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EFFECT OF SLIDING VELOCITY IN WEAR STUDIES OF PLASMA NITRIDED AISI 316 LN

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ABSTRACT

SS 316L (N) is employed in PFBR grid plate sleeves. The suitability study of Chrome nitriding for PFBR grid plate sleeves for subassemblies and tribological testing of SS316L (N) discs were carried out. Discs and pins of SS 316L (N) were subjected to chrome nitriding at 525°C and for 24 hours time duration. The surface modification has resulted in fine surfaces with homogenously hardened structure with a case depth of 50 micron in an average. The micro hardness measurements clearly indicated that the appreciable increase was achieved in hardness. Subsequently friction and wear tests were carried out under high vacuum at PFBR working temperatures. Sliding wear experiments were carried out at various elevated temperatures at constant load (40N) and with sliding speeds of 0.8 and 1.2 m/s using the high vacuum pin-on-disc test rig as per ASTM standard G99-05. SEM analysis of the worn track with respect to sliding velocity revealed that the mode of material loss is more severe in higher sliding velocity. The worn tracks depicted a clear ploughing type of material removal in the SEM analysis, which is a typical feature of an abrasive wear.

Keywords: *Sliding wear, Plasma Nitriding, AISI 316 LN, Abrasive wear.*

1.Introduction

Stainless steels show outstanding corrosion resistance, which is lost during conventional hardening processes at temperatures above 500°C, like gas or plasma nitriding which improved the low hardness and reduced the high wear rate. The decrease of corrosion resistance is probably due to the formation of CrN precipitates and ε-nitrides in a γ'-nitride matrix [2]. Pulsed plasma nitriding of electroplated Cr on stainless steel substrates resulted in chromium nitride coating which is not brittle and the wear resistance was found to be higher than the chromium [3]. Plasma nitriding resulted in the best wear performance when compared with nitro carburizing in dry and lubricated sliding which is probably due to reduced layer fragility [4]. In plasma nitriding of SS 316 L, a nitrided layer consisting of 3-layered structure was formed on the sample nitrided at 510 and 540°C. The surface microhardness values and the thickness of the hardened layers increased as the nitriding temperature increased and thereby the wear resistance property also increased [5]. The plasma nitride treated 316LN SS rings exhibit excellent wear resistance against 316LN SS pin and Colmonoy pin at temperatures namely 25, 200 and 400°C [6].In tribological studies, the untreated 316 L experienced severe wear when compared to the nitrided steel, which was characterized by slight abrasion with shallow and narrow wear track [7]. In this study, the plasma nitrided (PN) SS 316L(N) steel was subjected to high vacuum wear testing at elevated temperatures and the worn surfaces are analysed by scanning electron microscope (SEM). The worn surface morphology was characterized.

2. Experimental Details

2.1 Chrome Nitriding of SS 316L (N)

Discs and pins of SS 316L (N) were subjected to chrome nitriding at 525°C and for 24 hours time duration. Optical microscopic images were taken to confirm the average depth of penetration of the plasma nitrided SS 316L(N) steel samples. Microhardness tests were carried out on the nitrided steel. XRD pattern was also taken for the plasma nitrided steel. Microhardness tests were carried out on the nitrided steel. XRD pattern was also taken for the plasma nitrided steel.

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2.2 Dry sliding wear test and SEM

Dry sliding wear tests were carried out in high temperature high vacuum pin on disk tribometer at 500°C in the untreated as well as plasma nitrided disk against the plasma nitrided pin. The tests were carried out with two different velocities namely 0.8 and 1.2 m/s. The worn surfaces were analysed by scanning electron microscope.

3. Results and Discussion

3.1 Optical Mircoscopy

Fig.1 shows the Optical microscopic image, which depicted the depth of penetration of the plasma nitriding carried out for 24 hours (~75µm). Wear resistance properties of austenitic stainless steels are enhanced by the formation of the S phase, also called expanded austenite. This phase is formed on the surfaces of austenitic stainless steels nitrided under certain conditions [6].

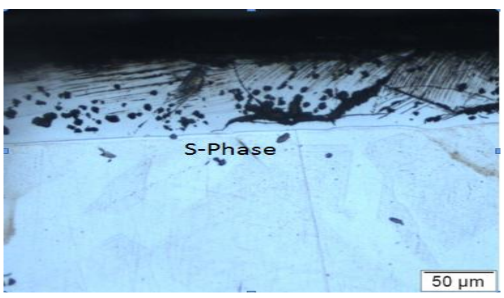

Fig.1 Optical Microscopy of PN SS 316 L(N)

3.2 Microhardness

The hardness profile shows a smooth rate of decline across the thickness since the profile approaches the substrate material SS316L(N). A peak value of 1250 HV was measured in the nitrided surface.

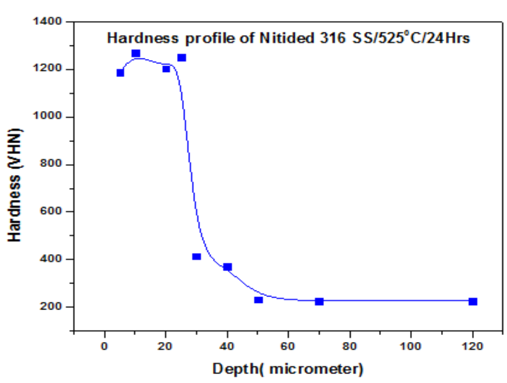

Fig. 2 Hardness profile of Nitrided SS 316L(N)

3.3 X-Ray Diffraction

Fig. 3 shows the XRD pattern of the plasma nitrided S316 L(N) elucidates the presence of prominent Iron nitride peaks in higher intensity.

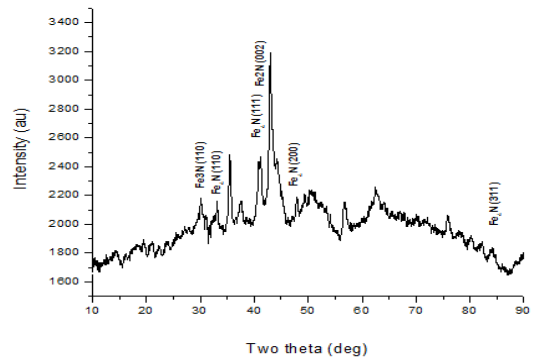

Fig.3 XRD pattern of PN SS 316 L(N)

3.4 SEM Analysis of Worn surfaces

After the wear test is carried out in two different velocities namely 0.8 and 1.2 m/s the worn surfaces were analysed by scanning electron microscope for the studying the morphological features of the Fig. 4a shows SEM image of the worn surface of the untreated SS316L(N). The worn surface is characterized by deep cleavage fracture and several layers were delaminated due to the predominant abrasive wear. The subsurface revealing of the worn surface depicts the higher amount of material loss during the sliding wear. Debris were found near the ploughed zone. Fig. 4b shows the SEM image of the worn surface of the plasma nitrided SS316 L(N) steel which was undergone dry sliding test with 0.8 m/s sliding velocity. The worn surface is characterized by less malignant sliding marks by the pin. The surface has resisted the plastic deformation without any decisive material loss. The wear resistance offered by the coating is well justified by the feature less areas with plain sliding marks with marginally lesser depth. Fig. 4c shows the SEM image of the worn surface of the plasma nitrided SS316 L(N) steel which was undergone dry sliding test with 1.2 m/s sliding velocity. The worn surfaces revealed exfoliation of layers and deep grooves when analysed by scanning electron microscope. Exfoliation is a prominent feature of damage and it is prevalently seen in this SEM image of worn surface. It is present due to the two reasons namely, the concentration of loads on the contact profile and the presence of residual expanding stresses on rubbing faces. The SEM picture clearly depicted the prevalence of the severe abrasive wear by the feature called plough marking and continuous lip formation along the sliding direction which is a characteristic feature of three body abrasion. Due to the higher operating temperature (500°C), the oxide layer formations are explicitly seen in the edges of the prows formed. From the work carried out it is inferred that the plasma nitrided (~75 µm) SS316 L(N) could withstand higher sliding velocity due to its poor wear resistance. It is further attributed to the cold welding of the debris formed and the built-up edges during the high temperature sliding wear experiments.

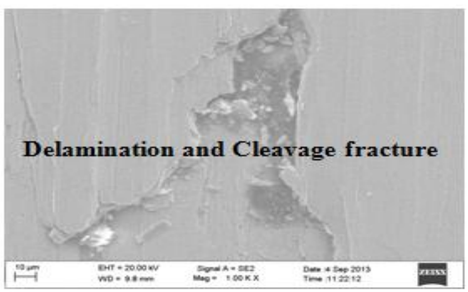

Fig.4a Worn surface of untreated SS 316L(N)

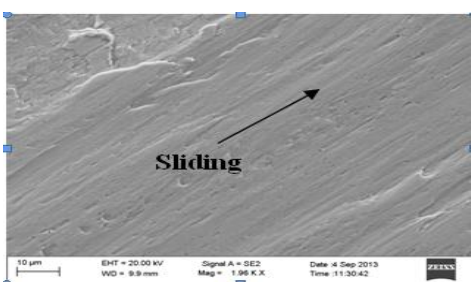

Fig. 4b Worn surface of nitrided SS 316L (N)

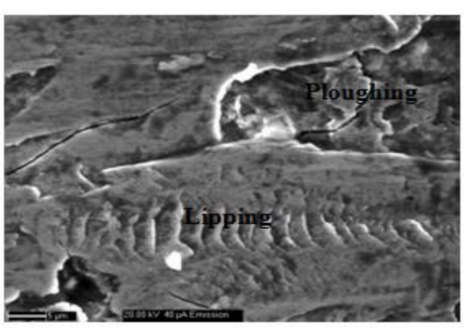

Fig.4c Worn surface of nitrided SS 316L(N)

4. Conclusions

The sliding wear tests were carried out at high temperatures using pin on disc apparatus and from the results the following conclusions were made:

- The plasma nitrided SS316L(N) showed convincing depth of penetration (~75µm) for a period of 24 hours and also possessed a higher hardness value of 1250 HV.
- Due to the subjection of higher sliding velocity of 1.2 m/s and higher temperature of 500°C, the plasma nitrided layer in the SS316L(N) steel failed due to the predominance of three body abrasive wear.
- Deep plough markings and lip formation again substantiate the decisive material loss during dry sliding wear at higher sliding velocity.

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