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Designing exploitation and dumping processes in brown coal mines using information technology techniques

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In the Integrated IT Systems proposed by Przedsiębiorstwo Robót Geologiczno-Wiertniczych—Geological and Drilling Company (PRGW) a network connects a database with all of the departments of a mining division. A key element thereof is the common graphics environment—MicroStation supplied by the firm, Bentley. PRGW's SoftMine software and GMSI's CadsMine that are used to design and schedule mining operate in this environment. The digital form of the design project facilitates the verification of information and the integration of technical solutions with SAP R/3 type financial—accounting systems. The system has been successfully implemented in the Brown Coal Mine in Poland.

Introduction

Access to information is a key element of effective decision making. This is true for all types of activities, particularly economic activities.

The dramatic development of computer technology and the consequential development of software have made it possible to access and verify information at a level facilitating the creation of completely new production management methods and this also pertains to the mining sector.

The new management methods are connected with:

- the possibility of collecting information in relational databases
- the verification of information using specialist IT tools
- the integration of the work of all of the technical and financial departments of a business
- the possibility of obtaining a rapid, multiple variant analysis of any given technical problem
- immediate access to all of the key information for mining business management purposes
- the possibility of creating variant-based designs for short-medium- and long-term periods plus the option of automatically verifying the selected solutions
- the creation of reports according to the management's specific needs.

An IT system serving the purposes of production management has been implemented at the 'Turów' Brown Coal Mine (BCM) Joint Stock Company and this is a groundbreaking innovation within the field of Polish mining[1]. The Turów mine is an open cast mine exploited in mixed floors (coal-waste rock) and overburden layers. Exploitation is accompanied by the process of dumping occurring on an external dumping ground and also inside the open mine.

General characteristics of the solution

The tools supporting the designing of mining and dumping processes include CadsMine supplied by the firm, GMSI, Modeller and Reserver forming part of the I/Mine 2000 suite and PRGW's SoftMine. This software functions in the Windows operating system on the MicroStation graphics platform supplied by the firm, Bentley. The system utilizes data in the form of *.dgn graphics files (MicroStation), continuous *.sn models (Modeller) and tables in a relational database. The final form of the results are recorded in reports constituting tables, graphs and schedules as well as digital maps for individual planned exploitation and dumping states. The design process is performed in stages in a strictly defined order. The system is totally comprehensive and integrated and the stage-based structure means that the designer is able to monitor the correctness of data obtained (Figure 1).

Course of the work connected with creating a design of exploitation and dumping

Modelling

In the first stage a structure for opening out and exploiting the deposit is created[3]. This consists of digital models of working and planned levels. The models of the levels are based on a digital mining map, structural and qualitative models of the deposits and the designated exploitation limits (projected scarps, safety pillars). The data for each level are inputted into a dgn design file of the MicroStation program. Modelling is performed using the Modeller application from the I/Mine 2000 suite. The model is updated with the latest information made available by surveyors, geologists, geotechnicians and other mining personnel.

Subsequently, models of floor thickness and of useful minerals in the floors arise. Thickness is calculated using IML batch programs operating in the I/Mine Modeller environment.

The IML program utilizes models of the surfaces of roofs and floors of recoverable beds, the model of working levels and models of interlayer thickness to calculate the thickness of useful mineral beds within workings. The models of the surface of average beds and interlayers within these beds are created on the basis of the results of borehole profiling

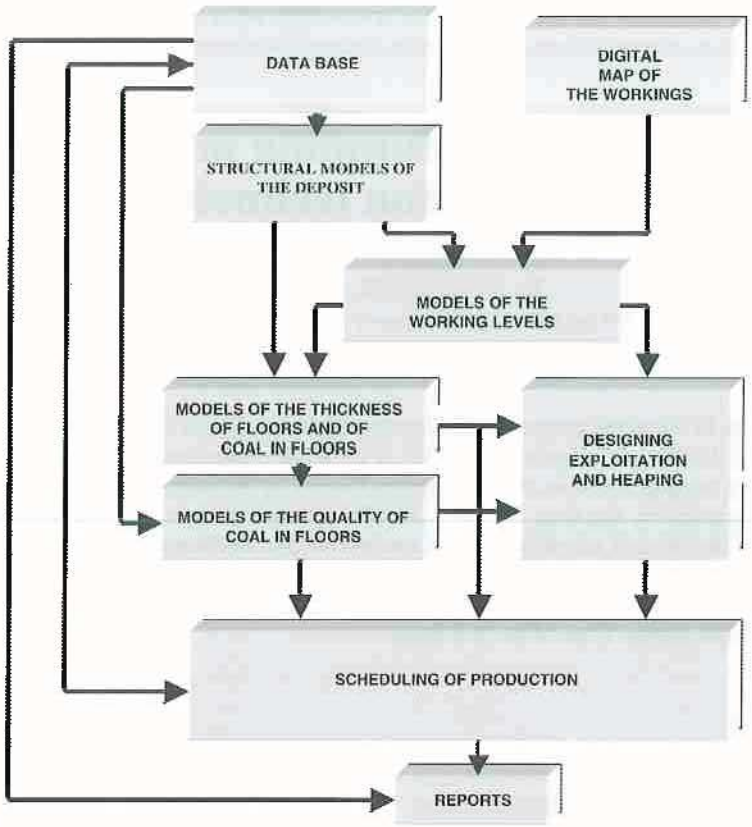

Figure 1. Diagram of the information flows within a mining division during the process of designing and scheduling production

and scarp charting stored in the database. The database is updated on an ongoing basis by geologists, who draw up the aforementioned models and pass them on to designers (Figure 2).

At the next stage the qualitative parameters of coal in the floors are modelled. The input data for these models, the results of the sampling of bore hole cores, groove sampling and protection holes are also collected in database tables. The data are obtained using the 'Jakość' ('Quality') program, which is an element forming part of the SoftMine PRGW Sosnowiec suite. It collects data on the values of qualitative parameters from databases and calculates their weighted averages for the working floors. The program transfers the results obtained to the MicroStation graphics environment. On the basis of the calculated weighted average parameters that have been transferred to a graphical format using the I/Mine Modeller application, a digital model of the selected qualitative parameter of the useful minerals in the working face is drawn up. The accuracy indicator consists in the evaluation of the error relating to the average contents of the analysed parameter, determined on the basis of the results obtained using exploratory bore holes or mining works. The presentation of information on the reserve estimation error in this manner indicates the level of risk connected with undertaking investment. The level of the estimation error is calculated using geostatistical methods (kriging).

The design process

Exploitation is designed within the MicroStation graphical environment using the Mine Design application forming part of the CadsMine suite supplied by the firm GMSI. The design objective consists in the division of the floor into working panels, within which the scheduling and simulation of mining processes is to take place. (Figure 2).

The working panels are determined by the range of excavation and the assumed shortwall width, whereas the central line is determined by the direction of excavation within a given panel. CadsMine Designer is equipped with tools automating the procedures connected with designating panels and any other underground workings. Each working face is allocated information relating to the symbol and type of mining machinery used together with its progress, as well as the symbol and the type of conveyor. During the design process, constant access to external information is ensured. This information consists in the following: tectonics, the contents of the useful minerals and their quality, the status of works and archival statuses, hazards within the design area and the localisation of technological production lines.

Scheduling and simulation of the progress of working and dumping faces

Scheduling performed using the Scheduler application from the CadsMine suite consists in assigning detailed information to workings that have been designed previously. At this stage, the dates of commencing mining work in a given working face, the sequence thereof, technological standstills, changes in progress due to local conditions and many other factors are determined. This information is inputted into an internal database. As part of the simulation, on the basis of the defined parameters, the workings arising during the exploitation design process are divided into parts corresponding to periods that have been previously defined in the exploitation calendar.

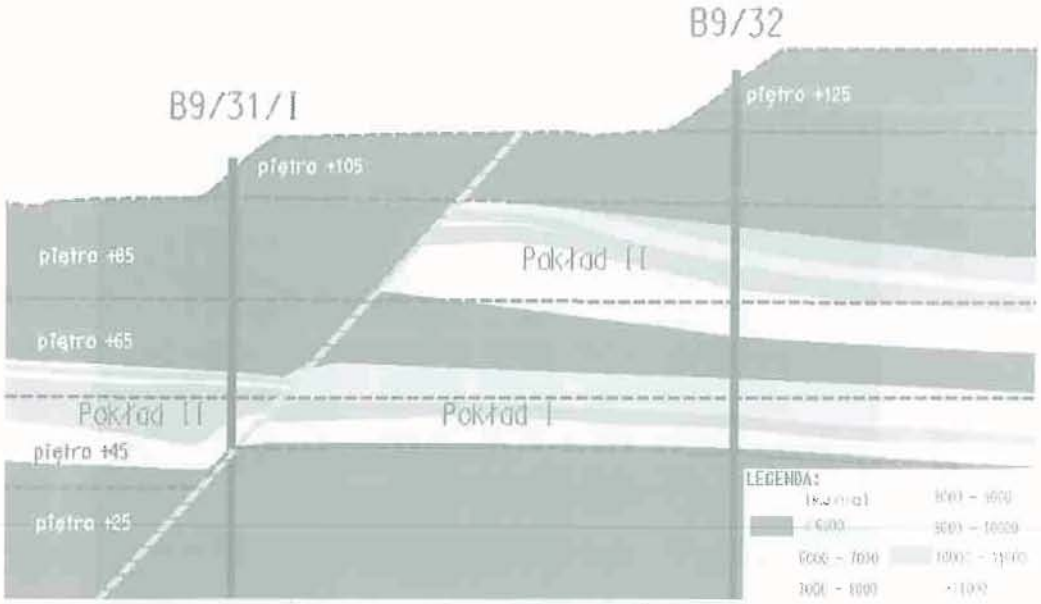

Figure 2. Cross section of exemplary mining floors. The deposit structure and the calorific value of coal in the beds is shown. Translation of expressions on the object: piętro—floor
pokład—bed
Legenda-Key

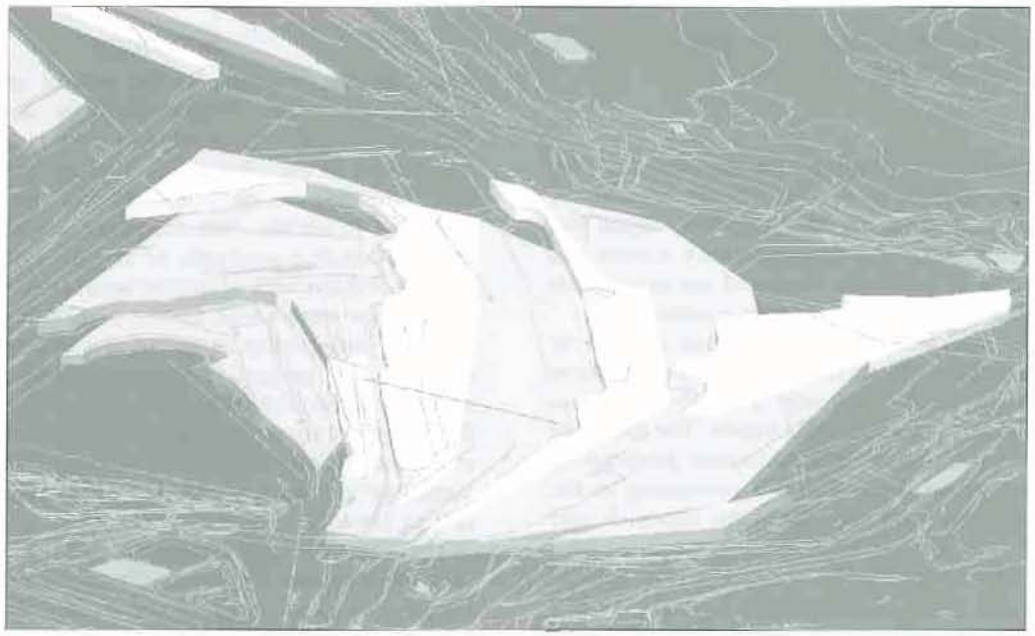

Figure 3. Working panels against a background of existing scarps and yearly rates for the seven working floors

The calendars are defined by the user and may be freely defined in accordance with the scope or specific characteristics of a given design.

Calculations

Using the Reserver[2] program the information concerning the mining range in a given period is combined with the relevant models. Models of the thickness of working floors and models of the thickness and quality of coal in floors are used to perform calculations. The results of calculations in the form of the mass of coal and overburden, the weighted average qualitative parameters of coal and information concerning the progress and standstill of excavators in consecutive periods of time in accordance with the defined mining calendar are automatically stored in the database that constitutes the basis for creating reports.

Reports and schedules

The final stage of the design process consists in reports in the form of tables, graphs and schedules obtained using the SoftMine program (Figure 4). Reports may be attached to the overall design or to any given part thereof, according to requirements. It is possible to generate summary and comparative reports. After the optimal variant has been

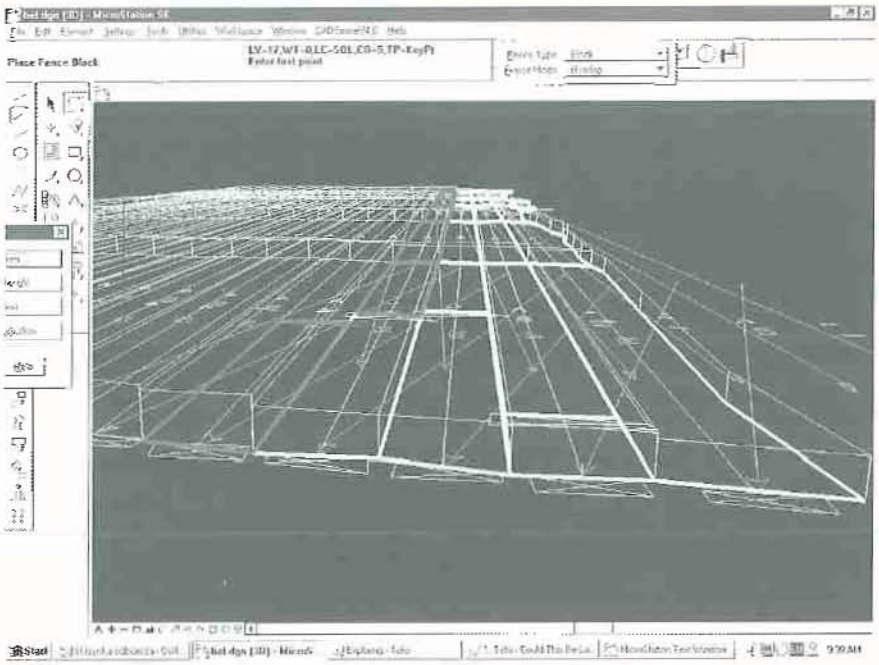

Figure 4. Simulation of working face advance in a mine level. View of panels and scheduling elements

selected, the results obtained may be printed out and attached to the descriptive part of the design.

Optimization

During optimization the various design variants are analysed. The objective of this process is the selection of the best solution. Furthermore, when the best variant has been initially selected, the designer may adjust the parameters defined at particular stages of the design and scheduling process until the optimal result is obtained.

The CadsMine software contains a module facilitating automatic optimization. On carrying out this optimization process, the designer defines not only the preferred values of parameters, but also their threshold values. The threshold values specify the minimum and maximum progress of individual machines in the conditions prevailing at the working face, the minimum and maximum standstill time and the date of commencing exploitation in a given area, etc. Subsequently, an objective is set, e.g. the desired quantity and quality of useful minerals for a given period of time and the program achieves this objective at the same time operating within the limits of the threshold values and aims at attaining the preferred values.

Dumping

Designing and scheduling of the dumping process is fully co-ordinated with the results of the exploitation design, i.e. the excavated quantities of waste rock in particular periods are automatically transferred to the heaping design and are presented as the progress of the dumping conveyor. This is facilitated by the SoftMine program. The quantities of overburden are allocated to dumping conveyors by the designer. It is possible to connect up the machinery in any given geometric forms and to divide it up with respect to the percentage or volume of overburden mass excavated per machine. The design process is conducted analogously to the exploitation design process.

Summary

The solutions presented in the present article have been implemented at the 'Turów' BCM on an industrial scale. The system makes its possible to carry out multiple variant simulations of the advance of working and dumping faces and eliminates the laborious and time consuming analysis of output materials. This facilitates the performance of a comprehensive analysis of the designed production configuration and also the selection of the optimal exploitation variant with respect to maintaining the required quantity and quality of output depending on the market situation. The process is characterized by its high level of accuracy and it eliminates the impact of the human factor to the largest extent possible. The system facilitates the economic analysis of the profitability of the exploitation of particular sections of the deposit in relation to various cutting variants.

The system is connected with dispatching programs, so that information stemming directly from production is inputted into the database and is used during the design process. When designing the system, it was assumed that communication will be conducted with SAP type business systems. Similar systems, which to a great extent are based on the same tools as those implemented in the 'Turów' BCM (e.g. Amplats RPA) communicate with dispatching, business and decision making support systems (EIS). Thus management of the mining business may draw on all of the possible information.

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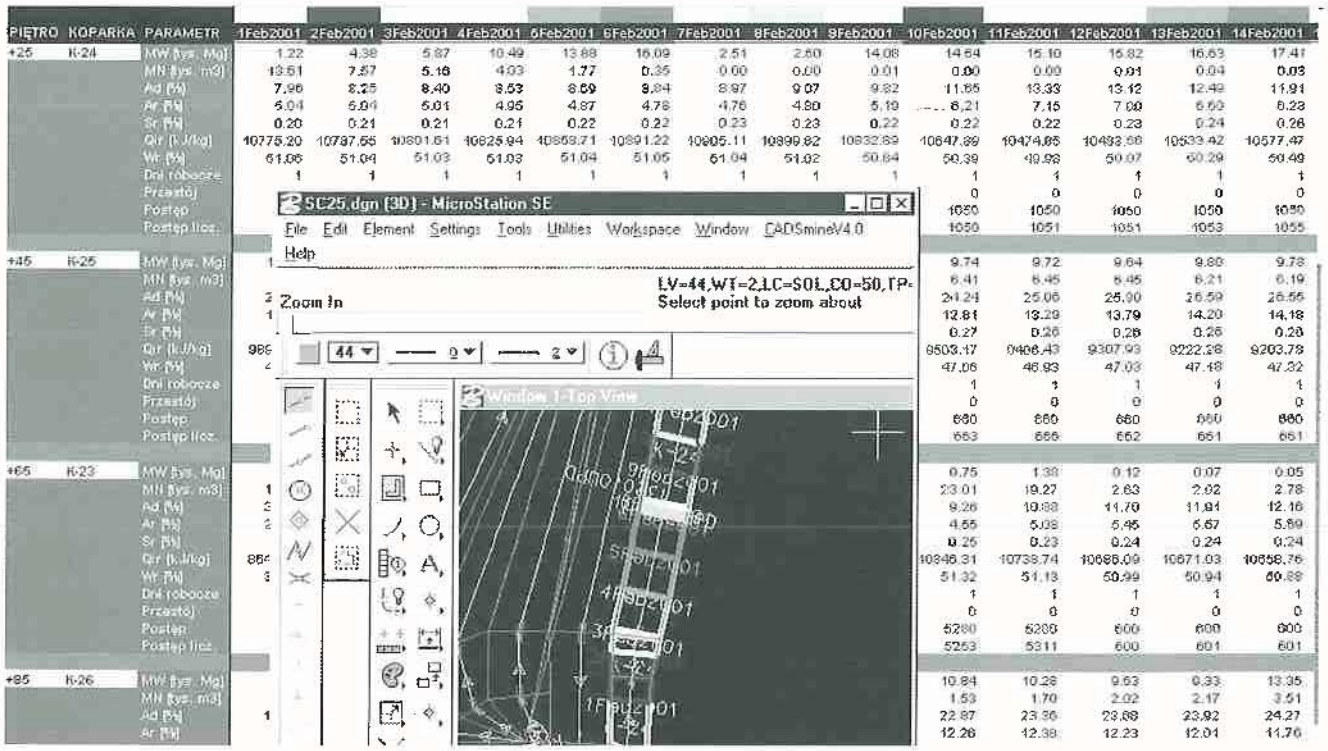

Figure 5. Tabular form of the report with a preview of the design in the MicroStation environment

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