ANALYSIS OF FAULTS IN EXPLOSION PROOF ELECTRIC DRIVES AND CONCERNS FOR MODERNIZING THE MAINTENANCE AND REPAIRS OF MOTORS OPERATING IN EXPLOSIVE ATMOSPHERES

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ABSTRACT: *The purpose of the paper is to perform a thorough analysis of the types of breakdowns, which are likely to occur in the case of Ex-proof electric motors. Several solutions are identified, in order to enhance the reliability in exploitation and the maintenance of electrical drives consisting of Ex proof electric motors commonly used in the oil and gas industry. These solutions can be used both by explosion proof motor manufacturers and the end users of this equipment in oil and gas applications, in order to enhance the safety against explosion hazard.*

KEY WORDS: *electric motor, explosion proof, maintenance, reliability*

1. INTRODUCTION

Presently, the high cost of the electric drives made up of explosion proof electric motors, their higher and higher complexity and technicity, as well as the need of accomplishing an exceptional safety in operation require organizing, at a particularly high level, the operational surveillance of electric drives of machinery employed in atmospheres with explosion hazards, specific to the petrochemical industry, their maintenance and repairs in order to ensure production process continuity and cutting down the maintenance expenses [2].

As far as electric motors working in a hazardous location, are concerned, there are two aspects which need to be considered:

a) the correct functioning of the motor from its technical parameters point of view;
b) the correct functioning of the motor from the point of view of the safety parameters which are related to explosion protection.

For this reason, the flameproof electric motors maintenance and repair issue, aiming to increase reliability in operation, rise certain specific aspects, both regarding organizing this activity, to maintain the technical potential available to economic agents, and due to the requirement of keeping the explosion proof feature after repairs, in order to maintain safety concerning explosion hazard [1].

Figure 1 shows a section through a flame proof electric motor, specifying its components.

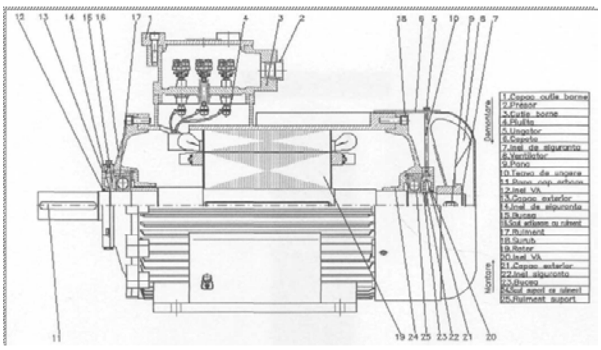

Fig. 1. – Components of a flameproof motor

2. INDUCTION MOTORS ENERGY LOSSES

There are five types of loses in an induction motor [4]:

- Core losses in the stator and rotor;
- Stator I^2R losses;
- Rotor I^2R losses;
- Friction and windage losses;
- Stray load losses.

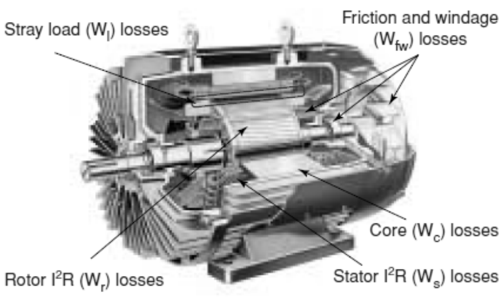

Fig. 2. – Losses in the various parts of a motor

The core, friction and winding losses do not significantly change with the motor load, provided the motor is operated from a fixed frequency. The I^2R and stray load losses increase significantly as load is increased.

Both core and I^2R losses (and particularly the rotor losses) may be higher when the motor is supplied from a variable frequency converter.

In many cases, losses can be decreased during the repair process when good practices are followed. Figure 3 illustrates how the losses vary in relation to load for a typical 4 – pole induction motor [4].

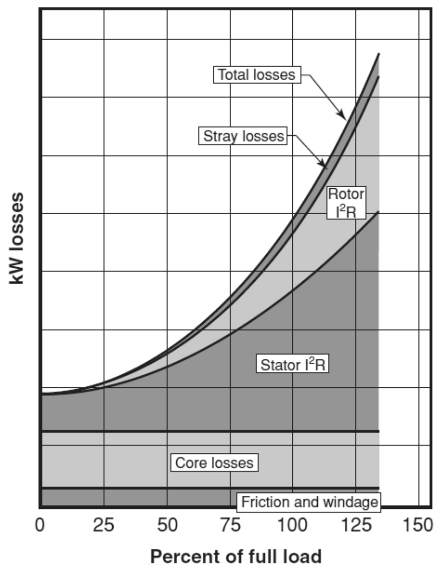

Fig. 3. – Typical components of induction motor loss plotted against load

3. FAULTS ANALYSIS IN EXPLOSION PROOF ELECTRIC MOTORS

3.1. Analysis of the causes that lead to breakdown in explosion proof motors

During its serviceable life, the electromechanical equipment may show numerous faults in the electric motors designed for its electric driving, due both to some constructional deficiencies and improper exploitation. These faults could be remedied in some cases by maintenance works whilst in other cases only by repairs performed after taking the equipment out of operation [3].

In order to determine the causes of the frequent breakdowns of electrical motors of technological equipment from different applications in potentially explosive atmospheres, it was carried out an analysis of the behaviour and of the working regime of these motors while working, the nature and the frequency of occurrence of faults that have been identified while carrying out the maintenance and overhaul of these motors at INSEMEX authorized repair organizations.

From analyzing the faults identified, it resulted that these can be systematized in two main categories: mechanical faults and electrical faults, some of them common for any motor and others specific only to certain types of motors. There are also cases where electric motors with faults, taken out for repairs, show simultaneously several mechanical or electrical failures or even mechanical and electrical combined faults.

3.2. Causes leading to mechanical faults in explosion protected electric motors

The main mechanical damages occurring in electric motors operating in petrochemical industry are the following:

- bearing block (jamming), for over 50-60% of the motors, a complex failure consequence of the following causes:

  - inadequate quality of bearings;
  - under-sized bearings compared to the real stresses;
  - inadequate mounting: faulty alignment between the motor shaft and bearings, resulting in vibrations (noise) or shaft clattering in the bearing base, and in some cases even small shifting of the motor in any direction if the clamping bolts were not properly screwed in.
  - degradation or premature loss of grease before the technical revision, and in some cases employing an improper grease.

The residual bending of shafts (deformation), most of the times having values that cannot be visually ascertained but high enough to cancel the flameproof joints gaps, occurs due to the following:

- local overheating in all states, inducing bearing jamming (previously mentioned faults);
- mechanical overloading, over the allowable limits for transportation, mounting or during operation;
- dismantling operation following a motor or coupling failure, when forcing the coupling

or the fan blades out of the shaft, if they had a too high fastening when assembled.

3.3. Causes that lead to electric faults in motors used in potentially explosive atmospheres

The faults occurring in the electromagnetic system of explosion protected electric motors are mainly the following:

♦ winding deterioration (total or partial), representing a 20-30% of the total faults, due to repeated or long overloads, not disconnected in due time. Besides mechanical failures that can induce these faults, listed in the previous subchapter, the following situations, generating faults, may occur [4]:

- overloading of work mechanisms of the machinery driven by the motor;
- re-winding with electro-insulating materials having an inferior insulation class compared to the one in the original working documentation;
- worsening of cooling conditions, due to multiple causes as: cooling fan airscrew faults, and motor rotation speed lowering due to supply voltage and frequency drop down;
- lack of proper thermal protection of the motor (in the feeding switch or directly on the windings) or its incorrect adjusting (due to frequent start-stop operating or different thermal constants of the thermal relays);
- lack of protection "at tilting" (short-circuit of motors in cases where the operating regime does not allow a correct adjustment of the thermal relays);

♦ short-circuit in the coils, between the phases or between the phases and mass (magnetic circuit laminations or various elements of the electric motors enclosures) are faults occurring more frequently in windings than overloads. The causes are:

- improper quality of the winding conductor (manufacture faults);
- water ingress (resulted from the condense accumulated on windings and on the metallic parts of the electric machine, coming from the outer atmosphere having a high humidity) on the shaft (or on the gaps) in the areas with a weak impregnation;
- the insulation resistance drop down, between phases or towards the mass;
- accidental overloads, overheating the insulation and hence breaking down.

Following repairs, respectively dealing with the faults found out, the motors are brought at the initial state, fulfilling the operating conditions at the initial parameters of safety and protection for explosion hazards environments.

4. CONCERNS FOR MODERNIZING THE MAINTENANCE AND REPAIRS OF MOTORS OPERATING IN EXPLOSIVE ATMOSPHERES

Within operators in petrochemical industry there are serious concerns for improving the maintenance and repair activity of equipment [2], [3]. This is materialized by approaching a new concept in this field, which is the one of "operational maintenance".

The theoretical and practical substantiation of the need of this concept is given by the following aspects:

- the operational maintenance of technological equipment represents a component of the production function, having independent tasks and responsibilities;
- the need of a concordance between the product manufacture technology and the maintenance of equipment and machinery corresponding to a technology, economic efficiency of the maintenance and repair works, correlated with the real productivity of each machinery, as well as with the product quality;
- carrying out a model making use of the experience and ability of specialists in industrial companies, designing institutes and so on.

The model of operational maintenance takes into consideration the technological equipment maintenance as function integrated within the production activity of the company. Thus, accomplishing the tasks of a production unit, under certain quality, expenses, and deadlines conditions, implies analyzing the following factors:

1.Professional training of personnel, both of the ones exploiting the equipment and the ones ensuring its maintenance and repairs, strictly correlated with the professional competency (C_p), due to the following requirements:

- knowledge of the activity specifics, the established norms and solving all the operating problems for the equipment exploited or maintained, all these being part of the elements characterizing the personnel (P);
- ability regarding the task fulfilling correctiveness, and aptitudes of comprising the whole set of obligations comprised in the personnel ability (A_p);
- abilities regarding technical and economical responsibility of personnel (A_t).

Thus, the functional model of the professional training degree may be represented in the following way:

$C_p = f(P, A_p, A_t)$ (1)

2. The technology used, respectively the technological analysis has in view in particular two large groups:

- the product manufacturing technology;
- the maintenance and repair technology, appropriate to each technological equipment.

3. Production organizing, related to equipment maintenance and repair - this suppose conceiving, designing and applying methods and techniques ensuring fulfilling the fundamental goal of the operational maintenance.

4. Performing statistic tests related to the operational feature of technological equipment:

- using new techniques for equipment surveillance, as for example, vibration measurement, temperatures recording, greasing, cooling elements analysis etc.

5. Designing and carrying out the informational subsystem. This represents the synthesis instrument, offering the possibility of tracking the development of main activities and assesses the risk level for the case, and based upon this, making the decisions ensuring a maximum of efficiency. This sub-system must keep updated the board panel of the maintenance activity responsible - repairs in companies, as follows:

- grouping all significant information regarding development of the scheduled activities;
- shows in a systematized manner the information needed to perform economical-technical analyses;
- contains all information that give the phenomena through their evolution in time;
- provides all information required for decision making in the shown cases.

By adopting such a maintenance model, the following results may be obtained:

a) number of failures lowered at a minimum, which leads to a global efficiency increase, through the following:

- using a preventive maintenance system that ensures knowing the equipment wear out state, finding out the weak spots, prevention of states of uncertainty in exploitation and failures;
- increased quality of maintenance and repair works of equipment;
- optimal exploitation according to the instruction given by the equipment manufacturer.

b) Optimization of repair durations, as consequence of applying the methods based on operational research.

c) Ensuring spare parts in the needed amounts, with required reliability and deadlines. Further on, the paperwork proposes a model structuring the maintenance and repair system, of operational type, through the logic diagrams in figures 4 and 5.

Analyzing this, it can be mainly noticed that the model of operational maintenance comprises two sub-systems, as follows:

- the system of maintenance and repair activities, in figure 4, consisting in: preventive and corrective maintenance components; spare parts and failures; programming, preparing and tracking activities, performing specific works; goal fulfilling check-out; technical analysis of the way activities develop;
- the economic system, in figure 5, comprising: outline of maintenance expenses and fitting into the approved budget, failure expenses and identifying the high cost works, these being comprised in an overall economic analysis;

The two types of analyses: technical and economical ones, would lead to defining the optimal variant in regards of the repair and maintenance decision for each equipment.

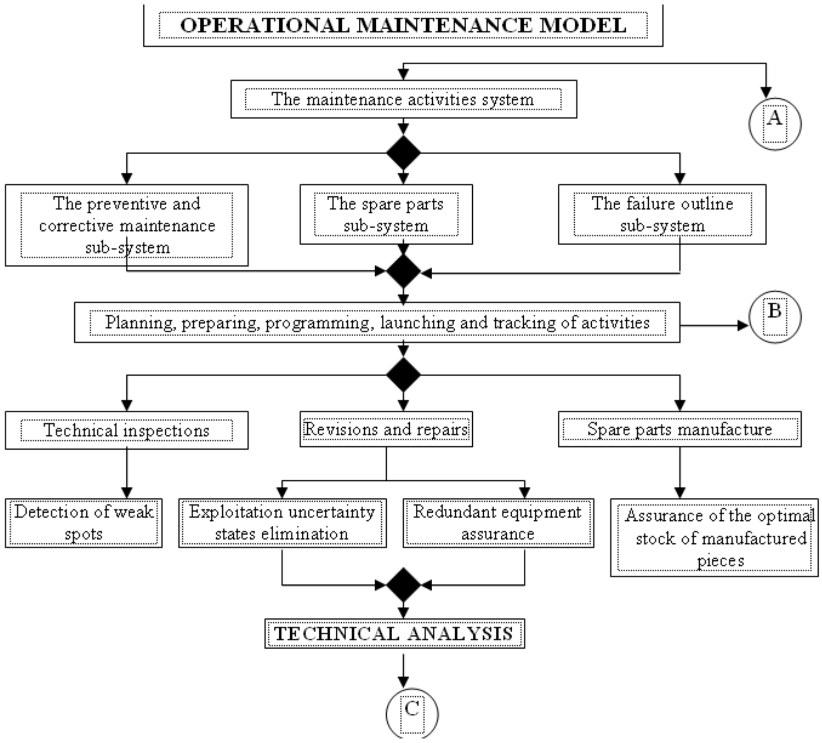

Fig. 4. – Logical diagram of the operational type of maintenance and repair system

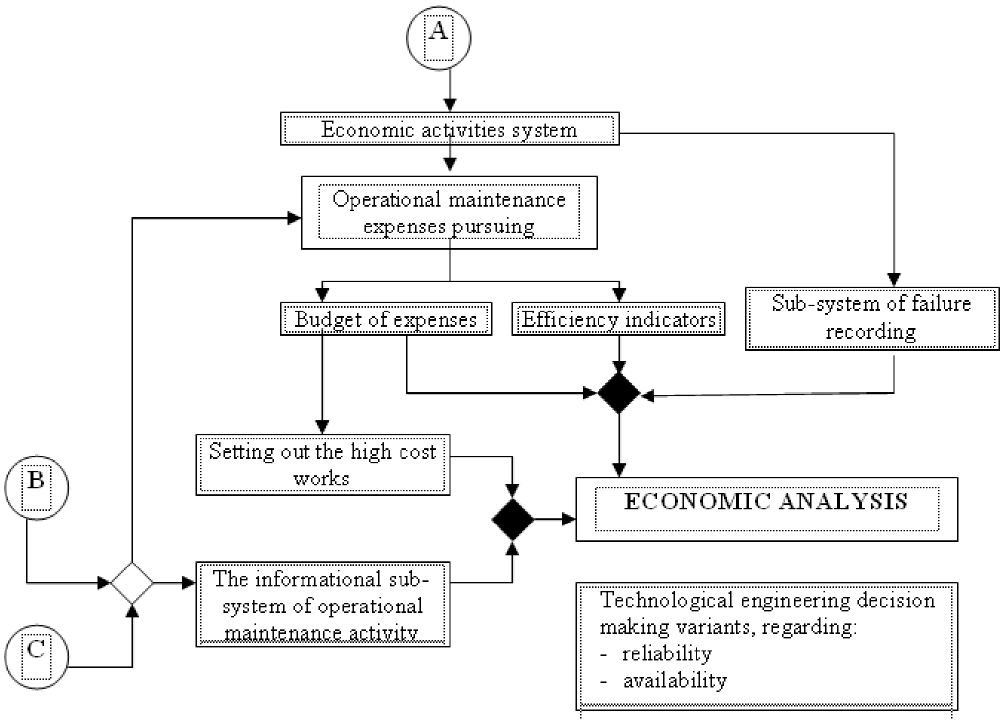

Fig. 5. – Logical diagram of the economic activity sub-system within the operational type of maintenance and repair model

5. CONCLUSIONS

The measures to improve the quality and lower the number of failures can be grouped:

1. Technical measures to improve quality and lower the number of failures for the conceiving-constructional stage of the electric motors, whose beneficiaries will be the manufacturers of explosion protected electric motors.

2. Technical and organizational measures, at users of explosion protected electric motors in order to lower the number of failures in the exploitation, maintenance, revisions and repair stages of the electric motors, whose beneficiaries will be the economic agents in the petrochemical industry.

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