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Friction Units Durability Estimation Method Based on Friction Surfaces Limiting States Criteria System

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Abstract

This article presents the fundamentals of calculation modeling of a well-known tribological triad "interaction - damage - destruction of the friction surfaces" as exemplified with the plain bearings. In order to analyze the terms of interaction between the friction surface, the algorithms of finite element method are developed for the following tasks: fluid flow in the gap; contact interaction between the surfaces taking into account nonlinear properties of the "third body".
Furthermore, the article describes the durability estimation scheme, which accounts for the possibility of the simultaneous occurrence of several damaging processes: caused by the bulk fatigue and caused by the wear-contact damages of different nature. The technique is based on the spatial and temporal discretization of processes of damage accumulation (various types of damage) in the object with a non-uniform field of external actions. The levels of accumulated damage caused by fatigue and by different types of wear are evaluated in separate sections of the loaded volume. The probabilistic models of these processes of damage are used. Damage of groups of sites related by certain conditions of wear compatibility and such fatigue damage characteristics as the probability of small crack occurrence (first and any subsequent) or the probability of macro-crack occurrence (first and any subsequent) are estimated on the basis of simple formulas of probability theory. The article describes the basic principles of an approximate estimate of interference of various damage processes. Basic algorithms of general calculation methods are implemented and their working capacity is shown.

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Keywords: Friction units; interaction and damage of surfaces; wear by different mechanisms; fatigue damage from the volume of the stress field; mutual influence of fatigue and wear; plain bearing; implementation of algorithms.

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1. Introduction

Increase of friction units durability is an urgent task. One of the ways to solve this problem is the computational modeling of contact interaction and accumulation of damages on the friction surface. The availability of such calculation methods allow to evaluate the durability of friction units at the design stage and to reduce the time of their development in order to achieve the required durability parameters. Plain bearings (PB) are selected as an example of friction unit.

PB is one of the typical units of friction, which are subject to a complex of effects and damages. The pressure and other stress tensor components of PB are always unevenly distributed. Various modes of friction can be realized at the same time in different parts of the surface (liquid, boundary and even dry). Therefore different types of damage can be manifested. And these damages may occur separately in different parts of surfaces, but more often various damage processes influencing each other can occur simultaneously in certain areas. On the basis of author's own experience and classifications used by different companies, we have proposed a systematization of damages of PB elements [1,2].

Liquid-friction bearings may be damaged due to overheating, bulk fatigue, changes in pressures at small surface areas, chemical exposure of lubricants (corrosion and gum formation). Oil always contains solid particles that pass through the filters and can have erosive effect. If the particle sizes are larger than the minimum PB gap, there may be abrasive damages. Contact damage by any known mechanism of wear may occur in the bearings of dry friction depending on contacting conditions and material properties of the friction pair. Damage typical for PS of two mentioned types of friction may occur on different parts of the surface of bearings of mixed friction mode.

It should be noted that an important place among the wear mechanisms is occupied by such mechanisms, which are explained by fatigue processes in the material: fatigue wear, delamination wear, rotary wear and others. The manifestation of the mutual influence of bulk fatigue and wear is possible due to accelerated fatigue damage accumulation in the subsurface layers or the removal of the surface layers, which are the most damageable due to fatigue.

2. The general scheme for the calculation of plain bearings durability

Fairly common methodology of PB durability estimation with consideration of the fatigue and wear-contact damages and interference of all damaging factors [1,2] was previously proposed. The generalized model of damage accumulation and the destruction of the material by V.V. Bolotin [3], as well as numerical techniques of V.V. Grib [4] for the calculation of wear of surfaces are the theoretical basis of damage calculation. The following explanations are based on a schematic representation of the computing process (Fig.1).

The methodology is based on the spatial and temporal digitization of accumulation processes of the damage of various types. Different models of damage accumulation, which describe different types of wear and fatigue damage to the material, can be applied for separate discrete areas. Models and properties of materials are grouped into the corresponding library databases, and a user can select options for the implementation of the individual steps of the computing process in accordance with various models of real processes. Calculations are cyclic and performed over time after start.

The first stage includes parameter definition of the impact on details of the bearing assembly using a variety of analytical, experimental or numerical methods. According to our assumptions, the most promising is the use of modern numerical methods such as finite element method (FEM).

The second stage includes a series of preparatory operations. It determines possibility of occurrence of certain types of wear-contact damages or fatigue damages using any criterion of their manifestation. In addition, the wear limit criteria are determined for each of the types of simulated wear. Our works [1,2] include the systematization of used limit wear criteria and criteria for fatigue damage of the sliding layer.

The schemes of connections between the areas are analyzed in accordance with the classification of the kinematic conditions of wear in areas [2-5]. Kinematic interconnections of sites are postulated in order to calculate the probability characteristics of the occurrence of various macro-manifestations of wear of these groups of areas.

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