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ORIGINAL RESEARCH ARTICLE

Comparative Study on Tribological Performance of Laser Textured GCr15, SS 316L, and SS 304 under Dry and Lubricated Sliding with Hexagonal Boron Nitride Nanoparticles

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This study investigates the synergetic effects of hexagonal boron nitride (h-BN) and laser surface texturing on GCr15 and Cr-Ni austenitic stainless steels (SS 316L and SS 304), analyzing friction and wear with varying dimple pitch distances. An Nd: YAG laser with a wavelength of 1064 nm and a pulse duration of 5 ns was used in the texturing procedure. Textured surfaces were assessed for morphology, roughness, and wettability, and their tribological performance was tested using a ball-on-disk tribometer under both dry and lubricated conditions (i.e., PAO-4 and PAO-4 + 1% wt h-BN nanoparticles). The contact angle test using PAO-4 oil showed that P-100 (39.31°) exhibited superior oil spreading compared to U-T (86.19°), P-150 (71.52°), and P-200 (77.8°) surfaces. The range of analysis identified 100 μm (P-100) as the optimal dimple pitch, with the GCr15 surface exhibiting the best tribological performance. It achieved CoF reductions of 15.3% under dry conditions, and 62.4% and 78.1% under lubricated conditions. The wear coefficient decreased by 50.9% in dry, 65.3% with PAO-4, and 87.1% with PAO-4 + 1% wt h-BN NPs compared to U-S. The analysis considered factors such as wear debris trapping, the contact area between sliding surfaces, and the presence of h-BN as a solid lubricant, all of which influence low friction and improve wear properties. This investigation highlights the potential of laser texturing combined with solid lubricants to enhance metal tribological characteristics, benefiting surface engineering applications across industries.

Keywords bearing steel, Cr-Ni austenitic steels, friction and wear, hexagonal boron nitride (h-BN), surface engineering

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1. Introduction

Cr-Ni austenitic stainless steels like SS 304 and SS 316L offer remarkable corrosion resistance, good weldability, and superior mechanical properties. These desirable characteristics make them extensively utilized in various industrial sectors, including aerospace for components, medical devices, and critical chemical environments for various apparatus (Ref 1, 2). Bearing steels, especially GCr15, are essential in engineering applications like ball bearings, and extrusion tools, offering excellent corrosion resistance, high hardness, abrasion resistance, and contact fatigue resistance (Ref 3-5). GCr15-bearing steels, produced through electric furnace melting and forging, exhibit varied microstructures based on heat treatment. Spheroidizing yields a ferritic matrix with chromium carbides (207 HV), annealing forms ferrite-cementite (210 HV), and quenching results in martensite (>840 HV) (Ref 5, 6). Several researches have been conducted to improve and assess the mechanical, corrosion, and tribological characteristics of GCr15. This initiative for development stems from the need to achieve higher performance in increasingly demanding and harsh environmental circumstances (Ref 7, 8).

Austenitic stainless steels (ASS) have drawbacks, including high work hardening, low thermal conductivity, and poor wear resistance. To overcome these limitations, various efforts have been made to enhance their tribological performance. The current characteristics can result in significant adhesive wear and a shortened wear life, particularly in dry sliding conditions