

ASPECTS REGARDING THE SURFACE TEMPERATURE FOR ELECTRIC MOTORS USED IN POTENTIALLY EXPLOSIVE ATMOSPHERE

Dragoș Fotău^{1*}, *Diana Sălășan*¹, *Dragoș Păsculescu*² and *Teodora Lazăr*²

¹National Research and Development Institute for Mining Safety and Explosion Protection – INSEMEX, G-ral Vasile Milea Street, no. 32-34, Postal code: 332047, Petrosani, Hunedoara County, Romania

²Univeristy of Petroșani, 20 University Street, Petroșani 332006, Hunedoara, Romania

Abstract. Most of the equipment operating in potentially explosive atmospheres in oil and gas industry is represented by electric motors, which in most situations act on various other elements (e.g. pumps, valves, fans etc.).

Evaluation of explosion-proof protected electrical equipment in scope of certification is extremely important considering the risk of explosion that has to be minimized in order to ensure life safety and health of workers and to prevent damaging of property and the environment, as well as free movement of goods when they meet the essential safety requirements at European level.

Even if electric motors for explosive atmospheres are designed and manufactured following some of the same principles as the ones used for other electric machinery, they have certain particularities related to their field of use. Thus, a series of specific restrictions and tests are required to be considered in their case.

A very important component on which the explosion protection depends is the surface temperature of the equipment. This is the highest temperature reached in operation under the most unfavorable conditions (but within the tolerances set), by any part or surface of the electrical equipment (in the case of gaseous explosive atmospheres which may occur in technical installations operating in oil and gas industry, this temperature may appear on an internal component or on the outer surface of the case, depending on the type of protection used).

To prevent an explosion it is very important that the tests performed on the equipment are done correctly and in the most unfavorable conditions. The purpose of this paper is to present the importance of performing tests to determine the surface temperature for electric motors designed to be used in explosive atmosphere generated by gases and vapors.

* Corresponding author: dragos.fotau@insemex.ro

1 Introduction

Using electric equipment in potentially explosive atmospheres brings forward several particularities therefore the problems that appear during the design, construction and operation of electrical devices and installations brings forward numerous difficulties, their approach requiring special attention considering all the technical, economical and labor safety aspects. Due to this fact, it is very important that the equipment is properly tested during the certification process. The purpose of this paper is to identify improvements that can be made to the test stands to determine the surface temperature of the electric motors that are used in potentially explosive atmosphere.

Evaluation of explosion-proof protected electrical equipment in scope of certification is extremely important considering the risk of explosion that has to be minimized in order to ensure life safety and health of workers and to prevent damaging of property and the environment, as well as free movement of goods when they meet the essential safety requirements at European level [1] [6].

The evaluation of explosion-protected electrical equipment is carried out by means of tests and verifications performed on the basis of the reference standards (IEC 60079-0 - which includes the general requirements for all explosion-protected electrical equipment and the standards specific to the types of protection involved in the manufacture of the equipment). In the case of flameproof enclosure type of protection, the specific standard is IEC 60079-1, and for equipment with increased safety protection type, the specific standard is IEC 60079-7 [2], [3], [4].

This paper presents the importance of the test for determination of the maximum surface temperature applicable to electric motors with flameproof protection type and increased safety protection type.

2 Determination of surface temperature test for electric motors used in potentially explosive atmosphere

One of the most important components on which the explosion protection depends is the surface temperature of the equipment. This is the highest temperature reached in operation under the most unfavorable conditions (but within the tolerances set), by any part or surface of the electrical equipment (in the case of gaseous explosive atmospheres, this temperature may appear on an internal component or on the outer surface of the case). [2]

In the case of electrical equipment that can normally be used in different positions, the temperature must be determined for each position.

Measuring devices (thermometers, thermocouples) and connecting cables must be chosen and arranged so as not to significantly affect the thermal behavior of the electrical equipment. The final temperature is considered to be reached when the temperature rise gradient does not exceed 2 K / h. [2]

In addition to determining the maximum surface temperature of the equipment, it is necessary to determine the service temperature. Testing for service temperature and maximum surface temperature are part of the technical tests to which electrical equipment intended to be used in potentially explosive atmospheres is subjected. [2]

The test to determine the service temperature must be carried out at the rated voltage of the electrical equipment, but without taking into account the faults. The temperature must be determined at the hottest point for all enclosures or the non - metallic parts of the enclosure on which the type of protection depends. If the input voltage does not directly affect the temperature rise of the equipment or the temperature of the Ex component, such as a terminal box or a switch, the test current must be 100% of the rated current. [2], [5]

The test to determine the maximum surface temperature must be carried out at the most unfavorable values of the nominal parameters, with an input voltage between 90% and 110% of the nominal voltage of the electrical equipment that determines the maximum surface temperature. [4], [10]

For electrical machines, the maximum surface temperature may alternatively be determined at the most unfavourable test voltage in "Zone A" according to CEI 60034-1. In this case, the equipment must be marked with the symbol "X" and the specific conditions of use must include the information that the surface temperature determination was based on "Zone A" (CEI 60034-1) operation, generally $\pm 5\%$ of the nominal voltage. For electric machines driven by a converter, the variation of the test voltage for determining the maximum surface temperature must be applied to the motor-converter system, taken as a whole, that is applied to the input of the converter and not to the input of the motor. [4], [9]

Small asynchronous machines with a rated output of less than 5 kW generally display the maximum surface temperature when operating at a voltage that is higher than the rated voltage, due to core losses and magnetization current, which increases rapidly as the magnetic core becomes saturated at higher applied voltage.

Asynchronous machines with a rated power between 5 kW and 20 kW are influenced by several factors that determine performance and it is not possible to predict the priority effect without having detailed knowledge of the specific concept.

Asynchronous machines with powers greater than 20 kW generally exhibit the maximum surface temperature when operating at a voltage that is less than the rated voltage due to the higher I^2R losses due to higher currents. In this case, these losses are generally higher than those that would result from core losses and magnetization current resulting from an applied voltage that is greater than the nominal voltage. [4], [5], [8]

For rotating electric machines powered by a frequency converter, the increase of the maximum surface temperature should be determined under the most unfavorable conditions using one of the test methods below [7]:

- Specific converter (the machine should be tested with the intended converter).
- Comparable converter (the machine can be tested using a comparable converter when there is sufficient information to evaluate the comparison). Additional security factors can be applied to take account of the degree of comparability.
- Sinusoidal power supply (in this case the torque of the machine should be proportional to the square of the engine speed, the engine should be loaded with maximum load at rated speed. Additional security factors can be applied to take account of the degree of comparability).
- Electric machines with the type of protection "d", "p" or "t" tested with sinusoidal voltage source (providing a direct thermal protection, normally within the stator winding, which has a sufficient limit to be able to detect and prevent excessive temperatures at the rotor bearings and bearing caps. The limit can be determined by test or calculation. The mandatory use of thermal protection is presented as a specific condition of use).

The rotor can become significantly warmer than the stator. The significance of the problem varies depending on the type of protection. Determination of rotor temperature is very important for motors using protection type "e", but it can also be important for motors using protection type "d" when the hot rotor leads to the transfer of those high temperatures to the bearings and to the outside of the shaft. [3], [4].

3 Testing facilities

At present INCD-INSEMEX has a test stand for rotating electric machines (for powers up to 50 kW), but which does not allow the tests to be performed under the conditions described by the applicable standards. The important parameters of the electric motor

cannot be monitored when performing the test to determine the maximum surface temperature.

Figures 1 and 2 show some of the equipment that can be used to determine the surface temperature, such as: laptop, infrared thermometer, data acquisition board with thermocouples and high voltage source.



Fig. 1. Test stand for determining the maximum surface temperature of electric motors



Fig. 2. Power supply AMETEK model MX45-3PI-400

For this reason, it is necessary to modernize the test stand for electric motors by using high-performance equipment to ensure the necessary test conditions, as well as the possibility to monitor the important parameters when performing the tests. In this regard, a research project will modernize the test stand (to meet the requirements of specific Ex standards) by using high-performance equipment and components to create the possibility of testing electric motors powered by the grid or by means of frequency converters, having a rated power of up to 30 kW, with a rated voltage of up to 400 V.

4 Conclusions

Because many electric motors are used in technical installations that operate in potentially explosive atmosphere, it is very important that they are built and maintained properly, in order to prevent an explosion.

A very important component on which explosion protection depends is represented by the maximum surface temperature of the equipment. This represents the highest temperature reached during operation under the most unfavorable conditions (but within the established tolerances) by any part or surface of the electrical equipment (in the case of explosive gas atmospheres, this temperature may occur on an internal component or on the outer surface of the casing, depending on the type of protection used).

It is necessary, in addition to determining the maximum surface temperature of the equipment, to determine the service temperature. Tests to determine the service temperature and to determine the maximum surface temperature are part of the thermal tests to which equipment intended for use in potentially explosive atmospheres is subjected.

To be able to perform the test to determine the surface temperature for electric motors designed to be used in explosive atmosphere correctly, we decided that we need some new equipment in our laboratory:

- Precision data acquisition system for temperature measurement - with isolated channels at a minimum of 400V and accessories (thermocouples, software, etc.). To these is added an apparatus necessary for making (gluing) thermocouples in order to benefit from thermocouples to the desired size;

- Milli-ohm meter / micro-ohm meter with overvoltage protection and PC connectivity (USB) for measuring the temperature rise in windings (it will measure the winding resistance before the test and immediately after it - when the supply voltage is stopped);

- Couplings, for connecting the motor to be tested to the drive unit (load - brake).

- High-performance thermal imaging camera for heating analysis and setting measurement points for thermocouple placement.

According to the requirements in force, in the process of certification of Ex equipment electric motors must be tested in order to verify if the explosion protection characteristics are maintained at their level. In this paper was revealed the test to determine the maximum surface temperature.

To protect people who work in explosive environments, it is important that equipment operating in such areas to comply with the requirements in force, and be properly maintained.

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