

THEORETICAL STUDY ABOUT THE INFLUENCE OF PREDICTIVE MAINTENANCE ON PROCESS EQUIPMENT LIFETIME

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Abstract: This study shows the benefits of the modern methods application of the predictive maintenance in order to detect and diagnosis of rolling bearings wear. From the large amount of domains where predictive maintenance has been applied, there have been chosen to be case studied the equipment which have rolling bearings as components. Rolling bearings are predisposed to a premature wear because of the execution and mounting quality, of the very numerous cycles of operation, of loading conditions during the production operation, or of the improper lubrication, etc.. By applying modern wear detection methods of rolling bearings, the causes of producing it can be identified and all of them could be set aside in order to get an increasing lifetime of rolling bearings and of the process equipment.

Keywords: predictive maintenance, process equipment, rolling bearings, lifetime

1. INTRODUCTION

The activity of maintenance, through its entire complexity of concepts and actions, ought to assume more than what is currently understood by the activity of "maintenance and repair". The development of monitoring and diagnostic techniques of maintenance and their implementation on the process equipment, ensure the lifetime increase, their safety operation and performance, with positive effects on reliability and productivity. The lack of a maintenance program or an improper maintenance activity can lead to large-scale disasters, with negative consequences for humans and for environment [1].

As in other industrial fields, the types of maintenance, which are applied on the process equipment, are: reactive, corrective, preventive and predictive maintenance.

Reactive maintenance is characterized by two elements, namely: poor planning and incomplete repairing. It is taken action on the equipment, only when the defect appears, and the activity must be focused on the defect, without seeking the appearance of its cause [2].

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In the case of **corrective maintenance**, in contrast with the reactive one, the activity focuses on tasks which are planned at regular time intervals which makes to ensure the maintain of equipment in running order at optimal parameters [3]. The activity consists in locating and diagnosing defects and in acting to restore a proper functioning of the equipment [4].

Preventive maintenance emphasizes on "prevention" and not on failure "remove". The failures prevention, with some probability, allows to make known the phenomenon before operation and it nominates the components which are to be replaced [2].

Closely related to preventive maintenance it is defined the **predictive maintenance** - which, by continuously or periodically monitoring of particular manifesting ways of equipment's operating during the exploring process or of some working parameters, it may be predicted a preventive maintenance planning. Predictive maintenance uses specific instruments (wear, vibration and oil analyzers) by ensuring the fact that maintenance interventions might be executed before the appearance of the defect [5].

2. THE INFLUENCE OF PREDICTIVE MAINTENANCE ON THE LIFETIME OF PROCESS EQUIPMENT

The final objective of predictive maintenance is the execution of maintenance operations at the "opportune moment" before having the equipment to be deteriorated during a production operation [5].

Scheduled (preventive) maintenance requires regular interventions on equipment, many times without responding to an emergency. Maintenance program involves a large volume of work, being costly and ineffective in identifying problems that arise between scheduled overhauls. In the case of predictive maintenance, the checkouts are made during the equipment's functioning, minimizing current interruptions activities [1].

In conclusion, the predictive maintenance for the process equipment is a way of evaluation without having contact and without interrupting the technological process of mechanical and electrical equipment condition, using a periodic or continuous monitoring. The technical operating condition of an equipment might be evaluated basically by "symptoms" which are manifested during the operation: vibration, noise, increasing temperature, temperature and pressure variation in the cooling circuit, etc. [6].

Predictive maintenance can help in improving the availability of process equipment, in increasing their lifetime, in assuring the safety, the quality, the reduction of maintenance costs, etc.. This fact has led to an increasing number of applied predictive maintenance programs, but the creation of such a program takes a long time [6, 7, 8]. The diagnostic techniques and the necessary tools for a predictive maintenance program application are selected according to specific criteria. The use of these criteria has made decision-making much easier in planning predictive maintenance program and it has conduct to a development of prediction techniques [7, 9].

There has been always a concern about policy makers' factors in choosing the maintenance strategy. These factors must be based on types of process equipment of the plant, on manufacturer's recommendations, on the own experience or of other users of similar equipment [2, 10].

Many companies have applied several forms of preventive maintenance, but the scheduled inspections and the lubrication routes have reduced, within a certain measure, the possibility of catastrophic failures [11]. Lately, the implementation of predictive maintenance, which has been stand out in numerous scientific papers, has shown its advantages [12]:

- the reducing in number of breakdown which involve the production's interruption and high costs of maintenance;
- the checkouts within the predictive maintenance activity are able to considerably extend, the intervals between maintenance actions;
- the lifetime of the equipment may be extended by detecting and correcting problems, just by reminding some of them: positioning problems, imbalances, defects of bearings, hydraulic problems, problems concerning kinematic chains, lubrication problems, electrical failures.

Even if, within the first stage, the acquisition price of monitoring techniques and the investments of material and human capital are high, the amortization of costs would come quickly due to savings by avoiding of equipment's breakdown during the producing operations, and due to the decline in numbers of usage parts etc. [8, 9].

Various statistics were also conducted about the increasing use of predictive maintenance, of the used techniques and of obtained benefits (Table 1) [13].

Table 1. Evaluation of maintenance activity which is applied on the process equipment in chemical industry [13].

Maintenance strategies (%): - reactive maintenance: 7%; - corrective maintenance: 9%; - preventive maintenance: 29%; - predictive maintenance: 55%.	Techniques used: - Vibration and noise: 35%; - Infrared: 5%; - Lubricant analysis: 13%; - Detection by ultrasound: 5%; - Nondestructive Testing: 41%; - Others: 1%.
Savings obtained from the application predictive maintenance: - Increased lifetime of process equipment: 33%; - Increased productivity: 2%; - Reduction spare parts: 23%; - Reduction labor costs: 16%; - Reduction waste: 2%; - Other: 24%.	

During the last years, the companies which have developed new strategies of maintenance (preventive and predictive ones), have obtained an increasing productivity and economic efficiency (Figure 1). By implementing a predictive maintenance program, the profit grows having an increased production time, and the costs which are related to the breakdowns or to the stock of spare parts, of labor, or of energy consumption etc., are reduced [14].

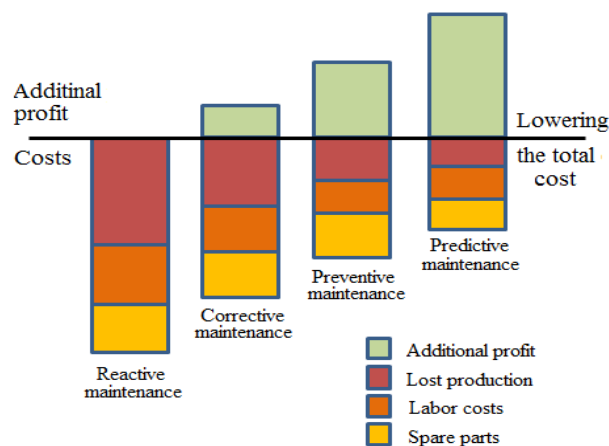


Fig. 1. Evaluation of profit increase and cost reduction based on the maintenance strategy [14].

3. THE INFLUENCE OF PREDICTIVE MAINTENANCE ON ROLLING BEARINGS LIFETIME

Dynamic equipment, in their vast majority, have rolling bearings in their components which are meant to support and to make the relative rotational motion of components as shaft and axles types, in a regard to them.

Many predictive maintenance programs use modern methods for rolling bearing monitoring during the exploring operation, in order to detect failures and to diagnose the equipment, but also to avoid the using removal of these. The most common causes which lead to the appearance of vibrations, noises and of rolling bearings' temperature increasing are: bearing misalignment, imbalance, time of use, improper design, montage etc. [15].

For example, by measuring vibration and noise and by tracking on time of their intensity values in different parts of the bearings equipment, it can be identified their usage condition, but it may be also given a prediction concerning its evolution in time of their technical condition [16, 17].

Thermography uses the thermal images of rolling bearings in order to compare temperatures during functioning operation, in this way detecting their potential failures [18].

Early detection of causes that lead to the rolling bearings' failure and to its consequences, by using a predictive maintenance program, gives a longer life of bearings and of equipment [16].

4. MODERN METHODS WHICH ARE APPLIED IN PREDICTIVE MAINTENANCE FOR ROLLING BEARINGS LIFETIME INCREASE

4.1. Vibration analysis

The information provided by vibration analysis are most useful because they indicate whether equipment operates safely. Vibration analysis has been pretty much used during recent decades, for dynamic diagnose of equipment which contains rolling bearings. Recent papers has shown that vibration monitoring technique provides us beneficial information in order to get a more effective predictive maintenance program and to have effective applications in industry [16, 19].

Some authors show the analysis of enveloping the vibration signal of the entire structure and a method of extracting rolling bearing's vibration, by using the autoregressive model (Figure 2). For this model' validation the authors have conducted an experimental test in which they have used two radial ball bearings, type 6205-2RSR [20].

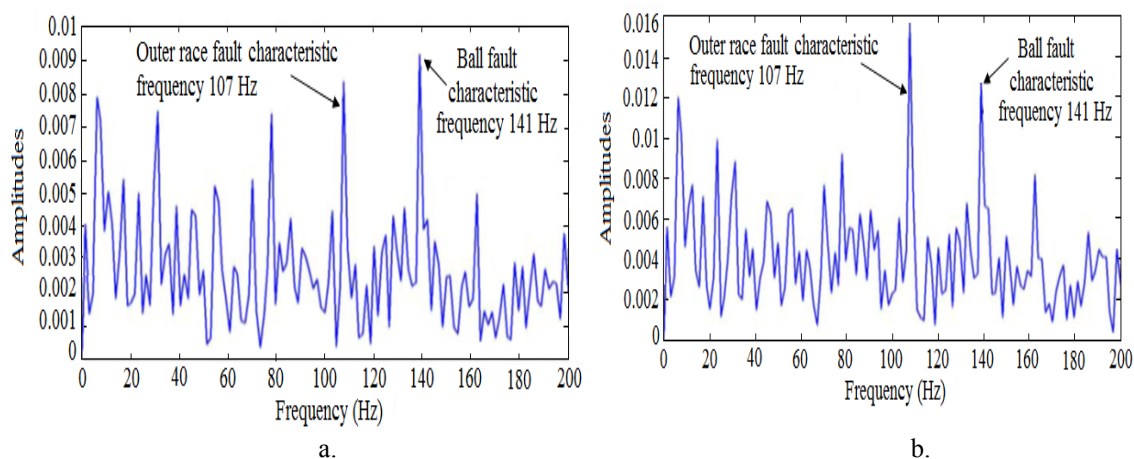


Fig. 2. The envelope spectrum of **a** channel 1 and **b** channel 2 at the end of the run-to-failure test [20].

Other authors have shown the detection - in an early stage - of existing defects in rolling bearings which operate at low speed by using the envelope analysis and/or PeakVue of vibrations [19].

Following the bibliographic research it has been found that the rolling bearing vibration analysis is the most used in a predictive maintenance program. By using vibration analysis, there can be earlier detected and identified all the rolling bearings defects, and their underlying causes, in this way leading to an increasing lifetime of rolling bearings and of equipment [17, 21].

4.2. Noise analysis

Rolling bearings are sources of noise due to the relative motion of component elements from their own construction: rings, rolling elements and the cage. The level noise is caused by the construction of rolling bearings (type, quality of execution), load, radial and axial clearance, presence of some defects on the component elements, methods of lubricating, protecting and sealing [22].

There has been much research on the application of acoustic emission analysis in defects diagnose of rolling bearing. Balerston H. L. [23], in 1969, was the first who introduced the acoustic emission technique for diagnosis of rolling bearings. Catlin J. B. [24], in 1983, and Mohrain. A. and Mba D [25], in 2003, discussed the propagation characteristics of acoustic emission in rolling bearings and they showed the success of monitoring the acoustic emission within those particular rolling bearings which had defects that had been found on the two raceways. Mba D. et al. [26] analyzed together, in 2006, the causes, the factors of influencing and the mechanisms which had generated the acoustic emission at rolling bearings.

Abdullah M. Al-Ghamd and Mba David [27] established, in 2006, the acoustic emissions relationship for the defect condition of the roller bearing, type 01B40MEX, and some failure conditions. Within his paper there were carried out two testing programs. A program was undertaken to establish the main sources of acoustic emission of bearing, but also to determine the relationship between defect size and acoustic sources intensity (Figures. 3, 4, 5 and 6). The second testing program was conducted to determine the relationship between acoustic emission intensity and defect size increasing.

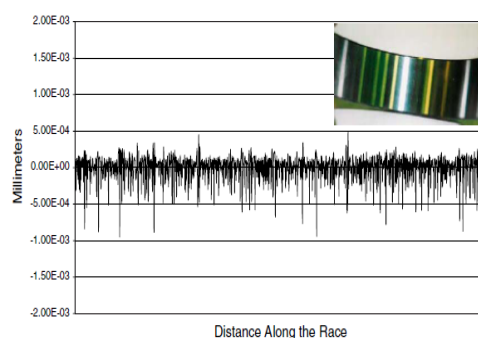


Fig. 3. Surface profile of defect-free condition [27].

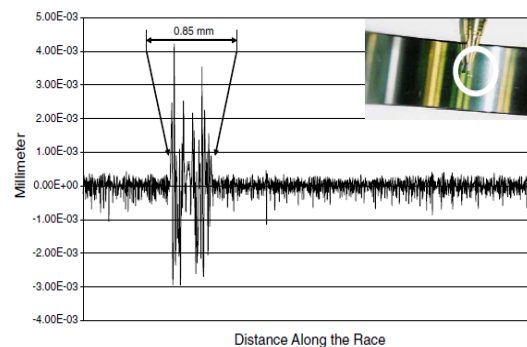


Fig. 4. Surface profile of point defect condition [27].

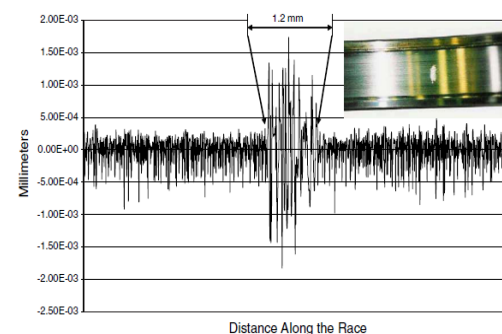


Fig. 5. Surface profile of a line defect condition [27].

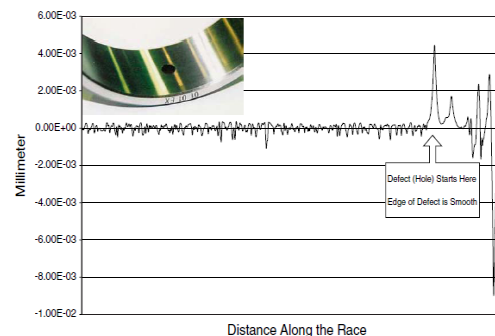


Fig. 6. Surface profile of a smooth defect condition [27].

4.3. Thermic analysis

Thermography (thermal analysis) is a predictive maintenance technique that can be used to monitor the condition of process equipment. Thermography is a method which is applied during operation without direct contact with the equipment, and by comparing thermal images of rolling bearings and of the housing, some possible defects can be detected and diagnosed [4].

In 2004, some authors [18] proposed to establish a link between temperature increasing and vibration increasing because of spalling defect. By using infrared thermography, it can be detected the existence of abnormal heat areas on the surface of bearing. Due to this study, the authors found a correlation between the mechanical (vibration analysis) and thermic (thermic analysis) effects (Figures. 7 and 8).

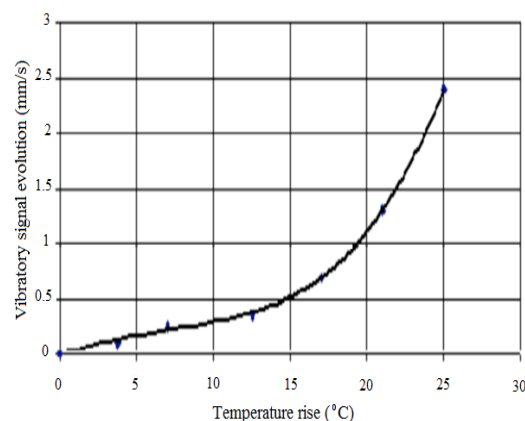


Fig. 7. Evolution of the temperature of the bearing cap according to the vibratory level (Mazioud A. et al, 2004) [18].

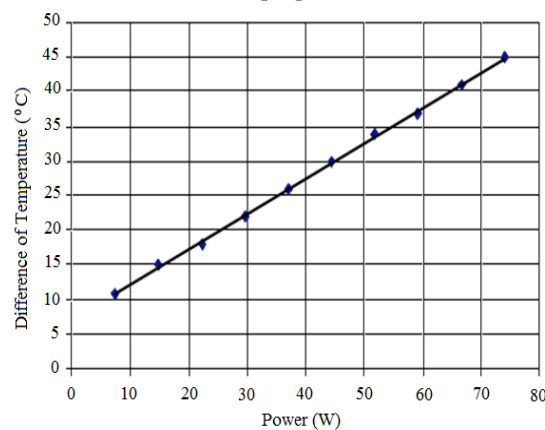


Fig. 8. Calculated evolution of temperature as a function of the power dissipated by the rolling bearing (Mazioud A. et al, 2004) [16].

Other authors [28] presented in 2011, an on-line method of measuring the components' temperature of an industrial blower with the help of thermographic analysis, in order to detect its components wear or other defects (Figure 9). They found that by precise monitoring of blower components' temperature and by early detection of this variation it can be predicted a remaining lifetime of components blower.

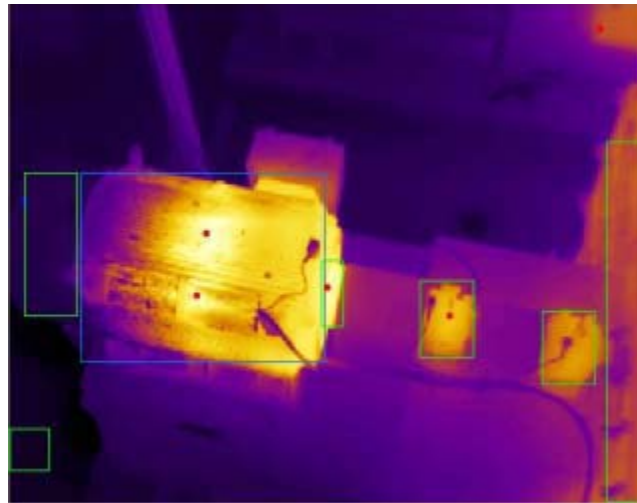


Fig. 9. A thermogram and the regions of interest in green and blue. From top left to right, ROI 2 (ROI - regions of interest), the fan cover; ROI 0, the motor; ROI 1, the drive bearing of the motor, ROI 3 the main bearing (coupling-side); ROI 4, the main bearing (blower-side); ROI 5, the blower; bottom left, ROI 6, the ground. The red spots are the position of local maxima, not used in this study [28].

5. CONCLUSIONS

By developing monitoring and diagnosis techniques within their maintenance and implementation on process equipment, there will be ensured an increasing lifetime, their safety and performance in operating, with positive effects on reliability and on productivity.

Starting with the considerations of a bibliographic study, it can be specified the fact that by predictive maintenance implementation the necessary data about ensuring maintenance activity can be provided. This implementation means to elaborate various methods of defects detection and diagnose which can determine the optimal timing of maintenance activity initiation and also avoid breakdown, finally leading to a reducing maintenance activity costs and to an accomplishment of production in predetermined quality terms.

Predictive maintenance has come to be applied to more than half of all maintenance strategies which have been applied to the process equipment. In the same way and time the predictive maintenance application ensures the best profit and the lowest costs compared to other types of maintenance.

Following the bibliographic research it has found that by using modern methods of predictive maintenance for rolling bearings monitoring during their operation, some defects could be identified, detected and diagnosed, so that to avoid the removal from use of bearings, but also of the entire equipment.

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