Power Plant Mátra. Research to development of a coal quality concept for the lignite deposits Visonta and Bükkábrány, Hungary

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Power Plant Mátra.
Research to development of a coal quality concept for the lignite deposits Visonta and Bükkábrány, Hungary

Master of Science Thesis
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Francien Troost
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Abstract

By Francien Troost, M.Sc. Mining Engineering at Delft University of Technology

This project stands under supervision of RWE Power AG in cooperation with Mátrai Erőmű ZRt.

This Thesis carried out research towards development of a coal quality concept on geological and mining engineering operational level of Mátrai Erőmű ZRt’s Visonta and Bükkábrány open cast lignite mines, with objective to reduce and avoid sub-optimal combustion behaviour at Mátra Power plant. RWE Power AG is the major shareholder of Mátrai Erőmű ZRt (50.9%).

Three improvable sub-optimal combustion behaviours were determined based on power plant performance (2012-2014).

A coal quality handling recommendation was developed for Mátrai Erőmű ZRt based on results of coal quality modelling carried out within this Thesis. Through a coal sort algorithm the Visonta (V) and Bükkábrány (B) coal was divided into coal sorts (German: Kohlesorte). A programme was written which creates a block model assigned with quality data from geological samples. Subsequently, the coal sorts in the production profile were predicted by modelling the mining of the blocks within the block model. In- and Inter-pit supply strategies and blend ratios were determined to provide an optimal direct coal sort or blend of coal sorts to the Mátra Power plant. A preliminary mine scheduling programme was developed within this Thesis.

The Thesis was preformed along the Mátrai Erőmű ZRt operational mining and processing value chain. A technical background introduces the deposit geology, Visonta and Bükkábrány Mine, fuels (i.e. coal and co-combusted biomass) and Mátra Power plant. A theoretical background describes the power plant components of focused sub-optimal combustion behaviour in theory and points out coal quality parameters and operational factors which potentially enhance sub-optimal combustion. The operational procedures at Mátrai Erőmű ZRt were studied on site, i.e.: sampling, geological modelling, mine planning, mining, transporting (logistics, rail supply of Bükkábrány coal and stockpiling facilities), blending and combustion. Historical operational data was used as modelling input, i.e.: geology database, overview on available qualities, technical constraints, blending constraints and acceptance algorithm. The quality modelling consists of determination of a coal quality algorithm (incl. power plant acceptance algorithm), coal quality modelling for the individual coal seams and evaluation of in- and inter-pit supply strategies. Finally, the coal quality handling description summarises the recommendations for the Mátrai Erőmű ZRt operation.

The resulting handling recommendation states the determined coal sorts, cutting technique guideline, power plant supply strategies, stockpile supply schedule and blending strategies.

The significant result from this Thesis is that the coal in Visonta and Bükkábrány Mine can be divided into minable coal sorts for which a standard combustion behaviour can be expected.
Acknowledgment

With full enthusiasm, I wrote my M.Sc. Thesis:

“Mátra Power Plant. Research towards development of a coal quality concept for the lignite deposits Visonta and Bükkabrany, Hungary”

It was the best and most interesting project I carried out, so far.

I am grateful to thank the following people who supported and helped me in different valuable ways to prepare, structure and improve my M.Sc. Thesis, to answer open questions and to just be around.

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Glückauf

Francien Troost

Köln, July 31st 2014
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1. Introduction

1.1 Mátrai Erőmű ZRt: a company overview

Mátrai Erőmű ZRt owns and operates two open cast lignite mines: Visonta Mine and Bükkábrány Mine which supply the power plant Mátra near Visonta Mine. Mátrai Erőmű ZRt is located in northeast Hungary, approximately 90 km east from the capital city Budapest and directly south of the Mátra and Bükk mountain ranges (see Figure 1).

The open cast mine Visonta and Bükkábrány produce approximately 8.8 Mt of lignite annually. Approximately 5 Mt/a of lignite are produced from the Visonta Mine, of which approximately 75,000 t are sold for Hungarian domestic end use. The Mine has a stripping ratio of 9.4:1 m³/t, overburden to coal ratio. Approximately 47 Mm³ of overburden is handled annually. Visonta Mine is located directly adjacent to the Mátra Power plant and supplies the power plant by belt conveyor. Temporarily storage of approximately 22 kt is possible in the Visonta Mine Stockpile. The Bükkábrány Mine extracts approximately 3.8 Mt/a and supplies Mátra Power plant via 60 km rail. Approximately 160,000 tonnes are annually sold for Hungarian domestic end uses or to other external buyers. Temporarily storage of approximately 30 kt is possible in the Bükkábrány Mine Stockpile, a stockpiling facility prior to train loading. The mine extracts approximately 26 Mm³ of overburden per year, the overburden to coal ratio is 6.7:1 m³/t. Based on the overburden to coal ratio Bükkábrány Mine may be considered as the mine with higher economic value, lower operating costs. The mineral reserve of lignite coal in Visonta and Bükkábrány is approximately 800 Mt (Mátra-Prüs, 2013).

Mátra Power plant consists of five lignite fired blocks, having the following capacities: Block I and II of both 100 MW, Block III with 220 MW and Block IV and V of 232 MW each. Additionally, two gas turbines were installed in 2007, each with a capacity of 33 MW. The total power plant capacity is approximately 950 MW. The overall efficiency of the Mátra Power plant is 50%. The gas turbines have an efficiency of approximately 34%. The gas turbines increase the flexibility of the power plant when peak energy is demanded. The Blocks III to V are supplied with approximately 250 t/h of raw
lignite. In addition to the lignite and gas fuels, approximately 10% of CO$_2$-neutral biomass is combusted in the power plant. The heating requirement lays around 11500 kJ per produced kWh to produce approximately 224 MWh/h. The power plant is supplied directly from the mines (Bükkábrány coal through railway) or from the power plant adjacent stockpile facility *Visonta Mine Stockpile or Power Plant Stockpile* (German: *Kohlenlagerplatz*). The planned operational life of the Mátra Power plant units is outlined as followed: The annual operating hours of the two 100 MW blocks will be reduced to 1550 hours per annum (~17%) up 2020, towards shut down of these units in 2020. The remaining three blocks (III, IV and V) and gas turbines and supplying mines will be shut down in 2025. (MERT-GP, 2013).

A potential future project at Mátrai Erőmű ZRt is the building of a photovoltaic installation with a capacity of 15 MW. The photovoltaic facility would be built on top of the reclaimed ash waste pond north-west of the power plant (MERT, 2013).

Mátra Power plant contributes 5536 GWh, or 15% to the Hungarian energy market (2011). Mátrai Erőmű ZRt is owned by three major shareholders, i.e. RWE Power AG (50.9%), Magyar Villamos Művek (MVM) (26.2%), EnBW (21.7%) and 1.2% other owners. The company generated an income of 62 M€, from which 13 M€ are generated from exports (20%), considering financial year 2012 (MERT-Prås, 2013).

### 1.2 The added value of a coal quality sort concept: the Rhenish coal sort concept as example

Throughout the past 15 years RWE Power AG achieved a reduction of ore loss and an increase of power plant availability after introduction and development of a coal quality based *lignite coal sort concept*. The special coal quality parameters per lignite deposit were described by narrowly conceived definitions, the so called: *coal sort algorithm*.

The *Hambach* and *Garzweiler* Mine of RWE supply approximately 100 Mt/a of lignite coal to the power plants and factories, to produce a rough 74 TWh of energy and about 4 million tonnes of briquettes per year (RWE, 2013). The developed coal quality management systems integrate following key systems: geological model, excavation techniques, stockpiling facilities at the mines, rail transport, power plant stockpiling facilities and power plant block specific combustion characteristics.

An extensive amount of knowledge about the deposits geology, mining operations and the operational behaviour of power plant’s individual boilers is needed to be able to divide the lignite in economically reasonable *coal sorts*.

**Coal sort (German: *Kohlesorte*):** (In situ) lignite coal for which one or multiple quality parameters (e.g. ash, sulphur, potassium content) lies within specified ranges so that by combustion of this coal a particular combustion behaviour can be expected.

In this Thesis the term “coal sort” was chosen over “coal type” or “coal kind” because of the logic parallel to the German word, i.e.: “Kohlesorte”. NB. Coal sort should not be confused with “to sort” coal or “sorted” coal.

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1 Exchange rate: 1 EUR = 294.715 HUF (= Hungarian Forint) (2013-10-17)
Deposit geology

The thick lignite seam in open cast mine Hambach is covered with a thick overburden layer which results in high calorific values (or low moisture content). In the southern area of the Hambach Mine siderite-layers are enclosed in the coal containing a high amount of iron. The lignite in the northern part of the mine contains high sodium concentrations. The sodium oxide content in the coal ashes varies approximately between 3 and 8%. This corresponds with ash contents between 4 and 2%, respectively. Dilution of coal commonly occurs throughout the entire deposit through co-extraction of clay, silt or sand rich sediments from the hanging and footwall sediments of the coal seams, also sediment inclusions dilute the coal (Lokay, 2013).

Garzweiler Mine consists of three by interburden separated coal seams, each having specific coal quality features: Seam Garzweiler has a strongly varying thickness. The lignite is poorly consolidated and has a high moisture content. The lignite partially has Xylit-rich structures and sporadically high iron content. Seam Frimmersdorf is a sand-rich coal with high sulphur content (i.e. 0.6 – 1.4 %). Seam Morken has a poor sulphur and ash content and is there with an excellent blending component to homogenise outlier qualities in Seam Frimmersdorf (Lokay, 2013).

Open cast mine Inden is not directly included in the coal quality sort concept because it supplies its own Power plant Weißweiler.

Coal combustion behaviour

Based on experience of RWE Power AG in combustion of sub-optimal coal (or coal sorts) hypothetical combustion behaviour statements can be made (Neuroth, 2013a). The operational behaviour of a boiler is strongly dependent on the air supply, temperature profile and residence time of the coal dust in the boiler. Air is the major initiator of the combustion- and oxidation processes. Insufficient air supply could cause incomplete combustion and oxidation of the carbon-compounds into carbon monoxide, which could encourage fouling and delayed combustion in the boiler. Furthermore, insufficient air supply could slow down the formation of sulphates in the flue gas due to which the dust in the flue gas is deposited on the heat exchangers and further reacts to form sinter. Slagging could be improved because of Fe$^{2+}$-formation with low melting temperatures. On the contrary, a surplus of air supply mainly avoids slagging in the boiler, however could lead to increased temperatures and NO$_x$ formation. The temperature influences the melting process of coal dust and condensation processes. High temperatures influence the stability of particular mineral phases, like Anhydrite (CaSO$_4$) and encourage potential fouling and slagging processes.

The following chemical elements could have a high influence on the slagging potential of Rhenish lignite blends: silicon, aluminium, iron, calcium, magnesium, sodium, potassium and sulphur. Sulphur, iron and calcium for example occur either organically or inorganically bound. For example: In Rhenish lignite sulphur can occur as Pyrite (FeS$_2$). In the Mátrai Erőmű ZRt lignite deposits also Gypsum (CaSO$_4$·2H$_2$O) is a commonly occurring mineral (Frerix et al., 2013), see Chapter 9B.2. The sulphur which is not bound in ash minerals reacts to SO$_2$ and is transported in the flue gas to the flue gas desulphurisation (FGD) plant. Calcium in combination with sulphur can cause sulphate caking and fouling on the heat exchangers. Dependent on the amount of sodium, temperature and residence time these fouling-coats could become extremely hard. Combustion of sulphur-rich lignite contaminated with clay could result in formation of alumino-siliceous-slags. High sodium contents in the lignite could increase slagging, sintering and fouling potential in the burning chamber and at the heat exchangers because of its melting point decreasing function against silicates and sulphates. Potassium mainly occurs in the lignite in combination with aluminium-rich clay minerals and feldspars and could
trigger slagging because of its melting point reducing function. In alumino-siliceous systems calcium and magnesium have a melting point reducing characteristic, which might increase the slagging potential. Silica is the key parameter when considering slagging potential, it increases the melting temperature in silica-rich ash systems and decreases melting temperatures when occurring in combination with calcium-magnesium-, or iron-rich combustion systems. Silica (in form of coarse-grained quartz sand) has a cleaning function against fouling on the heat exchangers, however causes extra abrasive wear on the equipment. Iron is mainly present in lignite inorganically bound as siderite (FeCO$_3$) or pyrite (FeS$_2$) but could also occur biogenically bound. Iron is uncritical against slagging in low ash environment (no reactants, for example silica, present), however in combination with silica strong slagging processes could occur.

Slagging can be avoided by taking operational measures. For example: spontaneous silica slagging can be prevented by combustion of critical coal qualities at low temperatures (fluidized bed combustion chambers or other boilers with low thermal heating chamber conditions) and by avoiding sub stoichiometric conditions at the exit of the burning chamber. Furthermore, it is prohibited to combust coals with low melting eutectic ash compositions at low temperatures because of their extremely critical slagging potential (dependent on basic-acid-ratio$^3$). Sulphate-sintering is a very slow fouling process. To prevent boilers from this fouling type the following operational measures were suggested: frequent cleaning with shoot-blowers or increase of the ash content (abrasive self-cleaning behaviour). Combustion of lignite with high calorific value, sulphur content and sodium content at the same time must be avoided. Also, a high temperature at the burning chamber exit point must be avoided.

**Rhenish coal sorts**

The Rhenish coal sorts are defined taking into account boundary conditions for ash content and multiple chemical elements: sulphur, iron, silicon, sodium and potassium. The coal sorts firstly divide the lignite deposits into briquette and boiler coal, based on the ash content. Briquette coal has an ash content lower than 2.5% and is only available in the Hambach Mine. The briquette coal is further divided in two coal sorts based on the amount of gel in the coal, i.e. HBG for Hambach Briquette coal Gel which might have a gel amount greater than 50%, and HBA for Hambach Briquette coal Poor (German: arm) with a maximum gel amount of 50%. The boiler coal in Hambach is divided into seven coal sorts, and Garzweiler coal in six. The Hambach boiler coal is divided into normal coal which can be used in every Hambach-boiler of the Rhenish power plants and sand/clay-rich coal which are preferably fed into the power plant boilers after blending with normal Hambach coal or Garzweiler coal. The normal Hambach coal is additionally subdivided based on iron and alkali (Na and K) enrichment. Hambach boiler coal that does not fit in any of these descriptions is called HKR: Hambach Boiler (German: Kessel) coal Rich. This coal is subjected to combustion trials before further classification to a particular coal sort. Garzweiler boiler coal is divided in coal from Seam Garzweiler with minimal amount of critical components iron and potassium (GGA), rich of critical components (GGR) and sand-rich coal (GGS); and blends of Seams Frimmersdorf and/or Morken, similarly named: GMA, GMS, GMR, also characterized by the amount of iron, potassium and ash (Jaetzel, 2013).

**Coal quality management**

From an economic perspective it is of equal importance that the mine extracts the lignite without capacity loss or delay in overburden extraction and that the power plant operates widely without un-

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$^3$Basic-Acid Ratio: $(\text{Na}_2\text{O}+\text{K}_2\text{O}+\text{CaO}+\text{MgO}+\text{Fe}_2\text{O}_3):(\text{SiO}_2+\text{Al}_2\text{O}_3+\text{TiO}_2)$, see Chapter 7.1
planned standstills or performs under capacity. Intensive cooperation between the mines and the power plant, supported by a sophisticated digitalised logistics system, is needed to make the coal sorts economically viable (Rosenberg, 2003 and Hagenbrock, 2013). Figure 2 schematically shows the simplified coal quality management system used at RWE Power AG.

![Schematic visualization of the coal quality management system at RWE Power AG](modified after, Hagenbrock, 2013)

The in-situ coal quality descriptions (LAVA geology database and geological model) is divided into by Bucket-Wheel-Excavator (BWE) minable slices, after mining each slice is characterized with this coal quality description, or Quality ID (IKOLA). Automated on-belt sampling proofs the coal quality ID. The quality ID consists of all relevant information: which BWE, extraction position, quality description, mass and time. After extraction the coal slice is stored in the stockpile facility. The material in the stockpiles is simulated per slice based on the quality IDs (QUABUS). The stockpiles are used for homogenisation of the extracted coal sorts, to reduce extreme coal quality outliers (e.g. sulphur outliers). From the mine’s stockpile the train wagons are filled with blend qualities of the different slices, each wagon gets a new Blend Quality ID (IBUKOM). Per wagon the coal is charged into the power plants stockpiles. A blend quality of wagons is finally reclaimed from the power plant stockpile and fed into the target power plant boiler or factory. Potential reactions between lignite and mineral sediments in the boiler were assessed, as well as caking potential of particular coal sorts (as described earlier). Based on these assessments each power plant and factory got their own lignite blend schedules which are described in the coal quality strategy rules (Hagenbrock, 2013). All material handling rules, coal sorts, blend rules, stockpiling strategies are described in a coal quality handling recommendation (German: Handlungsempfehlungen) (Jaetzel, 2013).

**Summary**

Summarising the components contributing to the coal quality sort concept currently practiced in the Rhenish Mining District by RWE Power AG, i.e.:

- Extensive knowledge on the geology of the lignite deposits (to determine coal sorts)
- Target-aimed (power plants or refining factories) plant feed allocation and delivery
- Utilisation of both mine and power plant capacity (high equipment availability)
- Understanding of the power plant operational behaviour for the particular coal sorts
  - Power plant performance and efficiency
  - Slagging and fouling behaviour of coal sorts, based on B/A-ratio, calorific value, ash melting behaviour and sediment contaminations (or other sub-optimal combustion behaviours)
- Technical operation limitations of mines, logistics, stockpiling facilities and power plant