Effect of velocity ratio on slip field during oblique landing of elastomer spheres

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Under increasing shear, the contact between a rough elastomer and a rigid surface, for example a tire on a road surface, may undergo significant changes in terms of morphology of the micro-contacts due to the presence of wear [1]. In this context, our research is motivated by the observation of surfaces characterized by heterogeneous wear patterns [2] that may originate from heterogeneous stress fields within the contact interface.

To better understand such contact heterogeneities, in this study, we analyze the displacement fields of an elastomer sphere subjected to kinematics that are representative of the local behavior during rolling. It consists in an “oblique landing”, where normal and shear displacements increase simultaneously. These analyses are performed by measuring in-operando not only the classical evolution of macroscopic normal and tangential forces but also that of the true contact area and interfacial displacement fields.

To do so, we conduct experiments on single normal loading/unloading cycles during a continuous shearing motion, simulating local contact stimuli during one tire revolution. We use an opto-mechanical device recently developed in our laboratory [3]. The latter enables complex contact loading with five simultaneous and independent degrees of freedom and high-resolution monitoring of all three forces and three moments at the contact interface. It also enables high-resolution visualization of the contact area, enabling in-operando measurements within the real contact area of the tangential displacement field through advanced image analysis techniques [4].

This experimental procedure allowed us to study the influence of key parameters, such as the ratio between “landing” and sliding speed or the maximal normal force. First, we performed preliminary tests on unworn spheres of uncharged elastomer (PDMS) seeded with markers to track the evolution of contact area and interfacial displacement fields via image analysis. Then, we compare our experimental measurements with predictions from a new analytical model, developed by extending existing frameworks from the literature [5]. It enabled us to identify and predict which contact state prevails at any instant of the cycle (sticking, partial slip or full sliding) as a function of the velocity ratio. Subsequent tests on pristine tire-type rubber extended our understanding to more realistic rubber materials and allow us to link wear patterns, interfacial fields and variation of macroscopic energy losses.

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