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Anisotropic friction sliding rule influence on the mechanical systems dynamics

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Abstract: Anisotropic friction can produce friction force which is not collinear with a sliding direction. How much friction deviates from a sliding direction is described with a so-called sliding potential or equivalently a sliding rule. A sliding potential is often described with an ellipse or a superellipse. In this paper we propose an oval curve which provides piecewise continuous mathematical description for a sliding rule and fits better to the experimental results than a typical superepllipse. For an exemplary mechanical system it is shown, that an anisotropic sliding potential can lead to an unstable equilibrium position in the system. Furthermore, for what parameters the unstable equilibrium occurs differs between sliding potential models. We have tested four different geometrical models of sliding potential in this regard.

Keywords: Anisotropic friction, Sliding potential, unstable equilibrium.

1. Introduction

If a friction force has different values for different sliding direction it is called an anisotropic friction. Besides all known static and dynamic frictional effects, there is an additional one characteristic for an anisotropic friction, namely friction force direction deviates from the sliding direction. Direction of friction is described by a sliding potential [1]. Friction co-linear with sliding velocity is represented by an circular sliding potential, whereas anisotropic sliding potential, in general, can be described by any closed curve. Typically in case of orthotropic friction an ellipse or a superellipse (Lamé curve) is used. This anisotropy can cause instability in the mechanical system [2].

2. Results and Discussion

There are not many frictional pair with a significant anisotropic characteristic. Surface roughness can lead to anisotropic friction characteristic only when finite deformation take place in the contact area [3]. In our measurements we used an experimental rig (shown in the Fig.1a) and frictional pair sample (corrugated cardboard and felt) inspired by [4]. Measurements of the friction force hodograph were taken and the sliding potential was numerically calculated (see Fig.1b). We propose mathematical description of the potential by an oval curve. An oval mathematical description is derived from its geometrical definition used in a technical drawing (see Fig. 1c). An oval fits better to the experimental data than superellipse. What is more, it is noticed that it is better to identify a sliding rule with a difference between friction and sliding direction, then with a sliding potential curvature.

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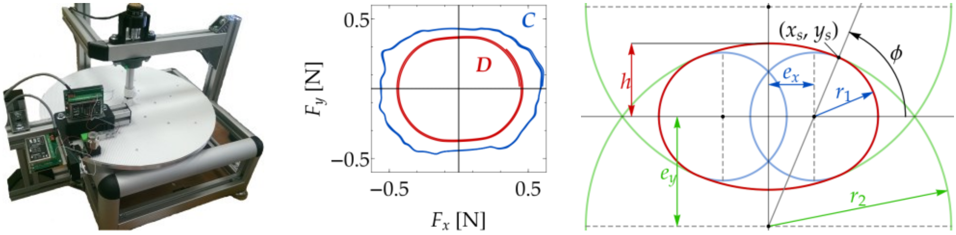
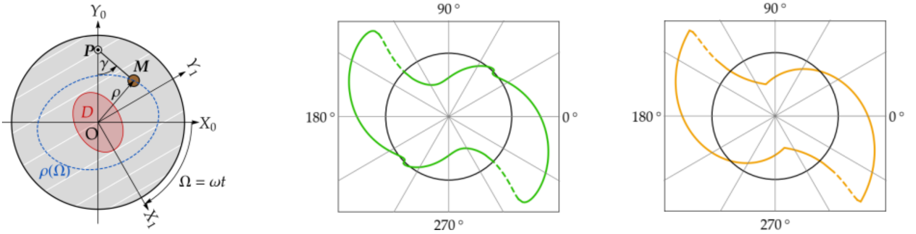


a) b) c)

Fig. 1. a) The experimental laboratory stand; b) the measured friction characteristic (hodograph C) and the calculated sliding potential (D); c) the oval curve (red line) construction.

Four different sliding rules were compared numerically in a simulative experiments. Mechanical system with anisotropic friction shown in the Fig. 2a was considered, where specimen M is sliding over the rotating table surface. Anisotropy is described in the X_1OY_1 coordinate system and its orientation is indicated by the angle Ω. Equilibrium positions given by the radius ρ for different orientations Ω were calculated. Exemplary equilibrium trajectories $\rho(\Omega)$ for the superellipse and the oval sliding rule are shown in the Fig. 2b and 2c.



a) b) c)

Fig. 1. The investigated mechanical system (a) and trajectories of the equilibrium position $\rho(\Omega)$ for sliding potential given by a superellipse (b) and an oval (c) (dashed line segments indicates unstable equilibrium position).

3. Concluding Remarks

Anisotropic friction force hodograph and sliding potential were measured experimentally and it's mathematical description was identified. Proposed oval curve fits experimental sliding rule with the best correlations among other tested descriptions. Sliding potential influence on mechanical system dynamics was shown regarding stable and unstable equilibriums. It was shown that correct identification of mathematical description for a sliding rule can be crucial in this aspect.

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