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MODERNIZATION OF THE TEST METHOD FOR NON-SPARKING MATERIALS INTENDED FOR USE IN EXPLOSIVE AREAS

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Abstract

For assessing the intrinsic safety to mechanical sparks, two dedicated methods are implemented in testing laboratories and further used for the conformity assessment of products with regard to explosive atmospheres ignition, namely: impact test and friction test. The purpose of the article is to present the results obtained by using the first method mentioned, results which shall be applied in further research for comparison with the ones resulting from the friction test. The article presents the process for developing the research facilities used for testing activities in the field of non-electrical equipment intended to be applied in potentially explosive atmospheres. Also, the paper highlights important aspects on non-sparking tools used to carry out the specific maintenance works within technical installations located in hazardous Ex areas, in compliance with the European workplace safety and health principles and practices. Theoretical and practical studies, laboratory research, assessment methods and tests for determining the ignition hazard by mechanical sparks generated by non-electrical equipment are developed in order to improve the performance of the actual testing system for the assessment and testing of non-electrical equipment intended for use in atmospheres with explosion hazard. The development of the test method for non-sparking materials and the test setup ensures the optimal performance of the tests required for carrying out the conformity assessment process for equipment and non-sparking tools intended for use in potentially explosive atmospheres, taking into consideration the provisions of international regulations in force.

Key words: explosive atmospheres, explosion protection, ignition, materials, mechanical sparks, non-sparking

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1. Introduction

From statistics recorded in mining and other surface industries, reported in the scientific literature, a significant part of ignitions of explosive atmospheres is caused by sparks and hot surfaces generated from mechanical frictions (Cheremisinoff, 2014; Krasny et al., 2001; Nolan, 2011).

The sources of ignition are generally characterized by their energy nature. Due to the large use of electricity, it is known that the most likely ignition sources of explosive atmospheres are the electric sparks and hot surfaces generated by electrical equipment. This situation has led to the development of explosion-proof safety systems for electrical equipment, in order to ensure their safe operation in potentially explosive atmospheres (Li et al., 2011; Pasculescu et al., 2019). Mechanical equipment used in underground mining or in other industries with explosive atmosphere hazard, confirmed in many cases that explosions of the flammable atmosphere had been caused by sparks or overheated surfaces of mechanical nature.

The interaction between solid bodies can be either and impact or a friction. Research on mechanical sparks or on the overheating process revealed that the impact after tangential trajectories generates mechanical sparks, while the continued friction may generate heat able to result in overheated surfaces (Pasculescu et al., 2015, 2017). Mechanical sparks are metallic or other types of particles detached from one of the friction surfaces, particles which are

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incandescent either from the initial detachment phase or from the oxidation process in contact with atmospheric air (Blanc et al., 1947). Due to the fact that mechanical sparks represent the effective products of friction, they are also known in literature as friction particles. After detachment, the friction particles in their trajectory through the explosive mixture can be heated to the visible lighting temperature depending on the initial temperature, on the existence of the oxidant and also on other factors (Meyer et al., 2017; Rigby et al., 2018).

When equipment and components are used in hazardous Ex areas, various verifications have to be performed in order to see if there may be generated any ignition sources. If there is a possibility for ignition hazards to occur, measures to eliminate ignition sources from the hazardous area have to be taken. If this is not possible, additional protective measures must be implemented in order to ensure the proper safety level (Paraian et al., 2013).

Protective measures have to make ignition sources inoffensive or have to reduce the likelihood of ignition sources occurrence. This can be achieved by a suitable design and construction of equipment, protective systems and components, by operation procedures and also by using appropriate measurement and control systems.

The importance of protective measures depends on the likelihood of an explosive atmosphere to occur and on the consequences of a possible explosion. In this regard, classification of non-electrical equipment is performed by making a difference between various categories of equipment and by protection levels, as specified in Directive 2014/34/EU, transposed into the Romanian legislation by Government Decision 245/2016. These categories reflect the measures for different areas and conditions of hazard (EU Directive, 2014; Guidelines, 2017).

The correspondence between the levels of protection - groups of equipment and Ex classified zone is shown in Table 1 (EN ISO Standard, 2016).

An equipment-related ignition source is defined as any possible source of ignition generated by the equipment considered, regardless of its ignition capacity. These sources are sometimes named "relevant ignition sources", however, this term may lead to misinterpretations if the ignition source is relevant from the existence point of view or with regard to its' ignition capacity (Moldovan at al., 2017). All possible types of equipment-related sources are taken into account in the ignition risk assessment in order to determine whether they may be potential sources of ignition or not (EN ISO Standard, 2016).

The potential ignition source is the equipment-related ignition source which is able to ignite an explosive atmosphere (thus becoming effective). The likelihood of becoming effective determines the category of the equipment (ignition sources may occur in normal operation, during expected malfunctions or during rare malfunction).

An efficient ignition source is a potential ignition source that can ignite the explosive atmosphere if preventive or protective measures are not used. For example, friction heating that can be produced by a bearing is a possible ignition source. This is an ignition source related to the equipment if the equipment contains a bearing. If the energy that can be produced by friction in the bearing is able to ignite an explosive atmosphere, then it is a potential ignition source. If the potential ignition source is effective or not, depends on the likelihood of occurrence in a certain situation (i.e. after the loss of lubrication) (EN 1127-1, 2011; Lupu et al., 2012).

2. Hazard assessment generated by mechanical spark ignition sources of the equipment

As a result of friction, impact or abrasion processes, such as polishing, the particles can be separated from solids and become hot due to the energy generated in the separation process. If these particles consist of oxidized substances, for example iron or steel, they can be part of an oxidation process, thus reaching even higher temperatures (EN 1127-1, 2011). These sparks can ignite gas / air mixtures and certain dust / air mixtures (especially metal/air dust mixtures). In the dust layer, sparks can determine a slow burning, accompanied by smoke but with no flame and an ignition source for an explosive atmosphere can be generated (Jurca et al., 2014).

The entry of improper materials into the equipment, such as stones or metals, can generate mechanical sparks. An impact involving rust and light metals (such as Al and Mg) and their alloys may generate a thermal reaction that can ignite an explosive atmosphere.

Table 1. Correspondence between equipment protection levels (EPL) - groups of equipment and Ex classified zone

EN ISO 80079-36, (2016) EN 60079-0		*Directive 2014/34/EU (GD, 2016)*		*EN 60079-10-1, (2016) EN 60079-10-2, (2015)*
EPL	*Group*	*Group*	*Equipment category*	*Zone*
Ma	I	I	M1	Not applicable
Mb			M2	
Ga	II	II	1G	0
Gb			2G	1
Gc			3G	2
Da	III		1D	20
Db			2D	21
Dc			3D	22

Light metals, titanium and zirconium can also generate sparks at the impact or friction of materials, sparks that are strong enough, even in the absence of rust. In special situations, light metals can generate by shock or friction mechanical sparks able to ignite the explosive gas/air or dust/air mixtures. Light metal surfaces protected or not, should be checked for protection against the formation (production) of mechanical sparks able of ignition.

Mechanical sparks are metallic or other particles detached from one of the friction / impact surfaces that are incandescent either from the initial phase of decomposition or from the oxidation process in contact with atmospheric air. Both the impact and the friction of the solid bodies are characterized by the friction phenomenon, so that this process can be considered as the main factor generating mechanical sparks and overheated surfaces.

For assessing the intrinsic safety to mechanical sparks, two dedicated methods are implemented in testing laboratories and they are used for the conformity assessment of products with regard to explosive atmospheres ignition, namely:

- impact test for the technical equipment whose predictable faults may generate single-impact interactions between components, and
- friction test for the technical equipment whose predictable faults may generate mixed contact impact-friction interactions between components, for this case the interaction between elements generating mechanical sparks and hot surfaces.

Within the article the results obtained by using the impact test method are treated, results which shall be used in further research for comparison with the ones resulting from the friction test.

3. Test method for non-sparking materials

3.1. Principle of the method - testing the non-sparking materials at single impact in explosive mixture

Impact test is performed in laboratory conditions and is represented by simulations performed on special test setups (test stands), reproducing the process of mechanical sparks generation by single impacts. Ignition of explosive mixtures from mechanical sparks is a complex process influenced by physical-chemical parameters, mechanical parameters and by the nature of materials involved in mechanical interaction (Prodan et al., 2016). The theoretical study of the ignition is required to be continued with the experimental study which shall confirm, correct or even infirm the theoretical considerations and hypotheses, but especially to verify the technical solutions for explosion protection applicable to technical equipment and tools intended for use in potentially explosive atmosphere (Darie et al., 2017). Simulations are carried out on a special test stand used for generating the impact between test specimens and a plate, which is 35^0 tilted from the vertical.

The impact energy is calculated using Eq. (1):

$$E = m\ x\ g\ x\ h \quad [J] \qquad (1)$$

where m – is the mass of the falling weight [kg], g - gravitational acceleration [m / s^2] and h – is the height [m].

The shape of the falling weight is chosen according to the destination of the material used in the construction of the equipment or of the non-sparking tools. For the impact test, parameters "*m*" and "*h*" shall be determined by mutual agreement between the parties or the applicable regulations. In particular, the test stand shall consist of an explosion resistant chamber equipped with:

- gas induction assemblies;
- equipment for measuring the concentration of the explosive mixture inside the chamber;
- explosion pressure discharger (one wall of the chamber covered with a thin plastic film which does not resist the explosion pressure);
- a device composed of two drums, on which the metal wire is wrapped, which determines the drop height of the sample;
- a controlled ignition source (electrical spark) to confirm the existence of the explosive atmosphere and to ensure operator protection at the end of the tests. The stand used is shown in Fig. 1.

3.2. Modernization of the stand for laboratory tests

The theoretical and practical studies, as well the experimental laboratory research carried out within the research-development project coded PN 16 43 02 06, were mainly aimed at improving the performance of the current system of testing and assessments. The overall objective of the research project was achieved by upgrading the test stand and by improving the test method for non-sparking materials. In this regard, in the process of testing the non-sparking materials at single impact a digital system for determining the impact energy was included, the process of explosive mixture homogenization was optimized in order for the tests performed in the explosion chamber to be carried out for the most sensitive to ignition concentrations (Jurca, 2016).

The modernization and development of the research capacity of the laboratory included the following stages:

a) Connecting the test chamber to the explosive mixture installation. For modelling the ignition by mechanical sparks, the achievement and determination the concentrations which are ignited most easily, respectively the most susceptible to ignition mixtures, are of theoretical and practical interest. According to specific test requirements provided by the regulations in force, the explosive mixture is achieved according to the intended use of the material (STAS 10449-86, 1986):

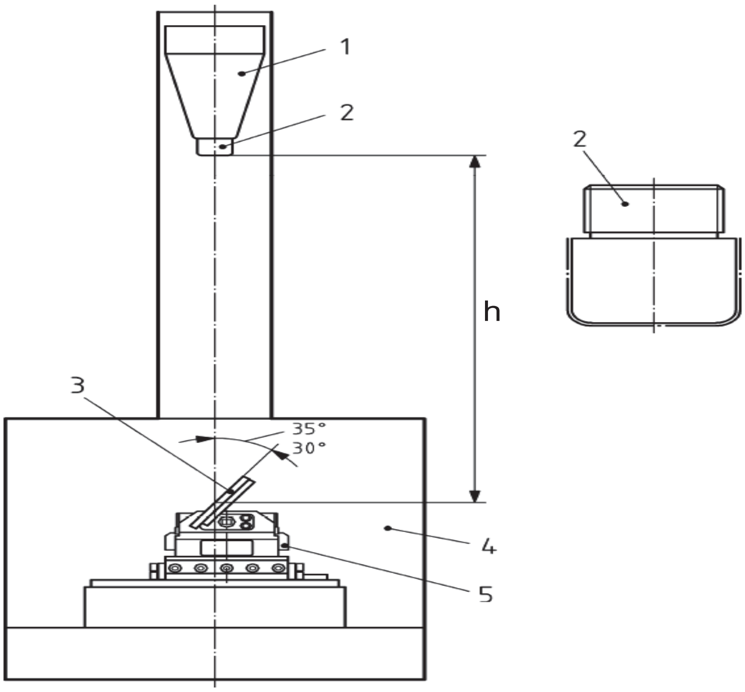

Fig. 1. Assembly for testing non-sparking materials at single impact in explosive mixture

Legend:
1 – weight/mass required to obtain the impact energy; 2 - test sample/specimen;
3 - rusty steel plate; 4 - test chamber;
5 - device for longitudinal / transverse movement and adjustment of the impact angle of the rusted steel plate;
h – drop height

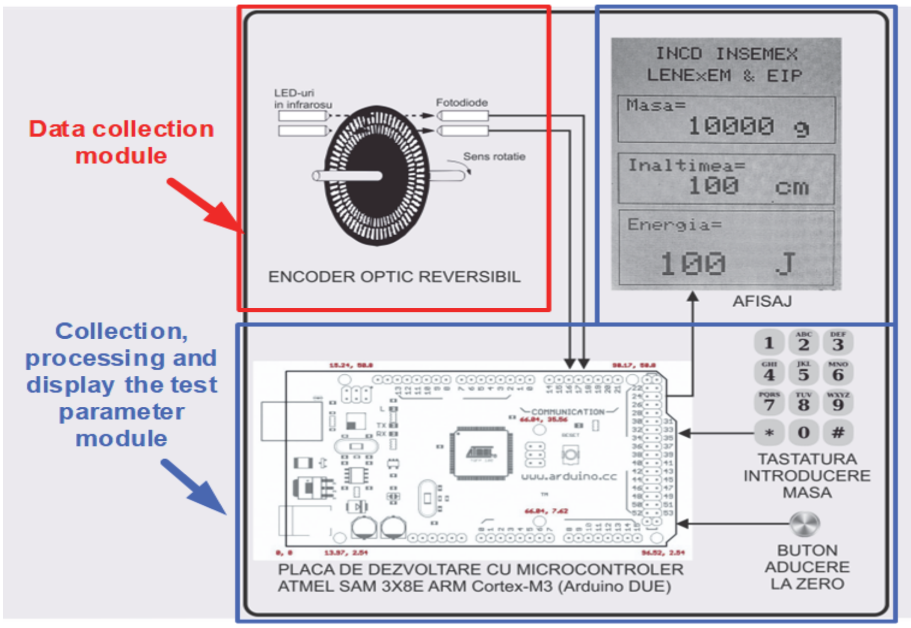

Fig. 2. Block diagram of the digital system for determining the drop height and calculate the impact energy

- the test of material for equipment/tools from group I and IIA uses an explosive mixture consisting of air with 6.5% CH_4;

- the test of material for equipment/tools from group IIB and IIC uses an explosive mixture consisting of air with 10% H_2;

- non-ignition tests are performed in explosive atmospheres with increased ignition sensitivity, consisting of the above mentioned explosive mixtures, but with additional oxygen up to 25-26%.

The crucial fact which can influence the test / assessment and acceptance process for non-sparking materials is represented by the manner in which the explosive mixture is achieved and on the accuracy of its concentration measurement.

b) Development of a digital system for determining the drop height and for calculating the impact energy.

For the impact test, the mass (m) and the drop height (h) test parameters shall be established by mutual agreement between parties involved in the conformity assessment process (between notified body and the applicant / manufacturer) or in accordance with the applicable references. The block diagram of the digital system for determining the drop height and for calculating the impact energy presented in Fig. 2 comprises two modules: the data collection module and the module for processing and displaying the test parameters. The digital system for determining the drop height and for calculating the impact energy resolved these requirements; the impact energy is an important parameter that can significantly influence the test / assessment and acceptance process for non-sparking materials (Jurca, 2016).

4. Conclusions

Physical instruments for analysing the capacity of mechanical spark generation by impact have been provided and implemented in order to upgrade and develop the research capacities of the testing laboratory.

The developed test stand has high precision in achieving the explosive mixture, in calculating the impact energy and it fulfils the requirements of EN ISO/CEI 17025:2005 (EN 17025, 2005).

The development of the testing method for non-sparking materials ensures the optimal performance of tests required for carrying out the conformity assessment process for equipment and non-sparking tools intended for use in potentially explosive atmospheres, taking into consideration the provisions of international regulations in force.

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