AN APPROACH FOR CREATING WEAR AND FAILURE MODELS SUPPORTING MAINTENANCE DECISION

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REZUMAT. Pentru a dezvolta cea mai bună politică de întreținere și a mări competitivitatea, producătorii ar trebui să ia în considerare avantajele sistemului Condition Based Maintenance (CBM). O parte din programele CBM sunt metode de prognostic care sprijină deciziile de întreținere. În această lucrare este prezentată o metodă de predicție a duratei de viață bazată pe modele de uzură și eșec. Sunt menționate și procedurile utilizate în prezent pentru gestionarea sarcinilor de întreținere și a ineficacității acestora. În final sunt date unele sugestii pentru îmbunătățirea situației actuale.

Cuvinte cheie: Condition Based Maintenance (CBM), modelul prognosticului, estimarea duratei de viață, model de uzură, model de eșec, lubrifiere uscată, contacte de rulare.

ABSTRACT. For the development of the best maintenance policy and the increase of the competitiveness, the manufacturers should take into consideration the advantages of the Condition Based Maintenance (CBM). A part of the CBM programs are prognostic methods which support maintenance decisions. In this paper, a prediction method of lifetime based on wear and failure models is represented. Additionally, the used current procedures for handling the maintenance tasks and its ineffectiveness are mentioned. Concluding, some suggestions are given for improving the actual situation.

Keywords: Condition Based Maintenance (CBM), prognostic model, lifetime estimation, wear model, failure model, dry lubrication, rolling contacts.

INTRODUCTION

In most of cases, the people/companies procuring equipment, which could be offered by different manufacturers in the same quality, choose the less expensive one. But if the equipment is used frequently you have to analyze the total cost of ownership. Carrying out a life-cycle cost, you can often ascertain that the equipment is not the costliest part throughout its life. The energy consumption and maintenance of the equipment can determine the main costs. Knowing the energy consumption, one can calculate the efficiency of the equipment. But the user can have difficulties in pre-estimating costs caused by maintenance. The manufacturers selling equipment should be able to provide the complete calculation regarding life-cycle costs. So the user can choose the producer with the most convenient life-cycle costs.

PROBLEM DEFINITION AND OBJECTIVE

The efficiency of the maintenance program is an important factor in enhancing the competitiveness of a manufacturer. Due to the different exploitation of the equipment by the users, it is a big challenge to design a maintenance program to meet the users' requirements efficiently.

Although advanced maintenance techniques have been available in the literature, there are still two common extremes in the current industry. One extreme is to always adopt a run-to-failure (breakdown) policy. The other extreme is to always apply an as-frequent-as-possible maintenance policy. Of course, the two conventional maintenance policies, namely the run-to-failure policy and the time-based preventive maintenance can be applied to some special cases with satisfactory results. However, in many situations, especially when both maintenance and failure are very costly, Condition Based Maintenance (CBM) is absolutely a better choice than the conventional ones [1].

Condition based maintenance (CBM) aims to achieve reliable and cost-effective operation of engineering systems. CBM is based on the understanding that a piece of equipment goes through multiple degraded states before failure. The health conditions can be monitored and predicted and optimal maintenance actions can be scheduled for preventing equipment breakdown and minimizing total operation costs [2]. CBM consists of three main steps: data acquisition, data processing and maintenance decision-making [1].

There are already a lot of works describing methods to handle the CBM steps. A further increase of the methods and research works in this area is to

be expected. The reason is that more and more companies begin to recognize the advantages of the CBM and are willing to invest in its development.

One of the objectives of CBM is the development of the prognostic methods making statements about the equipment condition. This paper represents an approach for lifetime estimation of the wear-exposed engineering systems, namely dry lubricated rolling contacts [3, 4]. Such approaches can support the maintenance decision-taking process.

METHODOLOGY

The lifetime estimation of a technical wear product can be carried out if the wear laws are known. There are two different ways to investigate wear laws [5):

- wear as a deterministic process;
- wear as a stochastic process.

A more justified and faster lifetime prediction of rolling dry lubricated contacts can be made if both approaches to wear study are combined. Thus, the developed prediction method is based on a mathematical wear model and a failure model which considers the stochastic wear phenomena.

To achieve a good result, a systematic treatment of the problem is carried out, which includes the following steps:

1) Elaboration of wear model;
2) Elaboration of failure model;
3) Working out a prediction method for lifetime estimation;
4) Wear analysis of dry lubricated rolling contacts.

Wear analysis and determination of influence factors. To develop a wear model, the tribological processes of the system should first be meticulously examined. A physical model of dry lubricated rolling contacts is worked out, which makes it possible to ascertain the influence factors on wear (Fig. 1).

This model allows for the consideration of all phenomena which occur during the friction and wear processes. It shows micro and macro-contacts of rubbing surfaces, heat exchange, volumetric and adhesion interacţion. If there is no physical model, researchers cannot examine the problem in detail. Thus, there is the risk of taking into consideration only one aspect which seems more important to researchers [6].

Wear model. Generally, the wear processes of dry lubricated rolling contacts can be described by the following formula:

$$\gamma = (v, \tau, p, \tau_R, s, F_A, \overline{HB}, \overline{E}, h, R_a, \overline{d}, \rho, z, \mu, \overline{T}, q, \lambda, \beta, c, \phi, A, p_{Atm}) \quad (1)$$

y is the examined factor. In this case, it is the volume of materials worn away which also defines the thickness of the remained coating. The factors on the right side of the formula (1) determine the wear amount. These factors usually result from the property of rubbing couple, lubricants, and operating conditions. To reduce the number of factors which determine the wear, a dimensional analysis is applied. In this way, non-dimensional criteria are generated, which have a physical explication. By applying the method of Drozdov [7] and Brown [6], which is based on a similar theory, a connection is established between the non-dimensional criteria. As a result, a mathematical model of wear is developed.

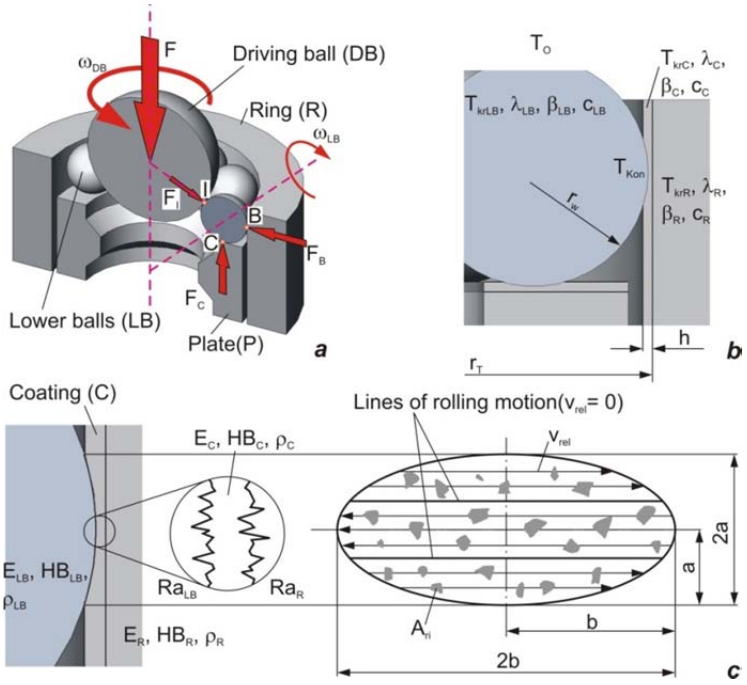

Fig. 1. Physical model of dry lubricated rolling contacts.

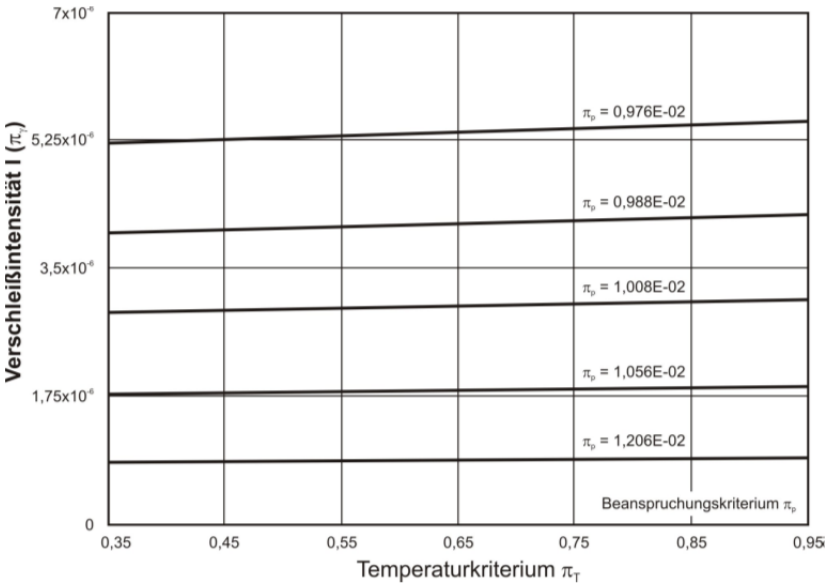

Fig. 2. Correlation between wear, load and temperature criteria.

Failure model. The friction and wear processes have a stochastic behavior [8]. The failure of the dry lubricated rolling contact is caused by continuous variation of the examined factor *y*, respectively the thickness of the coating. The failure model is built on mathematical statistical methods and includes stochastic factors like wear velocity, tolerance of coating and running-in. The application of the failure model allows one to determine the reliability of rubbing contacts and to estimate their lifetime.

Prediction Method. Finally, a prediction method is developed, based on wear and failure models. Prediction is based on the physics of failures when parametric failures are primarily considered. The calculation takes into account all the factors which determine the working capacity of dry lubricated rolling contacts, and as a result, reliability indexes can be calculated.

RESULTS

The approach contributes to reducing the influencing factors on wear and so the problem complexity is decreased. Hence, it was deduced that the dimensionless load and temperature criteria mainly describe the wear of the dry lubricated rolling contacts. The main result of this approach is a clear relation between the factors of influence and wear. The correlation between wear, load and temperature criteria is shown in Fig. **2**(4).

Working out the results, supporting maintenance decision could be taken.

PROSPECTS

This approach can be applied for other engineering systems besides dry lubricated rolling contacts which are present e.g. in the ball bearings. So a justified prognostic regarding life-time estimation of engineering systems becomes possible. The successful implementation of this approach depends on the quality of the realistic operating data received from users, its processing and the understanding of deteriorating mechanisms. This approach is a part of the Condition Based Maintenance (CBM) program, which aims at the optimization of the life cycle costs of engineering systems and increasing of the competitiveness.

Despite of the evident advantages of CBM, it is still not largely applied in the companies which manufacture engineering systems. Referring to Jardine et al., there are some reasons why CBM is not implemented on a large scale (1):

1) lack of data due to incorrect data collecting approach, or even no data collection and/or no data storage at all;

2) lack of efficient communication between theory developers and practitioners in the area of reliability and maintenance;

3) lack of efficient validation approaches;

4) difficulty of implementation due to frequent change of design, technologies, business policies and management executives.

In order to handle the above named issues and to develop the best maintenance policy at the company, an interdisciplinary team should be put together. It should incorporate experts with knowledge of the application field, as well as of the reliability and maintenance methods. Experts from research institution should also be involved. Advances in IT also allow a more effective implementation of CBM.

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