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Editorial

Advances in Contact Mechanics

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Advancements in contact mechanics play an important role in the design of modern mechanical and bio-medical systems, enhancing their efficiency, power density, and reliability. To meet the demand for these qualities, advanced analytical, numerical, and experimental methodologies have been developed. This Special Issue aims to expand our understanding of normal contact problems of layered structure and/or rough surfaces (Contributions 1–3), the tribological and dynamic behavior of interacting surfaces (Contributions 4–6), and the design and optimization of mechanical systems based on contact mechanics (Contributions 7–11).

Coated and layered materials are widely used in numerous engineering applications. The advancement of experimental, numerical, and analytical techniques for investigating the contact mechanics of these materials contributes a significant area of study. Lyashenko et al. (Contribution 1) conducted an experimental verification of the boundary element methods for adhesive contacts of a coated elastic half-space. Normal contact problems between an elastic layer of a finite thickness on a substrate and indenters of varying size/geometry were studied, and good agreement was observed when comparing the experimental results with the boundary element method (BEM). Forsbach and Willert (Contribution 2) introduced a general approximate analytical solution for the slightly non-axisymmetric normal contacts of layered and functionally graded elastic (FGE) materials. Any compact axisymmetric or nearly axisymmetric contact problem in FGE materials can be transformed into the problem of indenting the material using a rigid cylindrical flat punch, leveraging the concept of superposition. The contact problem between two interacting rough surfaces is prevalent in numerous natural and engineering phenomena. Jiang et al. (Contribution 3) proposed an efficient methodology to analyze the deformation of roughness asperities, assuming that the deformation is predominantly governed by the size-dependent plasticity. The role of strain gradient plasticity in contact is analyzed using a modified incremental contact model based on the mechanism-based gradient plasticity (MSGP) theory. The results indicate that the strain gradient plasticity does not alter the linear nature of the area-load relation but increases its slope.

Contact mechanics forms the basis of the research into friction, wear, lubrication, and even system dynamic behaviors. Although rolling friction typically has a smaller magnitude than sliding friction, it has attracted attention since the invention of wheel due to its important role in achieving high accuracy in motion and positioning through rolling systems in modern applications. Specifically, knowledge of the transient rolling resistance during the pre-rolling phase is essential. Gilavdary et al. (Contribution 4) developed a single-point contact pendulum to investigate the law of rolling resistance in cases where the dimension of the displacement zone of the rolling body is significantly smaller than that of the contact spot. Rolling resistance is shown to be determined by dissipative adhesive forces, internal friction forces, and elastic adhesion forces. Adhesive wear occurs at the contacting asperities of the mating surfaces. While models such as the Archard model can be used to calculate the wear volume in engineering applications, the wear coefficient needs to be properly calibrated in wear experiments. Furthermore, accurately predicting the

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locations of crack initiation and propagation remains challenging. Li et al. (Contribution 5) present an efficient finite-element sub-model for simulating adhesive wear in elasto-plastic spherical contacts using techniques based on local mesh refinement. Both normal and tangential mechanical responses are considered. The effects of the sphere radius and normal loads on the formation and evolution of wear particles were studied, and these provide the basis for wear analysis for rough surfaces. Additionally, the dynamic behavior of a mechanical system can be strongly influenced by the contact mechanics of rough rubbing surfaces. In Contribution 6, Maaboudallah and Atalla proposed a multi-scale computational method for the prediction of friction-induced vibrations, such as those in braking systems. In contrast to smooth surface modelling, the effect of surface roughness on system dynamic instabilities can be considered in addition to other influential parameters such as the shear moduli of the pads and the coefficient of friction. It has been shown that the resulting multi-scale model incorporating surface roughness significantly improves prediction accuracy at low frequencies.

Contact mechanics serves as the foundation for the design and tribological analysis of numerous machine elements and mechanical parts, including the cylinder-liner contact in combustion engines, wheel-rail contacts in the railway industry, seals in high-speed machines, and pitch bearings in wind turbines. To predict the performance of an automotive piston ring system, Chu et al. (Contribution 7) developed a mixed lubrication model that considers elastic-plastic rough contacts and lubrication mechanics across scales. The friction at the piston ring- cylinder liner interface was modeled, analyzed, and compared with experimental results. The model, based on contact and lubrication mechanics, can be used to enhance friction-reduction technologies in the automotive industry. In the lubrication practice for pitch bearings in wind turbines, fretting corrosion is a typical mode of surface damage due to oscillating motion and dynamic high loads. Han et al. (Contribution 8) investigated the variation in film thickness in a grease lubricated contact under cyclic load-varying conditions. The decay of the lubricating film thickness was monitored using optical interferometry, and the effects of the load-varying ranges, number of cycles, grease composition, and anti-wear additives were examined. The micro-structural degradation of grease in the contact was also analyzed. In various high-speed machines, dry gas mechanical face seals are used to prevent gas leakage. The dynamic coefficients determine the vibration and stability of a rotor-seal system. Park et al. (Contribution 9) studied the dynamic coefficients of a T-grooved dry gas seal under laminar, turbulent, and slip conditions with different clearances. For a better physical understanding of the changes in adhesion coefficient in wheel-rail contacts under sanded contacts, Suhr et al. (Contribution 10) conducted a comprehensive study into the grain crushing behavior of rail sands in both dry and wet conditions. Their research focused on the initial breakage behavior, as well as the size and thickness of the formed solidified clusters and fragments (running band), providing evidence for future modelling of the sanding process and adhesion in wheel-rail contacts. In a separate study, Rong et al. (Contribution 11) investigated the mechanical properties and tribological behaviors of flash-butt welded rail joints. They found that the high proportion of ferrite generated in the weld metal resulted in increased plasticity and decreased hardness, and yielding strength. Consequently, the wear mechanism transitioned from adhesive wear and oxidation to fatigue wear with slight oxidation.

Despite over a century of research and applications in contact mechanics, marked by continuous advancements in theory, modeling, numerical methods, and related experimental techniques, new challenges in the field of mechanical-biological engineering continue to propel this area of study forward. This Special Issue is a testament to this progress. The Guest Editors would like to express their heartfelt gratitude to the authors, the reviewers, and the editorial staff at *Lubricants* for their invaluable help in publishing this Special Issue.

Conflicts of Interest: The authors declare no conflicts of interest.

List of Contributions:

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