The dynamic behavior of sliding tribosystems in unstable operating conditions

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Abstract. The paper addresses the issue of the influence that the law of friction has on the dynamic behavior of the mechanical system that interacts with a tribosystem. The emergence of certain nonlinearities of higher order into the law of friction leads to an intensification of the dissipative process and to tribosystem destabilization. Consequently, friction excited self-oscillations are generated into the elements of the mechanical system with a wide spectrum of frequencies, sustained from the external source of energy. The theoretical and experimental modelling of the dissipative process and of the generation of is based on the frictional harmonic oscillator that interacts with the tribosystem. The oscillator is used as a sensitive element to the fluctuations of the frictional force and as a measure of the dissipated energy. Starting from the model, the elaboration of a method and of devices for experimental research provided the opportunity to study the behavior of the tribosystem in unstable operating

1. Introduction

As functional components of mechanical systems, tribosystems collaterally affect the former's dynamic behavior and have a predominant role in energy dissipation. The evolution character of the dissipative process is influenced and correlatively connected with the friction characteristic (law) occuring at the relative motion of contact surfaces. At present, a series of different laws have been formulated only for dry friction: simple-static; complicated-dynamic. Considering also lubrication (with Stribeck effect), the series of the friction laws diversify [2,5,8]. In fact, the laws of friction are complex and include the influence of a series of factors of a different nature related to working, geometric and micro geometric, to tribosystem structure, to the source, properties, and characteristics of the materials for triboelements, and to the working environment.

When nonlinearities of different orders occur into the friction characteristic (with fluctuations in the frictional force), in the mechanical system elements are generated noises under the form of self-oscillations with a wide spectrum of frequencies [2, 5, 8]. The structure of the spectrum, the amplitude and shape of the oscillations are influenced by charging parameters, the friction regime and energy dissipation factors, the properties and state of the materials for triboelements and the lubricant, the origin and intensity of processes arising in the contact area. For problems of such complexity a reliable research method remains the experimental one. However, experimental modelling should be formalized and executed within the framework of the fundamental equations of nonlinear dynamics.

2. Dynamic modelling of mechanical system-tribosystem interaction

A model commonly used to describe and study the oscillatory processes in different systems is the harmonic oscillator. The oscillator is the basis of both mathematical models and necessary technical devices for tests and the experimental research of the studied systems.
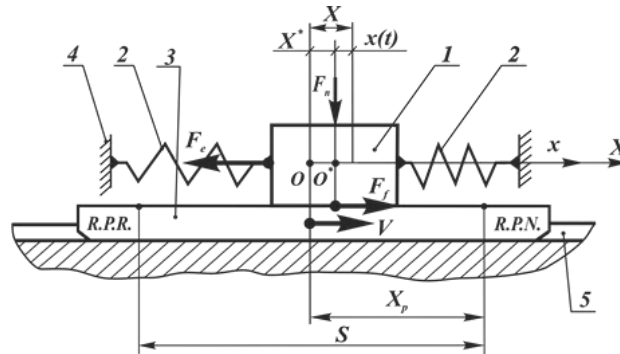

Figure1. Mechanical oscillator scheme.

The oscillator has been accepted as a model for studying the interaction between the tribosystem characteristics and the mechanical system (figure 1). It consists of block 1 with mass $\boldsymbol{m}$ linkconnected to housing 4, fixed on both sides by means of two similar elastic elements 2, of low rigidity $\boldsymbol{c}$. The angular frequency of the oscillator is $\omega = \sqrt{c/m}$). The tribological connection between the oscillator and the triboelements is realized through the contact between block 1 and platform 3. Platform 3, driven by a crank-type mechanism, performs a translational reciprocating movement on guide 5 within distances $\boldsymbol{S}$, with speed:

$$V = r\Omega\left(sin\varphi_m + \frac{\lambda}{2}(1 - sin2\varphi_m)\right) \tag{1}$$

where: Ω - the angular speed of the crank, r - the radius of the crank; l - the length of the rod; $\lambda = \frac{r}{l}$; φ_m - the rotation angle of the crank.

Initially, the X coordinate's origin of the gravity center of block 1 is in the stable equilibrium point O. When the platform begins to move with speed V on distance S distance, block 1, influenced by the friction force F_f, will move in direction X with speed $\dot{X}$. The relative speed between the contact surfaces of the friction bond becomes $v_r = \dot{X} - V$.

Connecting the oscillator to the tribosystem results in a system composed of two subsystems of different nature (mechanical and dissipative) with own dynamic behavior, influencing each other during working. The evolution of the dissipative process (of energetical essence) can be studied only from the perspective of Lagrangean formalism, according to which the generalized dissipative force Q_d derives from a force function called Rayleigh dissipative function [6, 7], defined by the relationship:

$$\Phi_d = \sum_{j=1}^{N} k_j \int_0^{v_j} f_j(u)du \tag{2}$$

where: k_j and $f_j(u)$ – the positive functions defined on spaces j of the contact real elementary areas that are dependent on the $q = X$ coordinate and on the generalized speed $\dot{q} = \dot{X}$ of the oscillator, on speed V of the platform, and on the internal and external parameters of the tribosystem; v_j – the relative local speed of the surfaces on the contact real elementary areas of the spaces; N – the number of real elementary areas within the boundaries of the contact nominal area.