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MACROSCOPIC MODELS FOR ACTIVE CONTROL OF FRICTION AND FRICTIONAL ACTUATORS

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Active control of friction by vibration has technically important and diverse applications ranging from reducing frictional losses and suppressing noise in heavy-duty contacts to precise actuation and positioning. Examples of the latter are traveling-wave motors that are commonly used to adjust focus in camera lenses, or nanometer-precision positioning stages used in the electronics industry and scientific equipment (e.g. inchworm motors or more sophisticated actuation schemes). Proper theoretical understanding of the interaction between friction and oscillation is essential for the effective design of frictional control and positioning systems both at the macro and the micro scales. However, it is the contention of the author that an essential element is missing from most discussions of such systems: contact mechanics. Popular models of frictional-drive behavior, such as the elasto-plastic model or the later LuGre model, generally focus on processes occurring at the micro-scale. The present work follows an opposite approach by deriving a workable model from macroscopic contact mechanics and Coulomb friction, which is nonetheless capable of reproducing all essential features of frictional drives and static and sliding contacts under externally applied vibration. The model consists of a simple sliding elastic contact under the influence of normal, tangential or combined oscillation. Depending on the phase difference between the oscillations, different operating modes can be realized, from simple control of friction, over frictional ratchets that have different resistance depending on direction of motion, to active drives. The operational characteristics of the different modes are analyzed and convenient dimensionless variables are identified. While the proposed model is likely too simple to achieve full quantitative agreement with experimental system, it does highlight that the compliance of the contact needs to be taken into account when modeling frictional drives and other vibrating tribosystems.