Coal Preparation from Geometallurgical Perspective

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Abstract

Geometallurgy as a link connecting geological features of deposit with metallurgical performance of a concentrator have found broad utilization in metals mining as well as for industrial minerals and black sands mining. However, coal industry yet stays uncovered by successful applications of geometallurgical approach due to certain specifics of a commodity. Production of coal preparation plant in terms of quality and quantity can be forecasted knowing behavior of coal bearing particles in process that is controlled by petrological and mineralogical properties. Application of process mineralogical tools together with comprehensive metallurgical testwork helps to acquire essential information for a simulation of coal preparation operations. Being combined with geological, geochemical and geotechnical data available for a deposit, outcome of process simulation will form holistic geometallurgical model. Once implemented, such models will become a powerful instrument for efficient utilization of resources and proper risk management, e.g. adaptation of the process to variations in run-of-mine coal quality, "what-if" analysis of alternative production strategies, forecasting of financial results, assessment of environmental impact.

Keywords: coal preparation, geometallurgy, modeling, process simulation

Introduction

Coal was used to be known for centuries as "black gold", this label is well changed in twenty-first century to "dirty energy". Paris Agreement regarding climate changes (COP21, 2015) was signed by 195 countries from all over the world with aim to limit global warming. One of the major causes leading to temperature changes is emission of so-called "greenhouse gases", which implicitly pointing to coal as unwanted energy source in the future. Domestic production of hard coal in European Union countries during last 25 years was reduced by more than 70% (Eurostat, 2015). Nonetheless, coking coal has been placed in the EU list of 20 critical raw materials with the second highest economic importance score after tungsten (European Commission, 2014).

Mining industry in general face similar challenges as coal industry in domain of environmental issues and more demanding market. Better utilization of mineral resources is possible with geometallurgical approach what was over and over again proven in metal ore industry as well as for industrial minerals mining. Once revised to suit specifics of coal industry, geometallurgical tools and methods could be applied worldwide.

Concept of geometallurgy

Geometallurgy is fairly new area and might be known under different names. It combines geological and mineral processing information to create spatially-based predictive model to be used in mineral industry for production management. Geometallurgy is not a pure science or independent subject because it takes parts of geology, mineralogy, geostatistics, mineral processing, metallurgy, economy and management.

Geometallurgy should be considered as a powerful instrument for efficient utilization of deposit resources and proper risk management, e.g. adaptation of the process to variations of ore, "what-if" analysis of alternative production strategies, forecasting of financial results, assessment of environmental impact. The reason for that is laying in acknowledgment of orebody heterogeneity and proper knowledge of the variability of orebody properties over the deposit.

Throughout the years several ways of introducing geometallurgy into mining operations were developed. The most advanced particle-based approach uses mineral particles as a key element to connect geological data with metallurgical performance (Figure 1). In metal industry particle approach fully based on the ore mineralogy, whereas in the coal mining it seems reasonable to link performance of processing plant with deposit geology via coal petrography.

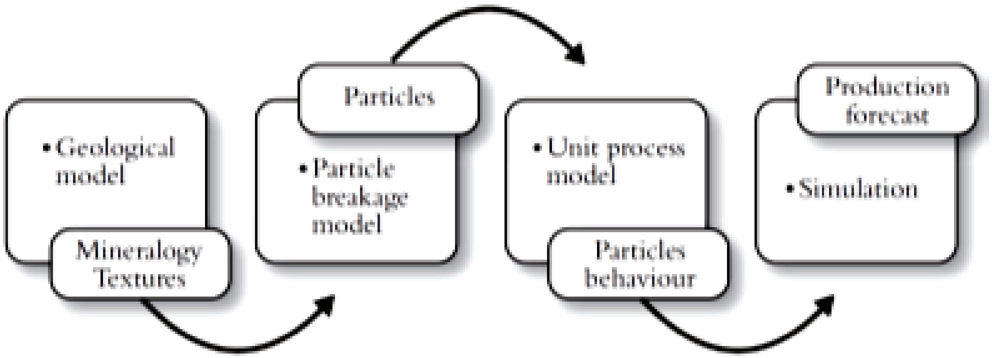

Fig. 1 The particle-based geometallurgical approach (Lund, 2013)

Rys. 1 Metoda geometalurgiczna oparta na analizie ziarnowej (Lund, 2013)

Basic qualitative information about mineralization for geometallurgical model is obtained mostly during the exploration campaign. Drill cores bring details about geological setting, lithological data, structural and textural information. Parameters to be quantified by geostatistical methods include but not limited to coal layer thickness, specific gravity, ash and sulfur content; for thermal coal its calorific value also can be used. If additional information (e.g., geophysical data, results of drillhole logging) is available, indicator kriging might be employed allowing to consider the uncertainty of the sampled values. Further, geological model is enhanced with metallurgical testwork outcome, allowing to carry out process simulation and being transformed into integrated geometallurgical model.

Coal preparation specifics

As it was mentioned before, geometallurgical model of deposit could not be built without determination of quality indicators of the ore and their variability. One of the possible approaches to characterization of coal is to use methods of process mineralogy to define rock properties of coal such as, for instance, petrological composition, coal texture, intergrowths of constituents and their liberation size. Petrographic assessment of coal is a standard method for characterizing the distribution of macerals and mineral matter in coal. The importance of petrographic composition for downstream processes is proven by numerous studies in the field of thermal, coking, and technological applications of coal.

Unlike in metal ore processing, in coal preparation practice final products are desired to be of coarse size classes, therefore microscopic properties have little impact on processing but are significant for downstream use of coal. Properties that describe coal particles on a macro scale and determine their behavior in the process are usually defined by laboratory testing. Most often used process of coal preparation is gravity separation., hence for the purpose of simulating the metallurgical performance data obtained via float-sink analysis is of utmost importance. Liberation of coal matter from waste rock could be also identified alongside with washability data (Oki et al., 2004). Coal washability shows distribution of the material by density fractions and allows to predict the performance of gravity separation processes, which are predominantly employed at coal preparation plants. For that reason, washability index and derived from it liberation degree could be used in geometallurgical models of coal deposits.

Case study

An example of what can be deemed as geometallurgical approach can be named a coal preparation unit of Taldinskaya Zapadnaya mine, SUEK Group, located in Kuznetsk coal basin, Russia. The major sellable product of the mine is thermal coal with calorific value of 25,100 kJ/kg and ash content less than 10%.

Comprehensive petrographic studies combined with proximate analysis of coal seams of the Taldinskoe deposit showed variability in coal quality between different layers in suite as well as along the same coal layer. It was shown (Gagarin and Gyulmaliev, 2009) that in some areas of deposit lightest coal fractions contain up to 88% of vitrininte having an ash content less than 4%. Data from float-sink analysis on a representative sample is given in Table 1.

Separation at specific gravity of 1.3 g/cm³ allows to obtain ultraclean coal concentrate with 3.5% ash suitable for application in metallurgical process as a reducing agent. This research has formed a basis for design of coal preparation unit which was commissioned in early 2008. The flowsheet of the concentrator comprised following operations:

- dry sieving at 6 mm screen aperture size;
- dense medium separation in WEMCO drum;
- product rinsing and dewatering;
- auxiliary operations (e.g., regeneration of dense medium and process water clarification).

Being rather simple, the flowsheet made it possible, instead of selling coal in bulk to power plants, to

Tab. 1 Washability data of 6–25 size class coal

Tab. 1 Wzbogacalność węgla w klasie 6–25mm

Density fraction (g/cm^3)	Yield (%)	Ash content (%)	Cumulative floats		Cumulative sinks	
			Yield (%)	Ash content (%)	Yield (%)	Ash content (%)
1.2-1.3	6.19	2.6	6.2	2.6	100.0	9.0
1.3-1.4	80.68	3.7	86.9	3.6	93.8	9.5
1.4-1.5	4.35	14.2	91.2	4.1	13.1	44.9
1.5-1.6	2.07	30.2	93.3	4.7	8.8	59.9
1.6-1.8	1.11	42.3	94.4	5.1	6.7	69.2
1.8-2.0	1.67	60.3	96.1	6.1	5.6	74.4
2.0-2.4	3.93	80.6	100.0	9.0	3.9	80.6
Total	**100.0**	**9.0**				

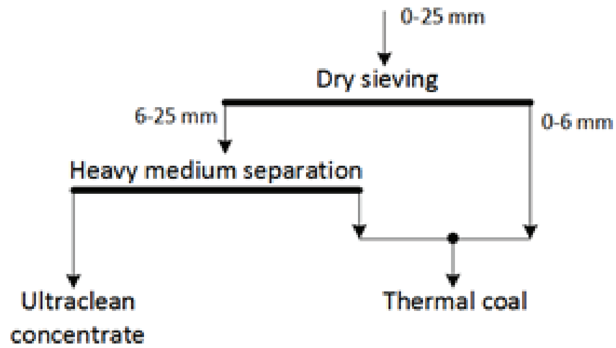

Fig. 2 Simplified flowsheet of Taldinskaya Zapadnaya concentrator

Rys. 2 Uproszczony schemat zakładu wzbogacania Taldinskaya Zapadnaya

Tab. 2 Product balance of Taldinskaya Zapadnaya coal preparation unit

Tab. 2 Bilans produktów wzbogacania węgla w zakładzie Taldinskaya Zapadnaya

Product	Yield (%)	Throughput (tph)	Ash content (%)	Moisture (%)
Ultraclean concentrate	10.5	21.0	3.5	5.8
Dense medium rejects	36.0	72.0	10.6	10.9
Dry screenings 0-6 mm	53.5	107.0	10.1	14.4
Total	**100.0**	**200.0**	**9.6**	

produce an extra product with higher added value thus increasing profitability of the mine. Another product is thermal coal that has lower calorific value (24,300 kJ/kg) comparing to run-of-mine material, but still meeting the consumers' requirements. Material balance of the plant is shown in Table 2.

Conclusion

It is undeniable that in near future coal will keep its place among other important raw materials. However, related environmental issues have to be addressed and utilization of resources has to be done in sustainable manner. Being initially developed for metal ore mining, geometallurgical approach provides instruments for optimized use of mineral resources. Regarding coal preparation, plant performance can be forecasted in terms of quality and quantity knowing behavior of coal bearing particles in process that is controlled by petrological and mineralogical properties. To some extent, an attempt to connect spatial, petrographic and metallurgical data in process model can be illustrated by an example of Taldinskaya Zapadnaya mine.

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Wzbogacanie węgla z perspektywy geometalurgicznej

Geometalurgia jest to ogniwo łączące cechy geologiczne złoża z wydajnością zakładów metalurgicznych, geometalurgia znalazła zastosowanie w górnictwie metali i innych surowców. Najważniejsze zastosowanie geometalurgia znalazla w przemysle węglowym. Geometalurgia pozwala przewidzieć wielkość i jakośc produkcji zakładu wzbogacania węgla wynikające z właściwości petrologicznych i mineralogicznych minerałów w złóżu. Zastosowanie narzędzi geometalurgicznych do analizy danych pomaga uzyskać kluczowe informacje dla symulacji procesów wzbogacania węgla. Połączenie danych geologicznych, geochemicznych i geotechnicznych umożliwiaja przeprowadzenie symulacji procesu wzbogacania na bazie opracowanych modeli. Po wdrożeniu modele staną się instrumentem efektywnego wykorzystania zasobów i właściwego zarządzania ryzykiem, dostosowanie procesu do zmian jakości węgla w trakcie eksploatacji, analiza alternatywnych strategii produkcyjnych, prognozowanie wyników finansowych, ocena oddziaływania na środowisko.

Słowa kluczowe: przerobka węgla, geometalurgia, modelowanie, symulacja procesu