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An expert system for equipment selection of thin coal seam mining

Introduction

Thin coal seam is abundant in China, of which the thickness is less than 1.3 m. According to incomplete statistics in 95 state-owned coal enterprises, there are about 445 mines with the occurrence of TCS. The recoverable reserves of TCS is about 6.5 billion tons, occupying 19% of the total recoverable reserves (He et al. 2012; Jiang et al. 2009; Han 2013; Sheng et al. 2007). In recent years, coal mining keeps high intensity in China. As a result of the predatory mining, thick seam mined with thin seam abandoned, thick and min-thick seam are becoming gradually exhausted in mid-eastern and some old mines. In order to balance productivity and prolong the service life of coal mine, the TCS are to be mined urgently in many mining areas, such as Huaibei, Huainan, Zibo, Yanzhou, Xinwen, etc. The intensity of TCS mining is increasing yearly. However, TCS mining will be situated in an

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awkward “three low one high”, namely low mechanization, low safety, low benefit and high labour intensity. As a result, the output of TCS mining only takes up 10.4% of the national coal production (Wang and Luo 2013), which is not matched with the recoverable reserves.

There is a considerable diversity in the form of FMM in TCS in China. As the most widely used in TCS, FMM method with shearer takes up about 85% according to incomplete statistics. The other methods with plough, auger and continuous miner only take up 15%. Thus, in general, the FMM method of TCS mining means the FMM method with shearers. Meanwhile, it is of great practical significance to conduct in depth research on the FMM method in TCS mining.

In the FMM face, the key to security, productivity and efficiency is closely related to the group of equipment mainly including: the shearers, hydraulic supports and scraper conveyors. In the narrow TCS face, reasonable equipment selection and matching should meet the demands of: characteristics, production capacity, service life and geometry relationship (Zheng 2010).

Theoretical analyses, laboratory tests and numerical simulations were used to analyze the evolution law of the overburden per meability in an AM face. A stress-damage-permeability coupling model was proposed, and a numerical simulation algorithm for fluid-solid coupling with FLAC software was established. Through this method, reasonable AM parameter design is the key to both safe mining operations in the AM face and pressure relief and permeability enhancement (Yuan et al. 2019).

1. Review

Currently, with the intensity of TCS mining increasing year by year in China, complete sets of FMM equipment have been localized. There are considerable diversities in the types of equipment. This equipment is able to meet our needs for the equipment selection of the FMM in TCS mining.

Faced with the physical condition of FMM face in TCS mining, it is a hard-working job to select the reasonable set from a great deal of equipment. In the equipment selection of the FMM face, scholars have made some efforts to realize equipment selection effectively and efficiently. Zheng Wei stated the theoretical basis and technical approaches (Zheng 2010). Zhang Mingqing et al. developed a fuzzy ES for equipment selection, which is helpful to conduct intelligent decision-making in thick coal seams (Zhang and Liu 2002). What's more, Fu Qiang presented the thought of design on the equipment selection computer program (Fu 2005). As far as I know, software for FMM equipment selection is varied. “Equipment selection and matching” software, developed by the China University of Mining and Technology Zhangjiakou Coal Mine Machinery Factory and Beijing Coal Mine Machinery Factory (Xiao et al. 1996), is one of the earliest softwares. In the Shendong Corporation, the database for equipment selection and matching was constructed to provide service for the FMM face (Gao and Liu 2012). Other softwares are also widely used in coal mining, such as the equip-

ment parameters matching software based on UG (Ma and Lu 2011), a complete set of equipment selection based on CAD (Yin et al. 2010) and mining engineering equipment selection software (Başçetin et al. 2005). However, most of these types of software are applicable to equipment selection for a thick and mid-thick seam and few are suitable for thin seam.

In terms of equipment selection for FMM face in TCS under complicated geologic conditions, an equipment matching scheme was proposed by Liu Jinrong in two hard TCS' with hard coal and a hard roof (Liu 2011). Apart from this, Yuan Liang put forward the principle of complete equipment selection in three soft and high gas TCS faces (Yuan 2011). What's more, Zhai Xinxian discussed the theoretical basis of equipment selection for FMM face with hard roof and soft coal in detail (Zhai et al. 2009).

Many aspects should be considered in equipment selection and matching for FMM in TCS, including thickness and hardness of: the seam, roof and floor, process parameters, ground pressure and equipment investment. In real life, equipment selection is one of the multiple attribute decision making (MADM) problems and decision makers have always had some difficulties in making the right decision in the multiple criteria environment (Nguyen et al. 2014; Dağdeviren 2008). Neural network, fuzzy mathematics, analytic hierarchy process, gray relational analysis and PROMETHEE (Zhu et al. 2001; Samvedi et al. 2012; Taha and Rostam 2011; Zhao et al. 2006; Yilmaz and Dağdeviren 2011) can provide theoretical support for this decision making problem.

During the process of equipment selection, the decision makers should have a comprehensive consideration and weigh the advantages and disadvantages. Obviously, the process, characterized by multiplicity, cannot be shown accurately by the mathematical model. However, experts, engaged in designing, manufacturing and operating these pieces of equipment for a long time, can deal with the decision making problem perfectly. ES is a kind of artificial intelligence computer program that can solve the complicated professional problems by experts' knowledge and reasoning mode (Baker et al. 2004; Fonseca et al. 2004; Yi and Li 2005). In the planning of mining operations in underground mines, an ES (MinePlanEx) is developed to support the designers of production planning in hard coal mines within the scope of equipment selection (Brzywczy et al. 2017). With strong adaptability, ES is very suitable to handle MADM problems. Faced with the hard-working job to select reasonable equipment, it is of great practical significance to develop the ES for equipment selection, which will meet the rapid development of FMM technology in TCS mining.

To sum up, this paper is to complete the equipment selection and matching of FMM face in TCS mining effectively. The ES related selection was carried out to fill in a gap in intelligent equipment selection. This paper is divided into six sections. Section 1 briefly presents the necessity of TCS mining in China. Section 2 provides an introduction into the studied problem and literature research about equipment selection. Then the emphasis of the paper is proposed. Section 3 states the structure of ES for equipment selection based on the basic principle of ES. In Section 4, an ES software is established by programming language. To examine the reliability of ES, some applications of the proposed ES software used for real world examples are involved in this section. Meanwhile, the technical approach to solve

these problems existing in the ES will be proposed. Section 5 involves the equipment selection results from the ES improved in another FMM face in TCS mining. The last section of this paper, Section 6, concludes the study with the discussion of the results and proceeds of the proposed approach.

2. Expert system theory

ES is a system based on knowledge, which is built up with experts' experience by computer. The system can provide intelligent advice or can make intelligent decisions for the processing function. In terms of structure, the core components of an ES include database, knowledge database and inference engine (Yi and Li 2005; Xu 2012), as shown in Figure 1.

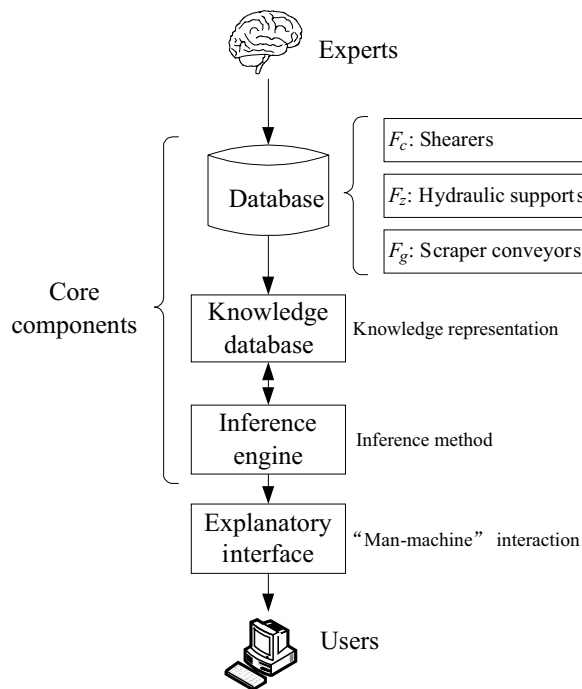


Fig. 1. Structure Diagram of Equipment Selection ES

Rys. 1. Schemat struktury doboru sprzętu ES

2.1. Database

Faced with the real condition of FMM face in TCS mining, the improved equipment database is set up by research and summary systemically. The database includes shearers, hydraulic supports and scraper conveyors.

2.1.1. Shearer

Shearers in the database cover almost all models of shearers and their basic parameters, which can be shown as C_{ij} :

$$C_{ij} = [h_{min}, h_{max}, \alpha, B, v, v_{max}, N, N_j, D] = \begin{bmatrix} c_{1,1} & c_{1,2} & \cdots & c_{1,9} \\ c_{2,1} & c_{2,2} & \cdots & c_{2,9} \\ \cdots & \cdots & \cdots & \cdots \\ c_{30,1} & c_{30,2} & \cdots & c_{30,9} \end{bmatrix}$$

where: i represents the code of shearer given by users, among which $i = 1, 2, \dots, 30$. In another word, there are 30 kinds of shearers which are shown as C_1, C_2, \dots, C_{30} . j represents the code of shearer's basic parameters in the database, among which $j = 1, 2, \dots, 9$. There are 9 basic parameters. Among them, h_{min} and h_{max} are the minimum and maximum mining height respectively, m. α is the maximum operating slope angle, °. B is the cutting depth, m. v and v_{max} are the average cutting velocity and maximum haulage speed respectively, m/min. N and N_j are installed and cutting power respectively, kW. D is the diameter of shearer, m.

2.1.2. Hydraulic support

Hydraulic supports in the database cover almost all models of hydraulic support and their basic parameters, which can be shown as Z_{ij} :

$$Z_{ij} = [H_{min}, H_{max}, P, q_d] = \begin{bmatrix} z_{1,1} & z_{1,2} & \cdots & z_{1,4} \\ z_{2,1} & z_{2,2} & \cdots & z_{2,4} \\ \cdots & \cdots & \cdots & \cdots \\ z_{42,1} & z_{42,2} & \cdots & z_{42,4} \end{bmatrix}$$

where: i represents the code of hydraulic support given by users, among which $i = 1, 2, \dots, 42$. In another word, there are 42 kinds of hydraulic supports which can be shown as Z_1, Z_2, \dots, Z_{42} . j represents the code of hydraulic support's basic parameter in the database, among which $j = 1, 2, \dots, 4$. There are 4 basic parameters. Among them, H_{min} and H_{max} are the minimum and maximum structure height of hydraulic support respectively, m. P is the rated working resistance, kN. q_d is the admissible floor specific pressure, MPa.

2.1.3. Scraper conveyor

Scraper conveyors in the database cover almost all models of scraper conveyor and their basic parameters, which can be shown as G_{ij} :

$$G_{ij} = [Q_g, N_g] = \begin{bmatrix} g_{1,1} & g_{1,2} \\ \cdots & \cdots \\ g_{48,1} & g_{48,2} \end{bmatrix}$$

where: i represents the code of scraper conveyor given by users, among which $i = 1, 2, \dots, 48$. In another word, there are 48 kinds of scraper conveyor, which can be shown as G_1, G_2, \dots, G_{48} . j represents the code of scraper conveyor's basic parameter, among which $j = 1, 2$. There are 2 basic parameters. Among them, Q_g is conveying capacity, t/h, N_g is installed power, kW.

2.2. Knowledge database

2.2.1. Selection principle

Knowledge database of an ES, used to infer and solve problems, is made up of knowledge, principles and experts' experience. The knowledge is used to make decisions and principles are used to equipment selection. The knowledge database is shown in Table 1.

Table 1. Expert System Knowledge Database

Tabela 1. Baza wiedzy systemu ekspertów

No.	Principles	Interpretation	Notes
C1	$D = M_{\min} - d$	The selection of drum diameter should consider the roof convergence after cutting, M_{\min} is the minimum mining height of the face, m. d is the roof convergence, which the value of 0.1 m.	Shearer
C2	$(M_{\min}, M_{\max} + x) \subseteq (h_{\min}, h_{\max})$	The minimum and maximum mining height of the face should within the limits of shearer's mining height. Among them, M_{\max} is the maximum mining height of the, m. X is amount of cutting floor and values 0.2 m.	
C3	$\alpha \geq \alpha_0$	The passable gradient should larger than the seam's inclination α_0	
C4		If $f < 2$, then $B = 0.8$ m. Else if $f \geq 2$, then $B = 0.6$ m. Among them, f is the protodyakonov's hardness of coal seam.	
C5	$v \geq v_0$ $v_{\max} \leq v_{0 \max}$	Theoretical operation speed cannot exceed rated value. v_0 and $v_{0 \max}$ are the average cutting velocity and the maximum theoretical value of operation speed respectively. They can be achieved by back-calculation between the average daily output Q_d of the face and operating type. For example, with the condition of bi-directional coal cutting with feeding at end, v_0 and $v_{0 \max}$ can be separately represented as $v_0 = \frac{Q_d(L + L_s)}{TKLHB\rho C}, v_{0 \max} = v_0 \cdot K_c.$ In the equation above, L is the length of the face, m. L_s is the length of feeding, m. T is daily working hours, h. K is the operating rate. H is the average mining height of the working face, m. ρ is the density of coal seam, t/m ³ . C is the recovery ratio of FMM face in TCS, which has the value of 0.98. K_c is the uneven coefficient of cutting velocity and is valued 1.5.	

Table 1. cont.

Tabela 1. cd.

No.	Principles	Interpretation	Notes
C6	$N \geq N_0$ $N_j \geq N_{j0}$	<p>Installed power and cutting power should meet the demand of cutting hard coal. N_0 and N_{j0} are the theoretical installed power and cutting power respectively that are calculated by back-calculation. They can be shown as $N_0 \geq \frac{60BM_{\max}v_{0\max}\omega K_n}{3.6}$, $N_{j0} = (0.8 \sim 0.85) \cdot N_0$ separately.</p> <p>In the equation above, ω is the unit energy-consumption of cutting coal, MJ/m³. In general, it values from 1.1 to 4.4. The upper limit is for hard or malleable coal. Meanwhile, the lower limit is for soft coal and tectonic coal. K_n is the extra coefficient of cutting, valuing from 1.3 to 1.5.</p>	Shearer
Z1	(H_{\min}, H_{\max}) $\supseteq (H_{0\min}, H_{0\max})$	<p>The height of support structure should meet the demand of supporting height. Among them, the theoretical maximum height $H_{0\max}$ and minimum height $H_{0\min}$ are shown as:</p> $H_{0\max} = M_{\max} - (0.2 \sim 0.3), H_{0\min} = M_{\min} - (0.25 \sim 0.35)$ respectively.	Hydraulic support
Z2	$P \geq P_0$	<p>Working resistance should meet the need of roof support in the face. It can be shown as</p> $P_0 = \frac{K_1 M_{\max} \gamma_1 S_1}{100 \eta_1}$ <p>In the equation above, K_1 is the thickness coefficient of roof that has effects on the support and is taken as from 5 to 8. γ_1 is the bulk density of roof, kg/(m²·s²). S_1 is the support area of hydraulic support and valued 6 m² generally. η_1 is the supporting efficiency and is given as 0.85.</p>	
Z3	$q_d \geq q_{d0}$	<p>Floor specific pressure q_{d0} should be limited in a permitted range. And it can be expressed as $q_{d0} = 0.9 P_0/S_d$.</p> <p>In the equation, S_d is the bearing area and valued 4.5 m² in general.</p>	
G1	$Q_g \geq Q_{g0}$	<p>Conveying capability of scraper conveyor should not be lower than the maximum cutting capability of shearer Q_{g0}. In general, it is valued as 1.4 times of the maximum production capacity of shearer, being shown as</p> $Q_{g0} = 1.4 \cdot 60V_{0\max}M_{\max}B\rho.$	Scraper conveyor
G2	$N_g \geq N_{g0}$	<p>The rated power should not be lower than full-load power N_{g0}.</p> $N_{g0} = \frac{[2q_g f_1 \cos \alpha_0 + q_0 (f_2 \cos \alpha_0 \pm \sin \alpha_0)] v_g L_g}{65 \eta_g}$ <p>In the equation above, η_g is the transmission efficiency and is valued as 0.9. L_g is the laying length of conveyor and can be shown as $L_g = L + (4 \sim 5)$, m. f_1 is the resistance coefficient of scraper chain that operates in the trough and can be from 0.25 to 0.35. f_2 is resistance coefficient of coal that is conveyed in the trough and can be from 0.6 to 0.8. Q_g is the quality per meter of scraper chain and is valued as 18kg/m. v_g is chain speed and is valued from 0.9 to 1.3 m/s. q_0 is the quality of coal in middle trough per meter and can be shown as $q_0 = Q_{g0}/3.6v_g$.</p>	

2.2.2. Knowledge representation

The process of ES involves a lot of professional knowledge and experts' experience. A large amount of calculation and analysis is needed in equipment selection. Knowledge representation of the system adopts the productive rule. In other words, the rule of If-Then is adopted to store experts' knowledge (Xu 2012; Liu et al. 1992; Zeng et al. 2009). It can be expressed as:

$$\text{If } A \text{ Then } B \text{ } f(B,A)$$

where A means the universal set of rules in the rule database. That is to say, it must meet any rule in the rule database under the condition of single equipment selection. B means the universal set of equipment selection results that satisfy A. $f(B,A)$ means the reliability degree of selection results when A is true. There is one corresponding reliability value that is matched with any equipment selection result. The range is $[-1,1]$, among which 1 represents that B is true, -1 represents that B is false and 0 represents that A has no effect on B.

2.3. Inference engine

Based on some inference strategies and related knowledge selected from knowledge database, an ideal conclusion can be drawn from inference engine by inferring the evidence that users provide. This ES adopts a forward reasoning model. The structure diagram of inference engine is shown in Figure 2.

As there is uncertainty in equipment selection experts' knowledge, the reliability of fuzzy inference is applied into the equipment selection process. The reliability model is a kind of imprecise inference tool. The tool is put forward from the famous MYCIN ES. As we know, MYCIN ES was developed by Stanford University in the early times. The stack algorithm of reliability is adopted to spread the reliability of inference in this paper (Liu et al. 1992), which can be expressed as:

$$\text{If } A_i \text{ Then } B \text{ } f_i$$

$$\text{If } A_j \text{ Then } B \text{ } f_j$$

Then If A_i and A_j Then B F, F can be expressed as:

$$F = f_i \theta f_j = \begin{cases} f_i + f_j(1 - f_i) & f_i > 0 \text{ and } f_j > 0 \\ f_i + f_j(1 + f_i) & f_i < 0 \text{ and } f_j < 0 \\ (f_i + f_j) / [1 - \min(|f_i|, |f_j|)] & f_i f_j \leq 0 \end{cases}$$

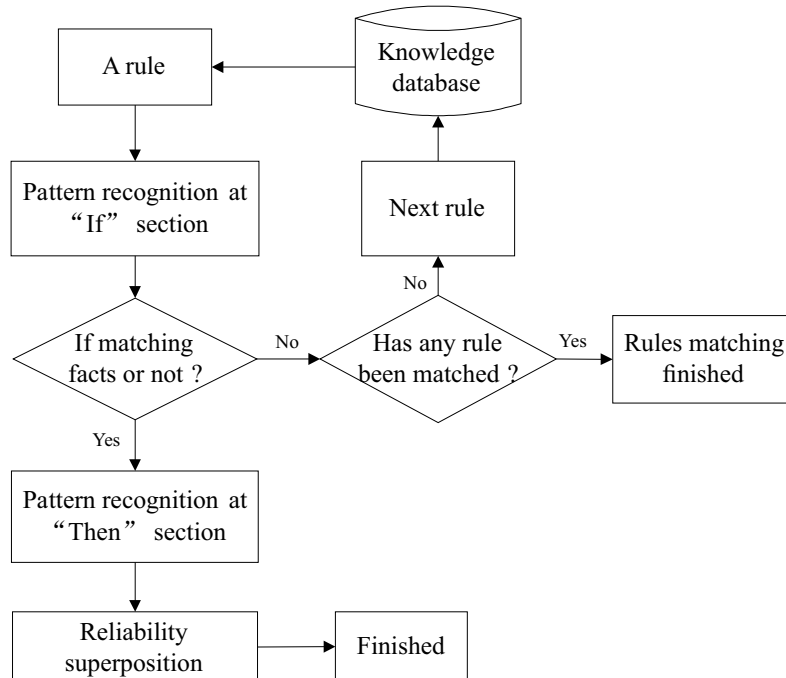


Fig. 2. Structure diagram of inference engine

Rys. 2. Schemat struktury silnika wnioskowania

Among them, θ is the stack algorithm of reliability. The reason for adopting this method is that it conforms with the thinking logic of experts. And meanwhile the calculation is simple. The stack algorithm of reliability of MYCIN is used to select the possible “three machines” matching set. The corresponding equipment set with $\max(F)$ can be given preference to.

The aim of ES in this paper is to solve the technological problem of equipment selection and matching the FMM face in TCS mining. It will also make the intelligent selection of complete equipment come true. There are three steps in the equipment selection of ES. The first step is to collect the basic parameters of FMM face related. Secondly, the ES is used to infer the collected basic parameters and then select the feasible equipment sets. Finally, after permutation and combination in the equipment set, the best equipment matching scheme is selected by making use of communication theory of reliability.

3. Software

3.1. Developing flow

According to ES theory above, ES of FMM in TCS mining is developed by the database and programming language of Visual Basic. The database is set up by Microsoft Office Access. The ES was developed to solve the technical problem of equipment selection and matching. The database is made up of the models and their corresponding basic parameters of shearers, hydraulic supports and scraper conveyors. Meanwhile, it stores a great number of successful examples of equipment selection and matching of FMM in TCS mining. These examples are taken as the reference of ES selection result. The flow diagram of developing software is shown in Figure 3.

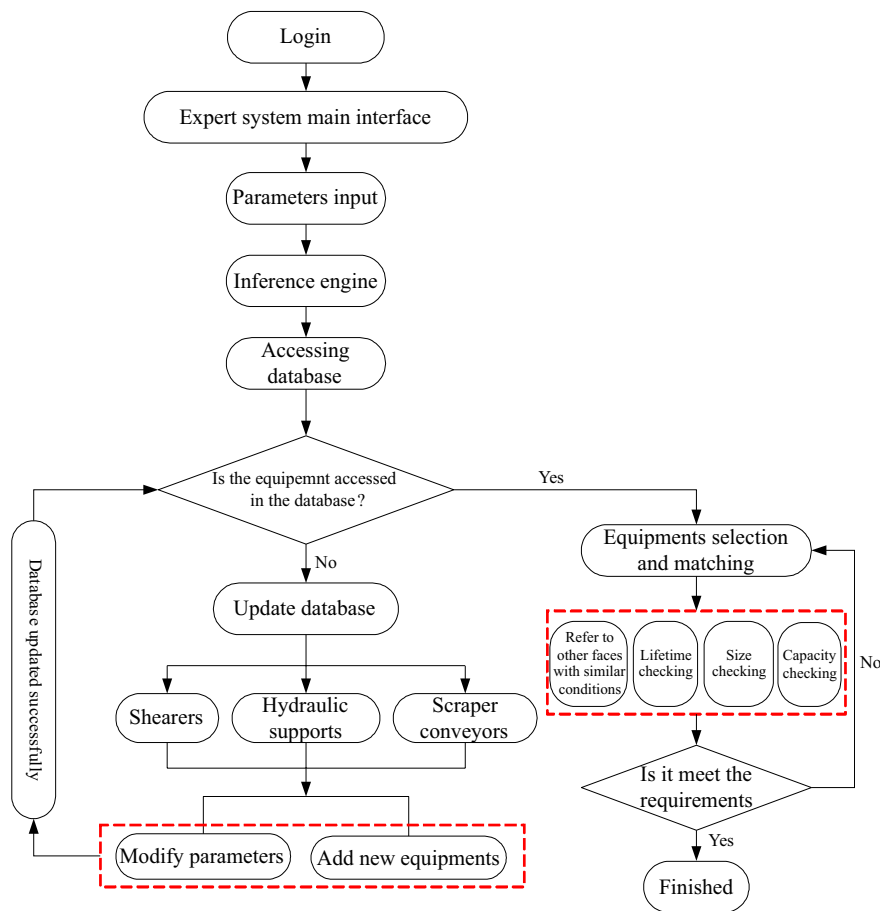


Fig. 3. Flow diagram of developing software

Rys. 3. Schemat przepływu oprogramowania

2.2. Instructions

Firstly, the program named “ES for TCS FMM face.exe” needs to be installed in the computer. Then start the program and enter into the login interface, as shown in Figure 4.

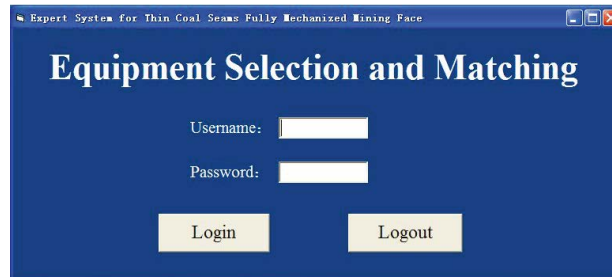


Fig. 4. Login interface

Rys. 4. Interfejs logowania

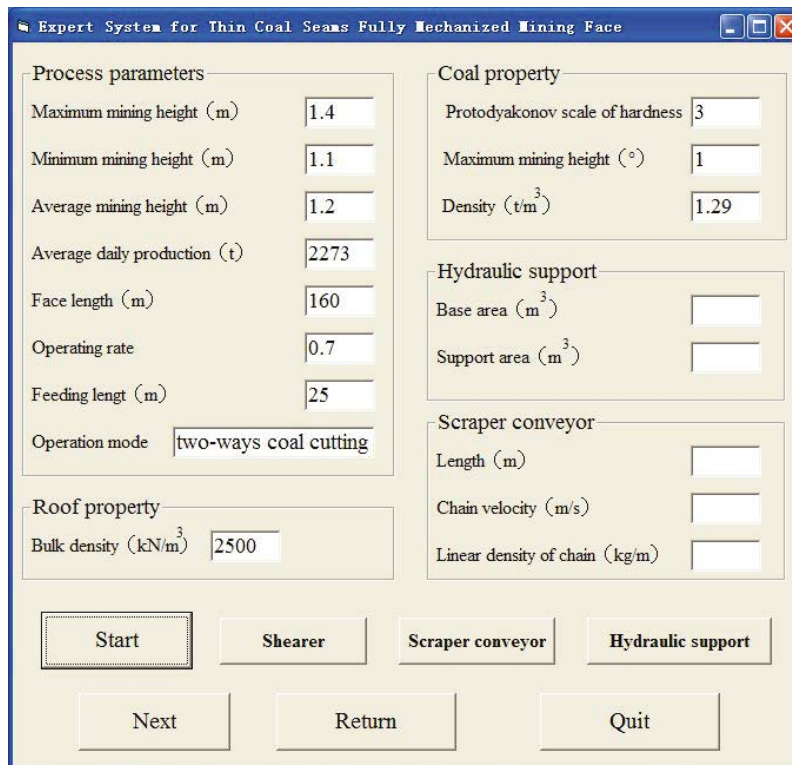


Fig. 5. Parameters related input interface

Note: Structure parameter of scraper conveyor and hydraulic support should be input by manual operation according to the equipment information in database

Rys. 5. Interfejs wejściowy związany z parametrami

Afterwards, input the user name and password and click “Login”. Then enter into the main interface of the system, as shown in Figure 5. Next, users input the parameters of FMM face in TCS and related geological conditions in the interface.

Next click “Start” and click “Shearer”, “Hydraulic support” and “Scraper conveyor” in turn. Finally, we can see the suitable “three machines” matching set, as shown in Figure 6.

We click “Intelligent Selection” and “Similar Working Face” to screen, then users can compare the intelligent selection result with the practical applications in another face with similarity. Then click “Lifetime”, “Size” and “Capacity” to check the matching of selection results, as shown in Figure 6. When all the checks are satisfied with the requirements, click “Export” to export the result of equipment selection. Finally, click “Close” to end the program, or click “Return” to re-select the equipment.

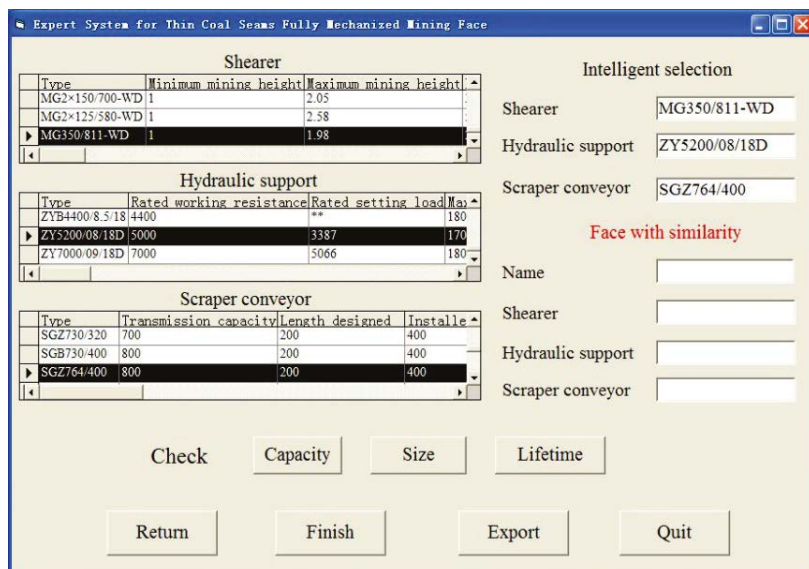


Fig. 6. Equipment selection results interface

Rys. 6. Interfejs wyników wyboru sprzętu

3.2. Feasibility analysis

ES is used in equipment selection and matching for the typical FMM face in TCS mining. The results obtained is shown in Table 2.

Comparing field applications with intelligent selections, we can draw a conclusion: the result of intelligent selection of shearers is reliable. However, for hydraulic support and scraper conveyor, a little deviation exists respectively. The main reasons for this situation are as follows:

Table 2. Intelligent selection result and field application

Tabela 2. Wynik inteligentnego wyboru i zastosowanie w terenie

Equipment		Working face	Zhuzhuang Mine 646	Daizhuang Mine 3303	Nantun Mine 3602	Xiaotun Mine 14459	Shaqu Mine 22201	Yangcun Mine 1701
Intelligent Selection	Shearer	MG200/456-WD	MG200/456-WD	MG200/456-WD	MG180/420-BWD	MG200/456-WD	MG2×150/700-WD	MG110/250-BW
	Hydraulic support	ZY4400/08/16	ZY3600/10/20	ZY2600/6.5/16	ZY3000/09/19	ZY3600/07/14.5D	ZY3600/07/14.5D	ZY3800/07/15
	Scraper conveyor	SGZ730/400	SGZ630/400	SGZ730/264	SGZ730/264	SGZ730/320	SGZ730/320	SGZ630/180
Field Application	Shearer	MG200/456-WD	MG200/456-WD	MG180/420-BWD	MG200/456-WD	MG200/456-WD	MG2×150/700-WD	MG110/250-BW
	Hydraulic support	ZY4000/09/20	ZY3600/10/20	ZY2600/6.5/16	ZY3000/09/19	ZY3600/07/14.5D	ZY3600/07/14.5D	ZY2600/6.5/16
	Scraper conveyor	SGZ730/400	SGZ730/400	SGZ630/264	SGZ730/264	SGZ730/320	SGZ730/320	SGZ630/180

Gray shadow means the inconsistent selection result.

Table 3. Improved selection result

Tabela 3. Ulepszony wynik wyboru

Equipment		Working face	Zhuzhuang Mine 646	Daizhuang Mine 3303	Nantun Mine 3602	Xiaotun Mine 14459	Shaqu Mine 22201	Yangcun Mine 1701
Hydraulic support	Shearer	MG200/456-WD	MG200/456-WD	MG180/420-BWD	MG200/456-WD	MG200/456-WD	MG2×150/700-WD	MG110/250-BW
		ZY4000/09/20	ZY3600/10/20	ZY2600/6.5/16	ZY3000/09/19	ZY3600/07/14.5D	ZY3600/07/14.5D	ZY2600/6.5/16
Scraper conveyor		SGZ730/400	SGZ630/400	SGZ630/264	SGZ730/264	SGZ730/264	SGZ730/320	SGZ630/180
		SGZ764/400	SGZ730/400	SGZ730/264	SGZ630/264	SGZ630/264	SGZ730/320	SGZ730/180

- ◆ Firstly, most of the selection rules of shearers in the knowledge database are rigid, such as: production capacity, operation speed and mining height.
- ◆ Soft selection rules of hydraulic support in knowledge database exist, causing some indicators to be fuzzy. For example, in the the practical production process, working resistance is decided by numerical simulation, filed measurements and theoretical analysis. In this ES, working resistance is decided only by theoretical analysis. As a result, the support selection result is less reliable.
- ◆ In addition, the alternative models of scraper conveyor in knowledge database are concentrated. Taking panel 3303 in the Daizhuang coalmine as an example, both SGZ 730/320-type and SGZ730/2×200-type scraper conveyor are feasible in this panel. Thus, there are various decision-making schemes for decision-makers.

Faced with the problems above, the authors have improved the ES. Firstly, numerical simulation is introduced to demonstrate in support selection rule for the second time. The improvement increases the reliability of the theoretical value of working resistance. Meanwhile, the scheme set of intelligent selection of the scraper conveyor is also achieved by the improvement. The improved ES was used to make the second equipment selection of working faces above. The results are shown in Table 3.

The second selection result shows that hydraulic support selected by improved ES is a reliable and the feasible scheme set of scraper conveyor selection is output, that is to say, decision-makers can choose any model from this set to meet the demand of selection and matching.

4. Case study

This improved ES is applied in equipment selection of panel 43101 in Shaanxi Liangshui-jing Mining co., LTD. In the panel, the mining height ranges from 1.1 m to 1.4 m and the average is 1.2 m. The coal inclination is between 0 and 1°. The Protodikonov's hardness of coal is 3 and the coal density is 1.29 t/m³. Mining the overall height at one time with bi-directional coal cutting with feeding at the ends is adopted. The length of mining face is 160 m and the length of feeding is 25 m. The average daily output is 2274 t. The “Four-six” working system is adopted, which means that three shift are to mine coal and one shift is for overhaul. The operating rate is 0.7. And the bulk density of roof is 25 kN/m³. Intelligent equipment selection results before and after improvement of the ES are shown in Figure 7 respectively, as shown in Table 4.

Equipment selection results interface in improved ES is consistent with the design proposal of 4301 FMM working face, indicates that the improved ES has a higher reliability than before. According to the above selection result, the conference about “Mining and Equipment Matching Technology Research of Thin Coal Seam” was held in Xi'an. The experts present approved the equipment selection and the matching scheme improved unanimously. Meanwhile, it received the “Computer Software Copyright Registration Certificate” awarded by the People's Republic of China. Thus, it has a promising application future.

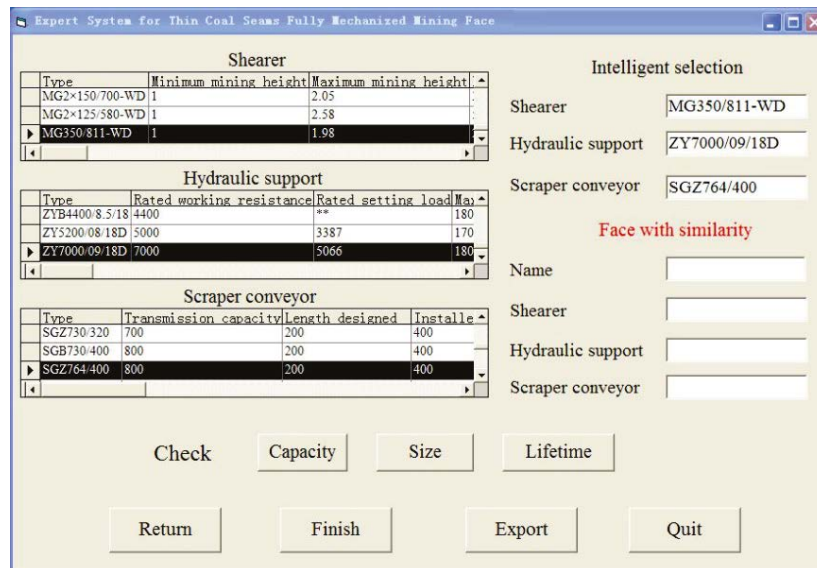


Fig. 7. Equipment selection results interface in improved ES

Rys. 7. Interfejs wyników wyboru sprzętu w ulepszonej wersji ES

Table 4. Equipment selection result of 43101 working face

Table 4. Wynik wyboru wyposażenia 43101 powierzchni roboczej

Equipment	Before improvement	After improvement
Shearer	MG350/811-WD	MG350/811-WD
Hydraulic support	ZY5200/08/18D	ZY7000/09/18D
Scraper conveyor	SGZ764/400	SGZ764/400

Conclusion

1. Research conclusion

- ◆ A database for the equipment selection and matching expert system in thin coal seam, fully mechanized mining face has been established, which contains device information of about 61 kinds of coal seam drum shearers, 41 kinds of hydraulic supports and 51 kinds of scraper conveyors. A total of 127,551 equipment selections and matching solutions were stored in the database.

- ◆ The equipment selection and matching decision-making software has been developed. Based on the intelligent selection and engineering verification of the expert system, the proposed system correction strategy of selection and matching of equipment for fully mechanized mining face is in thin seam. In addition, the improved and corrected ES has a higher reliability.
- ◆ Using the developed system to guide and complete the equipment selection and matching which design for the thin coal seam, fully mechanized mining face of 43101 in the Liangshuijing Mine. The credibility of the selection scheme has met the engineering requirements.

2. Prospects

The ES established in this paper is still in the feasibility test stage. Although it has achieved certain application results, it is only applicable to the FMM process of thin coal seam drum shearers. In order to further solve the technical problems about FMM equipment selection in TCS mining and optimize the performance, size and economics of the equipment, make it have an extensive range of application in the field of FMM in TCS mining. Thus, the following studies will be carried out step by step in the follow-up research concept:

- ◆ Using the Visual Basic programming language optimization ES, extend the model and parameters of a series of equipment such as belt conveyors, crushers, loaders and pump stations to the ES database, and improve the ES selection rules, and use genetic algorithms to improve the structure of the ES inference engine.
- ◆ Using software to compare and analyze the intelligent selection of the ES and the actual application of the site actually improves the reliability and rationality of the system.

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AN EXPERT SYSTEM FOR EQUIPMENT SELECTION OF THIN COAL SEAM MINING

Keywords

expert system, thin coal seam, equipment selection and matching,
decision-making software, field applications

Abstract

As one of the key techniques in the fully mechanized mining process, equipment selection and matching has a great effect on security, production and efficiency. The selection and matching of fully mechanized mining equipment in thin coal seam are restricted by many factors. In fully mechanized mining (FMM) faced in thin coal seams (TCS), to counter the problems existing in equipment selection, such as many the parameters concerned and low automation, an expert system (ES) of equipment selection for fully mechanized mining longwall face was established. A database for the equipment selection and matching expert system in thin coal seam, fully mechanized mining face has been established. Meanwhile, a decision-making software matching the ES was developed. Based on several real world examples, the reliability and technical risks of the results from the ES was discussed. Compared with the field applications, the shearer selection from the ES is reliable. However, some small deviations existed in the hydraulic support and scraper conveyor selection. Then, the ES was further improved. As a result, equipment selection in fully mechanized mining longwall face called 4301 in the Liangshuijing coal mine was carried out by the improved ES. Equipment selection results of the interface in the improved ES is consistent with the design proposal of the 4301 FMM working face. The reliability of the improved ES can meet the requirements of the engineering. It promotes the intelligent and efficient mining of coal resources in China.

SPECJALISTYCZNY SYSTEM DOBORU SPRZĘTU DO WYDOBYCIA CIENKICH POKŁADÓW WĘGLA**Słowa kluczowe**

system ekspercki, cienki pokład węgla, dobór i dopasowanie sprzętu, oprogramowanie do podejmowania decyzji, zastosowanie w praktyce

Streszczenie

Dobór sprzętu, jako jedna z kluczowych technik w pełni zmechanizowanego procesu wydobycia, ma ogromny wpływ na bezpieczeństwo, produkcję i wydajność. Wybór i dopasowanie w pełni zmechanizowanego sprzętu górniczego w cienkim pokładzie węgla jest ograniczone przez wiele czynników. W przypadku całkowicie zmechanizowanej ściany wydobywczej węgla (FMM) w cienkich pokładach (TCS) przeciwdziałanie problemom związanym z wyborem sprzętu, takim jak m.in.: wielość rozpatrywanych parametrów i niska automatyzacja, ustanowiono system ekspercki (ES) doboru sprzętu do w pełni zmechanizowanej ściany wydobywczej. Utworzono bazę danych systemu doboru i dopasowania systemu eksperckiego w cienkich pokładach węgla w pełni zmechanizowanej ściany wydobywczej. Jednocześnie opracowano oprogramowanie do podejmowania decyzji, dopasowane do ES. Na podstawie kilku rzeczywistych przykładów omówiono wiarygodność i ryzyko techniczne związane z wynikami ES. W porównaniu z zastosowaniem obecnym, wybór kombajnu systemem eksperckim (ES) jest niezawodny.

Wystąpiły jednak pewne niewielkie odchylenia w wyborze stojaków hydraulicznych i przenośnika zgarniającego, następnie ES został ulepszony. W rezultacie poprawiono wybór sprzętu w całkowicie zmechanizowanej ścianie wydobywczej o nazwie 4301 w kopalni Liangshuijing. Interfejs wyników wyboru sprzętu w ulepszonym ES jest zgodny z propozycją projektu 4301 FMM roboczej ściany wydobywczej. Niezawodność ulepszanego ES może spełniać wymagania inżynierskie. Promuje inteligentne i wydajne wydobycie zasobów węgla w Chinach.

