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Microstructural and tribological characterization of plasma- and gas-nitrided 2Cr13 steel in vacuum

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ABSTRACT

Plasma- and gas-nitrided 2Cr13 samples were characterized using optical microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), and microhardness testing techniques. Nitrogen concentration profiles in the cross-sections of the nitrided samples were obtained by glow discharge optical spectroscopy (GDOS). Residual stress profiles along depth of the nitrided samples were measured using an X-ray stress tester. The tribological behaviour of the plasma- and the gas-nitrided samples in vacuum was investigated in order to analyse the effect of nitriding on wear resistance of the 2Cr13 steel. The results show the tribological properties of the 2Cr13 steel in vacuum are improved considerably by plasma nitriding and gas nitriding resulted from microstructure modification and surface hardening during nitriding. The plasma-nitrided samples have better wear resistance than the gas-nitrided samples under 30 N, while the gas-nitrided samples have higher wear resistance under 90 N. With increasing normal load from 30 N to 90 N, the wear mechanism shows a transition from mild adhesive and abrasive wear to severe adhesive or even delamination wear. The plasma-nitrided sample has thicker compound layer than the gas-nitrided sample, resulting that it exhibits more intensive delamination under high load of 90 N.

1. Introduction

The hypoeutectoid 2Cr13 martensitic stainless steel has been commonly used in manufacturing turbine blades and valve parts due to its high corrosion resistance and impact toughness, which is also an alternative material for gears applied in space. However, low hardness and poor wear resistance sometimes limit its applications where contact and wear are involved [1–3]. Moreover, the high vacuum that is a critical factor for space applications generally results in an intensive adhesion between contacting surfaces of metal couples, leading to an inactivation of gears [4,5]. Therefore, it is necessary adopting suitable surface modification to improve the anti-wear property of 2Cr13 steel and avoid those problems in vacuum. Both plasma nitriding and gas nitriding are effective way to improve surface hardness and wear resistance of stainless steel without affecting either properties or dimension of the bulk material beneath the treated layer [6,7]. The nitriding produces a very hard surface layer which is consisted of a compound layer (white layer) with underlying diffusion zone [8,9]. The existence of the hard nitrided layer makes stainless steels more reliable in space applications. In practice, the compound layer is usually finished off because it often leads to spalling during friction. However, removing compound layer will reduce the adhesive resistance of the component especially in vacuum, and loose an ultimate shielding against surface damage induced by the friction stresses [10]. Therefore, removing or keeping the compound layer is still a disputed issue at present.

In the past decades, several studies [11–15] have analysed on tribological characteristics of nitrided steels under dry sliding in air. Sun et al. [11] reported that the plasma nitriding reduced the wear of 440C martensitic steel under sliding, rolling, and combined rolling–sliding in air, in which the oxidation and the delamination dominated the wear process of the nitrided steel. Previous work [16,17] showed that some nitrided steels had excellent property in vacuum exhibiting promising applications in space. The ion nitriding produced a significant reduction in friction coefficient of steel in vacuum [18]. The investigation from Spalvins demonstrated that the γ-Fe_4N phase has lower coefficient of friction than the ε-$Fe_{2-3}N$ phase in vacuum [19]. Unfortunately, few detailed analysis was carried out on tribological behaviour and wear mechanism of the nitrided layer in vacuum. Therefore, understanding the tribological behaviour and wear mechanism of the nitrided layer in vacuum is required for 2Cr13 steel to be used in space.

The aim of present paper is to conduct a comparative study on the plasma- and the gas-nitrided 2Cr13 steel. The main analyses were performed on microstructure, composition distribution, and tribological behaviour of the nitrided layers in vacuum, as well as

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