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DEVELOPMENT OF KALMAN FILTER APPROACHES FOR THE MONITORING OF MECHANICAL CLEARANCES

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1 INTRODUCTION

Clearance by wear in industrial machines has a significant impact on their performance and lifespan. The induced wear between moving parts decreases machine efficiency and causes heat, noise, and vibration, which can eventually damage components and systems and result in the premature failure of the equipment. Regular maintenance and replacement of worn out components are necessary to mitigate the negative effects of clearance.

The characterization and simulation of mechanical clearance have received considerable attention from the multibody system dynamics community [1, 2, 3]. The proposed methods require an accurate description of the dynamics of the bodies connected by the joints affected by the defect. The representativeness of this characterization relies, in turn, on the appropriate selection of physical parameters to describe the contact stiffness and friction, the geometry, and the inertial properties of the mechanism links. These parameters are subjected to uncertainty; in practice, they are frequently difficult to determine and may change over time, due to phenomena like aging and variations in the operation conditions of the machinery. Moreover, most of these parameters cannot be directly measured using sensor readings.

State estimators such as those based on the Kalman filter can provide an alternative way to detect the existence of joint clearances and to gain insight into their magnitude and growth. Kalman filters have been used in multibody dynamics to estimate forces and configuration parameters, besides the system state [4], but clearances and wear have not been addressed systematically, in particular in the context of experimental setups. The first steps towards estimation solutions that can be used to address clearance problems involve the selection of the best alternatives to detect and quantify the problem, including the location of the sensors, the filter configuration, and the identification of relevant magnitudes to be monitored.

2 METHODOLOGY

A slider-crank mechanism, shown in Fig. 1, has been selected as initial test bench for this research. The planar multibody model can be configured to feature clearances at its three revolute joints, as well as at the prismatic joint of the slider. Continuous contact force models have been implemented to represent the interaction between the links at the joints with clearance, while kinematic relations are used to describe ideal joints.

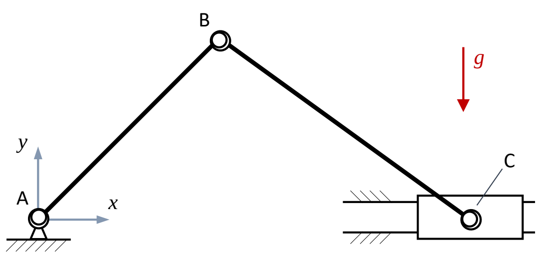

Figure 1: Slider-crank mechanism.

Figure 2 shows preliminary results of the relative motion between the connecting rod and the slider at revolute joint

C, delivered by the simulation framework for the case in which clearance is only present at that joint. This example will be used as test platform to evaluate the ability of estimation algorithms to identify the existence of clearances, as well as the impact of different configurations of sensors and clearance locations.

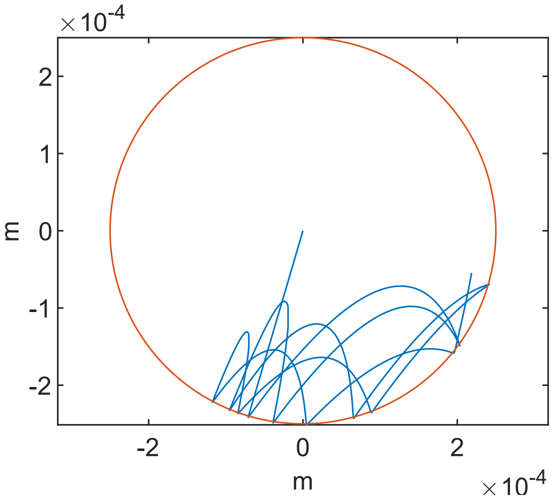

Figure 2: Relative motion between links at joint C.

Three approaches are currently being considered in order to identify the existence of clearances. First, the filters can be used to create virtual sensors to replace real ones that could not be mounted on actual machinery. Another possibility is studying the innovation, i.e., the difference between the readings of physical sensors and their virtual counterparts, to detect degraded behaviour of the equipment. Alternatively, forces or clearance dimensions could be directly approximated by means of input and parameter estimation. Initial results from the presented test problem will be used to orient the research along these three lines.

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