Effect of Partial Plasma Nitriding on the Tribological Properties of the AISI H13 Tool Steel

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Plasma nitrided material improves the surface hardness, wear resistance and fatigue strength etc. while maintaining the core properties. However, plasma nitrided sample have not be attained low friction coefficient same as samples nitrided by another nitriding method. In this study, plasma nitriding was performed partially to create surface texturing on the surface of tool steel. The effects of partially plasma nitriding were investigated, and the tribological properties of surface on the formed partially nitrided layer were clarified.

Keywords: *plasma nitriding, tool steel, tribological properties, surface texturing*

1. Introduction

Plasma nitriding has been extensively used for research and application for surface modification for various steels [1]. Plasma nitrided material improves the surface hardness, wear resistance and fatigue strength etc. while maintaining the core properties [2]. Some of the advantages of plasma nitriding over conventional nitriding are that plasma nitriding is a clean and non-toxic process that involves less nitriding time than gas nitriding [3]. However, plasma nitrided sample have not be attained low friction coefficient same as samples nitrided by another nitriding method. A mechanical part that contacts two surface requires a reduction in the friction coefficient. Friction accounts for about 23% of all energy consumption worldwide, among which 20% is needed to reduce friction and 3% is required to remanufacture replacements for worn-out parts and equipment [4]. Consequently, studying the characteristics of contact surfaces that reduce friction not only results in energy savings, but also extends the lifetime and dependability of the component. Surface texture technology is crucial for reducing the friction coefficient of contact surface and enhancing friction performance.

There is technology of surface texturing that create a series of regular microstructures on the surface of a sample using process techniques. The textures with suitable size can act as micro-bearing to increase the dynamic pressure between friction pairs, store lubricants, and capture debris produced during the friction process.

In this study, plasma nitriding was performed partially to create surface texturing on the surface of tool steel. The effects of partially plasma nitriding were investigated, and the tribological properties of surface on the formed partially nitrided layer were clarified.

2. Experimental apparatus and method

2.1 Sample

The sample material was AISI H13 tool steel. The discs had a 20 mm diameter and were 5 mm thick. Quenching was performed at 1,030°C in vacuum, with a holding time of 80 min; subsequently, the samples were tempered to 540°C for 240 min. The hardness of the heat-treated samples was 580 HV. The sample surfaces were ground and polished in several stages. The final surface finish was performed by buffing using 0.3 μm alumina. The average surface roughness of the polished samples was R_a = 12 nm, and they were polished to a mirror surface.

2.2 Experimental apparatus

Fig. 1 shows a schematic diagram of the electron beam excited plasma (EBEP) using as the experimental apparatus. The EBEP apparatus is composed of three regions: discharge region, acceleration region, and processing region. Ar gas is introduced into the discharge region, and DC discharge is developed between the cathode, lanthanum hexaboride (S_0) heated by a tungsten filament and the subsequent electrode, S_1. The emitted electrons produce plasma that allows the discharge region to be the source of electrons fed into the acceleration region. The acceleration region is composed of two parallel electrodes, an intermediate cathode S_2, and an anode Sa. The electrons in the acceleration region are then accelerated to the processing region by applying a voltage V_a to the anode. The beam current I_b, on the other hand, is controlled by the discharge current I_d.

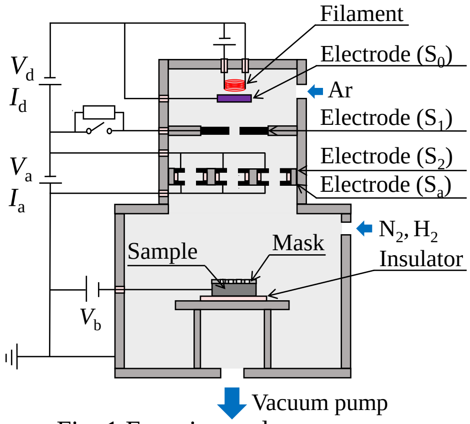

Fig. 1 Experimental apparatus

2.3 Experimental method and conditions

The bias of the sample was controlled to floating potential. The nitriding treatment time was varied in order to control the nitrogen concentration on the sample's surface. The treatment times were 6 h. The chamber was evacuated to a base pressure of the order of 1.0 × 10^{-3} Pa.

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The mass flow rate of argon, nitrogen and hydrogen was 5 sccm, 5 sccm and 2sccm, respectively, and the treatment pressure was 0.6 Pa. Acceleration voltage and beam current was 120 V and. 3.3 A, respectively The material of the mask was graphite. The diameter of the hole and the distance between the hole in mask were 1.0 mm or 0.5mm and 1.3 mm, respectively. The friction coefficient and the wear rate of the nitrided samples were investigated by 10 mm SUJ2 bearing steel (JIS G 4805) balls in a wet atmosphere (PAO4). The applied load was 9.8 N, with a rubbed 70 m in 1000 mm/min. The surface profile of the sample was measured using a surface roughness meter. The surface hardness and cross-sectional hardness was investigated using a Micro-Vickers hardness tester.

3. Results and discussion

Fig. 2 (a) shows surface 3D topographies of nitrided sample using mask with hole diameter 1.0 mm. Formation of islands with a diameter of about 1 mm was confirmed according to the pattern of the mask. The maximum height of island on nitrided sample was 2.5 μm. Fig. 2 (b) shows surface 3D topographies of nitrided sample using mask with hole diameter 0.5 mm. Formation of islands with a diameter of about 0.5 mm as well as a 1 mm hole pattern was confirmed. The maximum height of island was 1.0 μm.

Fig. 3 shows surface hardness of nitrided samples. The surface hardness of the nitrided sample in the unmasked portion was more than twice as high as that of the untreated one. The surface hardness was almost the same as SKD61 treated by the conventional plasma nitriding method. The surface hardness of the nitrided sample in the masked portion was almost the same as untreated sample. From the results, it is possible to simultaneously form a nitrided portion and an unnitrided portion by this experimental method.

Fig. 4 shows friction coefficient of nitrided samples. The friction coefficient of untreated sample and conventional nitrided sample was about 0.13. The friction coefficient of sample nitrided using 1mm mask was same as untreated sample. However, the friction coefficient of the sample nitrided using 0.5mm mask was decreased.

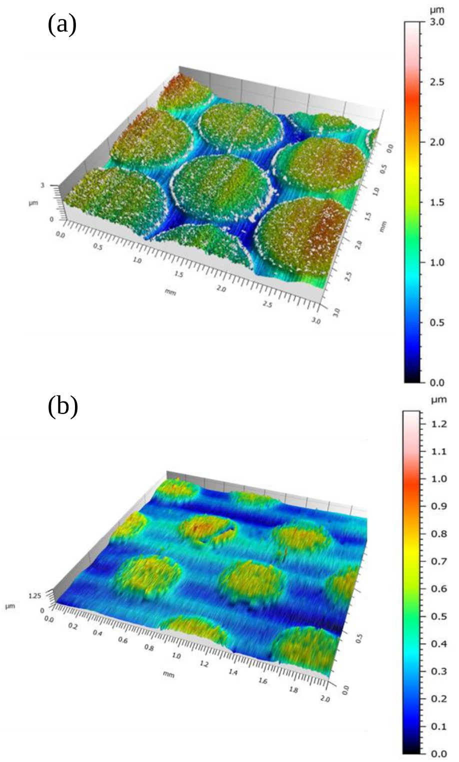

Fig. 2 Surface 3D topographies of nitrided sample:
(a) hole diameter 1mm, (b) hole diameter 0.5mm

Acknowledgments

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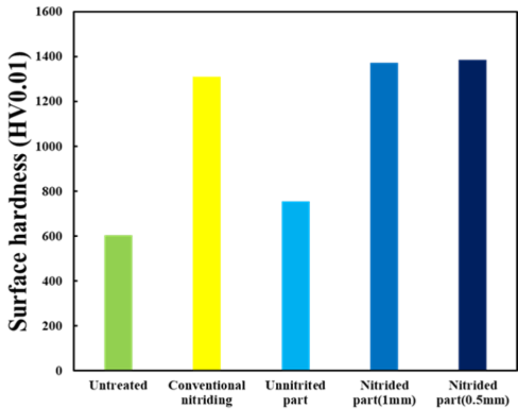

Fig. 3 Surface hardness

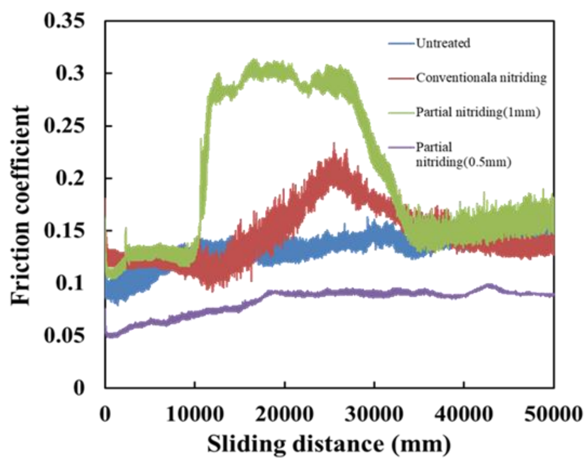

Fig. 4 Friction coefficient