UNIVERSITY OF PETROŞANI

DOCTORAL SCHOOL

DOCTORAL THESIS

ABSTRACT

Coordinator:

Professor Florin Dumitru POPESCU, Ph.D.

Doctoral student:

Eng. Daniela PEAGU (FURDUI)

2024

UNIVERSITY OF PETROŞANI

DOCTORAL SCHOOL

RESEARCH ON THE IMPROVEMENT OF THE EVALUATION METHODS FOR ELECTRICAL EQUIPMENT INTENDED FOR USE IN THE POTENTIALLY EXPLOSIVE ATMOSPHERES IN UNDERGROUND MINES

ABSTRACT

Coordinator:

Professor Florin Dumitru POPESCU, Ph.D.

Doctoral student:

Eng. Daniela PEAGU (FURDUI)

2024

ABSTRACT

The doctoral thesis entitled ***RESEARCH ON THE IMPROVEMENT OF THE EVALUATION METHODS FOR ELECTRICAL EQUIPMENT INTENDED FOR USE IN THE POTENTIALLY EXPLOSIVE ATMOSPHERES IN UNDERGROUND MINES*** approaches a topical issue that regards the assessment of electrical equipment with a view to estimate and evaluate the technological risk associated with unwanted events resulting in explosions which might occur in industrial premises with explosion hazards. The goal of the research is the prevention of the human and material goods losses through improving the methods for the assessment of the compliance of the electrical equipment used in environments with a potentially explosive atmosphere by means of computer modeling and simulation tools. The thesis represents a fundamental scientific approach meant to decrease the risk on non-compliance in physical testing.

The electrical equipment intended to be used in potentially explosive atmospheres are regulated by a lot of rules, standards and directives which it has to comply with.

The assessment of compliance and getting certification represents a laborious activity and is rather based on empirical elements.

During the planning stage, it is useful to provide compliance through a series of assessment methods relying on modeling and simulation, which are able to reproduce as accurately as possible the features of compliance trials as well as the extreme conditions that might occur during the operational stage.

This is an important element owing to the increasingly sophisticated features of the equipment and to the increasingly higher values of the operating parameters of the equipment (power, voltage, current intensity, etc.) as well as to the recent evolution of the computer modeling and simulation tools that are suitable for multi-domain environments.

As a result, the risk of finding non-compliance elements in the final stage of stand physical testing, whose repair involves increased costs, is reduced.

The electrical equipment intended to be used in the environments with potentially explosive atmospheres in the pit gas coal mines, compared with the equipment in other dangerous areas, displays a particular specificity as it has to face supplemental constraints that turn the issue of the safety from the danger of explosion even more difficult and complex in terms of gauge, difficult operational conditions, excessive mechanic strain, corrosive environment, decreased visibility, etc.

The goal of the thesis consists in identifying the sensitive elements that are appropriate for an approach where the need for progress is imperative and that are largely tributary to empirical methods.

Owing to this reason, the development of the thesis has been guided towards the elements that regard the mostly used protection means, namely blast-proof capping, and towards a group of complex phenomena that regard a component which is crucial for the safe functioning of the electrical commutation equipment, with implications for anti-explosive safety, namely contacts.

The subject approached is topical and relevant both from a practical perspective and from the perspective of scientific interest. The importance of the field addressed is pinpointed by the fact that it is at the intersection of three axes of ingterest, namely: safety in industry, environment protection, and durable capitalizing of resources.

Scientific interest is revealed by the need to rigorously substantiate a field which used to rely, decades on end, on empirical observations, witnessed rather legislative-normative-regulating incremental progress and is at risk to become obsolete or to restrain the increasingly rapid evolution of the technologies it governs. With this in view, the implementation of the increasingly performing modern modeling and simulation methods might bring a significat contribution to the progress of knowledge, to which this doctoral thesis adheres through topic, approach, content and results.

The thesis is structured in six chapters whose length, coverage and content match the logical flux of the research approach. The chapters are in line with the present share and stage of the issue the manner the results and contributions to its gradual, complementary and evolutional progress of understanding show.

The theoretical basis, the investigation tools, the theoretical results and the conclusions that might be put into practice are all displayed in a logical connection with a view to facilitating understanding and to pointing out the impact of the results upon the progress of knowledge.

Owing to the fact that the research approach could not be done without an appropriate presentation matching the requirements of the doctoral topic regarding the regulatory and certification framework for the type of equipment that represents the object of the topic, in CHAPTER 1, entitled *SPECIFIC REQUIREMENTS THAT COME OUT OF THE EUROPEAN AND NATIONAL LEGISLATION AND REGARD THE CARRYING OUT OF THE ACTIVITIES IN ENVIRONMENTS WITH DANGER OF EXPLOSIVE ATMOSPHERES*, I display the main requirements of Directive ATEX 94/9/CE concerning the safety level of the protective equipment and systems that are used in potentially explosive atmospheres.

I further display the general requirements for the electrical devices used in potentially explosive atmospheres, according to SR EN 60079-0 and regarding the building, trial and labelling of the electrical devices that are specifically used in potentially explosives atmospheres.

In addition, I also present the prescriptions which specific for the construction, inspection, maintenance and repair of the electrical devices involving an explosion proof capsular *d* protection to be used in potentially explosives atmospheres, according to SR EN 60079-1. Explosion proof *d* capsulation is a type of protection where the parts that might ignite an explosive atmosphere are placed within an encapsulation, which is able to resist the pressure occurring during the inner explosion of an explosive mixture and might prevent the transmission of the explosion to the explosive atmosphere that surrounds the capsulation.

In CHAPTER 2, entitled *RESEARCHES REGARDING THE METHODS AND TECHNIQUES FOR THE PREVENTION OF THE EXPLOSION RISKS DETERMINED BY THE EXPLOSIVE MIXTURES OF GAS, VAPOURS OR FOGS WITH ATMOSPHERIC AIR*, I display the technical requirements imposed to the electrical equipment used in potentially atmospheres regarding the materials employed and its construction as well as the general and specific rules and checking methods for the type of protection. I further analyse in detail the type of protection through explosion proof capsulation that represents one of the most widely known methods for providing the protection against explosion of cars, devices and electrical equipment to be used in potentially explosive environments.

The sizing checking calculations required with a view to certifying the enclosures are currently carried out through classical methods for sizing and checking the recipients with thin walls and rely on relations based on simplifying hypotheses and theoretical concepts belonging to materials resistance, which are complicated and display a low precision.

I propose and carry out in this chapter a simulation on a virtual model of an explosion proof enclosure with a cylindrical frame undergoing the action of a pressure determined by an explosion produced inside it; the model and the simulation are operated through SOLIDWORKS application.

The results obtained through the simulation of the model displayed show that von Misses tension displays decreased values in the area of the contact surfaces of the two component parts, which leads to the conclusion that the explosion inside the model analysed does not propagate towards the potentially explosives environment surrounding the enclosure.

The designing methodology proposed has the advantage that it enables the precise determination of the thickness of the capsulation walls, which might determine savings of metallic or non-metallic material.

CHAPTER 3, entitled *ANALYSIS OF THE EFFECTS OF ENVIRONMENT IONISATION INSIDE THE SWITCHING APPLIANCES UPON THE ELECTRICAL STABILITY OF THEIR INSULATION*, focuses upon the study of the influence of the parameters of atmospheric air, of the complex ionisation processes, of the energy changes that occur and of their influence upon the functioning of electrical equipment in environments with potentially explosive atmospheres. Relying on a theoretical analysis of the short-circuit current, I display a series of measures for preventing the occurrence of a short-circuit in switching appliances that affect the safety of explosion proof capsulation.

In CHAPTER 4, entitled *ELECTRICAL CONTACTS*, I present the theoretical and practical aspects of the various types of contacts that are used as part of the electrical equipment, in general, and of those used in potentially explosive environments, in particular. In accordance, in order to calculate the electrical resistance of stricture, I present two models, namely: the model of the infinite sphere of conductivity and the model of the flattened ellipsoid. I show, in the case of a punctiform contact and of a surface contact, the dependence between down force and electrical resistance.

In CHAPTER 5, called *THE WORKING REGIME OF ELECTRICAL CONTACTS*, I detail, based on a series of analytical models, the dependence between the absolute temperature of the contacts and their potential that defines the voltage drop between the contact elements. I pay special attention to the issue of the vibration of electrical contacts based on three calculation models that are specific for high switchgear, low voltage and strain sliding.

CHAPTER 6, entitled *MODELING AND SIMULATION OF THE WORKING REGIME OF ELECTRICAL CONTACTS USING NUMERICAL METHODS*, extends the analysis theoretically founded in the previous chapter regarding the dependence between the potential and the temperature of an electrical contact through using numerical methods by means of COMSOL application.

Relying on a virtual model of the electrical contact represented through SOLIDWORKS, I analysed by means of simulation the aspects regarding the dynamics of the solid as well as those aspects connected with the thermic transfer, with a view to pinpoint both the effect of contact pressure upon the features of the material contacts are made of and the Joule effect upon the features.

The results are graphically presented through screen shots made during the simulation and through dependence graphs of the parameters involved.

Let’s notice the advantage of the complementarity of using the two applications, SOLIDWORKS and COMSOL, in order to combine their advantages concerning the

precisions of the results, the easiness of geometrical modeling and the advantages of visualising the results, fields where the two applications, combined judiciously, determine the increase of the amount and relevance of results.

At the end of the doctoral thesis, I display a series of general conclusions, personal contributions and future lines of research.