Evaluation of Explosion Protection Means of Mine Electrical Equipment for Operation in Excavations of Coal Mines

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Abstract

Information of ensuring explosion-proof properties of mine electrical equipment is one of important problems of ensuring safe operation of electrical equipment in coal mines are provided. It is shown that this process is very difficult and a little studied. The analysis algorithm and identifications of influence of defects of constructional elements of a cover on explosion protection is offered. The analysis of existing normative documents is carried out and the directions of researches are offered.

Keywords: explosion protection, mine electrical equipment, explosion safety, defect, coal mine

In excavations of coal mines always there is a potential danger which under certain conditions can pass into the real. So, in particular, this danger can arise at coincidence of such events as existence in developments of the explosive atmosphere and a source of initiation of explosion which can be mine electrical equipment with faulty means of explosion protection. According to GOST 27.310-95, the equipment is reliabile . The analysis of types, consequences and criticality of refusals" loss of explosion-proof properties of electrical equipment can be referred to the IV category – "refusal which quickly and with high probability can cause a significant damage for the object and (or) for environment, death or heavy injuries of people, failure of performance of an objective" [1].

Explosion protection of the mine electrical equipment established in excavations of mines, is provided, generally application of a special design – the explosion-proof cover which explosion-proof properties it is reached due to use of special constructive elements: explosion-proof crack between separate elements of a cover, application of spring washers in knots of fastening, sealing plugs of cables, caps not used inputs, security rings round fastening bolts, etc.

Distinctive feature of ensuring explosion-proof properties of electrical equipment is that explosion protection is provided with set of a working order of all elements. Defect of one of them can bring, with a certain probability, to loss of explosion-proof properties and, besides with a certain probability, to explosion or a fire in excavations. It should be noted that control and diagnostics of emergence of defects of separate elements is difficult as many defects can't be measured in work process. Besides, defect of any element of explosion protection doesn't lead to transition of electric equipment to a non-working state (stopping the engine, shutdown of the electric device) but only translates it in faulty, but operating state. In the coal industry a number of normative documents [2, 3, 4] which define an inspection routine, audits of mine explosion-proof electrical equipment, including means of explosion protection works now. However in these documents critical pa-

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rameters of defects of the explosion protection which excess demands an electrical equipment conclusion from operation and adoption of a certain decision on its further safe operation (utilization, use out of an explosive environment, repair, prevention and adjustment) aren't established.

The analysis of a condition of explosion protection means consists in identification of the factors influencing explosion protection, and estimates of their importance as the factor having impact on explosion safety. It is known that any event, in this case explosion protection violation, is seldom caused by the only reason. Most often sources of emergence of defects are: the person (man) – the car (machine) – a method (method) – a material (material) – so-called 4M. In the conditions of excavations to them environment conditions, the natural phenomena, etc. are added.

The analysis of a condition of explosion protection of mine explosion-proof electrical equipment includes:

1.Choice of set of indicators of the separate constructive elements providing explosion protection, and determination of critical size of defect at which excess there is a high probability of formation of real danger (explosion, a fire).

2. Development of mathematical model and the program computer system for an assessment of probability of violation of explosion protection, both on a separate element, and on their set.

3. Carrying out necessary researches and tests in laboratory and working conditions for the data acquisition, characterizing process of loss by electrical equipment of explosion-proof properties.

The researches conducted by us on a number of mines of Kuzbass[5], are allowed to establish that loss of explosion-proof properties of mine electrical equipment is influenced by the following defects:

—absence or breakdown spring washers on fasteners;

—rust on explosion-proof surfaces;

—damages of rubber sealing rings to cable inputs;

—lack of caps on not used cable inputs;

—the increased gap between explosion-proof surfaces;

—damage of a carving of fasteners;

—mechanical damages of elements of a cover;

—damages of security rings on covers of introduction offices;

—damages of insulators through passage.

The histogram of distribution of probability of emergence of explosion protection defects for 672 units of electric equipment is given in fig. 1.

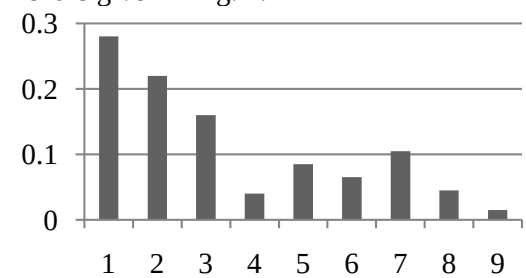

Fig. 1: The histogram of distribution of probability of emergence of explosion protection defects

The conducted researches are allowed to establish that decrease in explosion-proof properties of mine electrical equipment is influenced by various defects of constructional elements. Most often such defects of explosion protection as absence or breakage of spring washers, a rust on explosion-proof surfaces, damages of sealing rings (about 66% of all damages), but it doesn't mean meet that these defects are most dangerous to loss of explosion-proof properties. For example, such defect as damage of an insulator through passage meets seldom (1.3%), but on the consequences is more dangerous as in this case possibly short circuit on the case with possible emission of an electric arch

outside of the introduction device, especially if thus there are no caps of non-working inputs or are damaged there (do not correspond) sealing rings. Also on weight of consequences and formation of dangerous situations mechanical damages of covers are the extremely dangerous. It should be noted that development of one defect (for example, absence or damage of spring washers) leads to appearance of another (increase in a gap between explosion-proof surfaces). That is in certain cases there is a coherence of events (defects of elements of explosion protection) which develop both in parallel (independently) from each other, and is consecutive. Development of one leads to appearance of another.

For an assessment of level of explosion safety of electrical equipment it is possible to use the following technique [6].

By consideration of level of explosion safety of electric equipment it is considered three states:

—normal when the condition of separate elements of explosion protection allows to exploit him without any restrictions (2);

—pre-emergency when correcting influences directly in an electrical equipment installation site (replacement of washers, cleaning of explosion-proof surfaces of a rust, installation of sealing rings and caps, etc.) are required after which the decision on further operation of electric equipment is made(1);

—emergency when a condition of explosion protection such is that is required or repair in the specialized organizations (restoration of mechanical damages, replacement of separate details), with the subsequent decision on further operation (for example, as mine normal, removal a sign of explosion protection and further operation as not explosion-proof) or utilization (0).

The condition of explosion protection can be estimated:

$$F(S_i)=\begin{cases}2, S_i < S_i^1;\\ 1, S_i^1 \le S_i < S_i^0\\ 0, S_i \ge S_i^0;\end{cases} \qquad (1)$$

where n – quantity of observed elements of explosion protection; S_i – the actual value of a condition of $i$element of explosion protection; S_i^1, S_i^0 – value of pre-emergency and emergency threshold condition of i element of explosion protection.

Further it is necessary to define the importance of each element in the general scale of values, to find out "specific weight" in the general value of indicators of refusal of explosion protection. The most acceptable for the solution of this task, in our opinion, is the FMEA method (Failure Mode and Effects Analysis) [7]. Thus define:

—list of potential defects of explosion protection;

—potential reasons of emergence of these defects;

—potential consequences of the revealed defects;

—possibility of control of the revealed defects.

The FMEA method is expert method. Experts in 10-ball system estimate above the listed parameters. Thus the highest point is appropriated to defect with the most serious consequences, with the greatest probability of emergence and it is the most difficult revealed.

For realization of this method it is necessary to define:

1. Rank (point) of the importance of each defect of explosion protection and possible consequences on its influence on level of explosion protection (R).
2. Probability of emergence of this or that defect of explosion protection (E).
3. Probability of detection of defect at electric equipment survey (S).

The Complex Risk of Defect (CRD) of explosion protection can be defined as CRD = R ×E ×S. According to recommendations [7] at value of CRD ≥ 100 … 120, the explosion-proof electrical equipment has to be immediately taken out of service, is lifted on a surface and sent to the specialized repair organizations for carrying out repair and correcting actions or utilization. At CRD ≤ 40 operation of electric equipment can be continued without restrictions. At 40<CRD< 100explosionrisk of losses defined as the average. In this case it is necessary to carry out repair work in the conditions of our workings (e.g. installation of lock was hers for fastening parts, rubber sealing rings in the cable gland sand plugs for unused cable glands). But since in this case we have a very high risk(IV category according to GOST27.310-95) consequences of potential defects means of protection, the value of CRD should be toughened and determined by the results of research.

The decisions made by experts have to be reflected in the book "Registration of a Condition of Electric Equipment and Grounding" with the conclusion of the chief power engineer of mine.

Thus, it is necessary to consider that for receiving the most reliable results the assessment requirements of an expert have to be imposed to members of expert group, characterizing their knowledge and qualification in the matter. The quantitative structure of expert group can be determined by expression:

$$N \geq \frac{h^2 r_a r_o}{\Delta^2} \qquad (2)$$

where h = 0,95 – confidential coefficient; r_a, r_o– a share of sample units with existence and lack of the set defect; Δ – an error of a representativeness.

At r_a = 0.95, r_o = 0.05, Δ = 0.05 minimum number of experts will make 18 people.

For an assessment of comparative influence of separate elements on the general level of explosion protection the expert method of an assessment is used. For what the matrix comparative (in pairs) characteristics of defects of elements of explosion protection is formed:

$$\begin{matrix} 1 \\ 2 \\ \vdots \\ \vdots \\ n \end{matrix}\begin{bmatrix} 1 & \cdots & \cdots & \cdots & \gamma_{1n} \\ \gamma_{21} & 1 & \cdots & \cdots & \gamma_{2n} \\ \vdots & \cdots & 1 & \cdots & \vdots \\ \vdots & \cdots & \cdots & 1 & \vdots \\ \gamma_{n1} & \cdots & \cdots & \cdots & 1 \end{bmatrix} V_i = \frac{\sum_j^n \gamma_{ij}}{\sum_i^n \sum_j^n \gamma_{ij}} \qquad (3)$$

where V_i – the specific weight of i element of explosion protection in system of ensuring explosion safety of electric equipment; γ_{ij} – the conditional importance of i element of explosion protection in comparison with j element.

The integrated assessment of a qualitative condition of explosion protection is determined by an indicator assessment

$$B_{ij} = \begin{cases} 2, \sum_i^n V_i^2 \leq R_2; \\ 1, \sum_j^n V_i^0 < R_0 \text{ и } \sum_i^n V_i^2 > R_2; \\ 0, \sum_i^n V_i^0 > R_0; \end{cases} \qquad (4)$$

where V_i^2, V_i^0 – the specific weight of i element of the explosion protection which is in area of normal and emergency values respectively; R_2, R_0 – the coefficients characterizing level of achievement of a normal or accident condition respectively.

It is possible to assume that if the total specific weight of defects of all elements of explosion protection will make no more R_2 from the sum of all defects, the condition of explosion protection can be estimated as accepted or normal. At the specific weight of all defects of more R_0, the condition of explosion protection is emergency. In limits between the areas defined as normal and emergency there is a pre-emergency condition.

Besides, it is necessary to create the program computer system (PCS), capable to

calculate and simulate probability of emergence of accident taking into account external factors influencing electric equipment and a condition of elements of the design providing explosion protection. PVK has to consist of the following blocks:

— the information and analytical block providing collecting and preprocessing of information on a condition of means of explosion protection;

— the block of standard and technical documentation, including software of procedures of collecting, processing and adoption of the decision;

— the block of examination of the received results of preprocessing, development of operating decisions and recommendations, including about possibility of further operation of electric equipment;

— the block of modeling of process of emergence and development of an emergency (explosion) depending on a condition of explosion protection and environment.

By results of the analysis of a condition of means of explosion protection, except the operational actions directed on decrease in probability of possible explosions, it is necessary to consider possibility of constructive change of mine explosion-proof electrical equipment. So, we[8, 9] offered the design of explosion-proof electric equipment which is almost excluding possibility of explosion in a cover. The carried-out research and development, and also tests of prototypes confirmed prospects of this direction in increase of safety and reliability of electric equipment for explosive rooms and mountain developments.

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MINING 2014

THEME
CHINESE COAL
IN THE XXI CENTURY:
MINING, GREEN
AND SAFETY

TAISHAN
ACADEMIC
FORUM

PROJECT
ON MINE
DISASTER
PREVENTION
AND
CONTROL

OCTOBER 17/20, 2014
QINGDAO, CHINA

EDITED BY
WEIJIA GUO, YUNLIANG TAN,
YONGJIE YANG, SHASHA YAN,
DONGMEI HUANG – CHINA

ATLANTIS
PRESS

泰山学术论坛
Taishan Academic Forum

MINING 2014

Taishan Academic Forum – Project on Mine Disaster Prevention and Control

October 17–20, 2014
Qingdao, China

***Theme*: Chinese Coal in the XXI Century: Mining, Green and Safety**

Edited by:

Weijia Guo, China
Yunliang Tan, China
Yongjie Yang, China
Shasha Yan, China
Dongmei Huang, China

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AMSTERDAM – PARIS – BEIJING

Advances in Engineering Research

(ISSN 2352-5401)

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www.atlantis-press.com

ISBN: 978-94-62520-28-8

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Taishan Academic Forum – Project on Mine Disaster Prevention and Control

October 17–20, 2014
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***Theme*: Chinese Coal in the XXI Century: Mining, Green and Safety**

Hosted by:

- Education Department of Shandong Province, China
- Shandong University of Science and Technology, China
- Shandong Administration of Coal Industry, China

Edited by:

- Weijia Guo, China
- Yunliang Tan, China
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- Shasha Yan, China
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Sponsored by:

- Institute of mining and safety engineering, Shandong University of Science and Technology, China
- State Key Laboratory of mine disaster prevention and control, Shandong University of Science and Technology, China

Organizers:

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Foreword

Mining technology is an important issue on resource exploitation, which is related to mine production security and energy supply. In order to promote the scientific and technological progress and international exchanges of the mining technology, the Taishan Academic Forum – Project on Mine Disaster Prevention and Control is to be held on Oct. 17-20, 2014, in Qingdao, China. The aim of the symposium is to summarize the modern coal industry achievements, in safety green mining methods and the related fields. There will be experts and scholars to attend the meeting, from the coal industry enterprises, universities, research institutions and other related fields of China and Russia.

The main topics of the symposium include: safety green mining methods, mine construction and modernization, the mining theories, methods and technology, the construction safety of mining and underground engineering, the operation and management of mining and underground engineering, etc.

The symposium is organized by the Education Department of Shandong Province, Shandong University of Science and Technology, Coal Industry Bureau of Shandong Province. It is undertaken by Institute of Mining and Safety Engineering, Shandong University of Science and Technology and State Key Laboratory of Mine Disaster Prevention and Control.

We are convinced that the symposium is going to play an important role in the development of the coal mining technology and international communication. Heartfelt thanks are extended to domestic and overseas scholars who have given great supports to this conference and all the authors who have presented the papers.

Weijia Guo, China
Yunliang Tan, China
Yongjie Yang, China
Shasha Yan, China
Dongmei Huang, China

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