used successfully. Pseudomonas aeruginosa strains were isolated from oil well product as a part of the natural flora on oil covered medium. The selected bacterial strains called 785 and 1604 are proved to be used successfully.

Both strains produced high-quality biopolymer growing in special medium. This is an alginate-type polymer, which contains mannuronic and guluronic acid units. The balance of β-1,4-linked D-mannuronic acid and L-guluronic acid residues lead to viscoelastic behaviour of the polymer (see the inserted picture on Figure 3). Measurements on oscillation viscosimeter proved that the biopolymer produced by Ps. aeruginosa shows viscoelastic behaviour and this character is preserved in the diluted form as well. For the acquisition of structural information, we concluded on the basis of the frequency sweep measurements that the...
Our emulsion stability measurements showed that neither the '785' nor the '1604' strains has formed an emulsion which was stable for more than 24 hours. In addition, the thickness of the emulsified layer was larger in the '785' system under the same conditions after 4 hours (Figure 4). On this basis, it could be assumed, that larger amount of surface-active components are produced by '785' during the biopolymer production. These surfactants are rhamnolipids [13]. The produced rhamnolipids contain either one (mono-rhamnolipid) or two (di-rhamnolipid) linked rhamnose sugars with alkyl chains. The chain length can be varied from C8 to C14, which gives high variability.

MEOR TESTS

The distributions of the residual oil yield differ in situ sub-processes of laboratory MEOR experiments, depending on which bacterial cultures were used in the tests (Table 2). The results proved that the majority of the recovered oil during laboratory MEOR measurements was detected in the displacement water injection phase in the case of Ps. aeruginosa '785', while the '1604' marked polymer showed enhanced oil yield during its injection phase. This effect can be explained by the higher stability of the '1604' (core forming effect of the biopolymer) and the higher biosurfactant content of '785' (core forming effect of the biopolymer and oil emulsification of the biotensides).

We recorded on-line the pressure differences during the laboratory tests and we observed pressure rises between the two ends of the core during the biopolymer injection phase. Subsequently, in most cases we detected partial residual oil yield. This reinforces our hypothesis that besides the oil emulsification due to the secreted surface-active components the biopolymer has a special rock-forming role. Namely, after the sealing of larger diameter pores the displacement fluid, rich in biotenside molecules can flow to the low diameter pores. Henceforth it can easily emulsify the residual oil.

Table 2. Differences between polymer solutions during oil recovery processes

PILOT TEST

Based on the results of laboratory research a pilot test for the application of Ps. aeruginosa '785' biopolymer as MEOR fluid was carried out in 2008.

During the treatment of '22. well', the 9 m³ well treating fluid (composition see in part 'Materials and methods') was easily injected into the reservoir through the 'Huff and puff' way. Reopening the well after 7 days the production restarted without any problem and resulted in a significantly increased recovery. However some comments have to be made in relation to the treatment. The well treating 'Huff and puff' method rather leads to suppress the oil that hides in capillaries near the well base zone. In our case the biotenside-biopolymer solutions could clean the area around the well bore due to the surface-active substances allowing the residual oil to flow easier to the production tubes. The quality of oil produced subsequently to the treatment has clearly improved. Figure 5 shows the flow curves of the oil samples produced by '22. well'. We measured the viscosities at 20 °C to gain information on the water content of each sample. 8 days before the treatment the water content of well product was 20% (v/v), while the emulsified part of well product increased to 20-25% (see Figure 5). The excessive formation of emulsion is the clear evidence of the injected polymer solution ability to reduce the interfacial tension in the oil-rock system. Examining the '22. well' products we found that, the sedimentary, sandy phase ratio was specifically high before the treating procedure. All samples also contained a small amount of emulsion. Figure 6 clearly shows significant reduction of the sediment, owing to the well treatment with biotenside and biopolymer solutions made by Ps. aeruginosa '785'. Practically no sediments were detected in the oil sample, 29 days after the treating process.

After that the well treatment dynamometric well analyzer measurements were also carried out by the specialists of MOL Plc. They found, that the influx of liquid from rock-layer to well bore has been grown, and the amount of well product doubled due to the bacterial intervention. Already three years
have passed and the well is still producing similar results.

Conclusions

The scale-up production of biopolymer by Pseudomonas aeruginosa ‘785’ was successfully completed, and it was applied in 22 wells’ ‘Huff and puff’ treatment. The produced biopolymer is a viscous-elastic gel, which was proved with rheological measurement.

Based on the results of laboratory MEOR tests, the field experiment was carried out, where the ‘sanding’ effect of the reservoir consequently decreased. The amount of debris from bedrock was reduced in the samples after the treatment, thus the quality of crude oil is improved.

Based on the hydrodynamic studies by MCL Plc., the following conclusions can be made:

- The amount of produced oil was doubled compared to the initial state
- The quantity of oil / water emulsions was increased in the samples after the treatment.

Due to the effect of the biosurfactant and the biopolymer solutions, the entrapped oil fractions were mobilized in low-permeability regions, so the composition of well product was changed.

All the presented data confirm the necessity of further research and test of MEOR applications. All the presented data confirm the necessity of further research and test of MEOR applications.

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References


Keywords: microbial enhanced oil recovery, biopolymer, Pseudomonas aeruginosa, biosurfactant, pilot test

Reviewed by István Koncz, Dr.

Hajnalika Füvesi joined Zoltán Bay Foundation for Applied Research Institute for Biotechnology, as a PhD student. Within R&D activities, she practices oil-recovery processes on behalf of MOL on a model system. Furthermore, she has got a great experience in general microbiology and colloid chemistry. She is graduated as a chemist MSc in 2007 at the University of Szeged, Hungary.

Ákos Koós is employed by Zoltán Bay Foundation for Applied Research, Institute for Biotechnology as a chemist MSc since 2010. As a research fellow he takes part in the preparation and realization of national and international projects (R+D, FP7, etc.). He is responsible for the HPLC analytics. He had his PhD studies at University of Szeged from 2006 to 2009, where he was a member of Reaction Kinetic Research Group of Hungarian Academy of Sciences. He is the author and co-author of several international scientific publication (SCI).

Péter Kesserű, PhD is employed by Zoltán Bay Foundation for Applied Research Institute for Biotechnology since 1996. From 2003 he is the leader of the fermentation department of the Institute. Dr. Kesserű was the head of the Bioremediation Department since 2007, and established Industrial Microbial Department in 2011. Their main activities relate to MOL Group biotechnology development, like enhanced oil production and environmental research. He is the author or co-author of several original scientific publications. He has graduated as PhD at the József Attila University of Szeged on Environmental Chemistry Faculty at 2003.

Agnes Dergez joined Zoltán Bay Foundation for Applied Research Institute for Biotechnology in the theme of degradation of crude oil pollution in soil by biotechnological methods as a student of University of Szeged, Hungary. Then she started to work in the Institute as a PhD student. At the Institute, she has been working as project manager from 2009, then as research fellow from 2011. At present, her main scientific projects are the investigation of biorefinery of high added value plant materials and properties and bacterial products. She was graduated as Hungarian-English and English-Hungarian technical text translator in Biology MSc at University of Szeged.

Margit Balázs was graduated at University of Szeged as chemist at 2004 thereafter he became the Phd student of Imre Méc, Dr. at the Institute. From 2008 she worked as research fellow in BayBio Institute and from 2010 – after the structural reorganisation of the Institute – she became the leader of the Department of Applied Microbiology. Her research activities concentrate on environmental microbiological and soil diversity experiments. She has educational activities at University of Szeged and he was the supervisor of several PhD students. She finished her studies at Univ. of Szeged Faculty of Economics and Business Administration as economist (engineer) in 2011.

István Kiss, PhD was graduated at University of Szeged as biologist in 1995 thereafter he became the PhD student of Miklós Kálmán, Dr. at the Institute. He worked as a scholar at Jacob Blaustein Institute for Desert Research (Sede Israel) from 1998 to 1999. After returning he became a research fellow in BayBi Institute and he obtained his PhD in 2002. From 2004 he was the head of the Department of Applied Microbiology and from 2007 he is the leader of the Institute for Biotechnology. He has educational activities at University of Szeged and he was the supervisor of several PhD students.

Imre Méc, DSc, in the year 1954 received a degree as a biology-chemistry teacher. In 1958 received a doctoral status of the
Hungarian Academy of Science. He became the candidate of science in 1977 associate professor in 1979. Between 1957 and 1989 he worked as junior, later as senior scientist at Institute for Microbiology of Semmelweis University (Budapest). From 1989 he became the head of the Biotechnology Department of Szeged University. He retired in 1996, and later became the head of the Department of medical microbiology at the Zoltán Bay Foundation for Applied Research, Institute for Biotechnology. His main research fields of interest were development of environmental and bioremediation technologies. He passed away in 2011.

Sándor Puskás, Dr. is employed by MOL as a petroleum engineer MSc since 1985. He is a petroleum engineer and holds R&D senior expert position at the New Technologies and R&D Department at the Exploration and Production Division of MOL, in Szeged, Hungary. He has 25 years of experience as a field, research and development engineer in the crude oil production. He holds a Dipl. Eng. degree in petroleum engineering from Moscow I. M. Gubkin Petrochemistry and Gas University and a Dr. Univ. degree in colloid chemistry from Attila József University in Szeged, Hungary. He holds a postgraduate degree in R&D management and human management from Budapest University of Economic Sciences Management Development Centre. He is the author and co-author of several technical papers.
Upstream Information Systems developments from the perspective of integration in the last 5 years

Abstract
Thanks to the spread of efficient information technology (IT) systems over the past twenty years, but especially in the last decade, the upstream process has been accelerating significantly in the oil and gas industry.

Since the paper might lose its ability of preserving data and information, might become unreadable and fixed, it is time to fully give up working on paper. If every single professional idea exists in digital format, we could easily and effectively take step forward in a given topic. Otherwise we have to wait couple of days while the idea is digitized and translated, then loaded to the appropriate modelling systems. The preparation of datasets for different geo-modelling systems might be outstandingly time-consuming in particular cases. Based on international experiences this process might consume even the 60% of an entire modelling task from data preparation to the results.

On the way of MOL we think that the best solution is to provide specialized database and application system to each geo-discipline (geology, geophysics, drilling, reservoir management, production engineering, etc.), then put an integration tool on the top of that, like a large wing, which aggregates the different types of information on defined interfaces.

This article explains Exploration and Production Division (EPD)’s developmental milestones regarding special upstream IT from 2006 to the present day.

Összefoglalás
Integritált szemléletű upstream informatikai fejlesztések az elmúlt 5 évben

Közönségtől a hatékony informatikai rendszerek eltérésének az elmúlt húsz évben, de különösképpen az elmúlt évtizedben, az upstream folyamatok jelentősen felgyorsultak az olaj- és gáziparban.

A papír elvesztheti adat- és információ-tárolási képességét, olvashatatlanná váhát és megszűrhál, így itt az ideje teljesen felhagyni az adatok papír formában való tárolását. Ha minden egyes szakmai ötlet létezne digitális formában, akkor könnyen és hatékonyan tudnánk lépésetek tenni előre egy adott témban. Egyébként várunk kell pár napot, amíg az ötletet digitálisizáljuk, lefordítjuk és a megfelelő modellező rendszerbe betölthük. Az adatok előkészítése különböző geomodellező rendszerek számára rendkívül időigényes lehet bizonyos esetekben. Nemzetközi tapasztalatok alapján elmondhatjuk, hogy az adatelőkészítés a teljes modellező munkafolyamat akár 60%-át is kihettei.

A MOL-ban mi úgy gondoljuk, hogy a legjobb megoldás az, ha szakmailag specializált adatbázisokat és alkalmazásrendszereket biztosítunk minden egyes geodiszciplínának (geológia, geofizika, fürás, tárolómenedzsment, termelés, stb.), aztán pedig kiválasztunk egy integrációs eszközt, mely definiált interfészsen keresztül aggregálja a különböző típusú információkat.

2006-2010: Plan – Manage – Implement – Integrate

A közleményben bemutatjuk, hogy a Kutatás–Termelés Divízió milyen fejlődésen ment keresztül 2006-tól napjainkig upstream informatikai szempontból.

Initial state in 2006
We had several dataset gathering and database-like solutions of different professional areas (Geology & Geophysics (G&G), Production, Petrophysics, Drilling), but the digital fundamentals of information storing and managing was just partially existing or totally missing.

These so called geo-IT systems did work alone and separately in MOL Group. There was no standard way of how these systems would be connected to each other. It was obvious that we need a team who can manage projects for developments of databases and application systems harmonized with each other.

In 2006 a 7-membered upstream IT team was established with brand new strategy in order to mitigate and/or eliminate gaps within the EPD IT systems. Each expert of the team was responsible for a professional area to be improved such as Geology & Geophysics (G&G), Production, Petrophysics, Drilling), GIS (Geographic Information System), Document Management, Production, Petrophysics, Drilling and Well Planning, and Knowledge Management.

First of all we had to launch a comprehensive analysis in order to get a real and clear picture on the information technology status of Exploration and Production Division (EPD). It meant that alongside the upstream value chain we sat together with the key users of each geo-discipline and asked them on the core processes in which they worked. As a result of the analysis we created the process map of EPD and revealed the IT gaps of the division.

In the first project plan covering the period of 2007-2008 we set several target areas aimed to eliminate the biggest gaps. Figure 1 shows what kind of gaps we faced in 2006. As an overall evaluation we found e.g. in case of Field Engineering that there were pretty large gaps in their processes caused by missing engineering database and suitable technical applications.

On the basis of analysis of other upstream processes we planned introduction of new systems to facilitate integrated approach. It means that we planned one joint solution to eliminate even more gaps. For instance in case of well planning we took into account...
Table 1. Overview of completed upstream IT projects in the period of 2006-2010

<table>
<thead>
<tr>
<th>Projects in 2006-2010</th>
<th>Scope and target(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum Resource and Reserve Inventory - IHS® Energy</td>
<td>To provide geotechnical and business information and database for the EPD projects</td>
</tr>
<tr>
<td>IPIMS</td>
<td>To provide geo-professional e-learning systems</td>
</tr>
<tr>
<td>Digital Well Archive (DocPort)</td>
<td>To set up the digital well file library, to provide a favourable and reliable environment for the change management of the wells’ documentation, to create a single physical archive for the paper well files</td>
</tr>
<tr>
<td>Centy Enterprise Content Management (ECM) - Laboratory Information Management System (LIMS) (GIS) users</td>
<td>To provide a solution to register, store, backup and make reusable the primary laboratory data and published analysis reports of Upstream Laboratories (in line with legal obligations)</td>
</tr>
<tr>
<td>Regional Asset Management Desktops</td>
<td>To support on-site data acquisition, processing during data room visits, data and information exchange with partner companies, to create the infrastructural environment of geotechnical asset and project evaluations</td>
</tr>
<tr>
<td>Petroleum Resource and Reserve Inventory - MERAK System</td>
<td>To create information management background for the petroleum resource tracking, assessment and reserve evaluation processes of MOL</td>
</tr>
<tr>
<td>Integrated Geological and Reservoir Modelling System Development - RECALL</td>
<td>To implement the one-off modernization of the IT operation supporting system of the G&amp;G application and to consolidate the result of this development (including PetrisWINDS® Recall for petrophysics)</td>
</tr>
<tr>
<td>Uniform platform for Geographic Information System (GIS) users</td>
<td>To focus on consolidating and technology update of the existing upstream application portfolio. According to main goals we should further develop and modernize our current Integrated Drilling, Geological and Reservoir Modelling System (license extensions, change, migration, training elements)</td>
</tr>
<tr>
<td>Upstream Application Portfolio Development (yearly)</td>
<td>To support on-site-data acquisition, processing during data room visits, data and information exchange with partners, to create the infrastructural environment of geotechnical asset and project evaluations</td>
</tr>
<tr>
<td>Drilling Information Management Development (DIMD)</td>
<td>To replace several, partly technologically obsolete software currently in use, and drastically reduce cycle times of technical planning and reporting jobs. At the same time, by creating an integrated database will improve the quality of performance. As an additional outcome the technical database will be used as an information source by relevant E&amp;P units</td>
</tr>
<tr>
<td>Seismic Re-mastering</td>
<td>To decrease the risk of the data loss with re-mastering of seismic tapes, and uploading them to archived storage system</td>
</tr>
</tbody>
</table>

The team always strove for ‘off-the-shelf’ upstream solutions, namely purchasing industry-standard databases and applications which are easily supportable and have relatively cost-effective operation. In the beginning of 2006 we had all the necessary information to start individual projects to ‘erase’ systematically the gaps. Table 1 contains a list of the completed tasks. Four projects were significantly larger in their size, scope and budget than the others, these are:


Fig. 2. Web interface of DocPort document management system for well files

The Drilling Management’s processes. Since both activities are in close relationship and their processes are intertwined very well, it was a straightforward and reasonable solution to build up a common database and application system for both upstream units. It was Landmark’s Engineer’s Data Model™ (EDM™) solution which is natively linkable with G&G’s OpenWorks® system.

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Fig. 2. Web interface of DocPort document management system for well files

We had to electronically reserve in safe environment the paper-based well files library. It meant that we had to elaborate a kind of document management system which included scanned documents of million pages of different sizes. It had to meet the criteria to be searchable, indexable, structured, scalable and 7/24 available.

DocPort is planned to create a digital database of documentation of those wells drilled under the operational control of MOL. The wells supply relevant information today for the planning and execution of exploration, field development projects and the production operation.

In the period of 2003-2004 the EPD Kiskunhalas Production Unit executed the scanning of 847 analogue files of wells located in the operational area of the Unit. The digital archive was available for production and drilling experts working in the Unit’s area through user interfaces developed accordingly. The work handled as the pilot of DocPort. The DocPort project in fact, was the extension of the Kiskunhalas area pilot. In the frame of the project we intended to increase this database within one year that it should contain the documentation of all the wells located within the area of the existing mining plots, exploration licences and additionally on areas which might reasonably be potential operational areas in the near future. As
OpenWorks as well, so the relevant drilling information can be displayed (without long preparation) even in our basin model.

The geocommunity who just needs drilling parameters, various reports in their daily activities can also follow the operation via web-based interface of the database iWellsFile™. This intranet portal is ‘read-only’, so its users can read various reports, export technical data or grab the results of individual predefined requests even in Excel format.

Summarizing, the project had a very tough, but successful introduction. Nevertheless we will never be ready with the system. It is always on the way of changing by the regulations, processes, updates and working mechanisms. It needs constant supervision, support and development. It is the nature of database systems. Year by year we set new targets to widen the scope and tasks aiming new elements to be implemented. In 2011 we are now adjusting the database according to the professional processes in order to handle well site geology, logging, coring, Drill Stem Test (DST), logistics reports and laboratory results.

**Fig. 3. Infrastructure and networking of MOL’s solution in terms of OpenWells®/EDM™**

**Fig. 4. Functions of OpenWells® and Engineering Data and Application Model**

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**In 2006 Drilling Management department still operated a phone- and document-based reporting system. These reports were not internationaly standardized and the information was collected in paper-based well archives. Reutilising drilling information by associated engineering units in the course of the daily work was very time-consuming and roundabout. It was obvious that a new software tool is needed to organise and record information in a database, thus eliminating multiple data mining and long preparation work phase.

In the same time the well planning unit needed a new well design application package in order to replace their obsolete technical software. The majority of their actually used programmes were in-house developed in the mid 90’s. These softwares did not follow the latest technology (DOS platform), furthermore they were not supported by general desktop IT since 2002. In 2006 the well planning team had already Landmark well construction software package, but it was not sufficient in capacity and integrity to do well planning.

Originally the project had two main phases. One of them targeted the domestic customization and introduction of Landmark OpenWells® system. The other was for creating the database of the international sites such as Pakistan, Kazakhstan and Iraq. Of course in case MOL will have new upstream activities anywhere in the world we can provide our standardized solution in a package to the remote offices. In December 2008 the Pakistani system, in November 2009 the Kazakh one, in October 2010 the Iraqi database went live. They are still in production. Since January 2010 the system has been working smoothly for daily reporting of drilling and well work over activities in Hungary as well.

The system infrastructure and networking layout is displayed on Figure 3. Every rig has an own local database which can be synchronized automatically into the corporate database (available for the office workers) as per the administrator selects the ‘Transfer’ option of the software.

Figure 4 shows the wide usage of the drilling system. The biggest advantage (vs. Excel sheet) is that after the drilling or work over activities are finished we can make statistics and analyze data in a smooth way. It brings the next fact that the well designer experts can digitally follow their technical plans in the light of the real performance in the course of the drilling and/or well work over activities.

OpenWells® database can link directly to OpenWorks® as well, the relevant drilling information can be displayed (without long preparation) even in our basin model.

**DRILLING INFORMATION MANAGEMENT DEVELOPMENT (DIMD)**

In 2006 Drilling Management department still operated a phone- and document-based
INTEGRATED GEOLOGICAL AND RESERVOIR MODELLING SYSTEM DEVELOPMENT (RECALL: 2008-2009)

The project was planned to implement and introduce PetrisWINDS™ Recall database and its petrophysical processing applications in order to ensure accessibility and security of petrophysical data.

RECALL project was designed as a full-cycle integrated information technology for storing any borehole data recorded as a function of depth or time. This coverage includes standard single sample wire-line measurements, multiplex sample image data and waveforms, mud logging data, core data (including Special Core Analysis Laboratories (SCAL) and complex core data types), scanned core and thin section photographs, zones and complex zonation, etc. RECALL covers online corporate database of petrophysics as well original format digital well archive (raw and edited tape image files of borehole data, films, plots, photos and reports, in industry standard digital formats, received from logging contractors, service companies and other oil companies).

“The database itself is an integrated suite designed to store geological, geophysical and petrophysical data in a geoscientific environment. Its scope extends well beyond the simple wire-line well log data including mud logs, borehole images, waveforms (including Nuclear Magnetic Resonance), zones and zonal attributes, and more. The system provides comprehensive history tracking, identifying workflow, and maintenance of key environmental information.

Recall Corporate databases exist in two different implementations:

- Recall Online Corporate Database is used to store all types of borehole data in structures designed to optimize the speed of bulk data access and the efficiency of bulk data storage. Recall Online Databases can store any type of borehole measurement sampled as a function of depth or time

- An Original Format Digital Well Archive consists of Well data in its original digital format. It includes raw and edited tape image files of borehole data, films, plots, photos and reports, in industry standard digital formats, received from logging contractors, service companies and other oil companies. A Recall Archive or Original Format Database (OFDB) is a mechanism for cataloguing and organizing all of the data in an Original Format Digital Well Archive. The Original Format files are managed by Recall and can be archived on online, near-line or offline storage systems” [1].

As a result of the project we combined the above mentioned implementations in order to achieve strong integration. Figure 5 shows the workflow of combined using Recall Online and Original Format Corporate Databases.

INTERNATIONAL PETROLEUM INDUSTRY MULTIMEDIA SYSTEM (IPIMS: 2004-)

IPIMS is the product of International Human Resources Development Corporation (IHRTC) which is a comprehensive e-learning system covering all areas of upstream petroleum technology. This is a corporate solution for building competencies of EPD professionals at all levels. It includes petroleum geology, petroleum geophysics, petroleum engineering and formation evaluation.

Starting from 2007 we systematically manage training programmes for the geodepartments from different types of perspectives. Figure 6 displays the usage statistics for the last years.

In the following part we list the training programmes that have been organised and managed since 2004.

Training for different typed employees involved in US business processes

IPIMS can offer training
- for employees who have to obtain skills for independent work and task performance
- for senior officers who have to obtain skills for professional leadership in team work
- for experts who have to improve their professional / business skills for leading interdisciplinary teams (covering all upstream processes). In case of success the participant might be taken into account as potential manager in relevant upstream project. Precondition regarding the employee is to have 3-5 year experience in E&P sector.

E-learning training programme for Upstream Talent Programme participants

The role of E&P e-learning systems in talent management is unique. In this category the goal is not to acquire special, expert-level technological knowledge, but to offer a wide background material for interdisciplinary communication and wide range of E&P knowledge (Wide Range Knowledge).

The training period starts from handing over the talent tasks and ends with the reception of the evaluated tests.

The purpose of the training is to develop business / professional intelligence along the full spectrum of E&P business processes.

The individual training programs consist of 4-6 modules, and one is common. This common module explains the functionalities of the IPIMS competence development system and offers user skills. The other 3-4 modules do not contain overlaps on group level, or only at minimum degree, and it is selected from the IPIMS Background Learning Encyclopeda.
proactively capture the knowledge of those nearing retirement, through a series of interviews. Pre-retirement interviews focus on key decision paths, key documents, personal networks & experience such as tips and tricks, best practices.

We have several new ideas in order to improve knowledge sharing, knowledge retention processes such as:
- Collaborative intranet portal for geocommunities
- Collaborative upstream software and tools like a visualization room equipped with special 3D environment and aided by e.g. DecisionSpace® integrative application system from Landmark
- Social media tools like a company-Facebook
- Knowledge sharing portal in digestive manner like Wikipedia
- Brand new techniques to grasp senior’s knowledge
- Brand new methodology for critical knowledge retention.

Acknowledgement
I would like to say ‘Thank you very much!’ I really appreciate those experts’ great efforts who have been actively taking part in different geo-IT systems introductions starting with the professional contributors, through procurement and management to the end-users.

References

Keywords: integration, integrated, Upstream IT, Information, Data Management, G&G, drilling, reservoir

Reviewed by Marilla Bodrogi and Elek Turtegin

Tamás Krasznaiügyi is a Senior Upstream Information Systems engineer. He joined MOL Group in August, 1998 immediately after graduation from University of Miskolc. He worked as a petrophysicist between 1998 and 2006. Through this position he got acquainted with the upstream value chain and its working mechanism. In 2007 he joined the Upstream Integrated Information Systems Development team and led the project of Drilling Information Management Development. Since August 2010 he has been leading the Upstream Information Systems team.
Abstract

A new approach to modelling conventional and special core analyses has been studied and implemented as a feasible answer to challenges arising in certain aspects of data acquisition processes in this field. The present phase of development comprises studying the current trends in modelling and identifying those areas where new approaches have to be applied that are tailored to our specific requirements, constructing particle models of depositional rocks in a slightly modified way, analyzing and applying geostatistical methods for pattern generation of clastic rocks and developing lattice-Boltzmann method for modelling one-phase flow through porous rocks and porous systems’ characterization including pore size distribution. The following results of the R&D project iCore are inspiring, and prove that there is a considerable potential in developing and applying such models for both technical and economic reasons.

Összefoglalás

iCore – Fejlesztési eredmények és kilátások

A hagyományos és speciális magviaságtani előírások modellezésének új megközelítését tanulmányoztuk, és potenciális megoldástésként azonosítottuk ezt az új előírást és szakterület bizonyos adatadélok, aspektusai szempontjából. A jelenlegi fejlesztési munka a következő területeket öli fel: a modellezés irányzatnak vizsgálata és azon pontok azonosítása, ahol a követelményekhez szabott megoldásokra van szükség, üledékes közekek részecskéjelekeinek előállítása némileg módosított előírással, geostatisztikai módszerek tanulmányozása és alkalmazása törmékelés közekek mintázatainak előállítására, a rács-Boltzmann módszer tanulmányozása egyfázisú porózus közönet át bekövetkező áramlás modellzése céljából és a porózus rendszerek jellemzése, beleértve a porósumértést és eloszlását is. Az iCore K+F projekt első eredményei biztatni, amit alapján jelentős lehetőséget látunk az ilyen modellke fejlesztésében és alkalmazásában mind technikai, mind gazdasági szempontból.

Introduction

Computer modelling in the last decade gained lots of attention and a rapidly increasing number of applications. The reasons for that achievement can be found in the intensive theoretical development of various branches of science and a massive development of porous computers and computational technology that took place in the past ten years. These two facts together raised considerable interests in exploiting the new technology’s capabilities both in technical and economic terms finding those fields of applications where synergies between these achievements could be identified. The main drivers of such developments can be divided into two categories. The first is of technical nature, in details this is to find out what could not be known before and on account of either technical constraints of data acquisition or processing and speed. The other is about to do something better and faster than our competitors do – putting it simple: economic development.

In Upstream, especially in exploration there is a specific area where a technological breakthrough has been taking place and some scientists speak about a change of paradigm in conventional and special core analyses [1]. The aforementioned theoretical development referred to a new approach in flow modelling. This is the lattice-Boltzmann (IB) method that has been standing in the centre of intensive attention of scientists for a bit more than ten years long period of time and the fields of its applications are growing rapidly. In core analyses lattice-Boltzmann proved to be a useful modelling tool at pore size level of the rock and has found applications in both one phase flow studies and multiphase investigations.

An intensive development could be seen in the field of imaging technologies as well supported by huge improvements in computational technology. This considerably influenced the subject matter of flow simulations – the rock sample and its numerical equivalent. A bit more than ten years ago the technical limitations of computer tomography (abbreviated as CT) could not allow scientists to get a deep and detailed insight into the real structure of the rocks at pore size level. Therefore the numerical model of the rock sample was built up from elemental particles using computer models of rock formations. That meant considerable efforts to model the process of sedimentation, compaction and diagenesis with some advances in imitation of all these processes that originally affected the rock formation [2]. These works yielded physics-based sedimentation models among other approaches [3,4]. These and similar models, especially discrete element methods form an important branch of research and nowadays they find increasing number of applications in powder engineering technology in the first place [5]. As the imaging technique continuously developed scientists started to use real rock samples for mapping the nature of porous media at micron size. These techniques are micro-CT, nano-CT and focused ion beam scanning electron microscopy (FIB-SEM) that are capable of mapping the rock sample with a resolution of 1-5 microns and in the range of micrometer fractions down to ten nanometre scale, respectively [6]. These techniques have been being used intensively to explore the internal structure of the porous material and constructing its 3D numerical equivalent in the size of a few mm³. Today there are still some limitations on the quantity of data that can be processed within a reasonable timeframe therefore a trade-off should be kept between the size of the sample and the resolution of the mapping.

The above described stages of developments could be discerned if we take a closer look at one of the most advanced development teams. This is Numerical Rocks AS, the Norwegian team which has been developing its numerical rocks applications for 15 years [7]. They provide a wide range of core analytical services for companies. Other important teams are an American company, Ingrain, established by a former Stanford professor [8] and an Australian company, Digitallore, whose technology derives its origins from R&D and has been conducted at the Australian National University and the University of New South Wales over the past ten years [9]. They basically focus on two key areas like imaging technology and IB applications. They also provide a complex and fast service in the field of core analyses for companies.

The numerical equivalents of real rocks produced either by particle models or imaging technique were used for IB applications to model the rock sample’s permeability. Beyond this parameter many other can be calculated like pore size distribution and shear moduli and relative permeability that are very important for geologists and reservoir engineers to construct their models of the reservoir [10]. Using the achievements of such developments a considerable amount of analytical time and costs can be saved since real experiments are not only costly but time-consuming processes, as well. Of course modelling cannot substitute real measurements on real samples and neither do we intend to believe that, but in certain cases the amount of sample is limited or the total length of measurements exceeds a reasonable time modelling can be very useful. Simulation of flow of various fluids might be one of these areas in those cases when the experimental conditions are beyond the capabilities of our instruments. We had to experience many times that there
might be samples that are not appropriate for measurements at all because the conventional sample shape of core analyses can not be formed from the bulk sample consequently measurements can not be performed on them. These two latter fields of applications can be our targets in present R&D efforts and in case of success it might deliver some of the technical and economic advantages described above for geological and reservoir modelling at MOL.

Particle models show a wide range of approaches and solutions. The first trials focused on process-based and statistical solutions [2,3,13]. In the early phase of developments, the process of sedimentation was in the centre of attention and the whole process finished at that stage. Later on new solutions were achieved regarding the sedimentation and it continued with modelling the effects of compaction and some aspects of diagenesis in case of consolidated rocks. More sophisticated, so called physics-based models came into existence that took account of the effects of grain-grain contacts. This approach revealed some important results in the field of grain motion within tight packs of particles. Diagenesis and its effects on the grains forming a specific rock especially a consolidated one was still too difficult to be explored totally [14]. This was probably an important constraint on such models of consolidated rocks and this is why the attention of scientists turned towards the investigation of rocks and cements in powder engineering applications. In the late 1990s, the Saucier principle 

### Preludes to current developments

Though the aforementioned applications in imaging and IB modelling are highly sophisticated and cover a wide range of modelling areas and apply special techniques, they are limited to the size and character of the sample investigated in terms of what can be concluded from that sample volume regarding whole of the reservoir. In case of a particle model it is vital to compare the model with the real sample in order to prove its correctness. Since these systems are rather complex, comparison methods of comparison also bear some complexity. Possible inputs of the comparison are thin section investigations carried out by both geologists specialized in this field and the imaging of rocks and cements in and the powder engineering applications. In the late 1990s, the Saucier principle was another important constraint on such models of consolidated rocks and this is why the attention of scientists turned towards the investigation of rocks and cements in powder engineering applications. In the late 1990s, the Saucier principle was another important constraint on such models of consolidated rocks and this is why the attention of scientists turned towards the investigation of rocks and cements in powder engineering applications.

For such relations there can be simple rule of thumbs like the Saucier principle applied more or less successfully in sizing the bridging agent in various applications. Another path was taken by following other researchers who applied a different approach to forming closely packed particles. It could be applied to any packings but the best field of its application was in condensed matter modelling, consequently from our point of view it could not improve the results considerably [15]. As a result of the massive developments in computer technology, huge computational performance became available for small scale users as well. This enabled further jump-like developments in particle-based modelling of grain packs but this in the case powder engineering applications first of all [16,17]. By today discrete element methods (DEM) became prevalent in this field. They apply a totally physics-based approach giving account of precise grain-grain contacts and the forces between them. Supported by simple but very sophisticated mathematics and computer science procedures the DEM became applicable to powder technology problems. They can very precisely describe the motion of the particles in particle-based modelling of grain packs but in this case in powder engineering applications for instance in drilling fluid or sand control technology [18], and more precise methods as well [19]. In case of Saucier principle the on-site information gained from the GSD of the drill cuttings and applying the statistical rule between GSD and PSD the proper size of the bridging agent can be determined within an hour and decisions can be founded. Actually this approach gave the first spark to this project and served as a starting base [20]. GSD can be determined with various techniques, of which the most powerful and economic is the low angle light scattering (LALLS) method. Though the GSD techniques seem to be very straightforward, it is vital to know their limitations and how to interpret their results [21]. In case of an unconsolidated sample at least we do not have to deal with the problems of how to disintegrate the grains of a consolidated rock sample because the grains in the latter case are more or less fully connected to each other or there is just a small cohesion between the grains and they easily fall apart. Nevertheless GSD measurements of consolidated samples are important from the point of view of model validation. Therefore disintegration techniques draw a lot of attention and require some considerations when they are applied.

A geometrical approach shall be applied if modelling in a wider sense is used and its results are interpreted not only for the sample investigated but for various types of sediments in the reservoir. The mathematical analyses applied in this study for clastic core samples were used for partly revealing the most important relations between petrophysical and textural properties and identifying the characteristic spatial (3D) continuity of the grain size compositions measured on hand specimens. In case of relations between textural and petrophysical characters of the samples the very first point to make clear is whether these relations depend on the size and shape of the grain or on diagenetic processes. In fact, these processes affect the petrophysical properties from shallow burial depth. Nevertheless, during the initial stages of diagenesis, these processes have also a control on petrophysical systems. Since the main goal of this project to predict the petrophysical properties from modelled grain composition, only hand specimens in which diagenetic processes are subordinate to depositional framework in forming petrophysics fit this purpose. The key question, when deciding whether the actual sample set is acceptable or not, is: which petrophysics-affecting systems have significant control in the samples? In our view, this decision can be made by using multivariate classification methods. For this purpose we applied a hierarchical cluster technique for the measured petrophysical properties. In this manner we described each sample by its effective porosity, horizontal and vertical permeabilities, and the average size of its pore throat system controlling the relative frequencies of the significant pore size classes. These properties were regarded as components of radius vectors representing the considered points on a hypersphere in a space with dimensions equal to the number of petrophysical properties. In this space, the similarly coefficient was the cosine of the angle between any two radius vectors. In the hierarchical solution the reduction method
was the nearest neighbour algorithm. The clusters were defined until the Mahalanobis distance between their centroids was significant. This latter constraint was controlled by distance. This latter constraint was controlled by distance. The end-groups with their hierarchical system contain those samples whose petrophysical systems are more similar within the groups than between the groups. The objects to these clusters were analyzed for their depositional history. If we found that the disjoint petrophysical groups were homogenous in their depositional history, too. The connectedness of primary depositional control on the petrophysical processes seemed to be valid. Otherwise there had to be chosen a new set of hand specimens.

Supposing that the sample set chosen is a representative result of the depositional process, the next step was to select the sufficient and necessary number of those measured textural properties which control the effective porosity and permeabilities. The necessary and sufficient conditions were important as they could avoid biasness and redundancy. In addition, these textural properties should be tuned when the virtual sample volume is being formed by an algorithm. The input properties for this study were as follows: (1) median diameter of the grain size distributions; (2) weight percent of standard grain size classes (i.e. clay, fine sand, medium sand, coarse sand, and coarser-than-medium-sand fractions); (3) relative frequencies of the pore size classes. The method which gives the required number and types of the above properties in the approximations of effective porosity and two permeabilities was the multiple stepwise regression analysis.

Several studies dealing with the petrophysical characters of recent depositional environments have shown that these physical properties are significantly affected by both the distributions of the grain size constituents (i.e. grain size distribution) and the spatial geometry of the grain particles. Sedimentologically this latter character is reflected by the bedding characters. For instance, horizontal laminations significantly decrease vertical permeabilities, in case of instance, horizontal laminations significantly decrease vertical permeabilities, in case of massive sandstones the poor spatial continuity of primary depositional control on the petrophysical processes seemed to be valid. Otherwise there had to be chosen a new set of hand specimens.

Lattice-Boltzmann methods gained widespread applications from macro-sized problems to micron-sized ones, or pore-size level applications in the past ten years. In contrast to the generally used fluid type view of flow problems in computational fluid dynamics, IB applies a particle type of view of flow via computing the interactions between fluid packets and fluid packets and its stationary surroundings using immersed statistical physics.

The purpose of the project

After the first feasibility study of the idea – still under development, eCore developments [2,10,13]. The algorithm that mimics the sedimentation process was developed beyond the current goal this will be a huge step toward the possibility of further developments focusing on two phase flow simulations or even more sophisticated solutions.

The Core development project is run by cooperative partners of MOL Integrated Fluid Applications (MOL IFA). Department of Fluid Mechanics at Budapest University of Technology and Economics (DFM BME) and Department of Geology and Palaeontology at University of Szeged (DGZ SzTE). In the framework of the work share scheme MOL IFA focuses on the particle model of unconsolidated formations and poorly consolidated formations as well as for validation purposes. The team's responsibility furthermore to work on pore size distribution modelling algorithms that are to extract this sort of information from the numerical model of the formations using percolation algorithms developed and tailored to the needs of the project. DGP SZTE will provide those geological data and expertise that determine that the particle model input parameters by analyzing a wide range of data with geostatistical methods and tools and supervision of the geological aspects of the development work. DFM BME works on IB method development focusing on pore size level applications in the first place and they also develop a pore size distribution calculation method that is based on Poisson differential equations and their solution in 3D.

Results of the current developments

The development work runs in a parallel fashion. All the data is shared among the cooperative partners with those focal points that ensure the homogeneity of the project and at the same time serve as the interfaces between the partners. The project is kept on an open track by the regular project meetings.

The first quarter of the two-year-long project the following results were achieved:

INPUT PARAMETERS OF PARTICLE MODELS

As it was shown that GSD is an important and sometimes the only input parameter for particle models, GSD methods using LALLS technique were studied along with sample preparation / disintegration methods. The literature research showed that during the disintegration technique GSD results might change even considerably, which might affect the model and its validation. Since LALLS technique applies 101 detectors it produces a quasi-continuous distribution of grain sizes that must be discretized so that GSD results can be fit for particle modelling applications. Discretization revealed that due to the number and types of the above properties in the approximations of effective porosity and permeabilities. The necessary number and types of those measured data into the geological model. The gas phase of data into the geological model. The gas phase of information from the numerical model of the formations using percolation algorithms developed and tailored to the needs of the project. DGP SZTE will provide those geological data and expertise that determine that the particle model input parameters by analyzing a wide range of data with geostatistical methods and tools and supervision of the geological aspects of the development work. DFM BME works on IB method development focusing on pore size level applications in the first place and they also develop a pore size distribution calculation method that is based on Poisson differential equations and their solution in 3D.
packings were used only for studying the effects of the algorithm’s input parameters on the density of the packings. The run time of the program was just a few hundreds of seconds in case of 30,000 particles, but we found it not satisfactorily enough with regard to the width of the target zone in which the packing density might change. In the process each particle was placed, as a result of the solution of a set of non-linear equations with a modified Newton-type iteration method. In case of polydisperse packings we used the above described GSD of real samples and these numerical models of poorly consolidated samples were further studied and used for other investigations (see Figure 1). This rigidity of the model and the constraint of using spheres only - this is inherent in the placing method - as particle representations, however led to the conclusion that we had to find another way to model packings of solid particles.

The random walk method itself is capable of dealing with particles of regular shapes or even irregular convex objects. This feature of it was demonstrated with a packing of very diverse, even concave objects like nails, discs and other shapes in a complex environment with obstacles in the way of the moving objects [23]. It resolves the problem of particle placement at the same time because it eliminates any mathematical calculations regarding the optimum position of a particle. In case of the former solution the contact between neighbour particles was subjected to numerical precision of the iteration and therefore it determined the quality of the packings regarding collision overlap between particles. The main principle of the method is that each particle has 26 directions of motion in 3D, this characteristic carries some resemblance with IB for that see Figure 2, and each of these directions might have specific likelihood of motion. Varying the probability distribution of these directions very different situations can be constructed. Including the possibility of upward movements for example and scaling properly its likelihood a never resting system can be formed, just like the one that can be discerned on a vibrating table. Life is governed by chances like in case of random walk, so particles may settle and find their position randomly after a great deal of collisions and if it can move in none of the 26 directions the particle is fixed by its neighbours. Actually it gets squeezed between them as it happens to real particles during burial processes. This situation might change if some of the neighbours move away form the particle giving it room for free motion again as if some vortex had stirred up the surface of the bed. In case of random walk method the particle-particle contact detection was put in the focus that uses simple processes though requires a vast amount of computations.

Collision detection might be approached in a number of ways. We applied the broad and narrow sense contact detection algorithms in a partly reinterpreted fashion. If the bounding box of the particle is defined, then in the broad sense of collision detection it is enough to check the contact of the bounding boxes of various particles. In the narrow sense of collision detection, if the broad check showed contact, the actual particles’ contact must be computed [25]. For this purpose analytical functions can be applied provided the particle has such a function at all. This is luckily the case for super-ellipsoids and therefore they are fit for such applications. They have an analytical surface that is called inside-outside function as well. This function for a general super-ellipsoid looks like the following:

$$f(x, y, z) = \frac{\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 + \left(\frac{z}{c}\right)^2}{\left(\frac{d}{e}\right)^2} \leq 1$$

where x, y, z is an arbitrary point in the space, a, b, c designate the super-ellipsoid’s radii in the directions of space, e₁ and e₂ are the shape factors. If e₁e₂=1 and a>b=c, then the super-ellipsoid becomes a sphere. By adjustment of these parameters a wide range of convex shapes can be produced. This range of shapes might represent the variety of the real grains in nature, at least to some extent. If F≥1, then the point is on the surface of the super-ellipsoid, if F<1, then it is inside the particle, otherwise it is outside. In this way it is easy to check two particles’ contact at reasonable computational costs. Another approach to this phenomenon is the Minkowski difference of convex particles [25].

The simple case of sphere representations of particles has already been tested for random walk model and the results showed that the variability of the packing is greater than it was in case of the process-based solution. The packing density changed in the favourable direction, it rose from 0.56 to 0.60-0.62 depending on the initial parameters. These were only the first trials using a rather weak or underperforming computer consequently the full power of the algorithm could not have been studied so far. Despite this fact, fortunately even in this trial and error way a very loose packing was turned to a poured random packing. In our view there is still considerable room for further improvements regarding the density and the nature of the packing.

**CHARACTERIZATION OF THE MODEL PACKINGS**

Characterization of the packing will give the basis of comparison between the model and the real sample. The following parameters can be used for this purpose: the porosity, the co-ordination number and the pore volume distribution. The last one will be discussed in details in a later section of this article. Each characteristic of the packing was computed by programmes written for that specific purpose therefore these programmes could be used not only for characterization of the packing, but they serve as an independent check of the packing itself regarding the neighbourhood of particles, overlapping, particles without any contacts, etc. Porosity was calculated using a hybrid method. The algorithm utilises the system by marking the internal space within the packing correctly. This rectangular shape’s volume can be calculated analytically giving the total volume of the subsample. Spheres being totally within the space investigated can be calculated analytically just like those spheres’ volume that are cut through by the particular slice of the internal space. The volume of other spheres that are mutilated by the edges or vertices of the internal space can be calculated by voxelization giving an approximate value for these fragments of spheres. From these data the ratio in the total void space and its ratio to the total volume can be given with some uncertainty.

**SEDIMENTOLOGICAL CONSIDERATIONS IN ASSEMBLING THE SET OF HAND-SPECIMEN**

Since this project is addressed to the clastic reservoir rocks of Pannonian age, the reference set of hand specimens must be representative for Pannonian reservoirs. Fortunately most of these reservoirs consist of sandstones in the lithification stage of sandstone diagenesis. In this stage the physical properties are controlled dominantly by depositional processes.
processes can be subdivided into delta, and basinial courses. In the former one the main sub-environments are the followings: (1) delta plain and delta front; (2) pro-delta. Within the delta plain successions the characteristic sandstone bodies are formed in (1) channel, (2) crevasse splay, (3) mouth bar environments. The pro-delta sequence is the place of pro-delta fans, which can interfinger with the deeper basin fan or ramp type sedimentation. Our goal is to collect representative hand specimens with representative sedimentary structures for the above mentioned depositional units. The other very important constraint is that both grain size and petrophysical analysis should be available from these samples. In the very first phase the delta plain sequence is targeted. One of the outstandingly sampled reservoirs is the Szőreg-1 of Algyő field (Hungary). From the laboratory analysis of the Szőreg-1 UGS (underground gas storage) project we were able to collect samples of fine and coarse sandstones, fine and coarse siltstones and argillaceous marls with channel, crevasse splay and mouth bar origin. The number of samples by sedimentary rock types belonging to these units was enough for statistical inference. The average grain size distributions with the corresponding average effective porosity and permeabilities as well as pore size distributions could be derived. On these data set we performed statistical analysis outlined before. What we have got is the following: (1) receipt for the weight percent of grain size constituents to derive virtual grain volumes; (2) receipt for tuning the virtual grain volume to fit the measured petrophysical properties.

For describing the inside geometry of samples, some other measurements were used. Some earlier studies have proved that in the same diagenetic stage, clastic rock types can be characterized by a time constant (Eq.3).

\[ G - L = \frac{f - F}{\tau} \]  

It can be shown, that the relaxation time is proportional to the Hounsfield transport coefficients such as kinematic viscosity. Any macroscopic field variable can be expressed as a momentum f in the velocity space:

\[ \mathbf{g}^T \mathbf{f} = \rho \]  

\[ \mathbf{g}^T \mathbf{f} = \mathbf{u} \]  

\[ \mathbf{a} = 1, 2, 3 \]  

\[ \mathbf{f} = \rho \mathbf{v} \]  

index 1 corresponds to Cartesian components x, y, z, thus \( \mathbf{v} \) refers to particle velocity components and \( \mathbf{u} \) refers to fluid velocity components. p and e represent fluid density and specific energy respectively. \( f \) must be discretely represented in numerical solution procedures. The most obvious way of discretization of the Boltzmann equation is the application of an equidistant lattice with the resolution of \( \Delta x \) and an even time stepping by \( \Delta t \). \( f \) must also be discretized in the velocity space, therefore \( f \) needs to be represented in multiparticle velocities at every simulation point. Various approaches exist for 2D and 3D flows, two of them are shown in Figure 3. The simplest possible representation is D2Q9 which assumes that movement is possible in two dimensions only – and 9 possible directions of movement. For each direction \( f_i \) represents orthogonal velocities, while \( f_0, f_1, f_3, f_5, f_7 \) stand for diagonal velocities. As can be seen in Figure 3, discrete representations of 1 are selected on the way to point towards the neighbouring points, therefore the right hand side of Eq.2 is easily modelled – at least in the absence of external force. \( f \) is passed to the corresponding neighbour in each time step. Actual calculation is necessary only for modelling collision effects. With this assumption the discrete form of Eq.2 reads:

\[ \Delta f^i + \mathbf{w}^i \mathbf{x} \cdot \frac{\mathbf{F}}{m} \rho \mathbf{v} \mathbf{f} = G - L \]  

![Fig. 3. The pattern of a clastic rock sample visualized by Hounsfield values.](image)

LATTICE-BOLTZMANN METHOD DEVELOPMENT

Lattice-Boltzmann method is derived from the kinetic theory of gases. The method is used with benefits for solving problems of continuum mechanics, such as the numerical solution of the governing equations of single phase and multiphase flows. Giving some insight into its formalism, see the next simplified description (Eq.1) for it. We can introduce \( \Delta n \), which is the average number of particles around position \( \mathbf{x} \) and particle velocity \( \mathbf{v} \).

\[ \Delta n = \frac{1}{\Delta x \Delta v} \int_{\mathbf{v}} N d\mathbf{v} \]  

(3)

The most commonly used implementations of the lattice-Boltzmann method utilize the second order Taylor series approximation of the Maxwell-Boltzmann distribution for calculating the equilibrium population, which leads to Eq.6.

\[ f^* = \rho \mathbf{v} \mathbf{f} \]  

(6)

In Eq.6 \( \mathbf{e} \) and \( \mathbf{u} \) are the particle velocity and fluid velocity vectors, respectively. \( \mathbf{w} \) is the weight of the i-th component defined below, and \( c^{2L2}_{3D} \) is the square of the model sound speed. c=\( \Delta x/\Delta t \) is the grid velocity, \( \mathbf{c} \) is displacement vector, e.g. in D2Q9 model \( \mathbf{c} = (1, -1) \). The numerical process involves 3 consecutive steps in any internal points: promotion of \( f^* \) to neighbouring points, calculation of \( f^* \) equilibrium populations and updating \( f \) according to the collision formula Eq.5.

A comprehensive description of the discretization method is given by Succi [26]. One advantage of lattice-Boltzmann method is its ability to simulate multiphase flows involving finely structured interfaces. This makes the method particularly suitable for some porous media application in oil industry.

A number of general purpose commercial and free open source implementations are known. In this research, the PALABOS (Parallel Lattice Boltzmann Solver) is used, which is open source (Gnu) C++ library for the development of single phase and multiphase lattice-Boltzmann applications. PALABOS allows efficient parallel computing, which is very important for practical applications. Software utilities have been developed in the framework of the present research CT – for automatic reading and for the visualization of the results. The lattice size – number of lattice nodes in each co-ordinate direction – in an example run of the programmes was 256x256x256 and the corresponding computing time of a single phase flow in this lattice was 2 hours on a 16 core 64 bit PC with PALABOS solver.

EXTRACTION OF PORE SIZE DISTRIBUTION FROM THE MODEL

At this stage of the R&D project there are two possible candidates for the purpose of extracting PSD information from either the numerical model or the 2D/3D image of the real sample. First of all we are very important to determine precisely what is meant by pore size distribution in our industrial practice. As it was already mentioned this sort of information

\[ \Delta n = \Delta \rho \mathbf{v} \]  

(5)
is produced by laboratory measurements. Pieces of real porous material are put into the instrument’s sample holder and the sample is then flooded with mercury. Mercury invades the porous material from all directions at a specific pressure applied and the pressure value and the change in mercury volume are recorded. This is repeated many times at different pressure values up to 200 or in some cases 400 MPas. The whole measurement consists of the penetration and the retraction phases, which means that the measurement is carried out in both directions. As mercury can enter the porous system – the pore spaces through the pore throats, through processing the series of data we actually get how much pore volume can be flooded with mercury through a specific size of pores that belongs to a specific mercury pressure. The theoretical baseline of this measurement is described by the Washburn relation [27]. PSD computations shall reflect this sort of nature of the laboratory data because the geological and petroleum engineers’ practice is based on this laboratory measurement and interpretation.

The pore size distribution of any porous material can be determined in a number of ways. They mostly apply the inscribed spheres techniques and / or the Voronoi tessellation methods making difference between pore spaces and pore throats. Some of the methods are better than others but all are computationally very intensive applications and despite their correctness in geometric terms they do not meet the above mentioned requirement. They cannot handle the problem in a way that is more or less like the laboratory measurement itself. The laboratory measurement method’s inherent nature is that it is capable of detecting and identifying those constraints or better phrased as bottlenecks that are in the way of any fluids flowing through the porous material and it quantifies it. In our comprehension percolation algorithms might be one of the best tools for such purposes. Percolation theory is part of statistical physics not fully explored and explained yet, though successfully applied for many problems [28,29]. This is also a quickly developing area of science and practical applications of it. The current state of this development direction of the project is in its initial phase. A 2D algorithm has been developed and written by us and applied for a numerical representation of a spheres packing. The algorithm’s performance and capabilities were studied on this random set of circles. This set of circles was made by cutting horizontally through the aforementioned spheres pack at \( z=1,000 \) – for example see Figure 4 regarding the black circles only.

This is an imaginary thin section of a numerical rock sample and it was used without further modifications, which means that the wall effect was not excluded. The circles or spheres in case of the 3D version, form clusters that might encompass areas within the plane or space. These areas, subsections of space might only be invaded through narrow passages between the cluster’s members. This might be applied for the whole of the set and this way it is quite understandable what was meant by bottlenecks. The invaded area can be registered as the function of the grid size. The grid size might be linked to the specific pressure through the interfacial tension of the mercury and its contact angle as a non-wetting fluid in a rock sample. Percolation can happen in two ways: there are site and bond percolations. When our 2D percolation algorithm was first constructed and run a special hybrid method tailored to the needs of the task was applied [30]. As the grid size was gradually reduced and the programme was self-modified, the increasing area flooded by mercury could be discerned. It showed that it behaved as it was anticipated (Figure 5).

The surrounded areas were only flooded by mercury if the grid size or its equivalent curvature radius was reached just like in case of real measurements. For better visualization of the porosity and the 2D percolation algorithm was written in this way, mercury invaded the porous material from one direction – mimicking the statistical evaluation function, local percolation probability applied in case of thin section numerical analysis. Percolation is not a dynamic method, much rather it shows the end result of a particular situation. This can be meant by reaching the state of equilibrium at a specific mercury pressure, and there is no further movement of the mercury fluid. This state of equilibrium can be shown by percolation as well.

The solution of Poisson differential equations approximated a different approach to this problem. It is a dynamic method and identifies the pore spaces and throats as maxima and saddle points of the solution of the Poisson equations in the same space. Size information is then flooded around pore space and throats within the corresponding radius and the pore structure can be visualized as shown in Figure 5.

Results so far and further development plans

We managed to clarify the basic assumptions about this approach to model conventional and special core analyses and lay the foundation of the project regarding particle models, the range of input parameters, the role of geostatistical parameters in recipe making of geological patterns, lattice-Boltzmann flow modelling and pore size distribution of the voxelized real samples and models. Two particle packing generators have been constructed and tested on both monodisperse and real, polydisperse packings. The results showed considerable difference between the two solutions in favour of random walk method. Our goal in the immediate future is to fully develop the random walk method for convex particles of general shape and test it for constructing numerical models based on real samples and their measurements. Parallel to this the model and the algorithm have to be developed further to be applicable in the case of thin section numerical analysis pattern construction feature using geostatistical methods. The requirements and conditions of IB applications for flow modelling of this type have been clarified and acting as bench tested in simple situations like ordered sphere-packings. IB programmes will be developed in order to comply with our expectations. The above mentioned potential solutions in the next three quarters of the total project timing and tested for random polydisperse packings. The numerical model’s results are compared to that of simple real models. Pore size distribution of the model was one of the most difficult problems to be solved. We believe that there are two potential solutions in our hands to this problem that were successfully tested so far and in the mid future these solutions will be further developed and tested. Nevertheless the biggest challenges of the project are undoubtly the appropriate particle packing generation, the IB modelling of flow through the particle packing and the extraction of pore size distribution from either voxelized real samples or numerical models. These challenges have to be addressed properly by the team members in the further development works and efforts.

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References


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Examination of the relationship between ESCR and the molecular structure of HDPE blow molding grades

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Abstract
The environmental stress crack resistance (ESCR) is an important property of HDPE (high density polyethylene) products especially of blow molded products. The ESCR result informs us about the prediction of the long-term behaviour of the products, how suitable is HDPE injection molding type of several final products without cracking and which basic material is adaptable for the product.

The ESCR measuring method (ASTM D1693) has a low number of possibilities and disadvantages. The purpose of our work was to develop and apply a new method in cases of TVK products, which method is suitable to replace the ESCR measurement.

The new method: tensile test propagation at 80 °C, stain hardening modulus determination from the real stress-stain curves (G.). This modulus correlates to the ESCR result.

Összefoglalás
Fűvási tipusú nagy sűrűségű polietilének ESCR – molekulaszerkezet összefüggésének vizsgálata

A feszültségkorrózió vizsgálat (ESCR) a HDPE (nagy sűrűségű polietilén) termékek, elsősorban fűvási típusúak (nakkán, hordók, palackok stb.) fontos vizsgálati módsere. A hagyományos ESCR vizsgálati módszer hátránya, hogy rengeteg hibaletetőséget rejt magában, amelyek az eredmények bizonytalanságához és nagy szórásához vezetnek (a szórás egy sarzshoz tartozó minősor esetén is akár 20% is lehet).

Munkánk célja olyan szerkezeti jellemző terjesztése, amely korrelál az ESCR értékkel, valamint olyan módon képeskodik, hogy a polymer feszültségkorrózió vizsgálata hatékonyabb, helyettesítse a gyors és abnormális pontos eredményt ad, valamint a TVK termékeinek eredményesen használtható.

Az új módszer 80 °C-on végzett szakítás vizsgálatának következménye, az ún. keményedési modulus meghatározása, amely összefügg az ESCR értékkel.

Introduction
The ESCR (environmental stress crack) is a damaging process of plastic products due to surface initiated micro cracks or fractures, which are caused by the combined presence of internal and external stresses and the effect of the environment. The polymer resistance to such failure is the environmental stress crack resistance (ESCR). The internal stresses are remaining by the production (extrusion, injection molding and thermoforming), the external stresses originate from the application; for example the bottle is filled with fluid (e.g. surfactant). If the ESCR value of the material is not high enough, micro cracks initiate and are growing; surface active materials accelerate the formation of microscopic voids within the polymer chains. These voids combine and grow to form larger crazes and cracks, which lead to the failure of the polymer material.

The ESCR value is a characteristic feature of HDPE blow molding type product, which limits its application. The development of HDPE product turns to the raw materials with higher ESCR value.

The ESCR value is an important property as shown, but the determination of this feature is not easy. The ESCR value of a HDPE blow molding type product can be 10 hour to 2,000-3,000 hour. In the course of product development this time is very long, the new experimental product can lose the market position, or the launch to the market become difficult without fast measurement results. Consequently, a rapid measurement method is required for the product development, and for the examination of other grades and for the customer claims investigations.

This article shows a new method, which predicts the ESCR result within some days after the production.

Theoretical overview
THE ORIGIN OF THE ESC
The semicrystalline polymer structure is built up from three regions: crystalline, amorphous and interface regions. The last is the most important and critical in the ESCR of a semicrystalline material. This region is the interface between the crystalline region and its adjacent amorphous region. This interface region connects the crystalline and amorphous phases and without it the polyethylene material would be very weak. This interface or boundary region is the zone through which the loads are carried and transferred between the long molecular chains and the different crystals. The stress cracking starts with breaking of the boundary chains. This break then develops into micro crack that will ultimately grow to form a crack big enough to be seen and cause product failure [1].

The long polymer chains form a 3D entanglement in the amorphous phase. In response to stress, the individual segments orientate to the direction of the maximum strain and micro cracks and micro voids are forming. The voids are separated by highly oriented polymer fibrils. Eventually the molecules untangle and the voids coalesce to form a crack [2]. At the end of the progress the stretched chains break, the voids open together and the crack propagates.

Figure 1 shows the mechanism of ESCR.

THE MEASUREMENT OF THE ESCR VALUE
There are a lot of test methods to examine the slow crack propagation and to determine the ESCR value. The methods are the models of real product damage but with faster progress. The most widely used method is the so called Bent Strip method of ASTM D1693. The sample is notched and bent perpendicularly to the direction of the notch then it is taken into...
and hence of the material in a pure plane stress uniaxial load as is schematically represented in Figures 4 and 5. This is why a simple tensile test to assess the strain hardening behaviour of a material will be predictive for the slow crack growth resistance" [4]. The similar fibrillar orientation can be seen in Figure 6, where SEM (scanning electron microscope) pictures (made by TVK – Product Development Department) show the ESC and tensile test mechanisms and the similar polymer morphologies. Microscopic aspects of surface deformation and fracture of HDPE are studied in [10].

Experimental part, results

EXAMINED MATERIALS

The samples were produced at TVK plc by polymerization techniques. The ‘PEI’ sample is a blow molding product and comes from the Phillips loop (using Cr-type catalyst), the ‘PEII’ blow molding and pipe samples come from the bimodal Mitsui technique (using Ziegler-Natta type catalyst). All samples contain antioxidant. Samples were prepared in the following conditions:

- Press temperature: 177 °C
- Preheating: 5 min, 3 MPa
- Pressing: 1 min, 10 MPa
- Cooling: 12-15 °C/min.
- Pressing: 1 min, 10 MPa
- Preheating: 5 min, 3 MPa
- Press temperature: 177 °C
- Cooling: 12-15 °C/min.

The samples were blank. The geometrical parameters of the samples which were used for tensile tests are shown in the Figure 7.

The tensile test result is transformed to true values using the following equilibriums. True strain is calculated as:

\[ \lambda = \frac{\Delta L}{L_0} + 1 \]

(no dimension)

where

- \( L_0 \) – gauge length at the beginning of the test (mm)
- \( \Delta L \) – strain (mm)

True stress is:

\[ \sigma_t = \frac{F}{A} \cdot \lambda \]

(MPa)

where

- \( F \) – measured force (N)
- \( A \) – area of the cross section at the beginning of the test (mm²)
- \( \lambda \) – true strain

THE NEW METHOD

Tensile measurement

The measurement is in principle a standard tensile test at 80 °C. The test specimen is extended along its major axis at constant speed (10 mm/min). The maximum strain value is limited by the length of the heated chamber. A 1 kN load cell is used for the load measurement. Prior to testing the test specimens are kept for about 20 min in the heated chamber at the envisaged test temperature so as to attain thermal equilibrium.

Figures 4 and 8 show the tensile test curve of a PE sample. At the beginning, at low shear force deformation is linear elastic. After the curve bending non linear elastic deformation takes place. After the yielding phase necking and orientation of the polymer chains start, just as in case of the ESC mechanism under the influence of stretching stress. Plastic deformation and the breaking of polymer chains take place at the end of the progress.
According to the ESCR vs. \(G_p\) curves we can establish that the correlation between the two values is good. After doing a simple tensile test, based on the received curves we can predict the ESCR value of the unknown or new, experimental materials. It is possible to predict the ESCR value of the samples with very high ESCR in a much shorter period of time.

Conclusions

Important property of the blow molding and pipe type HDPE products is their resistance against slow and rapid crack propagation quantified as ESCR value.

The invention of the bimodal HDPE was a significant event in the history of HDPE development. It has good processability and excellent mechanical properties. Presence of both low and high molecular weight parts would result in more than 1,000 hour ESCR value, but the measurement of this high value would take several months. A new, rapid measuring method has been developed to predict the ESCR value, and predict the crack grow process.

The strain hardening measurement offers a relatively easy way to predict slow crack growth resistance in materials without using surfactants. The presented test method shows very low standard deviation and furthermore, measuring times are dramatically reduced in comparison to traditional methods from thousands of hours to only a few.

This new way of assessing slow crack growth data can be applied in product development, quality control, examination of claims and others. Using this new method beside ESCR other test results are also predictable which are in connection with crack propagation, for example special pipe examinations such as S4 (Small Scale Steady State test, ISO 13477) and FNCT (Full Notched Creep Test ISO 16770) tests.

References


Keywords: polyolefin, ESCR, blow molding, crack propagation

Reviewed by Zsolt László

Zsolt Dudas joined TVK Ltd. in 1998 and has been working at Product Development Department. He is responsible for the electron microscopic measurements for the elemental analysis and plastic testing methods, for extruders and sample preparation equipments. His main areas in the Development Department are the development of HDPE products and the examination of customer’s complaints. He graduated at Budapest University of Technology and Economics (1998) and Kecksméd College of Mechanical Engineering and Automation (Hungary) (2011) Plastic and Rubber Technology Departments as development engineer and polymer processing technologist.
Examination of the effects of different internal electron donors of Ziegler-Natta catalysts on propylene polymerization

Összefoglalás
Ziegler-Natta katalizátorok különböző belső elektron donort tartalmazó propilén polymerizációban

Abstract
There are two polypropylene (PP) plants operating at TVK (Hungary) based on Spheripol process, at nominal capacity of 100 and 180 kt/y respectively. Basic properties of the PP grades produced by these plants highly depend on the technology and the polymerization materials, e.g. the catalysts (containing also improved internal electron donor (ID) and external electron donor (ED)).

The latest (6th) generation of PP catalysts contain such internal donors by which the basic properties of the final product can be varied more broadly than ever before, so we can alter the product and make it more versatile by using the same technology for more specific applications.

Our main goal was to replace the previously used phthalate ID containing catalysts by a novel 6th generation catalyst, containing diether or succinate type of internal donor and through this achieve improved physical, optical, organoleptic and morphological properties. Firstly, we tested the alternative catalysts in lab scale reactor. Based on the favourable results we recommended plant trial. Based on the results of the plant trial, we could achieve better morphology, organoleptic properties and in some cases higher production rate, so the two catalysts containing diether and succinate types of internal donors could be registered on the internal list of accepted polymerization materials.

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The first catalysts at the initial stage of the development of the Ziegler-Natta-type, were unable to connect the monomers in a regular manner, so large part of the product was not isotactic (atactic), moreover the catalysts did not have high activity, so additional steps had to be performed to separate the catalyst and the atactic phase from the isotactic PP [2-5]. Today with catalysts containing e.g. diether internal donor (ID) and using D (Dicyclopentyl- dimethoxy-silane) external donor (ED), isotactically up to 99% (w/w) can be reached (should the final application of the PP grade needs it).

The first catalyst was prepared by mixing a special crystal type of TiCl₄, and Al(Et₂O)₃. Today a support is used which is MgCl₂. The support is impregnated with TiCl₄ and an ID (i.e. Lewis base). The mix of this three components is not active in the polymerization media. The Ti⁺⁺ content partly needs to be activated (reduced to Ti⁺) with Al(Et₂O), a common cocatalyst and an ED is also needed in most cases for the required stereoregularity [6-9].

ROLE OF INTERNAL AND EXTERNAL DONORS
In order to obtain a catalyst system capable of polymerizing propylene monomer, resulting in highly isotactic PP, we need two donors. The first type is bonded directly to the support (ID). Direct connection of the donor and support suggests that the ID has a higher impact on the product properties than the ED, which is exactly the case. The ID takes part in the active site formation, while the ED only selectively poisons these sites and replace some ID from the catalyst during the lifetime of the catalyst to fine tune final product properties like activity or stereoregularity [10,11]. The main difference between these donors lies in their usage. The ID is catalyst dependant, but the ED can be chosen freely (from technical point of view, but legal restrictions should also be considered). In some special cases ED’s feeding can be eliminated, because the catalyst ID provides enough stereoregularity for the PP chains.

As noted above, ED has only limited impact on the product properties. If we want to change some parameters drastically, the only way is to change the catalyst itself.

The main groups of the IDs can be seen in Figure 1.
Benzoate type IDs are only used in less advanced plants because of their unfavourable polymerization capabilities, while their consumption decreases steadily.

Phthalate type is the most common type of IDs used nowadays. The best known members of this family are dibutyphthalate, and disobutylphthalate. The catalysts, that have phthalate type ID, are the so called ‘general’ type catalysts. Their polymerization capabilities are good still they are continuously replaced by alternative candidates to be able to gain more specific final products.

The catalysts containing diether and succinate type IDs are of the 6th generation ones. These IDs are free of aromatic ring and grades of special properties can be produced by them. Main features of the grades produced by diether catalyst are good physical, organoleptic properties and better transparency. The main areas of application for the PP grades produced with it are fibre, healthcare products and packaging materials. The main features of the catalyst are high activity, excellent hydrogen response, narrow molecular weight distribution (MWD), and low xylene soluble content (CXS) of the polymer. The catalyst needs very little amount of ED, in extreme cases it even works without any. The good transparency can be explained by the more even comonomer (in this case ethylene) incorporability. Ethylene units are located on every chain and more evenly throughout the chains contrary to the phthalate type catalysts, where the ethylene mainly incorporates into the short chains. The better comonomer incorporability results in lower CXS and melting point than in case of a phthalate type catalyst. (For some applications, the lower CXS is a requirement in order to obtain product of higher stiffness.) Another advantage of the diether type is the better hydrogen response which means higher melt flow rate at a given amount of hydrogen. Hydrogen acts as a chain transfer agent during the polymerization with Z-N catalysts [12]. The more the amount of hydrogen, the higher the flowability of the polymer obtained at 210 °C (MFR) will be. This has advantageous effect on organoleptic properties too, because we do not have to degrade the product directly with peroxides to achieve the needed high flowability (so called visbreaking or controlled rheology process), which are the major cause of the high C-emission values at these grades. Other advantage is good appearance due to the smooth surface of the final product at plastic converters.

The catalysts containing succinate type ID are mainly suited for the production of grades for special injection moulding and pipe extrusion applications. The polymerization properties of these catalysts are good, so the temperature control is easy and in case of reactor temperature overrun the catalyst deactivates itself, so we do not have to expect large chunks of polymer which could cause plugging at the bridge connection between the loop reactors like in case of a phthalate type catalyst. Other advantage is high stiffness / impact balance in case of copolymer products. MWD of the products made by this type of catalyst is broad compared to the phthalate type. MWD of the lab products is a very important property because the short and long-term properties are largely dependant on it. The shorter chains account for the good processability, while the longer chains for the physical properties and chemical resistance. Its hydrogen response is low, but in case of its main application i.e. pipe making, it is not a drawback.

Table 1 summarizes the main features of the catalysts described above.

<table>
<thead>
<tr>
<th>Phthalate ID</th>
<th>Diether ID</th>
<th>Succinate ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Average</td>
<td>High</td>
</tr>
<tr>
<td>Isotacticity</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Hydrogen response</td>
<td>Average</td>
<td>High</td>
</tr>
<tr>
<td>MWD</td>
<td>Average</td>
<td>Narrow</td>
</tr>
</tbody>
</table>

As it can be seen, the most comfortable tool at hand if we want to change a product parameter significantly is the change of the catalyst itself. This practice is widespread and used in many newly built plants where the product portfolio can only be covered by two catalysts, because of large differences among grades.

TVK also installed a second catalyst dispersion drum at each PP plant, not only to be able to use two catalysts simultaneously, but to decrease the risk of mixing the catalysts that can cause quality problems at more sensitive grades.

**Preparation for the plant trial**

The main goals of the plant trial were to make a better product at about the same operating conditions. In case of the PP powders made by diether type catalyst, this means better optical properties in case of random grades, low C-emission and shrinkage, higher stiffness / impact balance through better comonomer incorporability. In case of the succinate type catalyst, a sheet or pipe material with better processability and pressure endurance with higher stiffness / impact balance through broader MWD was required. In case of both catalysts, the main goal was to increase competitiveness and to eliminate bridge pluggings occurred very frequently lately. Because of the favourable morphological properties (higher average particle size (APS)) of the PP powders produced with the new catalysts, trouble free operation, lowering or totally eliminating the bridge plugging had been preferred.

**LAB SCALE TESTS**

The tests of the new catalysts were started in lab reactor of 4 l capacity (see Figure 2) at the following parameters (see Table 2).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor volume</td>
<td>4 l</td>
</tr>
<tr>
<td>rpm of the stirrer</td>
<td>250 1/min</td>
</tr>
<tr>
<td>Polymerization temperature</td>
<td>70 °C</td>
</tr>
<tr>
<td>Propylene amount</td>
<td>2 l</td>
</tr>
<tr>
<td>Cocatalyst</td>
<td>TEAL</td>
</tr>
<tr>
<td>Polymerizations' time</td>
<td>2 h</td>
</tr>
<tr>
<td>Hydrogen amount at fill up</td>
<td>0-800 mg</td>
</tr>
<tr>
<td>A/I molar ratio</td>
<td>1,300-3,000</td>
</tr>
</tbody>
</table>

As it can be seen, there are fix parameters which were held constant throughout the whole experimental plan, and there were variable ones, like the amount of hydrogen which had to be increased step by step to obtain a hydrogen cia libration curve.

The Aluminium/Titanium molar ratio was defined by separate experiments for each catalyst and kept constant after the calibrations.

**Measured parameters**

The following parameters were measured from the produced PP powders.

- **Activity**: measure the grams of polymer produced per gram of catalyst during 2 hours. MFR: measured at 210°C with a given weight according to MSZ EN ISO 1133 on a Dawenport type instrument. It relates to the flowability of the polymer melt.
- **CXS**: xylene soluble part of the polymer, defined by the evaporation method.
- **APS**: defined by regular sieve analysis according to ASTM D1921 on Octagon Digital sieve shaker with the following mesh diameters: 4; 2.5; 2; 1.25; 0.8; 0.6; 0.25; 0.125; 0.063 mm.

- **MWD**: measured by gel permeation chromatography (GPC) on Malvern Viscomtek 350 HT-GPC instrument.

Other parameters can also be measured by the Quality Control Department of TVK at request, like catalyst residue.

**LAB RESULTS**

**Activity** as a function of MFR depicts the activities at a given MFR value (see Figure 3) which is the most important product property. As it can be seen, the activity of the succinate type is very high at lower initial amount of hydrogen, but toward higher MFR values the activity decreases because of the dominance of the chain transfer effect of hydrogen over the reactivation of dormant (active sites on...
which the propylene connected irregularly, the methyl group of the propylene unit creates steric hindrance which can be reactivated by hydrogen) sites of the catalyst [13]. The diether type’s activity is also higher than that of the phthalate type, so based on productivity curves the two alternatives were proved to be promising. It should be noted that the upper MFR limit of the plant-made products is about 20 g/10 min (with traditional phthalate ID catalyst), thus above this value the results only have theoretical importance. The optimal Al/Ti ratio in case of the diether type was significantly lower compared to the succinate type’s.

Average particle size (APS) is an important powder parameter. The higher the APS, the easier the degassing and catalyst deactivation after the reactors will be, because the fluidization of the powder is less complicated. As it can be seen on Figure 6, the powders made by succinate type of catalyst, has the highest APS, while the lowest APS was obtained in case of powders made with phthalate type. However, it should be noted that APS is not in direct relation with the internal donor alone, but also depends on the particle size (diameter) and activity of the catalyst, since in case of Z-N catalysis the final polymer grain will practically be a magnified version of the catalyst particle. In case of the succinate type (which is designed to perform better after the bulk loop reactors in the gas phase polymerization too), the larger particle diameter is a requirement. In case of our phthalate type catalyst, particles of smaller diameter are also acceptable because the catalyst is mainly suited for the production of homo and random products where the pore size should not be large. APS values on the diagram were chosen from the same MFR range to make a fair comparison, since APS is activity dependent.

Based on the gel permeation chromatography (GPC) results, the broadest MWD was obtained in case of the succinate type and the narrowest was in case of the diether type (see Table 3 and Figure 7). These results are in conformity with those presented above, so in case of a plant trial, the same MWD curves thus better physical properties would be expected.

**DIETHER CATALYST**

Main goals are as follows:
- Improved plant operability
- Less volatile content of the final polymer
- Production of high MFR reactor grades (without controlled rheology)
- Products of improved physical properties.

These goals were achieved which can be summarized as follows. The bridge plugging and fluidization problems were eliminated mainly because of the higher APS thus more efficient drying.

Conclusions

TVK has a development chain which has to be followed when an alternative material has to be registered on the list of accepted chemicals. Before large scale consumption, lab reactor tests and analytical measurements have to prove that the new material has an equal, or in better case improved quality which would result in cost saving or in improved final product properties.

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References


Keywords: Ziegler-Natta, internal donor, phthalate, diether, succinate

Reviewed by Péter Suba

Imre Balogh is a development engineer at TVK Nyrt. He joined the company in 2008 as a fresh graduate. His main task is the management of one of the two lab reactors located at TVK’s site which is capable of carrying out polypropylene and high density polyethylene tests. He graduated at the University of Debrecen as chemical engineer.
New results in the Mesozoic stratigraphy of the East Drava Basin

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Abstract
This study is to show the minor achievements of a multilateral Drava Basin project. Based on the results of the hydrocarbon prospection and other wells, an attempt is made to delineate the southern and western boundary of the Villány–Bihor Zone with the identification of its most characteristic Mesozoic formations. Bedrocks of these formations could only be evidenced exceptionally but these kinds of rocks are common in the very thick coarse-grained basal beds of the Miocene succession. In addition to the predominating Middle Triassic dolomites and limestones Jurassic and even Cretaceous limestones typical for the Villány Hills they have been also identified here. As a consequence the nappes characteristic for the Villány Hills are proven in its western and south-western continuation as well.

Introduction
The present article is one of the conclusions of a thematically broad project dedicated to recognizing the regularities and clarifying the geological build up of the East Drava Basin located on the Croatian and Hungarian sides of the River Drava. Large majority of the geologists agrees that the nearby hilly and mountainous areas (Villány Hills and Slavonian [Papuk] Mountains respectively) are parts of the Tisza tectonic unit (Figure 1) called microplate but there are much less in accordance regarding the question which subunits they belong to. The Drava Basin is located between the Villány Hills and the
Slavonian Mts and filled with a few thousands of metres of Neogene successions, and in spite of the several dozens of wells that explored them there is no proper information about the lithology and much less about the age of the basement rock of the Neogene basin. One of our aims with this paper is to determine the extent of the Villány–Bihor Zone westwards and control how this unit is developed. Does it still contain the same or similar facies in the Triassic, Jurassic and Cretaceous as supposed that the latter two are also involved into the nappe stack of the Villány–Bihor Zone? The uncertainty is even greater regarding the question where the tectonic contact is between the Villány–Bihor and the Békés–Codru Zones. Just as an example according to [1] the Papuk Mts are part of the Biharia nappe system, while the majority of the geologists do not take sides. As these tectonic zones are built basically on the Alpine development and tectonics, practically there is chance to draw the boundary between these zones there where Mesozoic succession still exits. Luckily the Croatian (INA) and Hungarian (MOL) partners recognized in due time that when at least Jurassic is found on the surface on the frontal part of each nappe (5). In addition to these both Jurassic and Cretaceous foram forms were proved in three hydrological wells out of the Villány Hills at Gordisa. The results of this study are shown in Figure 2.

TRIASSIC FORMATIONS

Within a narrow belt of the Villány nappe stack area several wells and boreholes (Hegyőszentmárton K–5, –5a, –6, Dôlevszílo B–2, K–4, Csarnóta Cs–1, Cs–1, –2, –3, –4, Harkány B–58, Dravaszabolc K–7, Túróny T–1, Szava Sz–2, –3, –5) explored Triassic formations. Albeit Triassic bedrocks are known to occur only in a few wells to the west and south-west of the Villány Hills including the Hungarian (Cun–1) and Croatian (Podravska Slatina PS–5 Oršac Or–1, Or–2 and Mijanovci Mj–1) parts of the Drava Basin (Figure 2), but there are several other wells in which extremely thick dolomite and limestone conglomerate or breccia successions are found at the base of the Miocene. Usually the lower part of this mainly coarse-grained (occasionally medium-grained) clastic beds are composed of monomictic (Photo 1) or oligomictic brecia which turns into monomictic (or oligomictic) conglomerate upwards and the uppermost beds are already polymictic conglomerate (Photo 2). This regularity suggests that the lowermost part can already be bedrock or at least the place of source limestone and dolomite beds must be very close.

It is very difficult to distinguish them even in core without special studies therewithal corings are very scarce. That is why our paper is focused on the investigation of carbonate rocks, with special attention to the non typical Triassic rocks in order to clarify their origin. Because cores were taken rarely the majority of thin sections were made from cuttings. As the Triassic rocks have only a few micro- and macrofossils it is difficult to get obvious evidences for the presence of Triassic rocks and especially for their stratigraphic position.

The geological background of the Mesozoic formations

The basement of the study area is formed by the Slavonia–Dravia Subterrane [2] composed of metamorphic complexes and remnants of the carboniferous and Permian Molasse-type sequences deposited after the Variscan orogeny with some rhyolitic volcanic bodies in the middle part of the latter one. They occur in a W–NW–E–SE oriented narrow belt above the crystalline basement and below the Alpine succession of the Villány–Bihor Zone. The Alpine succession continued with the same fluvial clastic channel as it was upward in the Permian. The larger part of the basement of the study area was supposed to be part of the Villány–Bihor Zone and this idea was supported by the sequence of the Cun–1 well. The extent of the Mesozoic formations is restricted not far to the west from the surface occurrences of the Villány Hills [3], as it is evidenced by the following wells: Selélye Se–1, –2 Okorág Ok–1, –2, and Felsőszentmárton Fel–1) in which the base of the Miocene is Palaeozoic metamorphite. The model has not changed too much up till now as it is shown on the new map [4]. However, dolomite and limestone breccia and pebbles are the dominant rock types in the very thick basal formations of the Miocene succession along the Croatian–Hungarian border. More to the west, in the Darány area the basement is formed by metamorphites, or granitoid rocks, and they do not have Mesozoic limestone or dolomite fragments in the basal conglomerate and breccia beds, except the Potony–1 well in which a few have been mentioned but they may derive from the Permian as well.

Jurassic and Cretaceous formations are indicated outside the Villány Hills where at least Jurassic is found on the surface on the frontal part of each nappe (5). In addition to these both Jurassic and Cretaceous limestones were proved in three hydrological wells out of the Villány Hills at Gordisa. The results of this study are shown in Figure 2.

Photo 1. Matrix supported, monomictic breccia, core No 6 (2.407–2.413 m) Moslavina Podravska MoP–1 well. It can be correlated with the Budafa Fm (Photo by G. Császár)

Photo 2. Conglomerate of prevalently Triassic limestone and dolomite with varied sizes, roundness and colour; surface of a core No 5 (1.552–1.518 m), Cun–1 well. Picaszabolc Fm, Lower Badenian (Photo by Gy. Konrád)

There is only one (Cun–1) well in the area which contains Lower Triassic (Jakabhegy Sandstone Formation — Figure 3) All the rest explored only Middle Triassic limestone and dolomite beds. In the Cun–1 well Lower Triassic greenish-grey and purplish-red Jakabhegy Sandstone with a thickness of 119 m and the 306 m thick Middle Triassic dolomarl-, ality dolomarl- and anhydrite-bearing Hevehely Dolomite Fm of (Photo 3) are explored with tectonic contact between the Lower and Middle Triassic. That is why the lowermost Middle Triassic Palats Formation is completely
missing. There are no other occurrences of Lower Triassic known from the area. The situation is similar in the Orešac Or–2 well, where the highly brecciated Middle Triassic dolomite also contains anhydrite intercalation which can be correlated with the Hetvehely Fm. The contact between the anhydrite-bearing dolomite and the metamorphites without doubt probably left lateral displacement or overthrust.

The texture types of the Middle Triassic formations are summarized in Photo 4 compiled from pebbles of the Lower Badenian Budafa Fm of the Zaláta–1 well, core interval 3,322.0–3,322.5 m. The prevailing texture type is microsparite of varies crystallinity mainly barren of fossils, or with a few bioclasts (filaments, crinoid ossicle). The biomicrosparitic, bioclastic packstone with echinoderm fragments are less frequent, such as the sparitic micrite-microsparite occasionally with recrystallized calcitic bioclasts. The packstone- and grainstone-type texture relatively seldom occurs: oomicrospartic, bioclastic packstone to grainstone or pelletal grainstone with some bioclasts or forams. The results of partial or total neomorphism at limestones and dolomites are the microsparitic or complete spartic texture often involving the bioclasts, too.

It is very important to mention, that limestone fragments are found not only above carbonate basement rocks but seldom above crystalline rocks as well (Sellye Se–2). In the one time report of the MOL Lab, Békásnegyer Mesozoic type fossils were already mentioned from the limestone pebbles from this well. The revision of these thin sections was made by B. Szinger (in [6]). According to him in most cases the allochemical components are very few: micritic nodules, occasionally peloids, ooids and mainly badly preserved microfauna which are benthic forms (forams, ostracodes). Ooids have single core occasionally with micritic incrustation. The rare oncoids have multi-granular structure and multi-generation micritic incrustation. Radial-fibrous ooids are scattered. From the 1,741–1,753 m interval the following taxa have been documented: Pilaminella cf. semiplana (Kochansky-Devide & Pantić) Photo 5, Pilaminella cf. grandis (Salaj) Photo 6, Frondicularia sp. Photo 7, Nodosaria sp. Spirillind forams Photo 8, crinoid ossicles, Ostracode shells, fragments of Dasycladales (?) and Favreina sp.

The texture, the allochemical components and the taphonomic features clearly indicate a shallow water (platform) high energy depositional environment. The facies characteristics and the foraminifera content suggest Triassic, Anisian age. These data

![Photo 3](https://example.com/photo3.jpg)

Photo 3. Thin anhydrite layers in the Middle Triassic Hetvehely Fm, 1,710–1,712 m, Cun–1 well (Photo by Gy. Konrád)

![Photo 4](https://example.com/photo4.jpg)

Photo 4. Micrograph of typical texture types of the carbonate pebbles of the Lower Badenian Budafa Fm of the Zaláta–1 well from the core interval 3,322.0–3,322.5 m. a) biomicrosparite, bioclastic packstone with echinoderm fragments; b) oomicrospartic, ooidal-bioclastic packstone-grainstone; c) pelparite, pelletal grainstone with foraminifers (top); d) ooidal micrite-microsparite, with partly recrystallized carbonate bioclasts; e) microsparite, f) biomicrosparite, bioclastic, filamental wackestone; g) microsparite, with redeposited crinoid ossicle in the matrix (Micrograph by Gy. Konrád)

![Photo 5](https://example.com/photo5.jpg)

Photo 5. Micrograph of Pilaminella cf. semiplana (Kochansky-Devide & Pantić) in trispellar grainstone, 1,741–1,753 m Sellye Se–2 well (Det. and photo by B. Szinger)
Upper Jurassic Szársomlyó Limestone Formation was discovered in 53 m thickness without traversing the base of the formation. The highly karstified limestone is massive, light- or medium-grey in colour, micritic or microcrystalline in texture with frequent echinoid and a few molluscan shell fragments.

Varied Jurassic limestones are also found in Zaláta Zal–1 well (see Figures 3 and 4) as fragments in the lower half (3,322–3,515 m) of the basal conglomerate and breccia beds of the Miocene succession. The larger part of the breccia-conglomerate belongs to the Budafa Formation which to certain extent is different from the short definition of [7]. Its predominant component is Triassic dolomite and limestone but Jurassic limestones are prevailing in some horizons, especially in the interval between 3,394–3,420 m. Their most common types are as follows: mudstone with Globochaete alpina Lombard; bioclastic wackestone to packstone with Bositra fragments (Photos 9–11), calcareous benthic foraminifera (Lenticulina sp. Photo 12), Involutina liassica [Jones], arenaceous benthic ostracodes, molluscan shell fragments, Cadosina lapidosa Vogler, echinoderm and, Saccocoma fragments and dubious Calpionellids and green algae. There are also ooidic or pelletal grainstone (Photo 13) with ostracodes and Globochaete. The peculiarity of the situation is that the well is located within the Villány Zone but the fossil association seems to be more complete than it is known in the Villány Hills. It can be explained with the different tectonic influences, including the altitude differences of the blocks. This phenomenon can be recognized in the JURASSIC FORMATIONS

Jurassic formations are known to occur on the surface in the Mecsek Mountains and the Villány Hills in fundamentally different facies (Figure 4). The Jurassic of the Mecsek Zone forms a continuous succession while that one of the Villány Zone is highly lacunous.

A few uncertain indications were found in the Miocene basal breccias / conglomerate beds from a few wells. In the Gordisa Grd–2 borehole (see Figure 2), close to the surface derive from pebbles from an extraordinary situation, out of the recent extension of the sensu strico Villány Zone from above the metamorphic rocks.

Regardless of the above mentioned taking into consideration the geological condition in the Villány Zone the age can be Middle Triassic as this kind of platform carbonates were formed exclusively in the Middle Triassic.
Máriakéménd–Bár Range and Bóly–Mohács Basin where the Jurassic succession is more complete than it is in the Villány block itself.

Green algae fragments were reported from the lowermost Miocene core of the Selye Se–2 well, from a limestone pebble of the Budafa Formation. As this kind of fossils are also unknown in the Triassic rocks of the Villány Zone and common only in the Jurassic and Cretaceous formations of the close area, the presence of Jurassic and Cretaceous cannot be excluded from the basal conglomerate at Sellye either. A few Radiolarians were also mentioned from a limestone pebble of this well. It is very probable that they also derived from a Jurassic formation as they are also found in the Jurassic of the Mohács Basin.

According to the report of [8] Middle and Upper Jurassic fossils were identified in the limestone and even dolomite pebbles derived from the Budafa Fm of the Cun–1 well. Unfortunately the thin sections containing these fossils were not available for control.

In addition to the Middle Triassic forams within the interval 4,670–4,910 m of the Podravska Slatina PS–5 well the following fossils were identified in thin sections made from cuttings: Saccocoma (Photo 14), Bositra (Photo 15), Radiolarian (Photo 16), shell fragments, echinoderm spine and Globochaete (7).

The first two elements are clear indication of the Middle and Late Jurassic age. This association agrees with those found within the breccia of the Miocene Budafa Fm of the Zaláta Zal–1 well.

CRETAUCEOUS FORMATIONS
Cretaceous limestone is also known in situ in the Gordisa Grd–1 and Grd–3 boreholes with a thickness of 13 and 185 m respectively. The Urgon Nagyharsány Limestone Formation [9] is grey to dark-grey, rudist, gastropoda- and foraminifera- (Miliolidae-) bearing, with mudstone to packstone type texture. The lower 43 m of the Grd–3 borehole was suggested by the describer to belong to the Upper Jurassic Szászombát Limestone Formation but based on the description it is hard to find reason not to leave it as Cretaceous.

As Ethelia alba is known from the Cretaceous to Oligocene in this case the pebbles must have derived from the Lower Cretaceous.

While studying the thin sections made from the cuttings and cores of the breccias-conglomerate beds of the Zaláta Zal–1 well (3,394 m — Figure 3) in a few samples Miliolid forams: Glomospira urgoniana Arnaud-Vanneau, Veronella? sp., Quinqueloculina cf. robusta Neagu (Photo 17 — det. by Szuromi-Korecz), one Ethelia alba (Polystrata alba Pfender Photo 18), dubious green algae, 1 Orbitolina sp. (Photo 19), small fragments of rudist-like bivalve (Photo 20) and some other bivalves (Photo 21) were discovered.

Nagyharsány Limestone Formation. According to Píros there are also a few badly preserved, unidentifiable Dasycladalean algae (Photo 22), which can be Late Jurassic or Early Cretaceous.

Taking into consideration the fact that the great majority of the Jurassic fossils listed under the previous subheading indicate pelagic and deep water environment, these algae probably belong to the Lower Cretaceous.

In a report [10] Cremušina Cr–1 was the only well from which possible Cretaceous
sedimentary rock was mentioned. Although Ladislavči does not belong to the study area since it is very close to our field and part of the same tectonic unit it is worth mentioning that [11] reported varied size of Lower Cretaceous limestone fragments from the rockfall breccias and also olistolith of cataclasized limestone from there.

Discussion
There was only one well (Cun–1) from among the wells the Triassic could be investigated unfortunately this well the Triassic could be investigated. There was only one well (Cun–1) from among the wells the Triassic could be investigated. The rest of Middle and the hypersaline lower part of the Middle Jurassic from core of bedrock. Unfortunately this well could not pay a little bit more attention to coring on both sides of the River Drava.

Conclusions
The Jurassic (and Cretaceous) rocks may derive from the same distance (from the same nappe — probably the Babarcszőllős Nappe).

3. Based on Figure 5 it can be predicted with high likelihood that the Jurassic rock fragments are involved in the Miocene basal breccia of the wells Dravica Dra–1 and the Moslavina Podravska MoP–1. In brackets, we believe that this is the case with the tuff horizon marked in the wells PS–5 and Zalátá Zal–1. It is regrettable that the prospect could not pay a little bit more attention to coring on both sides of the River Drava.

References


Reviewed by Viktor Sőreg

Géza Császár is retired Research Professor at the Eötvös Loránd University, Budapest. He was co-leader of the IGCP Project 262, President of the National Committee for CBGA, Chairman of the Stratigraphic Commission of Hungary, Chairman of the Geological Scientific Committee for the Hungarian Academy of Sciences. His main interest is the stratigraphy, carbonate sedimentology, palaeogeography and regional geology. His main achievement is the recognition of a special type atoll developed on continental crust, called Mecsek type atoll. MSc (1966), PhD (1984), Habilitation (1999), DSc (1999).
‘Killing two birds with one stone’ – Barlahida 3D second stage: successful geological and geophysical interpretation

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Gold and silver are mined, then purified; the same is done with iron and copper. Miners carry lanterns deep into the darkness to search for these metals. They dig tunnels in distant, unknown places, where they dangle by ropes. Far beneath the grain fields, fires are built to break loose those rocks that have jewels or gold. Miners go to places unseen by the eyes of hawks; they walk on soil unknown to the proudest lions. With their own hands they remove sharp rocks and uproot mountains. They dig through the rocks in search of jewels and precious metals. They also uncover the sources of rivers and discover secret places.” Job 28:1-11.

Abstract
Updated play concepts and powerful integrated geoscientific interpretation resulted in successful renewal of exploration efforts approach in the Zala basin (Hungary). It is a ‘matured area’ in exploration possibilities. Every structure is penetrated by several wells. Thus the relatively deeper structural positions are the prospective area. Several successfully applied methods of visualization, delineation and definition of exploration targets as well as qualitative and quantitative approaches of seismic events are highlighted in the present article. Successful integration of geological methods led to better understanding and modelling of Pannonian turbidite bodies in the Zala basin. As a consequence, several stratigraphic and combined HC traps could be identified and delineated as prospects.

Introduction
Can exploration be renewed in a mature hydrocarbon basin where literally thousands of wells had already been drilled? The answer turned out to be – yes. Yes, even in the case of the Zala basin, the cradle of Hungarian oil exploration. And the clue is in updated play concepts and powerful integrated geoscientific approach.

As for the concepts, traditionally and conventionally exploration in this region targeted Mesozoic basement, however several wells encountered hydrocarbons (primarily gas) in the Pannonian sequence. Some of these hits were mere lucky chances of testing upper levels after a less successful target in the basement. In spite of these findings, many questions remained open in connection with the explored gas fields as well as with the future potential of the Pannonian until recent years. Without ignoring the further potential of the Mesozoic, exploration has now changed focus to Pannonian through updating play concepts and initiating systematic exploration efforts.

Geological setting
The Pannonian series are well known in the domestic exploration. Therefore we speak about its special feature in Barlahida area.

The areal extend of 3D survey covered the whole deposition system, from the alluvial plain to the basinal marls (Figure 1). Thus we could build the progradational sequences step by step.

The reader may refer to an earlier article mentioned.

What do the above mentioned facts mean? 1. Turbitides without erosion: - Rich sediment supply from the alluvial plain, minor deltas with several distributary channels - No shelf, no sedimentation near the coast line, the whole range of sediments moved into the basin by the delta slope feeder channels.

1. Turbitides without erosion: - Rich sediment supply from the alluvial plain, minor deltas with several distributary channels - No shelf, no sedimentation near the coast line, the whole range of sediments moved into the basin by the delta slope feeder channels.

Fig. 1. Progradational delta environments

- No shelf, no sedimentation near the coast line.
- Rich sediment supply from the alluvial plain, minor deltas with several distributary channels.
- Several successfully applied methods of visualization, delineation and definition of exploration targets as well as qualitative and quantitative approaches of seismic events are highlighted in the present article.

Successful integration of geological methods led to better understanding and modelling of Pannonian turbidite bodies in the Zala basin. As a consequence, several stratigraphic and combined HC traps could be identified and delineated as prospects.
techniques. In Barlahida primary focus was on detecting, interpreting and delineating turbidite channel sand bodies, and providing guidance for stratigraphic interpretation and model building. Fortunately, an arsenal of methods is available to help interpreters detecting and delineating thin channel sands. These range from simple attribute maps through spectral bluing to spectral decomposition techniques [4].

Geological interpretation technique

When we start to interpret a new 3D survey we exploit general knowledge and practice that lies within the organisation. But the key of success is to find individuality of interpretation technique and of the geological setting.

The speciality of the Barlahida 3D interpretation is the following.

Generally, the horizon interpretation technique depends on the purpose. Stratigraphic traps were the targets in the siliciclastic Pannonian deposition system. According to the basic concept people use the same reflector in the whole area. We know that it is impossible to keep on the 300 km² area.

There were individual decisions in several cases how to follow the convergent and divergent or disappearing reflections. The sedimentological model and feature as back knowledge helped to interpret the exact horizon (see Figure 3).

Attribute analysis is a well known working step. But how can we decide whether an attribute map has geological meaning?

In Barlahida 3D area there was a basic problem: the reflection pattern did not show the sedimentological feature according to attribute image. It raised the question how we can validate the geological content of attribute maps.

The paleoenvironment and sedimentological model represented another serious risk factor, because of mainly stratigraphical trap type. We detected many-many separated turbidite bodies and channels with different shapes in different deposition positions. The lithological prediction proved to be a great challenge because of the different clay and silt content of sand bodies. There is no clear sandstone generally, but clay and silt beds and grains in the reservoirs.

Separation of the potential reservoirs was performed on different aspects: such as the lithology and the good position of the targets regarding both lithological changes and the migration path (see Figure 4).

Extracting information from the 3D seismic cube

A 3D seismic cube contains a huge amount of digital data, of which interpreters extract information important for geological model building by elaborated processing and visualizing techniques. In Barlahida primary focus was on detecting, interpreting and delineating turbidite channel sand bodies, and providing guidance for stratigraphic interpretation and model building. Difficulties associated with the small thickness of these sand bodies had to be overcome.
reference horizon along which slicing is done, is crucial to obtain good quality slices, especially in the case of thin channels. Knowledge obtained on channel evolution was then extensively utilized and integrated into paleoenvironment reconstruction and stratigraphic model building.

3D visualization and model building
Advances in software technologies and computer graphics have an impact on exploration methods [5]. Today we are in a position to delineate and analyze underground geological objects such as sand bodies in three dimensions. Fancy 3D graphical representation of underground targets (such as on Figure 6) is not only l’art pour l’art visualization, but also a handy tool for interactive discussion and communication of ideas and problems among exploration team members as well as for 3D model building and well planning.

Seismic reservoir parameter estimation
Seismic attributes and attribute maps can be used not solely for qualitative interpretation, detecting and defining inner structure and boundaries of a geological object, but also for quantitative estimation of certain reservoir parameters.

Parallel to exploration, Bartahida seismic data were also used to help building a reservoir model of an already existing gas reservoir. (Another one of the birds to be killed.) Interpreted data helped defining the structure of the reservoir, while attribute analysis contributed to the estimation of reservoir parameters within the 3D model.

Multi-attribute analysis is always a statistical estimate, and as such it is probabilistic. However, with a suitable geological model in the background a physical, petrophysical casual link can be established between the spatial variability of the estimated parameter and the resulting petrophysical variability of rocks. Rock properties can directly influence the spatial variability of the shape of seismic reflection waves and the computed seismic attributes.

In our case the major rock property factors influencing seismic attributes were:
– Changes in thickness of reservoir
– Changes in rock matrix composition (clay content and type)
– Porosity changes and
– Saturation.

These effects can not be distinguished from each other by sole attribute analysis, but an integrated approach using well data (logs and tests) and seismic together is able to result in the 3D spatial distribution model of a specific reservoir parameter (e.g. porosity or rock matrix composition). 3D parameter distribution in turn can then be utilized in reservoir model building.

In the case of our reservoir we faced a somewhat unusual situation, where porosity estimation failed due to poor correlation with seismic attributes, and total porosity was also known not to be indicative of better or worse reservoir zones. To solve the puzzle, we introduced a novel approach, in which permeability was directly estimated from well data and seismic attributes. In order to give a scientifically sound estimate, two key components were required:
– An integrated geological background model to establish an indirect petrophysical link between spatial permeability variations and seismic attributes, and
– Proper pre-conditioning of well data (permeability) to achieve the best possible statistical correlation between permeability and attributes.

The former one was fulfilled by the model presented in preceding sections. An essential element was identification and differentiation of the role of different types of clay content of the sandstone reservoir.

The latter one is based on a special technique published also in MOL SM 2009/1 [6]. The key is to selectively correlate permeability values to seismic data according to macro- and microporosity classes.

Statistical multi-attribute analysis of seismic and well data by HRS ISMap resulted in parameter maps of the logarithm of permeability in the reservoir. Figures 7 and 8 show correlation of a seismic attribute to well test data and the associated permeability map of the reservoir respectively.

Summary
Successful integration of geological methods led to better understanding and modelling of Pannonian turbidite bodies in the Zala basin. As a consequence, several stratigraphic and combined HC traps could be identified and delineated as prospects.

Building a powerful model with integration of several geo-disciplines is a scientific success
in itself, which can not be underestimated, but the proof of the pudding is in the eating. And the primary proof of a geologic model is in a commercial well. In June 2011 the first prospect was targeted by a well and gave successful result (Figure 9).

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References

Keywords: mature area, turbidite, seismic event-geological information, seismic attribute, 3D visualization

Reviewed by István Czeller

László Pollner, PhD works for MOL since 1998 as seismic interpreter and modeller in domestic and Middle-East exploration and development projects (senior geophysicist). He graduated at Eötvös Loránd Science University, Budapest in 1994, and awarded PhD at University of Technology an Economics in 2000.

Marianna Vincze scope of activities: stratigraphy, sedimentology, geomodel developing in Pannonian series. Geographical areas: Hungarian Plain, Zala-basin, Romania and partly the middle part of the West-Siberian Basin. She is a member of successful groups of HC-exploration. She graduated at University of Szeged (geology - geology).
Gábor József
(1937-2011)

Mr. Gábor József (1937-2011), former deputy CEO of OKGT (Hungarian National Oil and Gas Trust), retired managing director of MOL (Hungarian Oil and Gas Company), passed away at the age of 75, on September 11, 2011. He was one of the founders of Tisza Oil Refinery (TIFO) and the former President of the Petroleum and Petrochemical Section of Hungarian Chemists’ Society. His funeral took place at the National Cemetery, Fiumei Street, Budapest on 29 September. His fellow colleagues, former superiors and classmates accompanied him on his last journey.

Mr. Gábor József was born in Dicsőszentmárton, Transylvania, in 1937. He and his family arrived in Hungary in 1940 and settled their home in the town of Ajka. He always delivered outstanding performance during his primary, secondary and university studies. He participated and won a national academic achievement competition in chemistry in the secondary school and was enrolled at the University of Veszprém without entrance exam. In 1960, he earned his degree ‘summa cum laude’ in chemical engineering, at University of Veszprém, Chemical Mineral and Coal Processing Industry Department.

Between 1960-1970, Mr. Gábor József worked as a factory manager and deputy head of the manufacturing facilities at Almásfűzitó site of Komárom Oil Company.

He became a member of the team conducting the large scale investment of Tisza Oil Refinery (TIFO) in 1970. From 1973, he worked as Head of Technology and Technical Development Department, at TIFO. As a culmination of his early engineering career, he formulated the technical concept of Tisza Oil Refinery and managed the implementation of the greenfield investment. As the Head of Technology and Technical Development Department, he had decisive role in the planning, the coordination of construction, and the implementation of subsequent improvements at the refinery.

Mr. Gábor József was selected and got the position of Deputy Chief Technical Officer of OKGT in 1985. Among his responsibilities, we would find the management of petroleum refining, hydrocarbon trading, gas distribution services and the monitoring of information technology of the Company Headquarter. He participated in the preparatory works aiming the privatization of the Hungarian oil industry, and in the foundation of MOL in 1991. Mr. József claimed that participating in the organisational reform of the Hungarian oil industry, which took place 20 years ago, was the largest-scale task of his professional career.

From October 1991 on, he held the position of Managing Director of MOL, and was responsible for international relationship management and PR works aimed at developing the identity of the newly formed MOL. In particular, his duties involved the development of international professional relationships, the coordination of cooperation with multinational companies, and the establishment of the corporate share office. In addition, he was member of the Expert Committee on Energy Policy of the Hungarian Academy of Sciences (MTA), and held the position of Secretary of the Hungarian National Committee of World Petroleum Congress. He was lecturer and co-presenter at numerous international oil business events and congresses.

He also held the position of President of the Petroleum and Petrochemical Section of the Hungarian Chemists’ Society during the 1990s.

Mr. Gábor József retired from his position in 1995 and gave back his technical and legal mandates afterwards.

Mr. Gábor József was an excellent oil industry professional. He was a man of continuity, a representative of high-standard team-work. Throughout his life, he aimed to find the answer if he did everything possible in order to continuously gain knowledge and how to master creativity. In his memoirs, he always considered himself a team player, and it was always his intention to achieve this. He also claimed that the clue to success, besides team work, lies in continuous learning.

He will be remembered for his outstanding human qualities and excellent leadership-skills. He will be deeply missed by his family, former classmates and colleagues. We will cherish Mr. Gábor József’s memory with respect and affection.
Ernő Rátosi, Dr. is 80 years old

Ernő Rátosi, Dr., the former general director of Duna Refinery (Százhalombatta), the doyen of the Hungarian crude oil processing industry, known and recognized by many people is 80 years old.

He is born on 4th of October, 1931 in a Western Hungarian village, Zalagyömörő. He graduates in 1960 as a chemical engineer at Veszprém University. Later he also receives degree in petrochemistry (1973) and technical doctor degree (1981) from the same university. Besides his native Hungarian he speaks German and Russian.

Mr. Rátosi starts his carrier at Csepel Oil Refinery (a former Shell refinery in Budapest) as a chemical engineer in 1960. From February of 1968 to June 1969 he works as a sectorial chief engineer in the Ministry of Heavy Industry. In 1969 he takes the place of the chief technologist of Duna Refinery (Százhalombatta), Mr. László Hága, who passed away in a tragic refinery accident in 1968. In 1973 he becomes the technical deputy director, and in 1975 as the successor of Mr. Béla Péceli the director (later general director) of Duna Refinery. He retires from Duna Refinery at the end of 1991 and subsequently becomes the member of the first Board of Directors of MOL headed by count Pál Teleki. After leaving this position in 1995, he remains an active participant of the modernization of the oil and gas industry and serves as an advisor at Refining and Marketing and Petrochemical Divisions up to the end of 2003.

His name is linked with the configuration of the complex oil refinery, implementation of a deep conversion process, introduction and production of high quality products recognized by both the industry and the market and laying the foundation of local and international co-operation with marketing and industrial companies. The most important investment linked to Mr. Rátosi is the fluid catalytic cracking (FCC) plant (1984) leading to considerably higher efficiency of crude oil processing and notable product quality improvements. As a result of this investment the oil industry became the most important ‘hard currency’ export sector in Hungary. In a later conversation Mr. Rátosi remembered FCC-investment as follows: “This was the culmination of my carrier, the greatest victory, and the best solution in technical terms... That time there was no such plant in the Eastern bloc... Such world class technology in the Western world was implemented only in a few refineries.”

As a result of his development-oriented policy Duna Refinery became the largest individual company in Hungary (in terms of yearly turnover according to the Hungarian weekly ‘Figyelő’).

He builds a team from excellent experts. His charismatic personality holds him up as a model for peers and subordinates. He supports the young people, draws attention to their professional education and stands for the promising initiatives.

For a long time he is a titular assistant professor of Veszprém University (Hungary). He is the vice-president of Hungarian Chemical Society in 1985-1990 and he plays a very active role in the implementation of the Society’s initiative to outline the prospects of the Hungarian chemical industry.

Mr. Rátosi’s activity is recognized and rewarded with, among others Eötvös Loránd-prize in 1979, Pfeiffer Ignác-medal in 1985. In 2002 the freedom of University of Veszprém was presented to him. In 2007 he receives the Life’s work prize of MOL.

Mr. Rátosi still keeps track of development activity and business results of MOL Group, inquires after young generation’s work. In the wide circle of his direct and indirect acquaintances he enjoys high recognition, esteem and respect up to now.

His eightieth birthday is remembered without the presence of his wife who passed away on New Year’s Eve of 2010 but in the company of their three sons with families, including six grandchildren. May God give him long life and good health.