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Hysteresis losses in oscillatory systems

V.P. Izmailov [a], O.V. Karagioz [a], V.M. Shakhparonov [b]

[a] National Institute of Aviation Technologies, Russian Federation
[b] Faculty of Physics, M.V. Lomonosov Moscow State University, Russian Federation

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ABSTRACT

Hysteresis losses restrict the quality factors of oscillatory systems. We have considered the energy dissipation mechanism using as an example the contact spots of the ball supports of a pendulum tribometer with plane samples. The bending of a contact spot leads to a storage of the system's elastic energy. Measuring the quality factor of the pendulum at oscillations, owing to the inclination of the contact spot, makes it possible to determine the coefficient of hysteresis losses in materials and thin coatings without destroying their structures.

1. Introduction

Vibrations of mechanical systems are accompanied by hysteresis losses. They depend on the physical characteristics of the materials. There are other means of energy dissipation. Loss-limitation of the quality factor in mechanical systems typically are not linear. The mechanical oscillations of a pendulum tribometer are accompanied by rolling of its supports along a plane surface. The motion of a contact spot leads to energy dissipation, whose value makes it possible to determine the value of hysteresis losses. The process of rolling takes place in quite different mechanisms, including those in transportation means and in precision mechanical instruments. It allows for a significant decrease in energy consumption in the motion due to partial replacement of sliding with rolling.

In [1] the seismic protection of structures is discussed. A system with double rolling can significantly improve the seismic isolation and thus reduce the amplitude of the displacement at an earthquake. Obviously, in this case, the rolling friction plays an important role.

Hertz contact theory also allows modeling the processes occurring in closed cracks [2].

Hysteresis of the dry friction allows controlling vibrations of a system [3].

Of practical interest are measurements of the coefficient of hysteresis losses and the rolling friction coefficient. In [4–7] it has been shown that a pendulum tribometer at small swinging amplitudes allows for determination of the physical parameters of the materials under study without destroying their surface. The main attention is paid to measuring the coefficient of rolling friction f_r. The authors believe that the value of f_r should be preferably measured at small amplitudes, such that the oscillations decay according to an exponential law. It is then not required to place the tribometer in a vacuum chamber because viscous friction in the air can be neglected. It has been pointed out that at small amplitudes there is no sliding of the balls, and the influence of base vibrations is weakened. In the authors' opinion, the swinging dynamics is mainly affected by adhesion forces.

In the present paper, we assume that at small amplitudes the adhesion forces provide, without breaking the adhesion coupling, a bending of the contact spot up to a certain angle. Some elastic energy is stored in this process. If the pendulum gravity center is situated in the plane of samples, then the potential energy is not added to the elastic energy. This provides the most favorable conditions for measuring the coefficient of hysteresis losses. A direct measurement of the rolling friction coefficient should be excluded because mutual displacement of the bodies in contact does not take place. The pendulum tribometer turns into an elastic system with mutual deformation of the bodies in contact. Since the ball supports are fabricated from stiff ball-bearing steel, the basic complex deformation only takes place in the flat samples under study.

1.1. Measurement of hysteresis losses in the contact spot

We have used the pendulum device (Fig. 1). The loads of the pendulum 1 are placed inside the tube 2, which is in a horizontal position at equilibrium. The pendulum is mounted on the base 3. The clutch 4 is fixed on the tube 2. The pendulum is supported by the flat

E-mail address: shah@phys.msu.ru (V.M. Shakhparonov).

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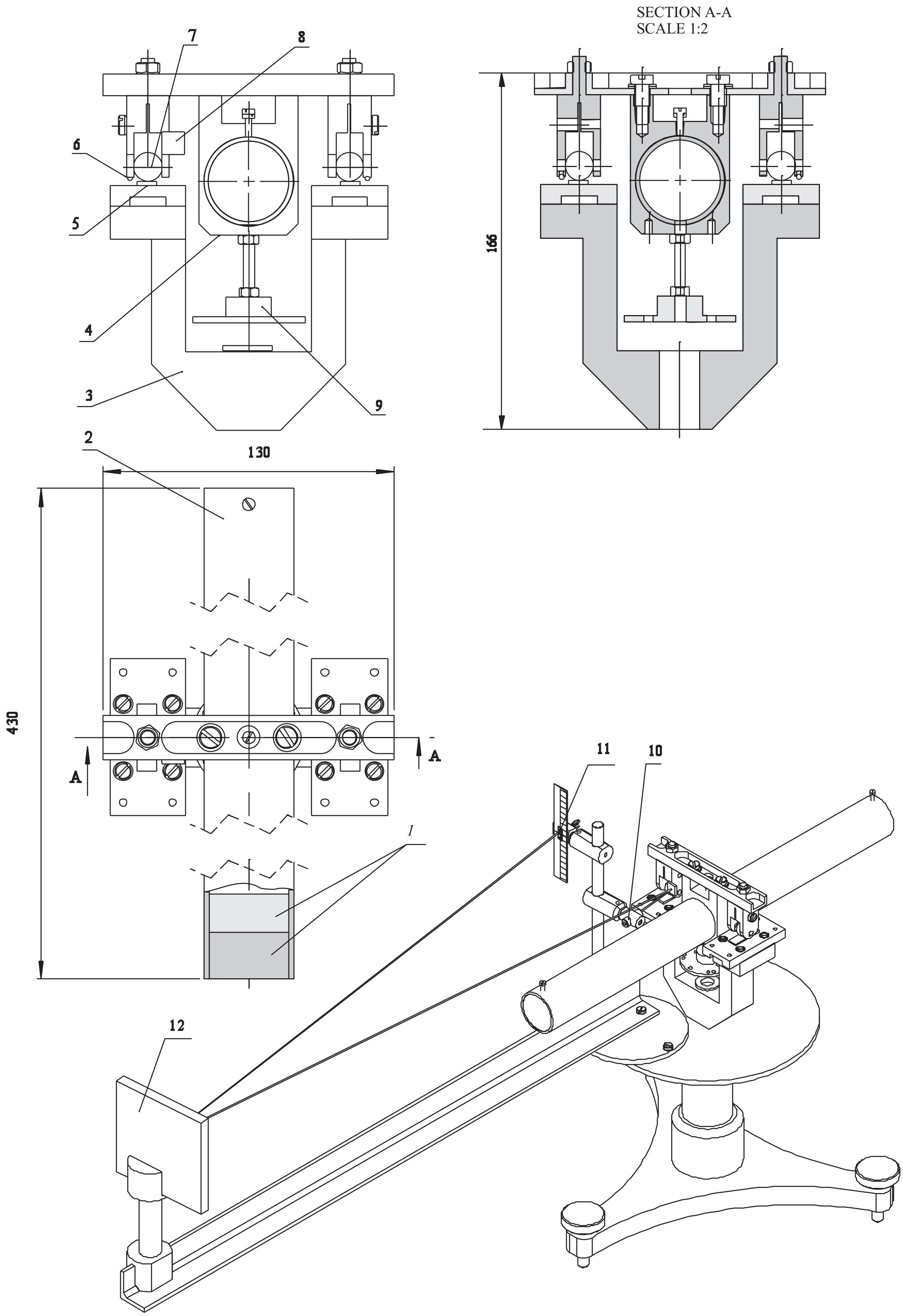

Fig. 1. Scheme of a pendulum tribometer on ball supports.

samples 5 either through two small balls 6 or through two large balls 7, which are tightly fixed to it by the clutch 4. Changes of the radius of the ball supports of the pendulum are accomplished by moving the samples 5. The mirror 8 is fixed to the pendulum body. The counter-weight 9, connected with the clutch 4, changes the distance from the rotation axis to the mass center of the pendulum, which is adjusted to the balls' supporting plane. The beam of the semiconductor laser diode 10, when reflected from the mirror 8 and the immobile