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Tribological behavior of brass fiber brush against copper, brass, coin-silver and steel

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ABSTRACT

The brass fiber brushes with various packing fractions were prepared by the method of filling and dissolving aluminum fibers. The compression tests of brass fiber brushes and brass block were conducted. The tribological behavior of the selected brass fiber brush of 23% packing fraction sliding against the copper, brass, coin-silver and steel discs was investigated. The microstructure, worn surface and wear debris of the brush and counterface materials were observed and analyzed to investigate the involved wear mechanisms. The compressibility of brass fiber brushes increases with the increase of packing fraction, and is much higher than the brass block. The brush against the four discs exhibits significantly high friction coefficient values range from 0.8 to 1.0 but the curves are fairly smooth. The brass fiber brush sliding against copper and brass discs experiences severe adhesive wear and gives a high wear rate compared with that against coin-silver and steel discs. The wear behavior of the brass fiber brush strongly depends on the counterface materials under dry sliding condition. The differences of the friction and wear mechanisms between fiber brushes and solid brushes were also discussed.

1. Introduction

Metal fiber brushes, composing thousands of aligned metal fibers of micron scale diameter, have attracted much attention recently, which can be potentially applied as high current electrical brushes to substitute for carbon brushes or metal–graphite composite brushes [1–4]. Electrical brushes are used to transfer electrical power and signals between two surfaces in relative motion. The aligned metal fibers of the diameter in micrometer scale work in the way with their tips contacting and sliding on the surface of slip rings. For the purpose of making most of the fibers in contact with rough surface of the slip ring, the packing fraction of the brush should be low enough to offer sufficient space for the bend of fibers. Since there are a great number of fiber tips keeping in contact with the slip ring surface during sliding, then each fiber just have to bear a correspondingly small normal load and electrical current, and the real contact area varies with time in a small degree. Therefore, the metal fiber brushes could possess the following characteristics: high current carrying capacity, low electrical contact resistance, low electrical noise, low wear rate and so on [5].

The research conducted on metal fiber brushes is still extremely limited comparing to carbon brushes and metal–graphite brushes. Argibay et al. [2,3] have investigated the friction and wear behaviors of the copper fiber brush and copper–beryllium fiber brush sliding on copper slip ring with high current density. In order to prevent the adhesion between the contact metal surfaces, humid carbon dioxide was introduced into the system to form a lubricating water film at the brush interface. They found that both metal fiber brushes showed a low friction coefficient below 0.4 and a relative high wear resistance. Elger [6] has reported that a metal fiber brush for submarine DC motors can operate on slip rings continuously for over 5700 h at the moderate current density of about 516 A/cm^2 in the open air, and the volume of wear debris of the metal fiber brush is about one sixth of that of the carbon brush. Kuhlmamm-Wilsdorf [7] prepared the gold fiber brushes by repeated drawing and bundling of copper tubes, which were inserted with gold fibers. The gold fiber brushes showed much lower electrical loss and noise than the silver–graphite brushes. Other kinds of fiber brushes, such as carbon nanotube brush, were also investigated and revealed excellent wear resistant and sliding electrical contact behavior [8]. For the purpose of reducing the electrical loss at the contact interface and improving the contact reliability, metal fiber brushes are designed to work at the configuration of direct metal-to-metal contact without lubricating oils or solid lubricants [9]. Hence, the counterface materials could have a significant influence on the wear of brushes. Understanding the tribological behavior of metal fiber brushes sliding against different counterface materials and the corresponding wear mechanisms is very important.

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In the present paper, the brass fiber brushes of various packing fractions (volume fraction of brass fibers in the brush) were successfully prepared by the method of filling and dissolving aluminum fibers. The compression behavior of the brushes and brass block was investigated. The friction and wear behaviors of the brass fiber brush with packing fraction of 23% were investigated as sliding against copper, brass, coin-silver and steel discs, which were usually selected as the ring material of the slip-ring, in other words, the counterface materials of the brushes. The microstructure, worn surfaces and wear debris of the brush and the counterface materials were observed. The effects of specific counterface materials on the tribological behavior of brass fiber brush were researched. The friction and wear mechanisms of metal fiber brushes were also briefly discussed.

2. Experimental

2.1. Materials preparation

Brass fibers (CuZn20), prepared by the cold drawing process, possess excellent elasticity, electrical conductivity, anti-wear and anti-corrosion properties. Brass fibers with the diameter of 50 μm are fairly soft and particular suitable for the production of brush. In order to make the slender brass fibers to be spaced regularly, the aluminum fibers of 120 μm in diameter were chosen as the filler fibers. The schematic diagram depicting the preparation process steps of the brass fiber brush is shown in Fig. 1. In the first step, a fiber bundle, made by two brass fibers and one aluminum fiber, was twined round a cylinder for many times, then cut the prepared coil with a certain length. By this way, a large bundle of fibers that uniformly mixed with brass fibers and aluminum fibers was fabricated. In the second step, the bundle of the mixed fibers was put into a mold and pressed at 300 MPa for 1 min. Since the aluminum fibers were much softer than the brass fibers, the aluminum fibers underwent severe plastic deformation during compaction. The relative density of the compacted block could reach 88%. In the third step, the block was machined to the final shape, and then one end of the block was immersed into the sodium hydroxide solution to dissolve away the aluminum fibers, exposing an array of brass fibers. The final step was wrapping the brush with a brass mesh for lateral support and to confine the fibers. Eventually, a brass fiber brush with the packing fraction of 23% was prepared. Applying this preparation method, fiber brushes of different packing fractions could be easily made by changing the ratios of brass fiber to aluminum fiber. Three other kinds of brass fiber brushes with the packing fraction of 7%, 13% and 30% were also prepared, and the corresponding ratios of brass fiber to aluminum fiber were 1/2, 1/1 and 3/1, respectively.

2.2. Friction and wear tests

The friction and wear tests of brass fiber brush were conducted using a CSM tribometer with a pin-on-disc contact geometry. The contact area of the pin was 72 mm^2. Four kinds of discs made of pure copper, brass (CuZn40), coin-silver (AgCu10) and bearing steel (GCr15) were selected as the counterface materials. The hardness for these four counter discs is 75 HB, 140 HB, 120 HB and 62 HRC (about 685 HB), respectively. Prior to testing, the surface of discs were polished by 2000 grit size SiC paper and cleaned with acetone. All the sliding tests were conducted at a fixed normal load of 5 N, sliding speed of 1.2 m/s and sliding distance of 10,000 m. The tests were carried out in an ambient environment with temperature around 20 °C and relative humidity of 50%. After each sliding wear, the brush was cleaned with acetone to clear away the wear debris that trapped at internal space and dried for weighting. The friction force was measured and converted into friction coefficient automatically by a computer during the test. The wear loss of the brass fiber brush was calculated from the difference in the weight measured using a digital micro-balance (0.1 mg precision) before and after wear testing. Three parallel tests were performed for each testing condition. The wear rate of the bass fiber brush was determined in terms of wear volume over sliding distance.

2.3. Characterization

The compression tests were performed using standard testing equipment (Instron 3369, 10 kN) with a cross-head speed of 1 mm/min. The cross section area of the samples for compression is 120 mm^2 and the height is 15 mm with the free length of fibers of 10 mm. In order to obtain insights into the wear mechanisms involved, the microstructure of worn surfaces and loose wear debris were investigated using a scanning electron microscope (FEI, Nova NanoSEM 230). Energy dispersive spectroscopy (EDS) analysis of the composition of the wear debris was performed.

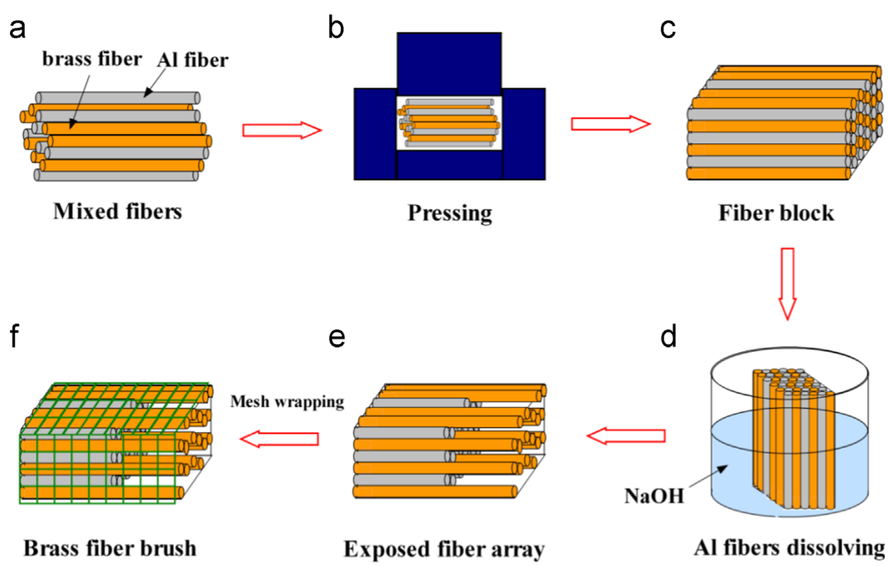

Fig. 1. Schematic diagram for the preparation process of brass fiber brush.