

# Study on the Effect of Surface Micro-texture on the Friction and Wear Performance of Brass

Junfeng Chen<sup>1</sup>, Xiaofan Deng<sup>1, 2, \*</sup>

<sup>1</sup> School of Mechanical Engineering, Tianjin University of Technology and Education, Tianjin 300222, China

<sup>2</sup> Tianjin TianSen Intelligent Equipment Co., Ltd., Tianjin 300322, China

\* Corresponding Author: Xiaofan Deng

## ABSTRACT

Brass is widely used in the manufacturing of various components due to its excellent mechanical properties, corrosion resistance, and good machinability. However, with increasingly complex working environments, the friction and wear performance of brass components has become insufficient to meet practical demands. In this study, precision ultraviolet laser machining technology was employed to fabricate four types of micro-textures—scale, rhombus, ellipse, and line—on the surface of H59 brass. The effects of micro-texture shape, diameter, depth, and area density on the friction and wear properties of brass under dry and abrasive wet friction conditions were systematically investigated. The results showed that elliptical micro-textures with a major axis of 200  $\mu\text{m}$ , a minor axis of 100  $\mu\text{m}$ , a depth of 125  $\mu\text{m}$ , and an area density of 10% reduced the friction coefficient from 0.22 to 0.12 under dry friction conditions, with a wear rate reduction of 17.3%. Under abrasive wet friction conditions, the friction coefficient decreased from 0.52 to 0.23, with a wear rate reduction of 28.9%. The results demonstrate that elliptical micro-textures significantly enhance the wear resistance of brass components.

## KEYWORDS

Surface Micro-texture; Friction and Wear; H59 Brass; UV Laser.

## 1. INTRODUCTION

Brass is commonly used in industrial applications such as seals, valves, and cooling system components due to its excellent mechanical properties, corrosion resistance, and machinability [1,2]. However, brass components often face complex friction and wear environments, challenging their performance stability. Under dry and abrasive wet friction conditions, brass shows high friction coefficients and severe wear, significantly reducing its service life and reliability. Improving its friction and wear performance in such environments remains a critical challenge.

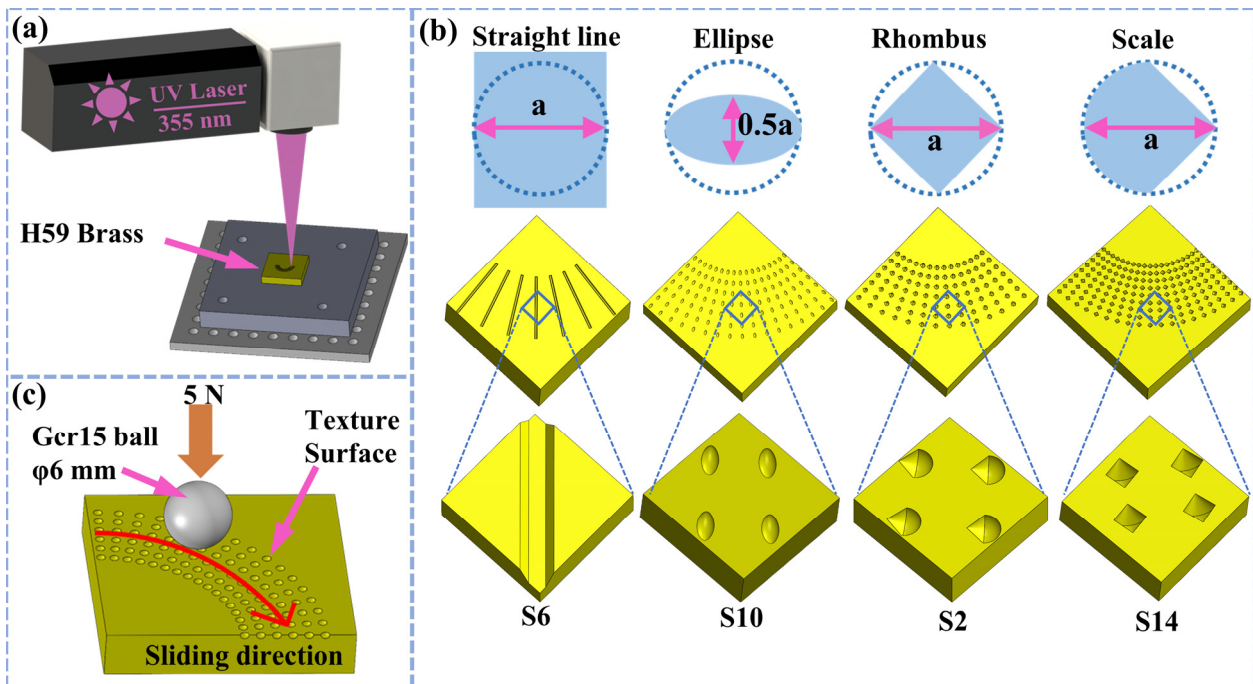
Surface microtexturing, an advanced surface treatment, effectively enhances tribological performance by reducing real contact area, capturing abrasive particles, and optimizing lubricant distribution [3-5]. This cost-effective method significantly lowers friction coefficients and wear rates, offering a promising solution for improving brass components' wear resistance. However, most studies focus on optimizing micro-texture parameters (e.g., size, depth, area density) for single shapes or specific conditions, with limited exploration of multiple micro-texture shapes under varying friction conditions. Designing tailored micro-textures for diverse environments is urgently needed.

Building on prior research [6], this study fabricated four types of micro-textures—scale, rhombus, ellipse, and line—on H59 brass. Friction and wear tests under dry and abrasive wet conditions were conducted to systematically evaluate the effects of different micro-texture shapes and parameters on brass tribological performance. The goal is to identify optimal micro-texture designs for various conditions and provide technical guidance for brass surface optimization in complex environments.

## 2. EXPERIMENTAL PART

### 2.1. Preparation of Test Specimens and Design of Micro-texture Schemes

H59 brass specimens with dimensions of  $20 \times 20 \times 4$  mm were polished to a surface roughness of approximately  $0.1 \mu\text{m}$  using a polishing machine and W10 diamond slurry. The specimens were then ultrasonically cleaned in 95% anhydrous ethanol for 15 minutes, dried, and sealed for storage. Micro-textures were fabricated on the brass surface using a Cypress-355-15 UV nanosecond laser system. The laser machining principle is shown in Figure 1(a), and the micro-textures were distributed within a circular annulus with inner and outer diameters of 5 mm and 10 mm, respectively (Figure 1(b)). After machining, the specimen surfaces were re-polished to remove the recast layer, followed by ultrasonic cleaning to eliminate residual debris.



**Figure 1.** (a) Schematic diagram of laser micro-texture processing principle; (b) Schematic diagram of the tribo-pair; (c) Schematic diagram of the micro-texture.

To comprehensively investigate the effects of micro-texture parameters on friction and wear performance, 16 micro-texture schemes with varying shapes, diameters, depths, and area densities were designed, along with a non-textured control group (Table 1).

### 2.2. Friction and Wear Tests

Friction and wear tests were conducted on a reciprocating ball-on-disk tribometer. A 6 mm diameter GCr15 steel ball was used as the counterpart to form a hard-on-soft friction pair. The test load was set to 5 N, with a circular wear track diameter of 7.5 mm (aligned with the center of the micro-texture). The sliding speed was 50 rpm, and the test duration was 15 minutes, as illustrated in Figure 1(c). Tests

were conducted under both dry friction and abrasive wet friction conditions. For wet friction, a slurry composed of 40  $\mu\text{m}$  white corundum particles and pure water at a 1:9 mass ratio was used as the abrasive medium. Post-test, the data were processed, and the mass loss of the brass specimens was measured to calculate the wear rate. A VHX-1000 microscope was used to characterize the wear morphology of the micro-textured surfaces, providing insights into the mechanisms of friction and wear reduction.

**Table 1.** Design parameters of micro-textures

Number	Shape	Diameter [ $\mu\text{m}$ ]	Depth [ $\mu\text{m}$ ]	Area Density [%]
S1	Scale	150	50	10
S2	Scale	200	75	15
S3	Scale	250	100	20
S4	Scale	300	125	25
S5	Line	150	75	20
S6	Line	200	100	25
S7	Line	250	125	10
S8	Line	300	50	15
S9	Ellipse	150	100	25
S10	Ellipse	200	125	10
S11	Ellipse	250	50	15
S12	Ellipse	300	75	20
S13	Rhombus	150	125	15
S14	Rhombus	200	50	20
S15	Rhombus	250	75	25
S16	Rhombus	300	100	10

### 3. RESULTS AND ANALYSIS

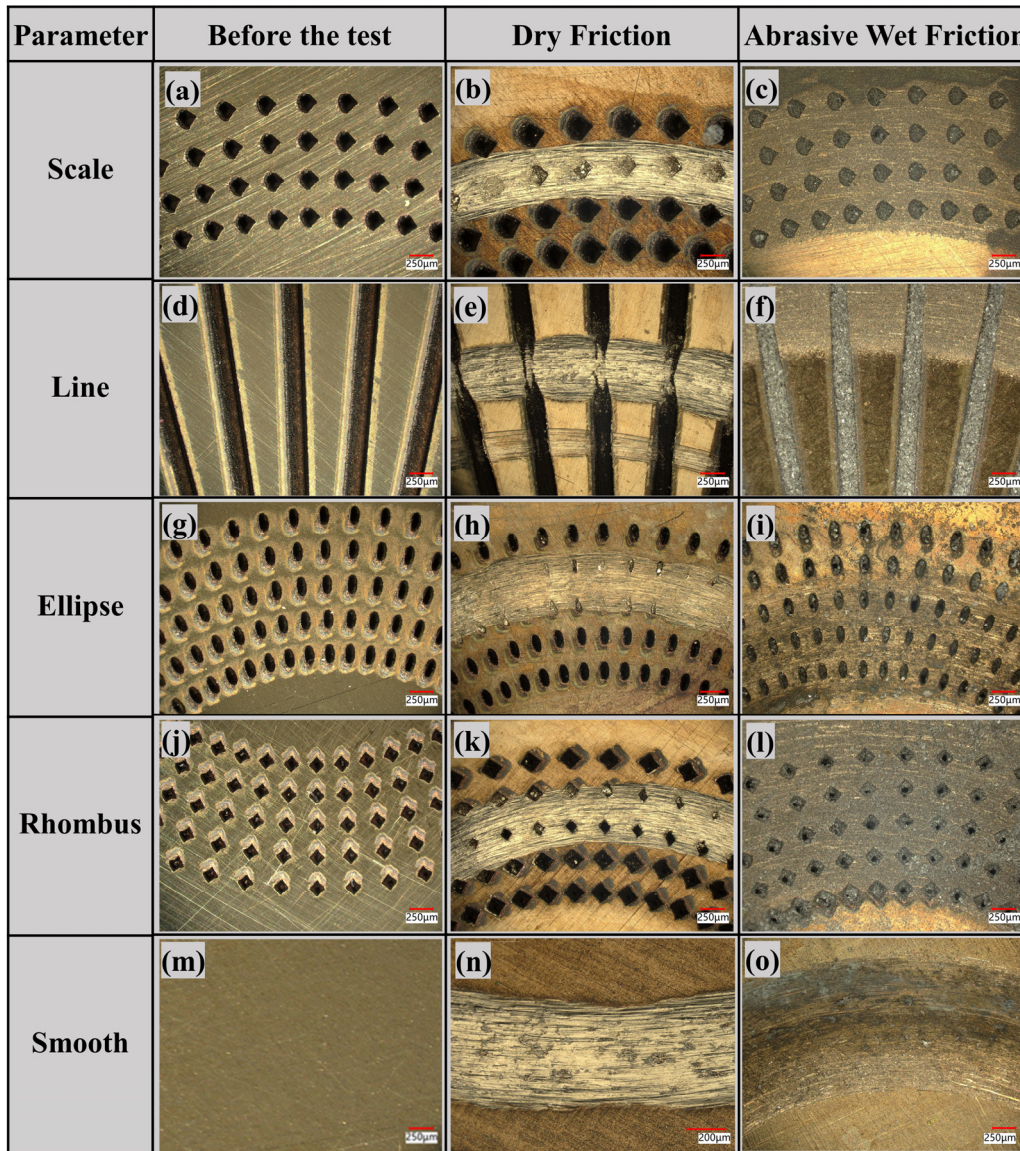
#### 3.1. Surface Micro-texture Morphology of the Specimens

Figure 2 shows the morphology of scale, linear, elliptical, and rhombus micro-textures, as well as non-textured surfaces, before and after friction tests. Measurements of the initial micro-textures revealed that the actual dimensions deviated by less than 3% from the designed values, with continuous and intact edges, indicating high precision in UV nanosecond laser fabrication. The wear morphology of the micro-textured surfaces under dry and wet friction conditions was analyzed in conjunction with tribological data to elucidate the mechanisms of friction reduction.

#### 3.2. Analysis of Friction and Wear Performance of Micro-textures

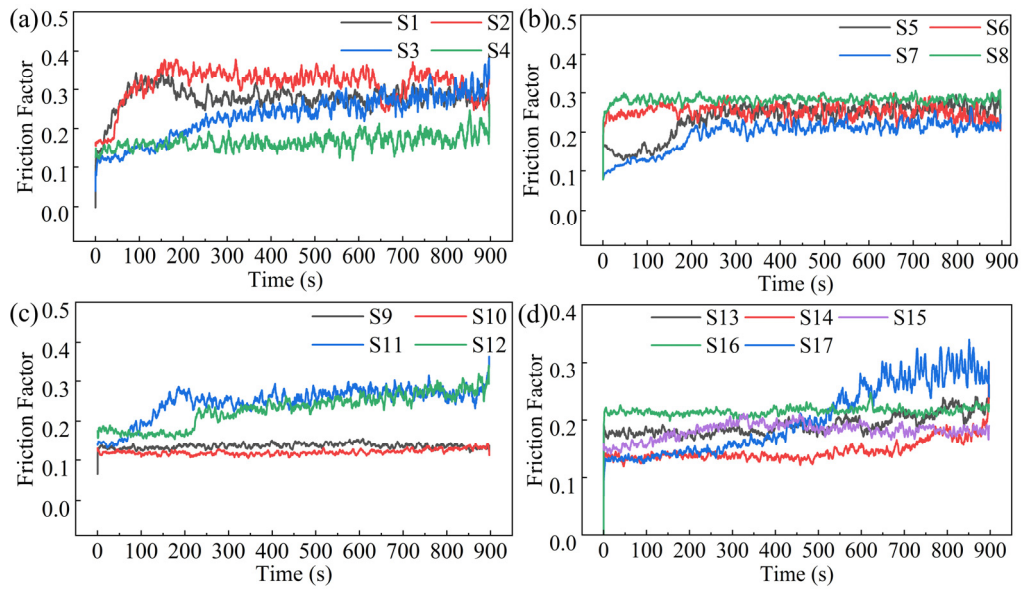
Figure 3 presents the friction coefficient curves for different micro-textured surfaces under dry friction conditions. First, the friction coefficient of the non-textured control group was analyzed (Figure 3(d)). Experimental results showed that the friction coefficient gradually increased from an initial value of 0.13 to 0.29, with an average value of 0.22, and exhibited progressively larger fluctuations during the test. This phenomenon is mainly attributed to the characteristics of brass as a

soft material. Under dry friction conditions, the brass surface is prone to adhesive wear. When adhesive junctions form between the contact surfaces and subsequently rupture, friction forces become unstable. The repeated formation and destruction of adhesive junctions not only amplify fluctuations in the friction coefficient but also, over time, elevate the temperature of the contact area. This leads to a reduction in surface hardness, intensifies plastic deformation, and eventually results in irregular pits on the surface (Figure 2(n)).



**Figure 2.** Morphology of micro-textured surfaces under different conditions: (a)–(c) Scale pit morphology; (d)–(f) Linear groove morphology; (g)–(i) Elliptical pit morphology; (j)–(l) Rhombus pit morphology; (m)–(o) Smooth surface morphology under different conditions.

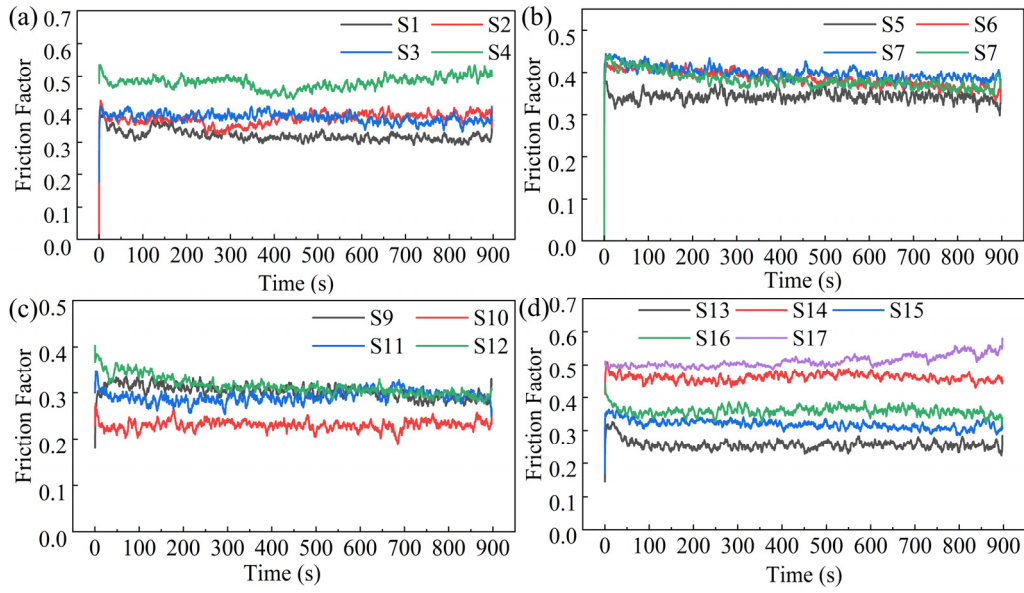
A comprehensive analysis of the friction coefficient for micro-textured brass surfaces revealed that, compared to smooth surfaces, the introduction of micro-textures significantly reduced both the fluctuation amplitude and the overall friction coefficient. Specifically, the minimum friction coefficients for scale, linear, elliptical, and rhombus micro-textures were observed in the following order: line (0.21, Figure 3(b)), scale pits (0.15, Figure 3(a)), rhombus pits (0.14, Figure 3(d)), and ellipse (0.12, Figure 3(c)).



**Figure 3.** Friction coefficient curves of different surfaces under dry friction conditions:(a)–(d) Scale, linear, elliptical, rhombus micro-textured surfaces, and the control group.

The higher friction coefficient observed in linear groove micro-textures is primarily due to their directional distribution. During friction, the grooves can partially capture and store debris, reducing debris accumulation (Figure 2(e)). However, under dry friction conditions, the directional nature of the grooves often results in the "slip-stick effect," which causes localized pressure concentrations and increases friction forces. Additionally, the higher shear stress at the groove edges further elevates the friction coefficient. Scale pit micro-textures, characterized by their relatively complex structure, effectively capture debris and distribute contact pressure (Figure 2(b)). However, their more intricate morphology and larger contact area contribute to stronger edge effects, resulting in a higher friction coefficient compared to rhombus and elliptical micro-textures, though slightly lower than line. Rhombus pit micro-textures, owing to their regular shape and uniform distribution, efficiently disperse contact pressure and mitigate adhesion at the contact interface. Under dry friction conditions, the rhombus pits effectively capture some debris (Figure 2(k)), significantly reducing random variations in friction forces. Furthermore, their weaker edge effects lead to a lower friction coefficient than scale pits. Elliptical pit micro-textures exhibited the lowest friction coefficient (0.12) among all tested surfaces. Their regular shape and minimal edge effects promote uniform distribution of contact pressure and reduce adhesion at the interface. Additionally, the ellipse efficiently capture debris, minimizing abrasive damage to the interface (Figure 2(h)) and substantially lowering the friction coefficient. Further analysis of the friction coefficient curves for ellipse revealed a notable reduction in fluctuation amplitude compared to smooth surfaces. A comparison of the mass loss before and after the test indicated that the wear rate of the brass surface with ellipse (major axis: 200  $\mu\text{m}$ ; minor axis: 100  $\mu\text{m}$ ; depth: 125  $\mu\text{m}$ ; area density: 10%) was 17.3% lower than that of the smooth surface, demonstrating a significant improvement in wear resistance.

In real working environments, brass components exhibit tribological behavior significantly different from ideal dry friction conditions due to the intrusion of abrasive particles and the involvement of lubricants. Abrasive wet friction tests simulate these complex conditions, providing a more accurate evaluation of the performance of micro-textured brass surfaces. The corresponding experimental data are presented in Figure 4.



**Figure 4.** Friction coefficient curves of different brass surfaces under abrasive wet friction conditions: (a)–(d) Scale, linear, elliptical, rhombus micro-textured surfaces, and the control group

Figure 4 illustrates the friction coefficient curves for different micro-textured surfaces under wet friction conditions. First, the smooth surface was analyzed (Figure 4(d)), showing an average friction coefficient of 0.52, which is noticeably higher than that under dry friction conditions. This increase is attributed to the 40  $\mu\text{m}$  white corundum abrasive particles in the slurry rolling or embedding between the contact surfaces, thereby increasing frictional resistance. Additionally, the abrasive particles form a third-body effect at the contact interface, transforming the wear mechanism from adhesive wear to abrasive wear, which significantly amplifies fluctuations in the friction coefficient. This process eventually results in the formation of irregular pits on the surface (Figure 2(o)). Furthermore, despite the presence of the slurry, the high concentration of abrasive particles (10%) may hinder the formation of an effective lubricant film on the surface, reducing lubrication efficiency. These combined factors contribute to the observed increase in the friction coefficient.

Analysis of the friction coefficients for different micro-textured surfaces under wet friction conditions revealed that most micro-texture designs reduced the friction coefficient compared to the smooth surface. The optimal friction coefficients for different types of micro-textures, ranked from highest to lowest, were: scale (0.34, Figure 4(a)), line (0.33, Figure 4(b)), rhombus pits (0.25, Figure 4(d)), and ellipse (0.23, Figure 4(c)). The scale pit micro-texture, characterized by its complex structure and large surface area, tends to retain and accumulate abrasive particles in wet friction environments (Figure 2(c)). This accumulation increases sliding and rolling friction of the particles at the interface, resulting in the highest friction coefficient among all micro-textures. The linear groove micro-texture facilitates liquid and particle flow to some extent in wet friction environments. However, its directional nature imposes constraints on particle flow, causing particles to accumulate within the grooves and form localized abrasive clusters (Figure 2(f)). These clusters lead to high localized contact pressure, further increasing friction forces. The rhombus pit micro-texture, with its regular distribution and wider fluid channels, effectively captures abrasive particles and guides their flow (Figure 2(l)). This geometric feature significantly reduces localized stress concentration, resulting in a lower friction coefficient compared to scale and linear groove micro-textures. The elliptical pit micro-texture exhibited the best performance under wet friction conditions. Its regular shape minimizes particle retention and, through the curved ends of the pits, efficiently guides abrasive particles and fluid along the interface (Figure 2(i)). This design prevents localized pressure concentrations and ensures uniform flow distribution. Additionally, the weaker edge effects of the ellipse further reduce friction forces, achieving the lowest friction coefficient among all tested designs.

A comparison of the wear rates between the elliptical pit micro-texture and the smooth surface under wet friction conditions revealed that ellipse (major axis: 200  $\mu\text{m}$ ; minor axis: 100  $\mu\text{m}$ ; depth: 125  $\mu\text{m}$ ; area density: 10%) reduced the wear rate by 28.9%. This result demonstrates a significant improvement in the wear resistance of brass components in abrasive wet friction environments.

#### 4. SUMMARY

This study investigates the effects of micro-texture shape, depth, and area density on the friction and wear performance of H59 brass components under dry friction and abrasive wet friction conditions. The main conclusions are as follows:

1. Under dry friction and low load conditions, elliptical micro-textures with a major axis of 200  $\mu\text{m}$ , a minor axis of 100  $\mu\text{m}$ , a depth of 125  $\mu\text{m}$ , and an area density of 10% reduced the friction coefficient of the brass surface from 0.22 to a stable value of 0.12. Compared to a smooth brass surface, the wear rate was reduced by 17.3%, indicating that micro-textured brass components exhibit significantly improved wear resistance in dry friction environments.
2. Under abrasive wet friction conditions with 40  $\mu\text{m}$  white corundum particles, the same elliptical micro-textures reduced the friction coefficient from 0.52 to 0.23. Additionally, the wear rate of the micro-textured brass components decreased by 28.9%, demonstrating that elliptical micro-textures effectively enhance the wear resistance of brass components in abrasive wet friction environments.

#### CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

#### ACKNOWLEDGMENTS

This work is supported by the Scientific Research Project of Tianjin Education Commission (No.2022KJ126).

#### REFERENCES

- [1] Huikko A P, Salonen N, Latva M. Dezincification of faucets with different brass alloys[J]. *Engineering Failure Analysis*, 2025,169:109202. <https://doi.org/10.1016/j.engfailanal.2024.109202>.
- [2] Zhanqi T, Hongxiang M, Gianni H, et al. Tribological behavior of carbon steel 45 and brass H90 in dry sliding on bearing steel GCr15 in the sand-dust environment[J]. *Industrial Lubrication and Tribology*, 2024,76(10):1149-1156. Tribological behavior of carbon steel 45 and brass H90 in dry sliding on bearing steel GCr15 in the sand-dust environment | Emerald Insight.
- [3] Luis C L, Esteban R M, T. V I, et al. Initial adhesion suppression of biofilm-forming and copper-tolerant bacterium *Variovorax* sp. on laser micro-textured copper surfaces[J]. *Colloids and Surfaces B: Biointerfaces*, 2021, 202 (prepublish):111656. <https://doi.org/10.1016/j.colsurfb.2021.111656>.
- [4] Wenfeng G, Junyan L, Xinjian W, et al. The Hydrodynamic Lubrication Performance of Protruded Surface Microtexturing Fabricated by Selective Laser Melting Ink-Printed Copper Nanoparticles[J]. *Tribology Transactions*, 2021,65(1):46-54. <https://doi.org/10.1080/10402004.2021.1983681>.
- [5] Li W, Liu R, Jin W, et al. Anti-friction and anti-infection properties on biomedical Ti3Zr2Sn3Mo25Nb alloy driven by high-precision cross-elliptical micro-texture and copper coating[J]. *Tribology International*, 2024,199:109990. <https://doi.org/10.1016/j.triboint.2024.109990>.
- [6] Hua L J, Jie Y P, Jun Z Y, et al. New insight on wheel flange/rail gauge lubrication: Effect of lasered micro-texture shapes on the wear and fatigue behaviour of wheel/rail steels[J]. *Wear*, 2022(prepublish):204310. <https://doi.org/10.1016/j.wear.2022.204310>.