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Influence of friction force description on fretting wear considering stick-slip phenomenon

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Various friction models were formulated [3, 4] to describe such a complex and naturally non-smooth phenomenon. Generally, there are two categories of these models – *static* and *dynamic*. Static models describe friction phenomenon via friction characteristics governing the dependence of friction force on the relative velocity in the contact point. The basic Coulomb model is commonly implemented using its approximations by smooth functions (arctan, tanh) and a modified version of the model incorporating Stribeck effect is also widely used to describe different values of static and dynamic friction. The dynamic models are usually based on the bristle-analogy. In the contact surface, fictive deformable bristles are considered. From the mathematical point of view, dynamic models add one or more extra ordinary differential equation describing an average deflection of the bristles in the contact surface. These additional differential equations are solved together with the equations of motion. One of the basic dynamic models are Dahl [3] or LuGre [2] models, nevertheless there are even more sophisticated models such as elasto-plastic model, stick-slip model, Gonthier model etc [4]. The choice of friction force plays important role during the simulations of various mechanical problems.

Fretting wear is a phenomenon that occurs during the relative vibration (in tangential direction) of two surfaces which are at the same time under the load (in normal direction). Due to the presence of friction, undesirable loss of the mass in contact sufrace occurs. In the field of numerical simulations of such a phenomena, a choice of the model of friction force is of crucial importance.

The presented research is motivated by the numerical simulations of fuel rods vibration in the nuclear power plants. The fuel rods are grouped together in fuel assemblies and they are linked by spacer grids with radial prestress. During the vibration of flexible fuel rods and their bending in the prestressed spacer grid cells, fretting wear can be experienced. It can possibly lead to undesirable leakage of fission product to coolant of primary circuit. In all of the former models [1, 5], complex models of fuel rods have been developed and one of the most general static models of friction was implemented. However, in this models the stick-slip phenomenon is described only in the first approximation. The aim of this contribution is the analysis of the description of stick-slip transitions and their influence on fretting wear in the contact surface.

Simple single DoF benchmark model [4] (see Fig. 1) was used to reach stick-slip vibration. The body of mass m is attached to the frame by the spring with stiffness k. The mass lays on the belt which moves with constant velocity v_b. The mathematical model can be written in the compact form for both static and dynamic models of friction forces F_f

$$m\ddot{x}(t) + kx(t) = \begin{cases} F_f(v_{rel}(t)) & \text{for static models,} \\ F_f(v_{rel}(t), z(t), \dot{z}(t)) & \text{for single-state-variable dynamic models,} \end{cases}$$

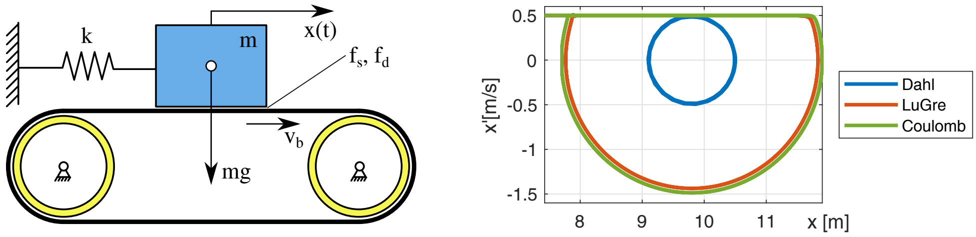

Fig. 1. Scheme of the considered system and an example of phase trajectories

where the static models depend only on the relative velocity in the contact surface $v_{rel} = v_b - \dot{x}$ and dynamic models have an additional dependency on state variable z and $\dot{z}$. In all of the analyses, smoothed Coulomb model with Striebeck effect is considered as a representative of static friction models and Dahl and LuGre models are used as a representatives of dynamic friction models. To estimate the fretting wear in contact surfaces, approach based on the work of the friction forces is used [1, 5]. For the illustration, examples of resulting friction forces are shown in Fig. 2. The comparison of resulting fretting wear values is provided considering variation of the key parameters of the system. The effect of an accurate description of stick-slip transitions is evaluated with respect to the hourly fretting wear introduced in [5].

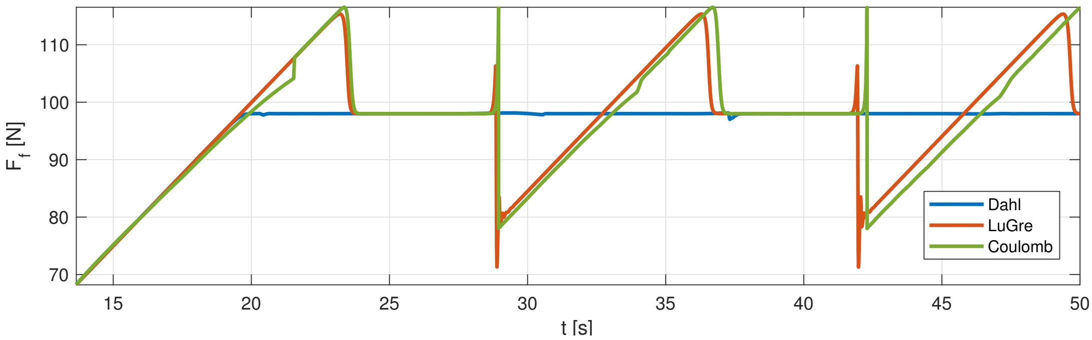

Fig. 2. Comparison of the friction forces in the contact surface

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