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Experimental identification of friction model parameters for selected materials

J. Zavřel[a], Z. Šika[a], M. Hajžman[b]

[b]Department of Mechanics and Mechatronics, Faculty of Mechanical Engineering, Czech Technical University in Prague, Technická 4, 160 00 Praha 6, Czech Republic
[b]Department of Mechanics, Faculty of Applied Sciences, University of West Bohemia, Univerzitní 8, 301 00 Plzeň, Czech Republic

Passive effects are present in all types of mechanisms, especially in imperfect joints. Their properties are reflected in all aspects of the system's behaviour. A mathematical models of imperfections are essential in not only modelling the behaviour of the system, but also in controlling it. Passive effects are based on various effects such as friction, slip-stick effect, adhesion and more.

Very often, simple models based on Coulomb friction are used. Such model considers the frictional force in the opposite direction of the velocity proportional to the normal force. These simplest models are independent on the relative speed of the moving parts, and the passive effects are directly proportional to the normal force. For more complex models of friction and non-linear effects, variant material properties and the influence of speed and damping of contact points or surfaces are considered. In the real cases, it is often a combination of several effects [1]. There is considered the sticking, sliding and Striebeck effect. One of the advanced models of friction with nonlinear effects is the LuGre model [3].

LuGre model can be expressed as follows

$$\mu = \sigma_0 z + \sigma_1 \dot{z} + \sigma_2 v, \tag{1}$$

$$\dot{z} = v - \sigma_0 \frac{\|v\|}{g(v)} z, \tag{2}$$

$$g(v) = \mu_c + (\mu_s - \mu_c) e^{-\left(\frac{\|v\|}{v_s}\right)^2}, \tag{3}$$

where μ is the coefficient of friction, z is the average deformation of bristles, $\dot{z}$ is the relative velocity between two surfaces, σ_0 is the bristle stiffness coefficient, σ_1 is the micro-damping coefficient, σ_2 is the viscous coefficient, $g(v)$ is a velocity-dependent function that can reproduce both the Coulomb friction and Stribeck effect, v_s is the Stribeck velocity, μ_c is the coefficient of kinetic friction and μ_s is the coefficient of the static friction.

Correct setting of friction model parameters plays a key role. Although there are known coefficients of friction for basic materials, these are approximate values that do not reflect the individual composition of the material, the current state of the surface or local conditions. It is also not easy to find the right parameters for different combinations of materials. It is even more difficult for materials that are not common. This applies for composite materials, such as various types of plastics or rubbers filled with glass or carbon fibres. The parameters for friction models for such materials can be determined only experimentally [2]. The question is also how to determine the material parameters if only a smaller sample is available.

For the identifying the parameters of different friction models, a measuring device was made (Fig. 1). This measuring device consists of a non-rotating part and a motor-driven rotating part. Samples of the measured materials are placed between these two parts. When the first sample rotates and the surface with the second sample comes into contact, friction occurs. It is possible to change the axial pressure force and the rotation speed. It is also possible to apply a radial force for measurement of ball-bearing or sliding-bearing. The torque is transferred from the rotating part through the sample to the non-rotating part and is measured.

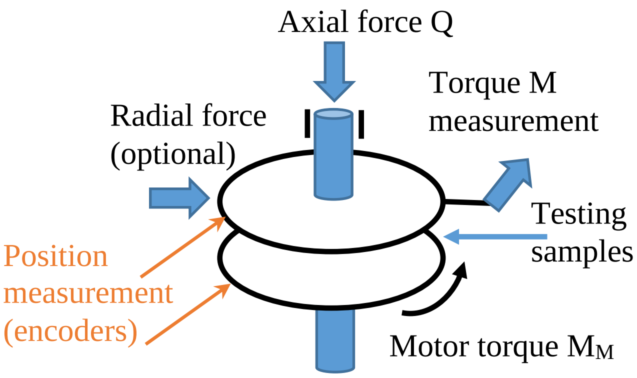

Fig. 1. Scheme of the measuring device principle

For two circular material samples with radius R, axial loading force Q and transmitted torque M, the friction coefficient μ can be evaluated for the Coulomb friction model from the equation

$$M = \frac{2}{3} Q \mu R \tag{4}$$

To evaluate non-linear effects, the relative rotation of the samples must also be measured (Fig. 1). This makes it possible to evaluate such effects as adhesion or slip-stick effect. The coefficients of friction of a combination of different materials under different conditions were experimentally evaluated. Both new materials and after running-in, or in the presence of lubricant. The methodology for obtaining the LuGre model coefficient was proposed.

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