Computer Aided Design of Mine Water Management

By Z. KESSERÜ

ABSTRACT

Based on twenty years of experiences of applying computers in mine water engineering in Hungary, a program package was developed for home utilization and for other users abroad as well. This program package has been adapted to the CAD System of Coal Mining of COMECON countries. The main features of the "mine water subsystem" in the CAD System of Coal Mining and short descriptions of the key programs of the package are presented in this paper.

Foreword

The serious water problems of Hungarian Mining pressed and/or stimulated its professionals to apply computers for supporting their problem-solutions. The first trials of these computer applications in mine water engineering were dated from the sixties.

Owing to its twenty years of experiences in computer applications in mine water engineering the Central Institute for the Development of Mining in Hungary was requested to work out the "Subsystem of Mine Water" for the Computer Aided Design System (CAD) of Coal Mines in COMECON countries.

This paper gives a brief presentation on the main features of this "subsystem" with reference to significant components.

SUBJECTS

The design of mine water management included the following subjects :

1. determining input data for planning the mine water management activity during mineral exploration,

2. forecasting the water hazard and environmental impacts related to mine waters,

3. design of mine water control,

.... design of protection against dangereous environmental impacts of the mine water control activity, and

..... determining inputs for the design of mine water utilisation.

The structure of the designing process of mine water management and their information connections with mineral exploration and with other activities of mine planning are illustrated in Fig. 1.

THE ROLE OF COMPUTERS IN MINE WATER ENGINEERING

The fields, where computers are the most effective aids, are outlined below.

Modelling of natural processes

The most important field of computer application is the modelling of natural processes related to mine water hazard and its control, including their environmental impacts. Some practical cases can also be handled by simplified formulas (e.g. Dupuit-Thiem function of linear water seepage around a well).

Some other complicated processes can be modelled by computerized numerical simulation only. According to experiences with the petroleum reservoir, geothermal reservoir and civil engineering, the numerical simulations of natural processes have been effective and reliable tools for designers and managers if the simulation models were carefully fitted to the nature (e.g. using the proper data of reservoir history).

Nowadays, the majority of mine water professionals are not hesitating to apply finite element or finite difference models of a water reservoir or a protective barrier layer for practical problem solutions. Finite element models are used practically in the rock-freezing practice as well (Refs. 2,7,12 & 3).

Keeping in mind the good experiences and following the the good practice of the petroleum and geothermal reservoir engineering, we are not hesitating to utilise these practices even in more sophisticated numerical modelling of more complicated natural processes (e.g. damages of thermal springs due to mine drainage; pollution transport in underground water reservoirs due to mining activity; dewatering of compressed air; rock freezing and water seepage simultaneously, etc).

System analysis and design

The mine water management activity is one of the subsystems, which form a connection between the systems of mining and natural environment. As a result of the theory and practice of system engineering computer aided analysing and decision making support methods have been developed. Many of them have been adapted for the mine water engineering practice. (Ref 5 & 6).

Some of these computer programs (e.g. reliability analysis and optimization of mine water control systems have been implemented in the design practice too. (Ref 1 & 13).

Computation of routine design operations

Each field of engineering design includes some parts of design operations, where a great number of computation without any important mental decisions should be done. These kinds of works should also be completed by computers or by microcalculator (e.g. the sizing of open channels, etc.)

Data processing, plotting

The data storing, processing, transmitting and plotting of maps, isolines, sections, graphs are considered as traditional fields of computer application. Many softwares are available in the market to fulfil all kinds of demands. We have selected and sometimes modified, the proper ones for our own needs.

The plotting and data processing softwares are mostly inserted as subroutines into the design softwares.

SOME BASIC FEATURES OF THE SUBSYSTEM FOR COMPUTER AIDED DESIGN IN MINE WATER ENGINEERING

The hydrogeological conditions of each mine show individual features since there are a large variety of technical solutions in mining. Consequently there are no standardized design tasks in mine water engineering. Under a large variety of hydrogeological and mining conditions, instead of a fixed system of computation, a library of softwares should be provided, where the users can find and select the proper softwares fitting to their own individual tasks.

Although many different tasks of design should be fulfiled by this software library, the physical basis of the natural processes modelled would be the same in many cases. (e. g. evaluating a well test, sizing a drainage system, forecasting the environmental impacts can all be regarded as linear water seepage tasks). Consequently some multi-purpose models can fulfil a wide variety of the user's demands.

Each software should provide interactive and friendly ways of communications between the computer and the user.

Let us illustrate this word "friendly" with some remarks:

In cases of modeling natural processes a finite-difference model seems to be a friendly e.e for an engineer or a geologi because the balance equations of the physical process are computed directly. The connection between nature and the model is adequate and its operating is more clear compare with a finite element model which is more elegant for a computer-professional.

In case of interactive communications with the computer the graphs, and isolines, relating to the inputs, intermedier and final outputs are more "friendly" for the users taking decisions during computation, compared with utilizing long print-out lists.

Although originally many of the softwares have been developed for large computers (VAX, Honeywell, CDC, IBM 360, etc.) now all of these softwares have versions also for IBM PC AT.

An independent IBM PC AT size computer with an A3 size plotter, digitizer and streamer is considered as a basic hardware facility for each user. This hardware configuration is "undersized" for some more sophisticated simulation programs of natural processes. For these special cases the IBM PC AT can be used as a satelite of a large computer centre.

BRIEF PRESENTATION OF THE SOFTWARE LIBRARY

Only the key pieces of the software library are drafted.

Simulations of natural processes related to mine water engineering problems

Multi-purpose models

The "LOCAL" is a two-dimensional finite difference model of linear seepage in undeformable, partly saturated, partly unsaturated reservoir with all kinds of recharge and discharge including springs. The network allows for the inser of a more divided network subsystem into each element.
As a result of the properly selected simplifications this model runs quite quickly, even in PC. The model has been used for designing local mine drainage activity and/or modelling large areas (around 30000 km^2) even for multilayer systems as well.

This is a friendly model for practical utilization but its application field is limited.
This model was sold to the German Democratic Republic and to Czechoslovakia as well.

The GR/STM is a three-dimensional integrated finite difference model for simultaneous simulation of the linear seepage of a compressible fluid in saturated or unsaturated elastic reservoir rocks and the convective and conductive heat transport and the convective-randomistic transport of dissoluted chemical(s) or nuclear wastes. The compaction of the reservoir rock can be one-dimensional consolidation. The heat transfer or the chemical transfer can be blocked optionally. The boundary conditions can be changed in time. More details are given in the references. (4 & 10).

In case of simulating the thermal and chemical interactions with 600-700 nodes, the run time of IBM PC varies between 0.5-10 hours. A simplified version of this model, which does not include the chemical transport, was handed over to Czechoslovakia.

The "PPMAPB" Program package for mechanical analysis of protective barriers consists of two models. One of them is a two-dimensional finite-element model of linear or non-linear elastic deformation (called FEMA) which was used from the early seventies.

The second one (called EVERLING-KBFI) is based on the simplified mechanical model of Everling and Mayer only the vertical components of the balance equation are taken into account . Despite of the above simplifications the model provides quite similar results compared with the conventional finite element analysis. But the proper mechanical simplification provides a lot of advantages for computation. For example spherical models consisting of 16000-20000 elements can be applied in home-PC size computers ; this model has been sold in China.

Softwares for special design tasks

The PIT-INH serves for evaluating and determining the reservoir conductivity and storage parameters by impulse interference tests.

The pulsation interference test method is generally used in the petroleum reservoir engineering practice. The same method has also been adapted for testing karstified water reservoirs in Hungary. This computerized evaluation method serves for separating the useful signals from the background noise and for determining the reservoir parameters. (Ref 14).

The "RF-WS" is a three-dimensional integrated finite difference model for simultaneous simulation of rock freezing and water seepage ; this model is unique in this field. For more details see Reference 9. This model has been sold to a construction company involved in rock freezing in Hungary.

The "HAM-KW1" is a hydraulic-randomistic analogous model of spontaneous mine water inrushes. The numerical simulation is based on the generalized Forcheimer-law of water flow, where the laminar field of seepage is characterized by deterministic reservoir parameters. In the close area of the inrush, where non-linear flows are considered, the parameters of the reservoir are randomistic ones. (Ref 11).

The effect of different types of protective barriers can also be taken into consideration. The model outputs are the average values and the probability distributions of 1) The number of inflows, 2) the total yield of inflows, and 3) the yields of the individual inrushes and their maximum values. These parameters are provided for each mine fields, and for the whole mine.

As an enclosure of the user's guide a manual for testing evaluating and sizing protective layers are also available optionally.Ref 8; this computer software with the manual has been sold to China as well.

The "DPA" is a 3D finite difference model of drainage supported by compressed air. This is a newly developed model. (Ref 15).

The GSM is a finite-difference simulation of grouting by slurry injection; this model is under development.

Some softwares for different technical tasks of design

The RM-MWSC model has been prepared for checking the reliability of mine water control systems. The inputs are 1) the operating reliablity parameters of each element, 2) the failure-tree of the given system and 3) the mine water inflows with their randomistic parameters. The HAM-KWI can serve as a subrutine to determine the randomistic parameters of inflows. One earlier version of this program is given in the reference 1.

The SWCH is a calculating programme for checking and sizing open channels in mines or at the surface.
The water yield, as an input for this program is given as outputs of other softwares(e.g. HAM-KWI, LOCAL, GR/STM).

The software OPC is a decision support model for determining the best strategy of operating the combined mine water control systems, where the earlier decisions on changing and operating the system impact on the later status and efficiency of the system. During the numerical simulation, more investment and operating strategies are compared and the optimum strategy appears as an output. More details on the first version of the program is given in reference 6.

The "CDSM" is a support model of compromising decision for mine water management systems, where contradictory goals of the mine water control, environmental control and mine water utilization should all be taken into consideration. The first version of the models and the first trials of their practical application are given in reference 13.

Some service softwares

Some softwares of data processing and plotting are also utilized individually for special purposes.

The DP-MH data processing software is prepared for fulfilling the demands of the hydrogeological services of mines.

The P-T/I is a software for plotting isoline-maps. Because of its special features it can be an useful tool for preparing computer aided tectonic maps.

Some other softwares should also be realized to fulfil more practical demands e.g. for planning safety strategies and for design preliminary measures of evacuating the personell in case of flooding; a simulating model of alarming and evacuating should also be developed. In this software the RM-MWSC and HAM-KWI will be inserted as subroutines.

Although the software library drafted above does not cover all possible design fields in mine water engineering, Fig. 2. illustrates that almost all important fields are either covered by existing softwares or, in some cases, are being developed.

CLOSING REMARKS

A computer aided design system has been presented here from a country, where the hardware facilities are rather poor compared with the hardware markets of more industrialized countries. Better hardware facilities surely provide better conditions to implement the computerized tools in the design practice.

The author has also to confess, that the subsystem of "mine water", as a part of the system of computer aided design, has not yet been operating as a whole. It operates only as a software library associated manually with a PPC size computer centre IBM PC AT, A3 size plotter, digitizer, printer and streamer where the proper softwares are used individually to support the solution of the given design or research project.

A computerized data-bank and fully computer-controlled data transmition between the data bank and the software operating in a given task or data transmition between softwares operating sequently have not yet been realized. This will be the next step in our country.

Although the fully computerized data processing system, mentioned before, will surely increase the productivity of the computerized design, the live-engineering considerations and decisions must not be excluded from the design process. The computer and its proper softwares should be regarded as useful tools only and the governing computer of the CAD system must remain the design-engineer himself.

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References

1. Bogardi, I., Szidarovszky, F. and others. Bayes Reliability Analysis of Mine Water Control Systems. /Ist Mine Water Congress of IMWA Vol. B. p. 51-73.

2. Del Guidence, Comini, G. Finite Element Simulation of Freezing Process in Soils /Int. Journal for Numerical and Analytical Methods in Geomechanics. /1978/

3. Faweett, R.J., Hibberd, S., Singh, R.N. An Appraisal of Mathematical Models to Predict Water Inflows into Underground Coal Workings. Int. Journal of Mine Water Vol. No.2. p.33-54. /1984/

4. Havasy, I. and Dusza, L. Simulation of Mass and Heat Transfer in a Large Karstic Reservoir for Mine Water Management. 2nd Mine Water Congress of IMWA, Granada Proceedings p.5o2-591. /1985/

5. Kaden, S., Luckner, L. and others. Decision Support Model System for the Analysis of Regional Water Policies in an Open Pit Lignite Area of GDR. /2nd Mine Water Congress of IMWA, Granada. Proceedings p. 5o3-514./1985/

6. Kesserü, Zs., Bogárdi,I., Szidarovszky, F. System Approach for Mine Water Control, Granada SIAMOS 78 Proceedings p. 778-8o4. /1978/

7. Kesserü, Zs. Determining the Necessary Thickness of the Layers Protecting Against Mine Water Inrushes in Velenje Lignite Colliery /Special issue of the Hungarian Central Mining Institute for the participants of the 1st Symposium of Mine Drainage held in Denver 1979.

8. Kesserü, Zs. Design and Application of Water Barrier Pillars /Design manual for CCMRI of China prepared in the Central Institute for Mining Development of Hungary 1987.

9. Kesserü, Zs., Dusza, L. and others. Simultaneous Modeling of Rock Freezing and Water Seepage and its Practical Applications /Int. Journal of Mine Waters Vol. No.1. 1987.

1o. Kiss-Máté, Cs. and Vermes, A. Numerical Simulation of Chemical and Nuclear Contamination Transport in Aquifers and its Possible Application for the Control of Environmental Impacts due to Mining Activity. Manuscript for the 3rd Mine Water Congress of IMWA, Melbourne 1988.

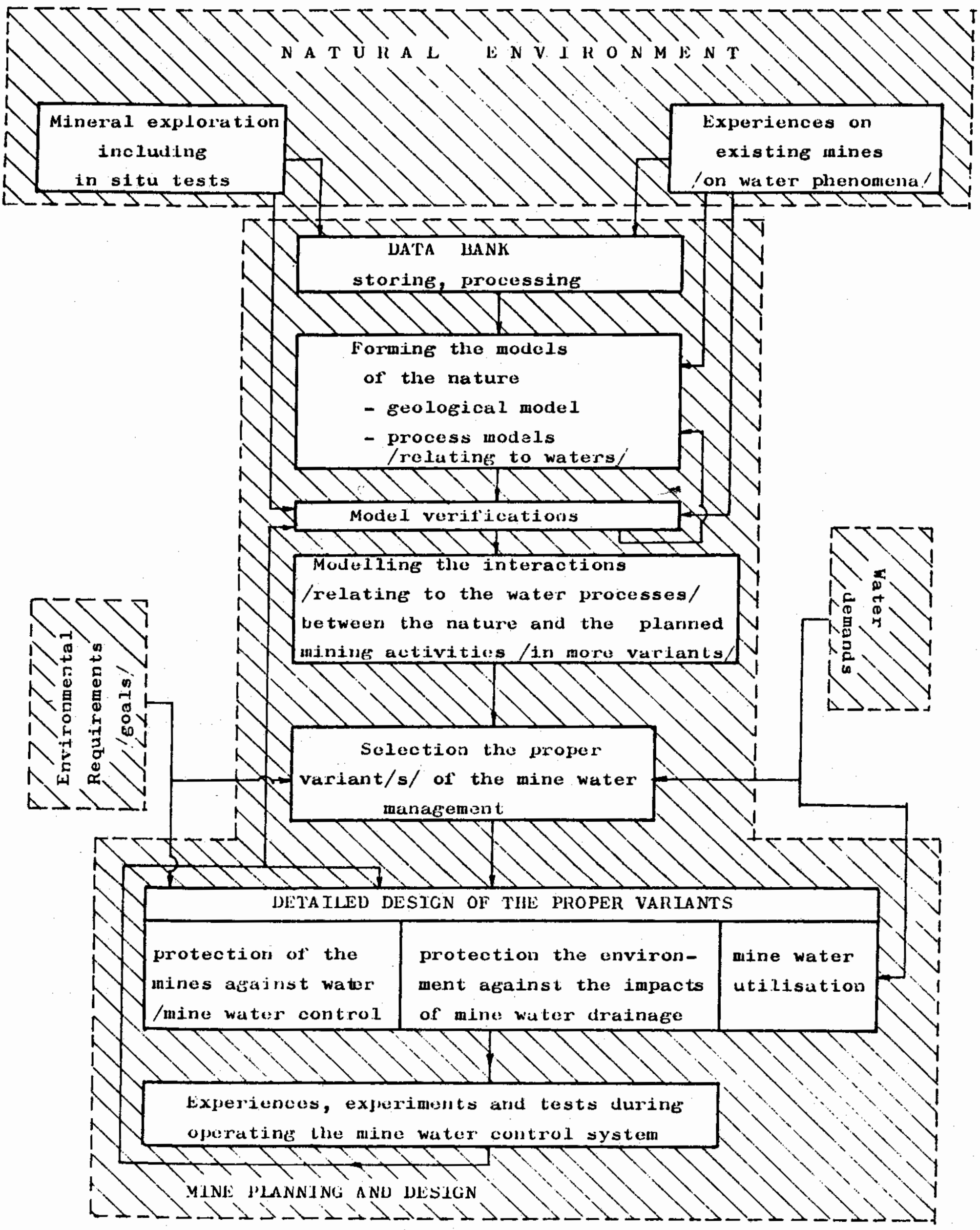
11. Schmieder, A., Bogárdi, I., Duckstein, L., Szidarovszky, F. Hydraulic Stochastic Forecasting Model of Mine Water Inrushes /Special Issue of the Proceedings of the Central Institute for the Development of Mining for the 1st Simpozium on Mine Drainage, Denver, 1979.

12. Szilágyi, G., Heinemann, Z. and others. Application of Simulation Model for a Large Scale Karstified Aquifer SIAMOS, Granada, Proceedings p. 951-964 /1978/

13. Szidarovszky, F., Bogárdi, I., Cherston, M. Multi-objective Analysis of Regional Mine Water Control and Environmental Protection. 1st Mine Water Congress of IMWA Budapest, Proceedings, Vol. C. p.129-143. /1982/

14. Tóth, B., Szilágyi, G., Megyeri, M. Interference Test by Applying Pulsation for Determining the Hydraulic Parameters of Aquifers Endangering Mine Sites. International Symposium on Hydrogeology of Coal Basins Katowice, 1987. Proceedings p.183-188. /1987/

15. Vincze, T. and Havasy, I. Application of Simulation Model to Two Non-mixible Fluid Transport for Modeling Special Mine Water Control Measures like Dewatering of Reservoirs Supported by Compressed Air. Manuscript for the 3rd International Mine Water Congress, Melbourne 1988.



The subsystem of mine waters in the CAD system of mining

Fig. 1.

DESIGN TASKS \ SOFTWARE LIBRARY FOR CAD			NUMERICAL SIMULATION OF NATURAL PROCESSES RELATING TO MINE WATERS – MULTIPURPOSE MODELS – Reservoirs: LOCAL 3D f.d. water seepage	Reservoirs: GR/STN 3D IFDM water, heat pollution	Protective barrier PPMAPB: FEMA 2D IFEM	Protective barrier PPMAPB: EVERLING-KUFI 3D model	SPECIAL MODELS: PIT - INH well testing	DPA 2D IFDM water - air	GSN 3D grouting	RF - WS IFDM rock freezing and water seepage	HAN - KWI karstic water inflows	TECHNICAL DESIGN: SWCH sizing open channels	SOFTWARES ON SYSTEM ANALYSES: RN - MWSC reliability of systems	OPC selection of proper combination	CDSN compromistic decision	SOME SERVICE SOFTWARES for special demands – PLOTTING: P-T/I plotting tectonic maps and izolines	P - RD plotting random distributions	DATA PROCESSING: DP - NH data proc. and process control for hydrogeological services of mines
COMBINATIONS		Selection the best combinations												■	■			
ACTIVE WAYS OF CONTROL /PRELIMINARY CONTROL OF THE NATURAL PROCESSES/ – Control of the energetic conditions	Drainage in the protective layers	Instantaneous depressurisation	■		■	■										■		■
	Drainage in the Reservoir	gravitational /normal way/	■													■		■
		supported by compressed air						■								■		■
Control of water conductivity	Grouting	efficiency	■	■												■		■
		extension							■							■		
	Rock freezing									■						■		
MINE WATER CONTROL MEASURES – PASSIVE - PREVENTIVE MEASURES		bulkheads			■	■												
		water barrier pillars			■	■					■						■	
THE PASSIVE WAYS OF CONTROL /SAFETY OF PERSONALS AND PUMPING/	FOR PROTECTING THE MINES	reliability of the water delivery											■				■	
		water channels /			■	■						■						
		settling			■	■												
		pumping			■	■												
	FOR PROTECTING THE MINERS /LIFE PROTECTION/	inflow rate /as inputs for sizing/			■	■					■						■	
		safety sumpfs			■	■					■						■	
		rescue			■	■												
		alarming			■	■							■					
		reliability of life protecting															■	
ENVIRONMENTAL CONTROL ASPECTS	FORECASTING THE DANGEROUS IMPACTS	water level sinking	■	■												■		■
		damage of thermal wells/springs	■	■												■		■
		underground water pollution	■	■												■		■
		land subsidence	■	■												■		■
	CONTROL MEASURES	water reinjection	■	■												■		■
		regional grouting	■	■												■		■
		hanging walls	■	■												■		■
INPUTS FOR MINE WATER UTILISATION		the volume/yield of utilisable mine water	■	■							■					■		■
		temperature/chemical parameters	■	■												■		■