Risk Evaluation of Gob Spontaneous Combustion Based on Fuzzy Mathematics

Liyan Tang, Zhaopeng Liu, Chao Xiong
College of technology,
Sichuan normal University,
Chengdu, 610000, China

***Abstract*—This method for fuzzy comprehensive evaluation by fuzzy mathematics evaluate gob spontaneous combustion risks, builds a risk index system of gob spontaneous combustion in combing the characteristics of combustion in the goaf and established a fuzzy comprehensive evaluation model of natural fire in goaf, realized the comprehensive evaluation of the risk of spontaneous combustion in gob. Case analyses, the results are handled strong and well by fuzzy comprehensive evaluation method in spontaneous combustion risk evaluation**

Keywords-gob spontaneous combustion; indicator system; fuzzy comprehensive assessment.

I. INTRODUCTION

The aim of Mine fire risk assessment determines the risks in order to develop targeted for mine fire prevention and control measures. Through an analysis of influence factors of mine spontaneous combustion in goaf, a variety of factors that the possibility of spontaneous combustion in goaf of coal mine were considered and evaluation index system established on fuzzy mathematical method, thereby contributing comprehensive evaluation for the risk of spontaneous combustion in goaf.

II. THE PROGRAM OF FUZZY COMPREHENSIVE EVALUATION OF SPONTANEOUS COMBUSTION IN GOAF [1] ~ [4]

Fuzzy comprehensive evaluation on spontaneous combustion in goaf, specific procedures is depicted in Figure 1.

III. ESTABLISHMENT OF THE INDEX SYSTEM FOR EVALUATION OF SPONTANEOUS COMBUSTION IN GOAF [5] ~ [6]

A. *Analysis of the cause and effect factors of spontaneous combustion in goaf*

Formation of spontaneous fire must have 3 basic conditions: 1) with low-temperature oxidation properties; 2) ventilation and oxygen; 3) large amounts of coal accumulation to be relief in a timely manner.

Therefore, according to the essential factors of formation condition of spontaneous combustion and characteristics of spontaneous combustion in Gob one-level index is divided into 6 areas.

B. *Establishing evaluation index system*

The fuzzy comprehensive evaluation index system of spontaneous combustion in goaf is divided into 1- level index and 2-level index.

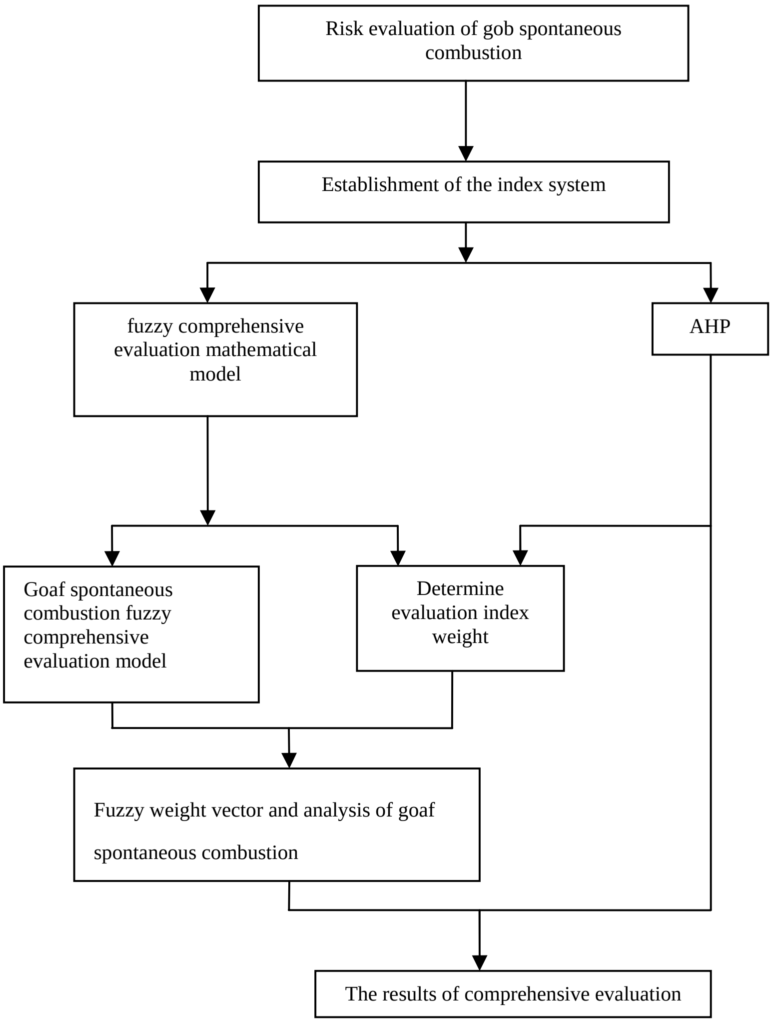

Figure 1. Fuzzy comprehensive evaluation on spontaneous combustion in goaf

TABLE I. THE FUZZY COMPREHENSIVE EVALUATION INDEX SYSTEM

1-level index	2-level index	1-level index	2-level index
Developing mining conditions U_1	Development, U_1 mining methods, U_{12} extraction order, U_{13} roof management U_{14}	thermal environment and steady oxidation times U_4	thickness and size of missing Coal, U_{41} seam depth, U_{42} promoting speed, U_{43} minimum combustion period U_{44}
coal spontaneous combustion tendency U_2	Composition of coal and rock, sulphur, U_{21} degree of carbonization of coal, U_{22} water of coal seam, U_{23} porosity and hardness of coal, U_{24} ash of coal U_{25}	prevention and control measures U_5	Filling, U_{51} nitrogen, U_{52} inhibitors, U_{53} equal presure, U_{54}
ventilation leakage in goaf U_3	Rationality of ventilation system, U_{31} air pressure and air quantity on face, U_{32} ventilation management U_{33}, strength of ventilation leakageU_{34}	security management U_6	Responsibility system for safety production, U_{61} safety education, U_{62} security, U_{63} personnel quality U_{64}

IV. ESTABLISH FUZZY COMPREHENSIVE EVALUATION MATHEMATICAL MODEL [6]

(1) Factors set U= $\{U_1, U_2, U_3, U_i, U_n\}$ equals, the evaluation object set composed of various factors.

(2) Judge set V= $\{V_1, V_2, V_3, V_J, V_n\}$,set of comments.

(3) Single factor judgment, the judgment of individual factors.

For a single evaluation factors μ_1, evaluation results can use the set v, which is the theory of fuzzy subset b to describe the domain, and $b = \mu_1/v_1 + \mu_2/v_2 + \ldots \mu_m/v_m$ ($b = [\mu_1, \mu_2 \ldots \mu_m]$ in short)

(4) To many index factors of comprehensive evaluation, finally still is the fuzzy subset theory domain of comments collection V, denoted by B

$$B = b_1/v_1 + b_2/v_2 + \ldots b_m/v_m$$

In practical evaluation, consider different evaluation factors of the importance of the difference between the evaluation factors set is set U of fuzzy subset theory domain, denoted by A,

$$A = a_1/u_1 + a_2/u_2 + \ldots a_m/u_m$$

$A = [a_1, a_2 \ldots a_m]$ In short, the a_j is membership degree of relevant elements in V, and $a_{j \in [0,1]}, \sum_{i=1}^{n} a_i = 1$

(5) Fuzzy comprehensive evaluation, the evaluation factor set U, a theory on the domain of A fuzzy set A of A theory of the fuzzy transformation for evaluation collection V on the domain of A fuzzy set B, i.e. $B = A \circ R$

This is the mathematical model of fuzzy comprehensive evaluation.

Establish goaf spontaneous combustion fuzzy comprehensive evaluation model.

V. SETTING EVALUATION INDEX FACTOR SET U

Goaf spontaneous combustion is influe[nced] by many factors; these factors can be divided into different indicators set. The primary level has six evaluation indexes: U= $\{U_1, U_2, U_3, U_4, U_5, U_6\}$; the second have 26 factors, detailed in table I.

A. Setting evaluation set V

Establish evaluation collection V = {security, not easy to spontaneous combustion, combustion, easy spontaneous combustion, extremely easy spontaneous combustion}, said evaluation levels of the system.

B. Determine evaluation index weight and index weight is calculated

In the fuzzy comprehensive evaluation, determine the evaluation factors weight vector: $A = (a_1, a_{2,\ldots,} a_n)$. The key is how to draw on the impact of a certain factor on spontaneous combustion of importance. This paper is according to the scores given by experts and on-site engineering and technical person, using analytic hierarchy process (AHP) to determine the evaluation index weights.

C. Determine the membership and the membership functions, and establish fuzzy relationship matrix R

In this paper, the determination of membership function reference literature, i.e.

$$f_{11}(u_{11}) = \begin{cases} 1, (90 \le u_{11} \le 100) \\ \dfrac{u_{11} - 80}{90 - 80}, (80 \le u_{11} \le 90) \\ 0, (u_{11} \le 80) \end{cases}$$

$$f_{12}(u_{11}) = \begin{cases} \dfrac{100 - u_{11}}{100 - 90}, (90 \le u_{11} \le 100) \\ 1, (80 \le u_{11} \le 90) \\ \dfrac{u_{11} - 70}{80 - 70}, (70 \le u_{11} \le 80) \\ 0, (u_{11} \le 70) \end{cases}$$

$$f_{13}(u_{11}) = \begin{cases} 0, (90 \le u_{11} \le 100) \\ \dfrac{90 - u_{11}}{90 - 80}, (80 \le u_{11} \le 90) \\ 1, (70 \le u_{11} \le 80) \\ \dfrac{u_{11} - 60}{70 - 60}, (60 \le u_{11} \le 70) \\ 0.(u_{11} \le 60) \end{cases}$$

$$f_{14}(u_{11}) = \begin{cases} 0, (80 \le u_{11} \le 100) \\ \dfrac{80 - u_{11}}{80 - 70}, (70 \le u_{11} \le 80) \\ 1, (60 \le u_{11} \le 70) \\ \dfrac{u_{11} - 50}{60 - 50}, (50 \le u_{11} \le 60) \\ 0, (u_{11} \le 50) \end{cases}$$

$$f_{15}(u_{11}) = \begin{cases} 0, (70 \le u_{11} \le 80) \\ \dfrac{70 - u_{11}}{70 - 60}, (60 \le u_{11} \le 70) \\ 1, (50 \le u_{11} \le 60) \\ \dfrac{u_{11} - 40}{50 - 40}, (40 \le u_{11} \le 50) \end{cases}$$

$$f_{16}(u_{11}) = \begin{cases} 0, (60 \le u_{11} \le 70) \\ \dfrac{60 - u_{11}}{60 - 50}, (50 \le u_{11} \le 60) \\ 1, (u_{11} \le 50) \end{cases}$$

Expert rating by rating probability generation into membership function formula, can get the membership degree:

$$r_{11} = f_{11}(u_{11}), r_{12} = f_{12}(u_{11}), \ldots$$
$$r_{21} = f_{21}(u_{11}), \ldots$$
$$\ldots$$
$$r_{n1} = f_{n1}(u_{11}), \ldots$$

Thus we can get the fuzzy relation matrix, and

$$R == \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}$$

D. Invite experts evaluation for its implementation by the side who use safety inspection table

According to safety inspection table score as a result, the corresponding points can be sent to:{80, 70, 60, 50, 90}, according to the results of each expert's safety checklist score according to the single factor evaluation, establishing the fuzzy subset R grade for the factors of the row vector is the statistical evaluation$(0.2,0.2,0.4,0.2,0)$, so as to get the fuzzy subset R according to the evaluation factors.

VI. THE GOAF SPONTANEOUS COMBUSTION RISK ASSESSMENT ANALYSIS

In the proposed algorithm, the multi-objective bi-level programming problem is transformed into a single-level problem by using interpolation functions of the lower level solutions. The process avoids solving the lower level problems frequently, and reduces the computational cost. The major advantage of this algorithm is that it can solve some complex issues, in which the lower level problems are non-convex and non-differentiable. Hence, it can be used to deal with hard multi-objective bi-level programming problems.

A. General Situation of Mine

LuAnzuo,QuanFusheng raw coal group co., field within 15 coal seam recoverable, minable seam thickness 3.17 ~ 3.17 m, average 6.01 m, geological structure is simple, coal seam oxygen intake is 0.47 cm3 / g, the self-ignition orientation of coal for the mine is spontaneous combustion, and this is a gas mine, and with coal and gas outburst danger.

B. Determine the evaluation rank theory domain

Establish evaluation collection V={security, not easy to spontaneous combustion, combustion, easy spontaneous combustion, extremely easy spontaneous combustion}, the level of system evaluation, according to the results of the safety checklist score corresponding points can be set to:{80,70,60,50 90}, as shown in table II.

TABLE II. SECURITY RATING CLASSIFICATION TABLE

rank	safety class	Scores
Class I	safety	90-100
Class II	Not easy to spontaneous combustion	80-90
Class Ⅲ	Spontaneous combustion	70-80
Class Ⅳ	easily combustion	60-70
Class Ⅴ	Extremelly easily combustion	<60

C. Determine the index weight

Primary indicators and secondary indicators index weights, using the analytic hierarchy process (AHP) to determine the index weight, and normalized processing, as shown in table III and table IV.

TABLE III. PRIMARY INDEX WEIGHTS

evaluation index	U_1	U_2	U_3	U_4	U_5	U_6
Weight U_j	0.075	0.329	0.201	0.201	0.132	0.065

TABLE IV. SECONDARY INDEX WEIGHTS

U_{ij}	*j*=1	*j*=2	*j*=3	*j*=4	*j*=5	*j*=6
i=1	0.30	0.28	0.22	0.12	-	-
i=2	0.23	0.20	0.17	0.15	0.13	0.12
i=3	0.23	0.36	0.21	0.20	-	-
i=4	0.29	0.22	0.22	0.27	-	-
i=5	0.40	0.35	0.25	-	-	-
i=6	0.20	0.20	0.28	0.32	-	-

D. Fuzzy comprehensive evaluation

According to the formula $B = A \circ R$ for calculating, we get the following results are calculated by the MATLAB software

$$B_1 = A_1 \circ R_1$$
$$= (0.0320,0.1460,0.5520,0.1300,0.1200)$$
$$B_1 = (0.2524,0.1151,0.4353,0.1025,0.0946)$$

In the same way. The coal's evaluation vector of self-ignition orientation

$$B_2 = (0.2208,0.1807,0.1897,0.1881,0.2208)$$

Goaf air leakage evaluation vector

$$B_3 = (0.0200,0.1230,0.2710,0.4570,0.1290)$$

Heat storage environment and oxidation duration evaluation vector

$$B_4 = (0.0502,0.1619,0.2208,0.1531,0.4141)$$

Prevention and control measures evaluation vector

$$B_5 = (0,0.0950,0.3650,0.2900,0.2500)$$

Safety management evaluation vector

$$B_6 = (0.1160,0.3440,0.3640,0.1640,0.0320)$$

Comprehensive evaluation vector synthesis

According To the Formula

$$B = A \circ R = (0.1129, 0.1603, 0.2658, 0.2412, 0.2241)$$

After normalization, $(0.1124, 0.1596, 0.2645, 0.2402, 0.2231)$

The comprehensive evaluation score value level

$$V = 100 \times 0.1124 + 90 \times 0.1596 + 80 \times 0.2645 + 70 \times 0.2402 + 60 \times 0.2231 = 76.964$$

Rating standard comparison shows that the mine goaf spontaneous combustion risk assessment for level 3 spontaneous combustion, there is a danger, and it is consistent with the field situation. The Mined-out area is dynamic, so the recovery period may have previously unrecognized flammability hazard, and cannot be taken lightly, the mined-out area must be strict management, improve the system of fire prevention and fire prevention work.

VII. CONCLUSION

(1) In this paper, combining with the characteristics of goaf ignition, build the goaf spontaneous combustion risk index system, the mined-out area constructs the fuzzy comprehensive evaluation model of natural fires according to the principle of fuzzy comprehensive evaluation, and implementation of goaf spontaneous combustion fire risk evaluation. in goaf spontaneous combustion fire risk comprehensive evaluation using the case analysis, proved that fuzzy comprehensive evaluation method in the goaf spontaneous combustion risk assessment in the operability is strong, and have a good effect.

(2) Through the fuzzy comprehensive evaluation method, to judge the relative safety of goaf spontaneous combustion state, which according to the result of evaluation, formulate fire prevention technology measures to reduce the risk of goaf ignition, by calculating the weight at the same time, according to its size, the measures to highlight key and having a comprehensive grasp.

(3) The goaf spontaneous combustion is influenced by many factors, the establishment of the factor set may not completely include all important influencing factors of expert evaluation of inconsistencies may also affect the impartiality and honesty.

(4) At present, the goaf spontaneous combustion risk assessment method in our country is still not perfect, and the author believes that, with the continuous development and improvement of safety engineering, the fuzzy comprehensive evaluation method will increasingly play a greater role.

REFERENCES

[1] Qixiang Yu. Theory and technology of mine disaster control [M]. Xu Zhou: China University of Mining and Technology press, 2008.

[2] Yumin Tian, Mao Liu. The probability of high-rise building fire risk fuzzy comprehensive evaluation method [J]. Safety evaluation, 2011.8.

[3] Xinkai Tian. Mine pit risk evaluation index method [J]. Journal of safety and environment, 2006.8.

[4] Mao Liu. The accident risk analysis theory and method [M]. Bei Jing: Peking University press, 2011.

[5] Kai Cao, Deming Wang. The mine ventilation system safety evaluation index based on AHP [J]. Coal mine safety, 2010.5

[6] Laitao Zhang. Study on spontaneous combustion of fuzzy comprehensive evaluation based on the mined out area [J]. Modernization of coal mine, 2009.2.