WEAR PROPERTIES OF PLASMA NITRIDED INCONEL 718 SUPERALLOY

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Abstract:

Inconel 718 is a nickel-based superalloy that is extensively used in a broad range of applications such as turbine blades, power generation, petroleum and nuclear reactor technology due to its good mechanical properties at intermediate and high temperatures. Contrast to its wide range of usage, high plasticity and good corrosion resistance, poor wear resistance of Inconel 718 limits its usage in some applications. In order to improve the wear resistance of Inconel 718 several surface treatment methods are used. One of the most important methods, that is used to prevent the metal from wear is to modify the surface with a nitride layer by plasma nitriding. In this study Inconel 718 super-alloy was plasma nitrided in different parameters and the wear mechanism of plasma nitrided Inconel 718 was investigated using a pin-on-disk wear tribotester. Microstructure and phase components of Inconel 718 were investigated using SEM and XRD before and after plasma nitriding process.

Keywords: Wear, Superalloy, Plasma nitriding, Inconel 718

Introduction:

Inconel 718 is a nickel-based superalloy that is extensively used in a broad range of applications such as turbine blades, power generation, petroleum and nuclear reactor technology due to its good mechanical properties at intermediate and high temperatures [1-3]. Although it has good corrosion and oxidation resistance, it is subjected to high wear levels where materials are slide one part to another and wear of alloy can cause the failure [4]. In the literature, there are different studies which examine the wear characteristics of treated and untreated Inconel 718 [1, 4, 5].

Plasma nitriding is a thermochemical surface treatment method, which bases on the nitrogen diffusion into the material surface in a plasma environment, used to enhance the wear, corrosion resistance and fatigue properties of ferrous and non-ferrous materials [1, 6-9] and the wear resistance of a nitrided material depends on the hardened layer formed on the surface after nitriding [10]. The aim of this study is to determine the effect of different nitriding times and temperatures on wear mechanisms and structural properties of Inconel 718 and to find out the best nitriding condition. For this aim, Inconel 718 substrates have been nitrided at different parameters and the treated samples have been investigated by pin-on-disk wear test, SEM, XRD and microhardness test.

Material and Method:

Inconel 718 alloy substrates chemical composition is tabulated in Table 1 [11] were used for plasma nitriding. Before the nitriding process, the specimens, whose dimensions are 15x11 mm^2 and with a thickness of 1 mm, were polished by using SiC emery paper with 1200-mesh grit and an alumina having 3µm grain size, respectively. After cleaning with alcohol, the specimens were placed into the plasma nitriding chamber and specimens were cleaned from surface contaminations by hydrogen sputtering for 15 minutes under a voltage of 500V and a pressure of $5x10^2$Pa. Then, the plasma nitriding processes were performed with DC voltage under a pressure of $5x10^2$ Pa.

Table 1. Chemical composition of Inconel 718 (% weight, max.)

C	Mn	Si	Cr	Co	Mo	Nb+Ta	Ti	Al	Fe	Cu	Ni
0.08	0.35	0.35	21.0	1.00	3.30	5.50	1.15	0.80	Balance	0.30	55.00

The specimens were nitrided at 400°C, 500°C and 600°C with times 1 and 4 hours (In this article, the specimens were coded as nitriding temperature-time like 400-1). After nitriding processes, X-ray analyses were performed by Rigaku diffractometer at 30 kV and 30mA with CuKa radiation. The hardness values of treated and untreated specimens were measured by using a STRUERS ODURAMIN 5 microhardness tester with a load of 10 g and a loading time of 10 second with Vickers method. The wear tests were performed by using Turkyus pin-on-disk tester under a load of 5N at 3000 seconds and a distance of 150 m. The wear tests were performed by using WC pin with a diameter of 6 mm. The diameter of wear tracks was measured as 8 mm for all specimens. After wear tests, the worn surfaces were examined by ZEISS EVO SEM. In order to calculate wear rate, the wear profiles and surface roughness values were recorded using Mahr M1 profilometer and then, the wear rates were calculated by using the equation of W=V/(DF)-mm^3/N.m [10].

Results and Discussion:

XRD patterns of untreated and nitrided Inconel 718 were shown in Fig. 1. When the XRD patterns were examined, untreated specimen showed Inconel peaks. After the nitriding processes, the reaction of Cr and nitrogen was given rise to the formation of CrN. In the meantime, the substrate peaks were shown in all nitrided specimens because of the thin nitride layer. CrN peaks were obtained at angles of 38 and 64 and this result is accordance with the another study [5].

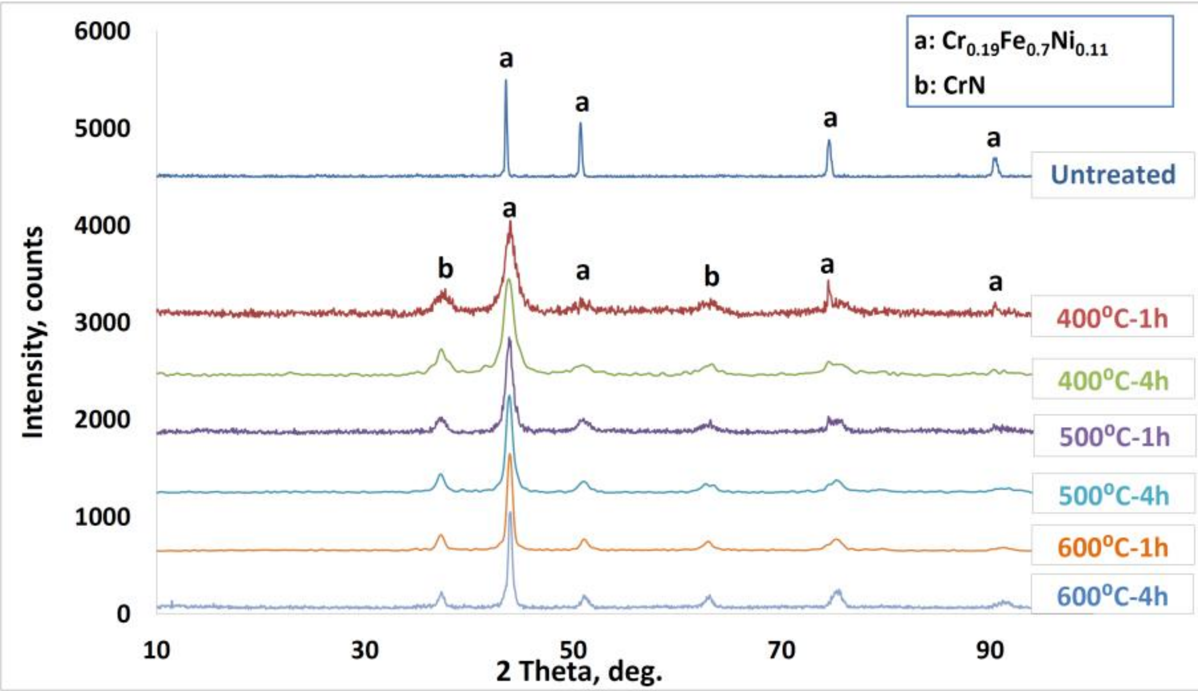

Fig. 1. XRD patterns of specimens

The microhardness and wear rate values were shown in Fig. 2. The hardness of untreated specimen was measured approximately as 500 $HV_{0.01}$. The increase of nitriding time and temperature provided 2-5 times hardening. The maximum hardness was obtained from specimen 600-4, roughly 2600 $HV_{0.01}$, among the nitrided specimens. Also, it was inspected that the increase of hardness was depends on the increment of process time and temperature. When the wear rates were investigated (Fig. 2.), it was observed that the maximum wear rate was obtained from the untreated specimen and the increase of nitriding time and temperature causes to the decrease of wear rates. There was an inverse proportionality between hardness and wear rate and the minimum wear rate was obtained from 600-4.

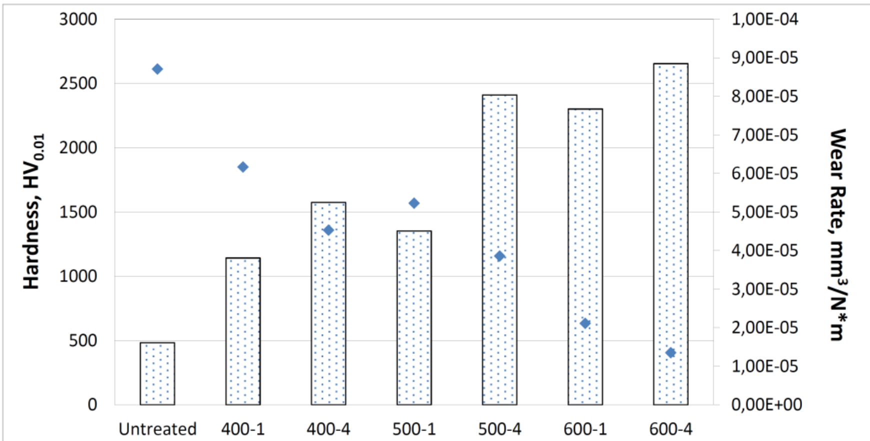

Fig. 2. Microhardness values of untreated and nitrided specimens

The surface roughness values are tabulated in Table 2 and as shown in table; it was found that the roughness values increased with the increase of nitriding time and temperature. The reason of the increase at the surface roughness was the effect on increasing ion bombardment. The specimens were more exposured to the ion bombardment at high temperatures and times.

Table 2. Roughness values at different nitriding conditions

Nitriding Parameters	Surface Roughness, µm
Untreated	0.030-0.035
400-1	0.050-0.550
500-1	0.062-0.065
600-1	0.086-0.900
400-4	0.122-0.126
500-4	0.134-0.139
600-4	0.175-0.178

The friction test results were shown in Fig. 3 and 4. When the figures were examined, it was found that the friction coefficients reduced correspondingly with the increase of hardness after the nitriding processes and the lowest friction coefficient was obtained from 600-4, which has the highest surface hardness. Depending on the increase of surface hardness, the contact area was decreased and this has provided the obtaining the lower friction coefficients in comparison to the untreated specimen. As shown in figures, the friction coefficients have the waviness form. The reason of that was the breakage and detachment of hard nitride layer from the surface during the sliding and this case caused the abrasive effect on the wear behavior. Also, this case was supported with the wear images.

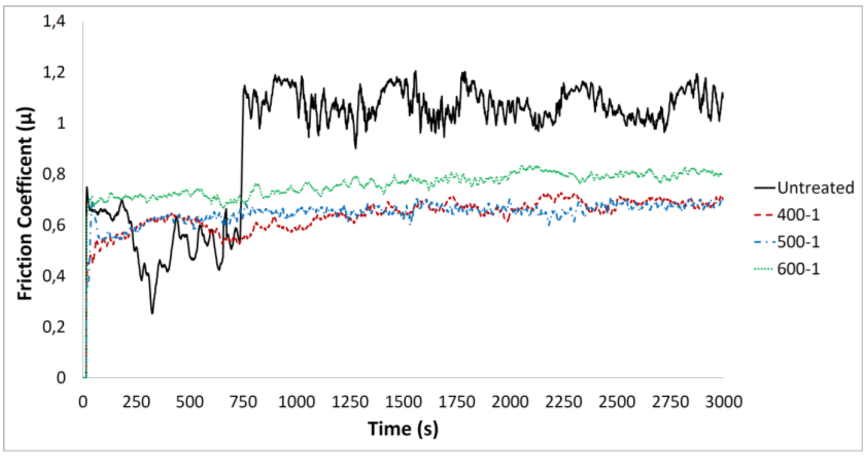

Fig. 3. The change of friction coefficient versus time at 1 h and different temperatures

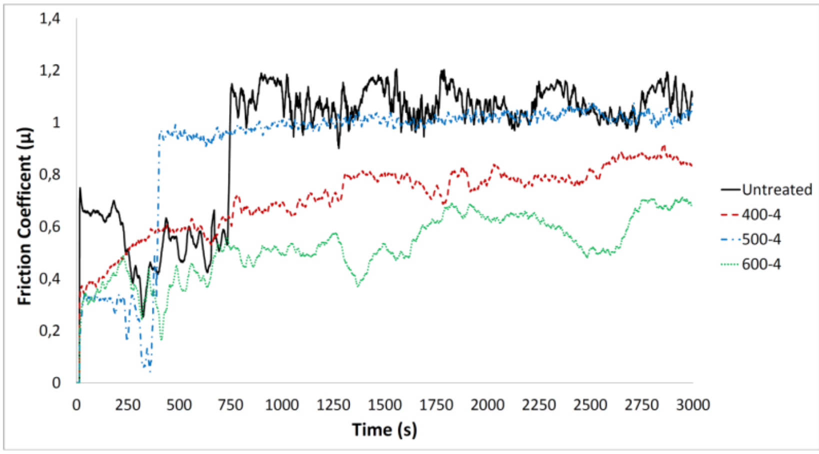

Fig. 4. The change of friction coefficient versus time at 4 h and different temperatures

The SEM images after the wear test were shown in Fig. 5 and 6. When the SEM images were investigated, it was observed that the untreated specimen was subjected to severe wear (Fig. 5-a). However, the increase of nitriding temperature and time caused the decrease of wear tracks. The lowest wear track width was obtained from 600-4, which has the highest hardness. When the SEM images were examined, it was found that the nitriding process significantly increased the wear resistance.

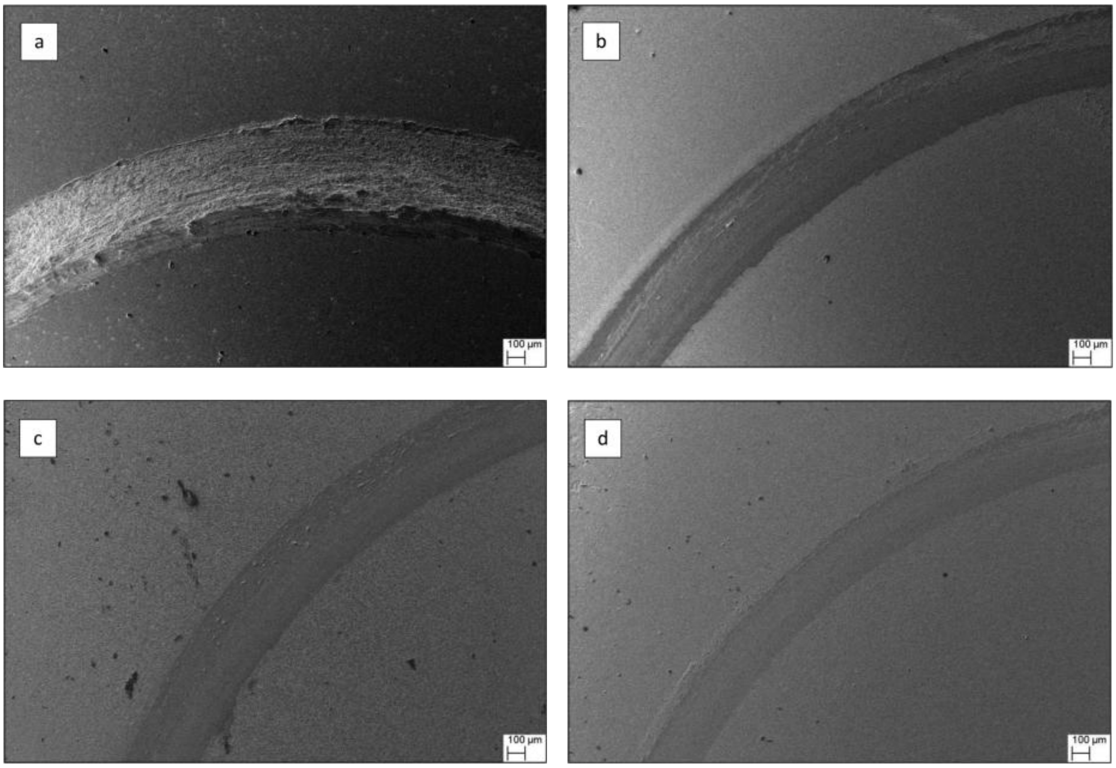

Fig. 5. SEM images obtained from different nitriding conditions; untreated specimen (a), 400-4 (b), 500-4 (c), 600-4 (d)

The cracks, which were occurred after the wear tests, at the nitride layer were clearly seen in Fig. 6. Also, it was found that the cracks occurred 400-4 and 500-4 were less than the 600-4 because of that the hardness and thickness of nitride layer for 600-4 were higher than the others. The detachment or crack wasn't observed at 600-4 and this case reveals that the optimum condition for selected nitriding parameters was 600-4 in terms of tribological investigations.

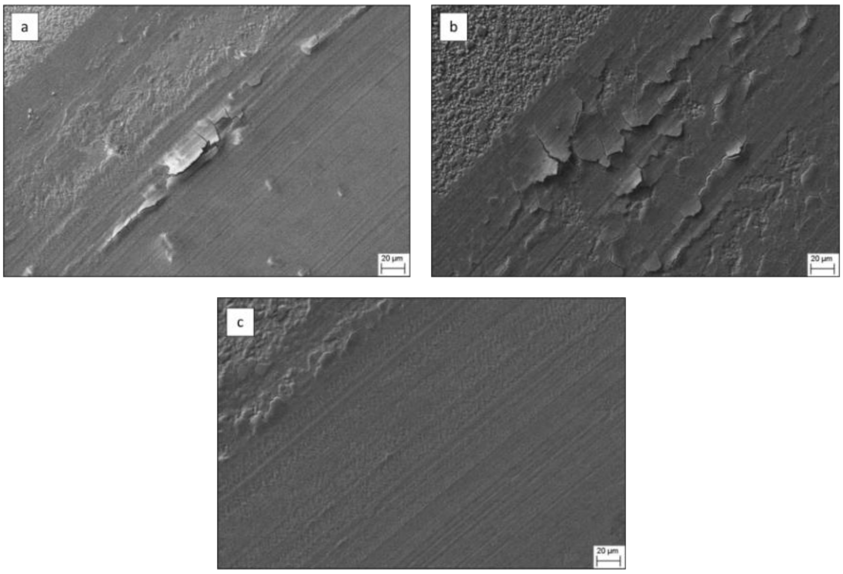

Fig. 6. Detailed SEM images obtained from different nitriding conditions; 400-4 (a), 500-4 (b), 600-4 (c)

Conclusions:

In this study, Inconel 718 was nitrided at various nitriding parameters and the nitride layer composed from CrN was formed on the surface. The nitrided specimens were investigated as structural and tribological. In consequence of these investigations, the obtained results were listed as bellows:

- ✓ It was observed that the increase of hardness was depending on the increment of process time and temperature. The maximum hardness was obtained from the specimen 600-4.
- ✓ The surface roughness increased with the increment of the nitriding time and temperature.
- ✓ The plasma nitriding process considerably reduced friction coefficient. The friction coefficients were improved with the increasse of the nitriding time and temperature.

As a result, it was found that the optimum condition for selected nitriding parameters was 600-4 in terms of tribological investigations.

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