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Effect of surface laser texture on friction properties of nickel-based composite

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ABSTRACT

Laser surface texturing (LST) was performed on the nickel-based composites by a Nd:YAG pulsed laser and the regular-arranged dimples with diameter of 150 μm were fabricated on their surfaces. The textured surfaces were smeared with molybdenum disulfide powder. The tribological properties of the textured and filled composites were investigated by carrying out sliding wear tests against an alumina ball as a counterface using a high temperature ball-on-disk tribometer. The tests were conducted at a sliding speed of 0.4 m/s and at normal loads ranging from 20–100 N and from room temperature to 600 °C. The friction coefficient of nickel-based composite textured and smeared with molybdenum disulfide was found to reduce from 0.18 to 0.1 at the temperature range from 200 to 400 °C. The texture with a dimple density of 7.1% was observed to prolong wear life of MoS2 film by more than four times in comparison to the texture with other dimple densities. The lubricious oxide particles stored in the dimples reduce friction coefficient at elevated temperatures and compensate for the extra lubricant owing to the degradation of MoS_2 caused by its oxidation at high temperatures.

1. Introduction

The friction and wear damage, fatigue failure always begin at the surface. So the resistance to failure by friction and wear can be improved by modifying the surface morphology of materials. The effective results of texturing for tribology application were obtained by machining, ion beam texturing, and etching technology. Laser surface texturing has been recently developed and applied commercially in tribology [1–3]. Laser surface texturing is a method used for fabricating artificial regular micro-dimples or channels on the material surface by laser scanning [4–6]. This morphology is helpful for the effectiveness of lubrication between frictional surfaces [7–10]. Furthermore, the dimples ablated by laser can store lubricant and trap wear debris, which protects the surface from scratching.

The method of storing MoS_2 by adjusting the roughness of substrate was reported previously [11], which was usually combined with hard coatings. For example, the discontinuous hard chromium coatings were prepared on the substrate. The cavities between hard 'island' were filled with MoS_2 powders, which acted as storage of solid lubricant [12]. Laser surface texturing was applied on hard coating surface to produce the storage of solid lubricant. The laser textured dimples trapped wear particles and protected tribology system from destroying. Voevodin [13] investigated an altogether new concept of three dimensional design of coating architecture with an objective of attaining an improvement in tribological properties of hard coatings. In their study, a nanocrystalline/amorphous functionally gradiant coating of Ti–TiC–TiC/DLC was ablated by laser and grooves were formed along the wear paths which were then filled with MoS_2. The grooves acted as storage for solid lubricant on the coating surface and provided the replenishment of the solid lubricant inside the friction contacts. They observed an increase in the wear life of coating by at least an order of magnitude in comparison to that for a hard gradient coating with a top layer of MoS_2 without any 3-D laser processing.

In view of the relevance of the surface texturing as an effective tool in improving tribological performance of contacting surfaces and the significance of the development of self-lubricating composites which can resist wear at high temperatures, in the present investigation, laser surface texturing (LST) was performed on the surface of nickel based composite (Ni–Cr–W–Fe–C) which has the potential to resist friction and wear at high temperatures by laser ablation. The effect of laser surface texturing on the tribological properties was investigated by carrying out the dry sliding tests on a ball-on-disk wear test apparatus.

2. Experiment details

2.1. Laser surface texturing

The nickel based composite with the composition of 44.8% Ni, 11.2% Cr, 10.0% W, 30% Fe, 3.0% C and 1.0% Si (wt%) prepared by

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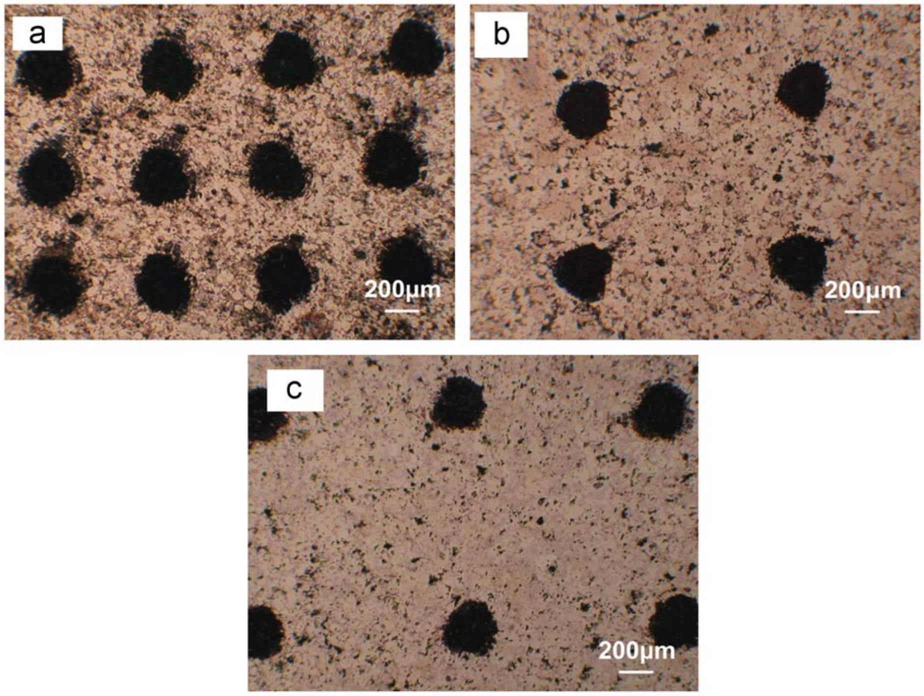

Fig. 1. Laser textured surface with various dimple density: (a) high density of 11.2%, (b) moderate density of 7.1% and (c) low density of 1.8%.

Table 1
The characteristics of micro-dimples.

Parameter	Diameter (μm)	Distance in circumferential (μm)	Distance in radial (μm)	Dimple area density (%)
High density	150	400	400	11.2
Moderate density	150	500	500	7.1
Low density	150	1000	1000	1.8

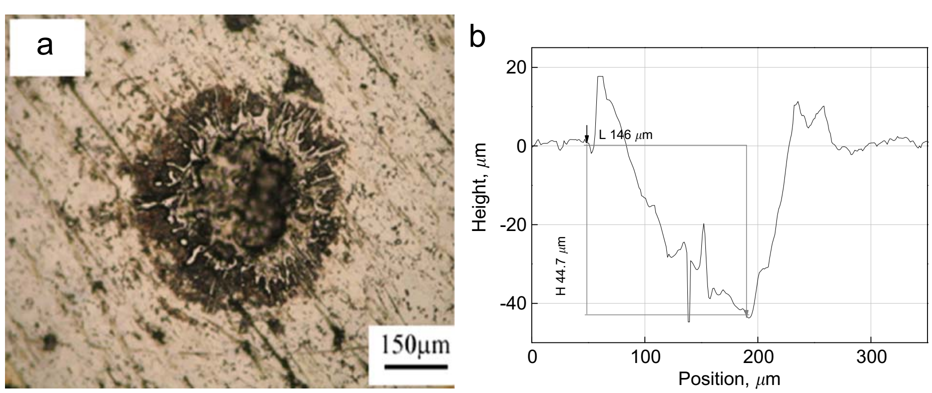

Fig. 2. Optical photographs (a) and cross-section profile (b) of the LST.

powder metallurgy was mechanically polished until roughness (Ra) below 0.1 μm. Laser surface texturing was carried out on the surface of Ni-based composite by a ND:YAG pulse laser using wavelength of 1064 nm, pulse energy of 30 μJ/pulse, period of 450 ns and frequency of 100 Hz. The dimples with some specific formula arrays were fabricated. The topographies and profiles of textured dimples are detected by white light interferometer. Fig. 1(a)–(c) show the optical micrographs of the laser textured surfaces of the composite with different dimple spacing and densities. A variation in the spacing between regularly formed dimples and hence, the variation in the density of dimples could be clearly observed from the above figures. The spacing between the dimples is observed to vary from 400 to 1000 μm as depicted in Figs. 1(a)–(c). The dimple densities (D_{area}) as calculated by using the formula $D_{area} = \pi(d/2s)^2 \times 100\%$ where, d is the diameter of a dimple, s is the distance between dimples which are 1.8, 7.1 and 11.2%, respectively, for high, moderate and low density patterns and are listed in Table 1.

Fig. 2(a) shows the morphology of a single dimple as observed under an optical microscope whereas the cross sectional profile of