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Friction and wear of a hybrid surface texturing of polyphenylene sulfide-filled micropores

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ABSTRACT

A new form of hybrid texturing is introduced and discussed in terms of friction and wear reduction. Texturing with four pore densities of 5%, 15%, 25%, and 35% was made by laser texturing on steel; the pores were filled with polyphenylene sulfide (PPS) powder followed by curing to form hybrid surface texturing. Ball-on-disk sliding tests were performed under dry conditions at sliding speeds of 0.05, 0.10, and 0.15 m/s, contact load of 9.8 N, and travel distance of 0.36 km. The hybrid texturing protected the metal surfaces by forming a polymer transfer layer. This transfer layer was crucial in the friction reduction and wear resistance of the hybrid texturing.

1. Introduction

Micropores produced by surface texturing methods are well known for storing lubricants and capturing wear fragments during sliding. Irrespective of texturing method, most texturing research aims to create mechanical components with low friction and increased wear lifetimes. Ironically, obtaining these desired outcomes in the application of surface texturing is only possible under lubricated sliding conditions. When considering dry sliding contact, surface texturing cannot be directly used, and solid lubricants such as polytetrafluoroethylene (PTFE), MoS_2, and graphite are necessary.

Some research groups have attempted to incorporate surface texturing and the solid lubricants mentioned [1–7]. For example, Voevodin et al. [1] developed a TiCN coating on an Inconel 718 substrate. Laser texturing was applied to create dimples of 10 and 20 µm diameters and 3–5 µm depths. Dry MoS_2 powder was burnished onto the substrate as a solid lubricant. In addition, MoS_2 was deposited by magnetron sputtering to create a mixture of MoS_2/graphite/Sb_2O_3 powders. Texturing areas with approximately 10% surface coverage of 10 µm dimples and 15% 20 µm dimples resulted in the maximum wear life. In addition, they reported that when graphite was used with MoS_2 in humid air conditions, graphite, rather than the MoS_2 powder, acted as the lubricant. Another study utilizing MoS_2 powder burnished onto a laser-textured steel surface was reported by Rapoport et al. [2]. The authors produced textured samples with different texturing densities and filled the pores with MoS_2 powder, creating a ~1 µm thick solid lubricant film. The results indicated that the wear life increased as the surface density of the dimples increased; the optimum density of dimples was found to be between 40–50%. In a related study [3], several nanoparticle species such as MoSe, PbSe, and ZnSe were used as a sub-layer and burnished to determine which nanoparticles had the highest adhesion to the steel surface. The wear life of the MoS_2 film was prolonged with a sub-layer of CdZnSe nanoparticles because of the increased adhesion between the CdZnSe nanoparticles and the steel substrate. Hu et al. [4] reported that LST surfaces with burnished MoS_2 film showed the reduction in friction and wear for all applied loads. Enhanced tribological performance was ascribed to the transferring of MoS_2 into the pristine Ti–6Al–4V surface.

Previous studies incorporating surface texturing with low friction particulate materials have all used solid lubricants. To the best of our knowledge, no attempts using an engineering plastic as a substitute for the solid lubricant have been reported. In this study, an engineering plastic, polyphenylene sulfide (PPS), was used to fill micropores produced by the laser texturing method, referred to here as hybrid texturing. The hybrid texturing samples were tested in the ball-on-disk configuration under dry conditions. The friction and wear behavior of the hybrid texturing were discussed with respect to the formation of a transfer film and micropore failure.

2. Materials and methods

2.1. Materials and surface texturing

PPS (LG Chem. Co.) was supplied in the form of a very fine powder. The material is well known for high wear resistance and

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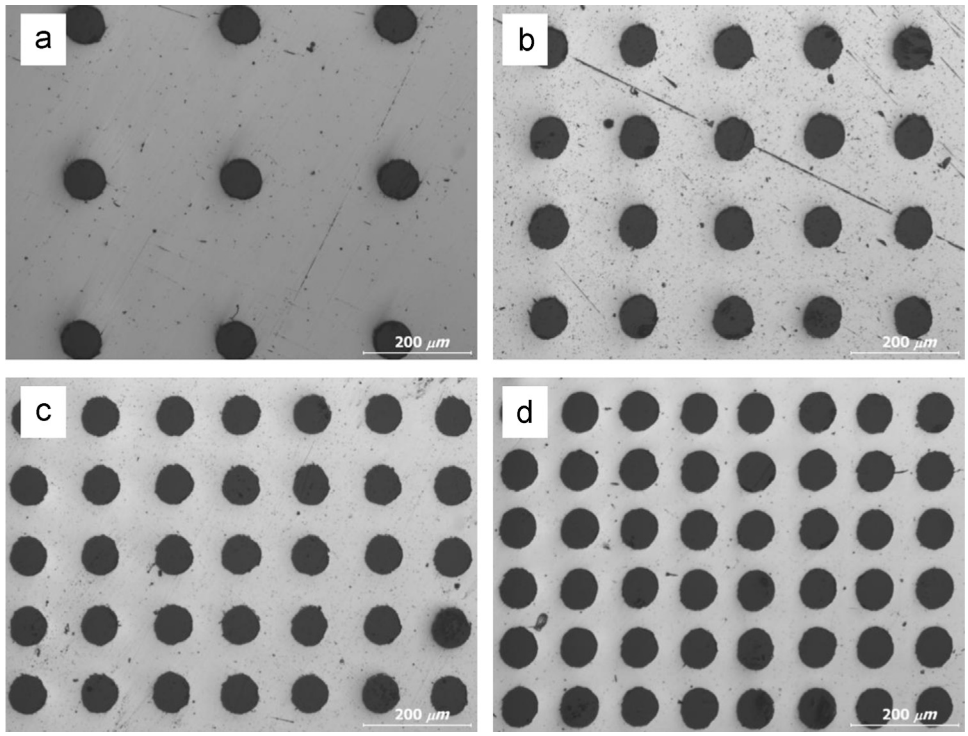

Fig. 1. Micropores filled with polyphenylene sulfide (PPS) for various area densities: (a) 5%, (b) 15%, (c) 25%, and (d) 35%. Pore diameters are approximately 75 μm. Curing temperature and time are 295 °C and 5 min, respectively.

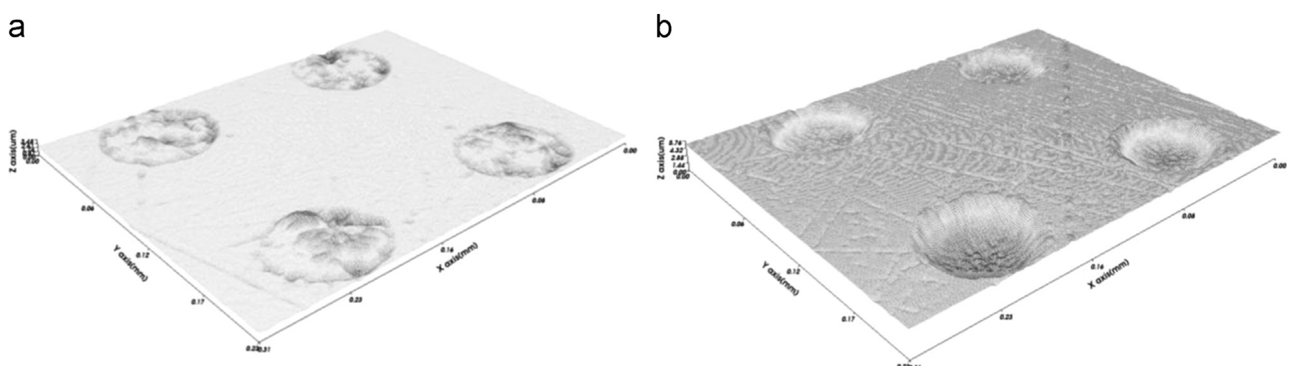

Fig. 2. A typical three-dimensional texturing shape (a) before and (b) after curing. The area density is 25% and the initial pore depth ~35 μm. The curing temperature is 295 °C. The scanned area of (b) is 230 × 310 μm.

anti-corrosion behavior. The density and melting temperature are 1.36 g/cm^3 and 285 °C, respectively. The as-received PPS powder is light brown in color; upon melting, the material becomes dark brown.

Micropores were developed on SCM 415 steel samples of 30 mm in diameter and 10 mm in thickness. Before texturing, the steel was lapped to remove grooves formed during the turning process. Surface texturing was performed using an Nd:Yb fiber laser with a pulse rate of 20 KHz, pulse width of 200 ns, and duration time of 1000 μs. Protrusions were formed around the pores because of the thermal melting induced during texturing; these were gently buffed prior to testing using 1000-grit emery paper. Finally, micropores of 30 ± 3 μm depth and 75 ± 3 μm diameter were obtained. The area coverages of the micropores on the different steel specimens were 5%, 15%, 25%, and 35%. Steel balls (12.7 mm in diameter) used for sliding tests are 100Cr6 (ASTM E52100) bearing steel. They were used as-received after cleaning.

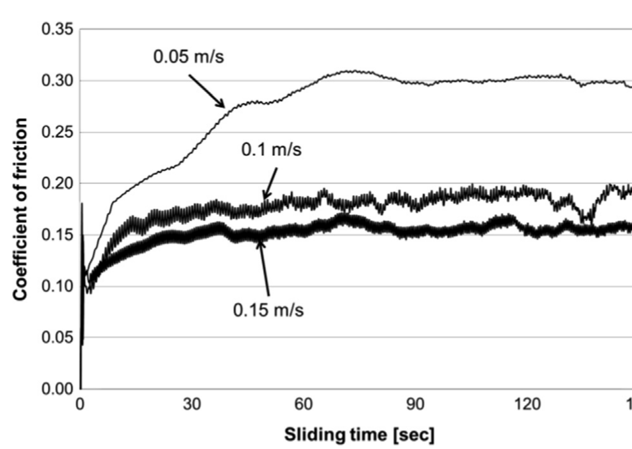

Fig. 3. Coefficient of friction of PPS as a function of sliding time for different sliding speeds. Contact pressure: 0.85 GPa. Texturing density: 25%.