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Influence of a relatively high frequency structure vibrations on the dynamics of real stick-slip motion

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Abstract: The work concerns the research on the impact of structure vibrations on the dynamics of frictional contact of bodies moving in relation to each other and remaining in frictional contact, causing a stick-slip motion. A literature review was carried out, describing mainly the phenomena concerning friction, but also the dynamics of vibrations and non-ideal energy sources that induce system oscillations. In the next step an experimental station for investigation of friction equipped with a new subsystem inducing high-frequency vibrations is presented to propose a modified physical model of the investigated frictional system. After analysing the most important factors influencing the behavior of the tested system, a mathematical description was prepared, which in theory showed the potential influence of the attached subsystem on the dynamics of the movement of the tested object - the frictional connection. Various methods of implementing the unbalance of rotors, being the source of high-frequency excitation, have been considered. At the final stage, a series of measurements of the displacement of the vibrating block on the moving belt was performed with the high-frequency excitation turned on and off. The prepared graphs were used to analyse the dynamics of frictional contact and the impact of non-autonomous vibrations on the occurrence of the stick-slip phenomenon.

Keywords: stick-slip, measurements, mechanical vibrations, experimental station

1. Introduction

Until today, scientists are designing new measurement systems to explore the stick-slip phenomenon, where technological advances in the sensors and measurement recording methods used are of great importance. New solutions allow for simulations of mechanical systems that are more and more close to reality, which translates into more complex research and obtaining more reliable conclusions. In the case of devices with dry friction, causing the stick-slip (creep-slip) movement of the active elements of the machine, vibrations of the structure can also be observed most often. Such oscillations affect the frictional contact, so they must also condition the stick-slip phenomenon. The discussed problem of vibrations caused by dry friction appears, among others, in brake systems [1,2]. The test stand used was created on the basis of the actual brake mechanism. In this work, a physical model and a mathematical description of the test system were prepared, taking into account the action of relatively high-frequency vibrations. The system introduces a high-frequency vibration inductor (simulating the excitation from cooperating machine elements). The constructed mechatronic system, simulating operating conditions in a drum brake, used in this work, was originally described in the publication [1] and continued in [2], see Figure 1.

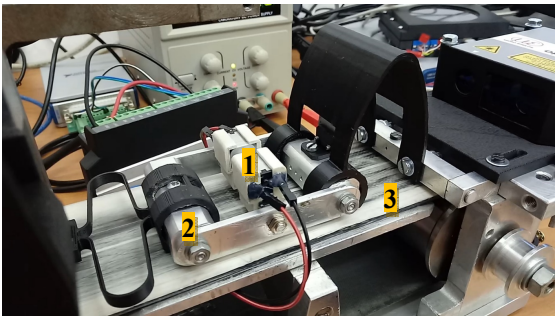

Fig. 1. The experimental station for investigation of self-excited frictional vibrations where two high frequency inductors (1) are mounted on a block mass (2) sliding on the moving belt (3)

2. Results and Discussion

The initial mathematical model of the problem is given by the following equations of motion:

$$\begin{aligned} M\ddot{x} + Kx - F_t &= F_x(t), \\ M\ddot{y} + k_b y &= F_y(t), \end{aligned} \tag{1}$$

where the mass of the entire object moving on the belt is $M = m + m_s$, the parameter $K = k_1 + k_3$, the friction is modeled by F_t and $F(t)$ it is the force of rotating unbalance, see Figure 2.

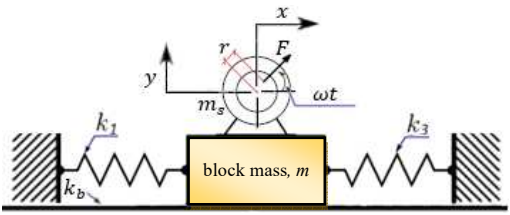

Fig. 2. A physical model of the braking system with an approximation of the object subjected to vibrations

3. Concluding Remarks

The influence of forced vibrations on the dynamics in frictional contact and on the occurrence of the stick-slip phenomenon was demonstrated. In the absence of imbalance on the motor shafts, the effect turned out to be negligible, but the situation changed significantly with its application. The regular time stick-slip characteristics (a saw-like shape) has been replaced by a curve changed by overlapping vibrations caused by excitations from the inductor.

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