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Editorial

Tribology of Textured Surfaces

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1. Introduction

Surface texturing has emerged as a transformative approach to improving friction, lubrication, and wear across a wide range of mechanical components. From bio-inspired micro-dimples to engineered macro-grooves, texture designs are increasingly applied in biomedical implants, bearings, seals, and automotive systems. This Special Issue, "Tribology of Textured Surfaces," compiles 14 papers that collectively cover fabrication techniques, multi-scale optimization, predictive modeling, and diverse application areas.

The following sections summarize the major themes of this Special Issue. Section 2 reviews the fabrication techniques and texture scales addressed by the authors. Section 3 examines modeling and numerical studies, while Section 4 categorizes the work by application domains. Section 5 highlights the balance between experimental and computational methods, and Section 6 outlines emerging trends and future directions.

2. Fabrication Techniques and Texture Scales

Several papers in this Special Issue focus on advanced fabrication methods for surface texturing. Laser surface texturing (LST) is a recurring theme due to its precision and versatility. Bennett and Zou (contribution 1) produced 5 μm micro-dimples on CoCrMo surfaces to enhance the tribological performance of artificial hip joints. Makowski et al. (contribution 2) used LST to prepare steel substrates for ta-C/MoSx coatings, achieving improved tribological performance in both air and vacuum. Similarly, Liu et al. (contribution 3) employed laser texturing to create millimeter-scale warhead-type grooves on rubber stators of screw pumps, optimizing their geometry to improve pressure generation and wear resistance. Yue et al. (contribution 4) conducted a detailed study of the combined effects of plateau roughness and laser-textured dimples under oil lubrication. By systematically varying dimple density and roughness parameters, they revealed how micro-textures interact with background roughness to optimize oil film formation and reduce boundary friction.

Hybrid approaches that combine coatings and surface textures are also prominently featured. Wos et al. (contribution 5) explored the synergy between diamond-like carbon (DLC) coatings and textured dimples, achieving lower friction and improved seizure resistance in reciprocating sliding. Makowski et al. (contribution 2) extended this concept by integrating micro-textures with coatings to meet the demands of different operating environments. Mechanical grinding and multi-scale texturing were also studied. Parameswaran et al. (contribution 6) demonstrated that controlled grinding of steel counterfaces can significantly reduce sliding friction against aluminum. Tewelde et al.

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(contribution 7) optimized multi-scale textures on prosthetic hip implant surfaces, improving lubricant film thickness and reducing wear.

The studies in this section highlight the wide range of scales that textured surfaces can cover, from micro-dimples (5–100 μm) (contributions 1 and 2) to macro-scale grooves approaching 3 mm (contribution 3). This diversity underscores the adaptability of surface texturing for applications requiring tailored tribological properties.

3. Modeling and Numerical Innovations

A number of contributions focus on modeling as a tool for understanding and optimizing textured surfaces. Ekşioğlu and Zou (contribution 8) developed a non-linear optimization framework for micro-electromechanical systems and nano-electromechanical systems, designed to minimize the real contact area between surfaces. Li et al. (contribution 9) employed computational fluid dynamics to study lubrication and frictional behavior in textured angular contact ball bearings. Shi et al. (contribution 10) presented a fluid dynamic model of rhombus-like textures in screw pumps, while Liu et al. (contribution 3) applied finite element modeling to evaluate the effects of warhead-type grooves.

Scharf et al. (contribution 11) conducted a comprehensive numerical study of wedge-shaped convergent oil film gaps, demonstrating how surface geometry can influence lubrication efficiency. Luz et al. (contribution 12) used deterministic simulations to examine the performance of piston ring/cylinder liner systems in free-piston engines. Ma et al. (contribution 13) combined multi-field coupling and experiments to evaluate the sealing performance of textured metal components used in roller cone bits. Cohen et al. (contribution 14) carried out a stability analysis of secondary piston motions, showing how surface texturing influences lateral and rotational dynamics. Their work highlights how micro-scale texturing can mitigate unwanted secondary motions, reducing energy losses and potential scuffing in reciprocating piston-cylinder systems.

4. Application Categories

The applications of textured surfaces span multiple industries and engineering challenges. In the biomedical field, Bennett and Zou (contribution 1) demonstrated that laser-textured micro-dimples on CoCrMo can reduce wear in artificial hip joints, while Tewelde et al. (contribution 7) optimized multi-scale textures to enhance lubrication and extend the longevity of prosthetic hip implants. For bearings and seals, Li et al. (contribution 9) showed how textured topographies improve lubrication performance in angular contact ball bearings, and Ma et al. (contribution 13) examined how surface textures enhance the performance of metal seals used in roller cone bits.

In energy and automotive systems, Luz et al. (contribution 12) evaluated the effects of surface texturing on the frictional behavior of piston ring/cylinder liner systems in free-piston engines. Cohen et al. (contribution 14) studied textured pistons, providing insights into secondary motion dynamics and frictional losses. Industrial machinery applications were addressed by Shi et al. (contribution 10) and Liu et al. (contribution 3), who investigated screw pumps and demonstrated how textured surfaces can improve wear resistance and efficiency. Coating and sliding surface studies, including those by Wos et al. (contribution 5), Makowski et al. (contribution 2), Yue et al. (contribution 4), and Parameswaran et al. (contribution 6), explored strategies to reduce friction and improve surface durability under diverse lubrication conditions.

5. Experimental vs. Computational Balance

This Special Issue achieves a balance between experimental and modeling studies. Experimental investigations, such as those by Bennett (contribution 1), Parameswaran (con-

tribution 6), and Yue (contribution 4), provide direct validation of tribological performance improvements. Modeling-heavy studies, including those by Ekşioğlu (contribution 8), Scharf (contribution 11), and Luz (contribution 12), offer predictive insights into surface behavior. Hybrid studies, such as those by Liu at al. (contribution 3) and Ma et al. (contribution 13), combine computational simulations with experimental validation, reinforcing the reliability of their findings.

6. Emerging Trends and Outlook

Several important trends emerge from this Special Issue. There is a clear emphasis on integrating computational modeling with experiments, enabling better optimization of texture parameters. Scale-aware design is another recurring theme, with micro-dimples (contribution 1) tailored for biomedical wear reduction and macro-grooves (contribution 3) engineered for fluid transport in screw pumps. The combination of coatings and surface textures (contributions 2 and 5) reflects an interest in multi-functional surfaces that can perform well under demanding conditions. Looking ahead, AI-driven optimization, additive manufacturing for customized textures, and the development of multi-functional coatings offer promising avenues for future research.

7. Conclusions

The 14 papers in this Special Issue highlight the diversity and impact of textured surface research. By advancing fabrication techniques, optimizing texture scales, and integrating computational modeling with experiments, these contributions provide effective strategies to reduce friction, enhance lubrication, and improve wear resistance across biomedical, automotive, and industrial applications.

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Conflicts of Interest: M.Z. is a co-author of contributions 1 and 8 in this Special Issue. The other authors declare no conflicts of interest.

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