A survey of empirical friction models for lubricated slotted joints in multibody dynamics simulations

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EXTENDED ABSTRACT

1 Introduction

In recent times, many industrial applications demand energy efficient innovative solutions. One of the main causes of energy loss is due to friction between bodies surfaces in contact. There is a great amount of research aimed to understand the friction mechanisms to allow a reliable prediction during simulation. During the Fifties and Sixties of the 20th Century, many investigations carried out experimental activities that led to coefficient of friction formulas for lubricated surfaces under a combination of sliding and rolling relative motion. The formulas have been mainly deduced by mathematical fitting of results obtained with experimental measurements on rolling disks and different load, lubricating and kinematic conditions. The idea of disks based experimental apparatus for investigating the friction between surfaces in lubricated line-contacts dates back to Merritt [1]. By means of this approach Merritt produced a series of plots that allowed a practical and prompt estimate of friction and mechanical efficiency of gears. As a result, the Merritt's testing analogy between rolling disks and meshing gears inspired many investigators that improved and adapted to their purposes the original experimental apparatus based on disks test machines. This greatly contributed to the interpretation and understanding of many complex phenomena governing the resistance between curved surfaces under relative motion. Distinguished researchers (e.g. [2, 3, 4, 5]) investigated the multibody dynamics modeling of lubricated joints. Within multibody dynamics simulations, empirically based formulas offer a concise and computationally efficient engineering approach toward the simulation of the complex friction phenomena in metal-metal lubricated slotted joints. These formulas have been often adopted in gear dynamics simulation (e.g. [6, 7]). However, it does not seem that a survey about their application in multibody dynamics simulation is available.

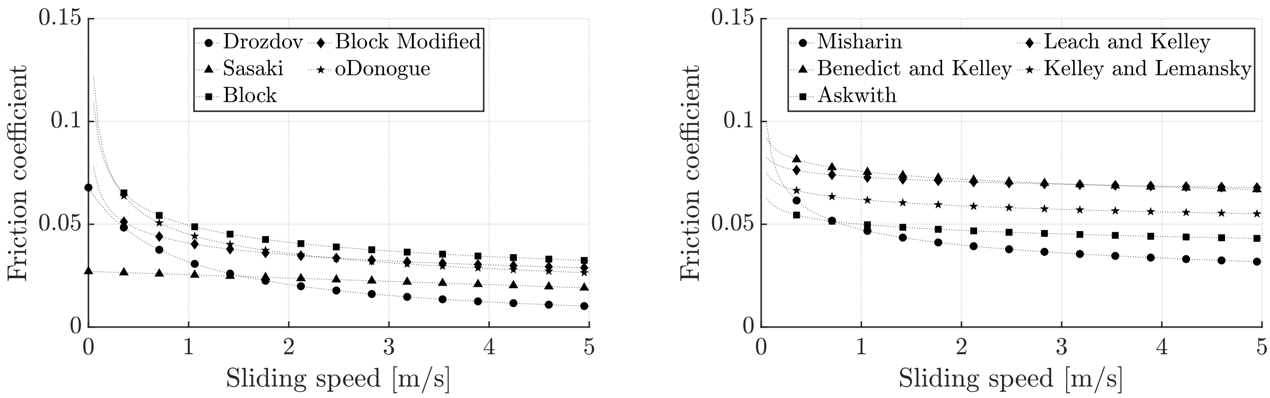

Figure 1: Friction coefficient using different formulations.

Focusing on the multibody dynamics simulation of a scotch-yoke linkage with a straight slot, the purpose of this paper is twofold:

- to review semi empirical formulas and provide a compiled list of friction coefficient formulations deduced mainly by fitting of experimental data;
- to embody and compare, in multibody dynamics simulation environment, contact force models (e.g. [8, 9, 10]) coupled with the metal-metal lubricated empirical friction formulas and evaluate the possibility of employing these formulations in multibody simulations.

Figure 1 reports comparative results of the friction coefficient computed through several friction models as a function of the sliding speed. The implementation of empirical formulas is straight forward and computationally efficient, but one can evaluate the performance of these models in characterizing the dynamics of lubricated joints. A multibody simulation of a scotch-yoke mechanism with contact between pin and slot (instead of prismatic joint) is conducted. In particular, a clearance is present between pin and slider slot. Using cylindrical contact force models for the normal contact force, the reviewed friction coefficients can be employed in the calculation of tangential force component in metal to metal lubricated contact. The difference between each friction model is emphasized by the means of both simulation output and computation time. The clearance existence causes the dynamic behavior of the system to be different from the ideal prismatic joint. The magnitude of contact friction force and therefore the mechanism efficiency is influenced by the friction coefficient model used (see Figure 2). It can be observed that some of the friction coefficient models produce negligible friction force in the considered operating conditions.

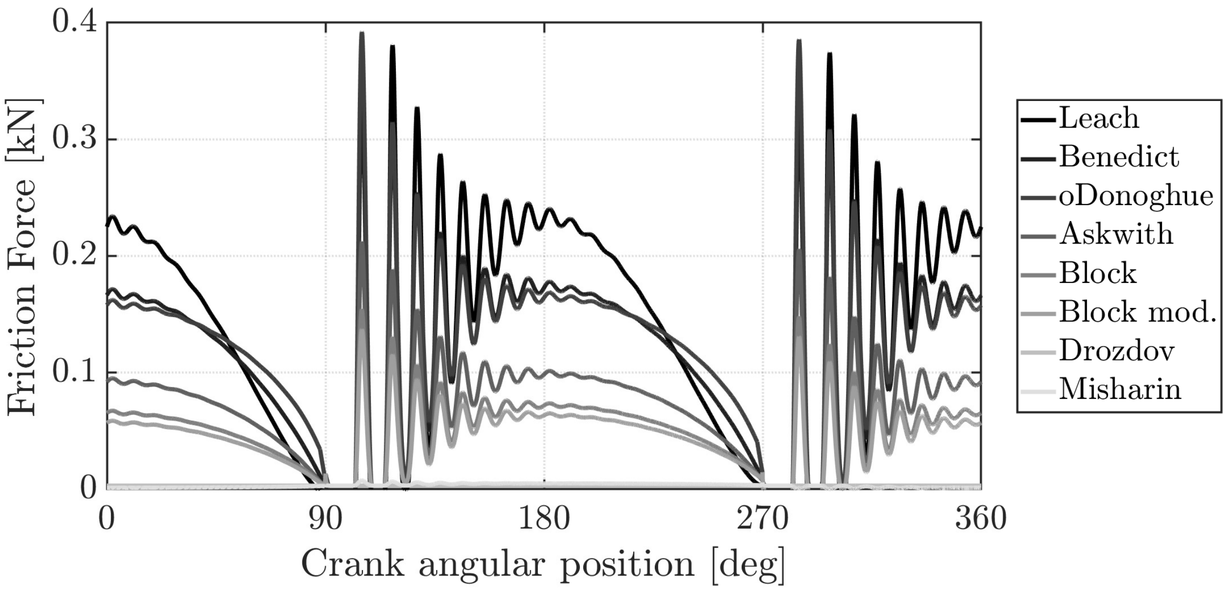

Figure 2: Friction Force with different friction formulations.

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