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Effects of Salt Bath Nitriding Process on AISI 309 Stainless Steel

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Abstract. AISI309 stainless steel is a type of austenitic stainless steel that contains a high percentage of chromium and nickel, along with a small amount of manganese. It is designed to be used in high-temperature applications, such as in furnace parts and heat exchangers. Low temperature salt bath nitriding process was carried out on AISI 309 stainless steel at 550°C for time duration of 80,160 and 240 minutes. The characteristics of the nitride surface were thoroughly assessed. The microstructure and phase components of the nitrided surface revealed a hardened layer of chromium nitride and iron nitride on the specimen surface. The case depth and the surface hardness were strongly influenced by the alloying components. To analyze the wear, a pin on disc machine was utilized and the wear test was carried out. From the wear test, wear loss were determined. Scanning electron microscopy revealed the variation between loss of material and the base material. A specimen which is untreated is kept aside and comparisons of results were done with nitrided samples.

1 Introduction

Stainless steel (SS) is attractive because of its aesthetic appearance and strong resistance to corrosion. The high levels of chromium and nickel provide excellent corrosion resistance, even in high-temperature environments. Additionally, AISI 309 stainless steel has good resistance to oxidation, and can maintain its strength and ductility at high temperatures. The application includes machinery parts, chemical industries, coal, and oil industries sectors

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[1-4]. The major disadvantage is that AISI 309 stainless steels possess poor tribological properties due to its low hardness. Austenitic stainless steels' surface mechanical and tribological properties can be enhanced by applying and using plasma or thermal-chemical surface hardening processes such as nitro-carburizing, carburizing, carbo-nitriding or cyaniding process [5-8].

The industrial technique of salt bath nitriding was created specifically to change the surfaces of steels made of iron. Global issues have been resolved by this method, which can also be utilized to effectively strengthen stainless and higher metal alloys [9-12]. High fatigue resistance combined with superior wear and corrosion resistance may be accomplished using an environmentally friendly technique. In reality, the procedure of salt bath is very simple, inexpensive, ease of use, cheap cost, energy economy, and stability [13-16]. As the content of nitrogen is present in the molten salt environment, the alloying elements plays a major role and a high hardened surface comprised with iron-nitride and chromium nitride were formed. The conventional salt bath nitriding processes were carried out at 650 °C and Chromium nitrides were precipitated on the surface [17-20].

In order to harden the surface of stainless steel, gas and plasma nitriding procedures are ineffective and the duration of process is long [21-25]. Various defects were identified because of diffusion of ammonia gas. Whereas by immersing the specimens into salt bath, the defects were minimized. Under sophisticated salt bath nitriding, the impacts of the nitriding on microstructure and the changes in phases were interpreted. One of the oldest and least expensive ways to change a material's properties is to apply salt bath fast treatments to the material's surface. Many characterization techniques were been utilized to analyze the composition of materials [26-29].

2 Experimental Procedure

2.1 Material Composition

AISI 309 stainless steel samples were taken for this research work and the composition was analyzed as follows Chromium (Cr) 23%, Nickel (Ni) 14%, Carbon (C) 0.20%, Manganese (Mn) 2%, phosphorous (P) 0.045%,sulphur (S) 0.030%, silicon (Si) 1% and Remaining (Fe) iron as shown in Fig.1.

Fig.1. AISI 309 Untreated Sample

2.2 Hardness and Wear Analysis

AISI 309 samples for the following dimensions were sliced to a length of 40 mm, 8 mm diameter. The specimen's edges were "U"-shaped sharpened with the aid of a lathe machine as shown in Fig.1. The samples went through the salt-bath nitriding procedure for 80 minutes, 160 minutes and 240 minutes respectively. The procedure of salt bath nitriding involves by immersing the work piece in a liquid salt solution comprised of sodium and potassium nitrate. The samples were heated to 550°C throughout the treatment process in a vacuum environment [30-34]. The samples were ultrasonically polished prior to experimentation and the surface hardness was measured. The hardness of austenitic stainless steel AISI 309 was evaluated and it was found to be 291 Hv. The hardness for nitrided samples for the duration of 80 minutes, 160 minutes and 240 minutes were measured and found to be 312 Hv, 328 Hv and 339 Hv respectively [34-36].

The wear test for a pin-on-disc device developed by Saini Scientific Industries, model SSITOM-012. A disc with dimension of 150 mm diameter, 10 mm thickness was treated to saturated limit of salt bath nitridng process and pin material with 8mm diameter, 40 mm length were utilized for the wear test. A load of 20N, speed of 800 rpm, and duration of 2 minutes were applied selected for pin on disc wear test. During the wear test, the wear loss was monitored by measuring the difference between the initial weight and final weight after the wear test.

3. Results and Discussion

The surface morphology of treated and untreated specimens was captured by scanning electron microscope model S-3700N, Hitachi make. The material peel off was clearly apparent on the surface of the untreated specimen.

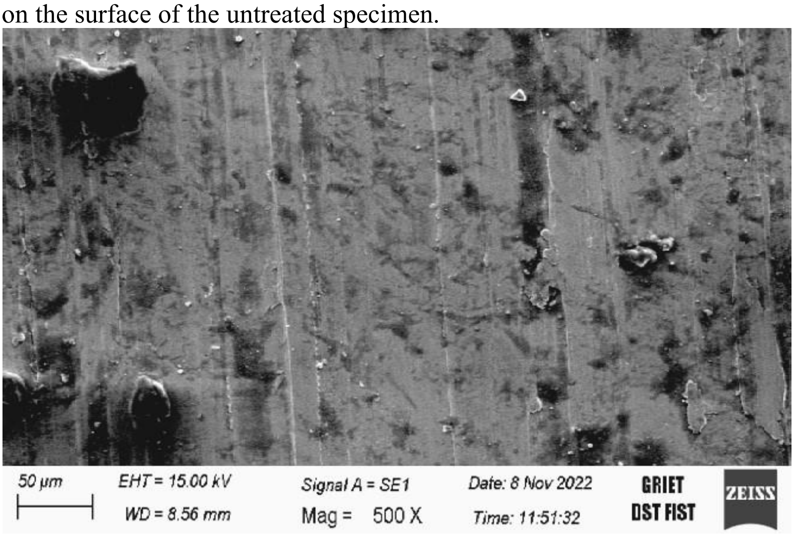

Fig.2. Microstructure of Untreated SS 309

The observations suggest the presence of surface fracture and material peels were noticed in Fig.2. As there is no case depth in untreated sample, the hardness of the material is poor and due to high ductility, several defects like cracks and microholes were observed on the surface. Tiny scratches and etching pits were noted in the compound layer and it was due to the load acting upon the untreated specimen. During the wear test, the untreated

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specimen lost a large amount of material. Wear loss was determined to be substantial because the grain structure was discovered to be of coarse structure.

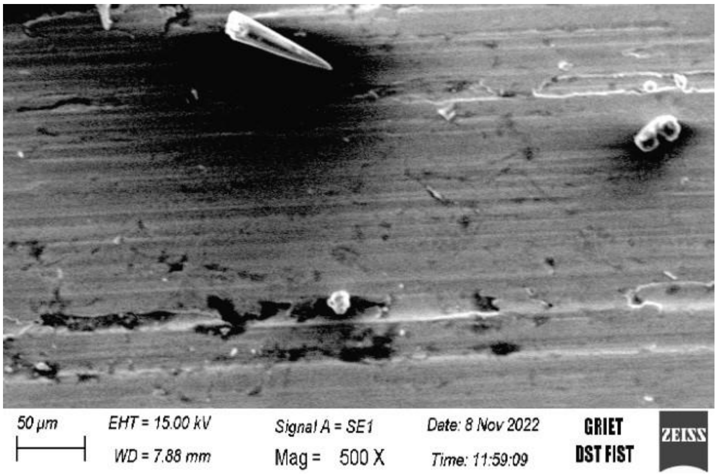

Fig.3. Microstructure of sample nitride at 80 Minutes

Fig.3 depicts the surface morphology of sample treated to 80 minutes had both carbon and nitrogen dissolution in a coarse-grained structure. Iron nitrides were noticed in the bonding zone, where nitrogen is diffused with alloying elements creating a hardened layer. Chromium nitride later provided good resistance to wear and the phase of the material changed from austenite to expanded austenite. The grain structure was slightly minimized and this is due to less duration of treatment time. Iron nitride development has an impact towards the little quantity of nitrogen diffused in the bonding zone. The case depth was found to be as 14 microns, thereby, the substrate's resistance to wear increases.

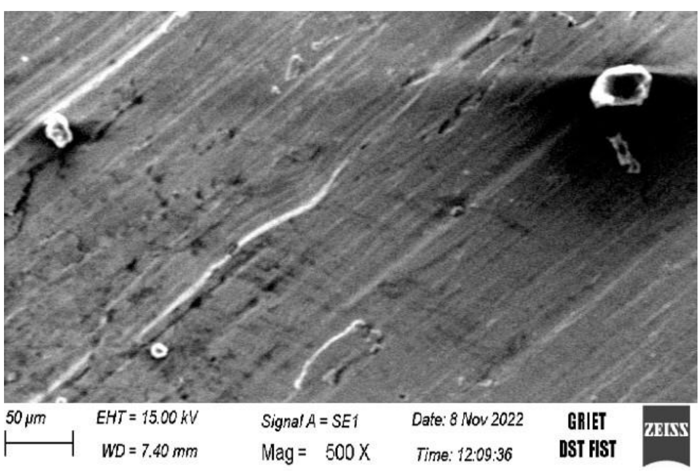

Fig.4. Microstructure of sample nitrided at 160 Minutes

Fig.4 revealed that a highly hardened surface had developed on the specimen's surface, protecting the metal from abrasive wear. The grain structure was confined as the treatment time of nitriding increases. The surface fracture, cracks, holes were minimized and the case depth was 19 microns. The phase change continued to expanded austenite confining the grain size.

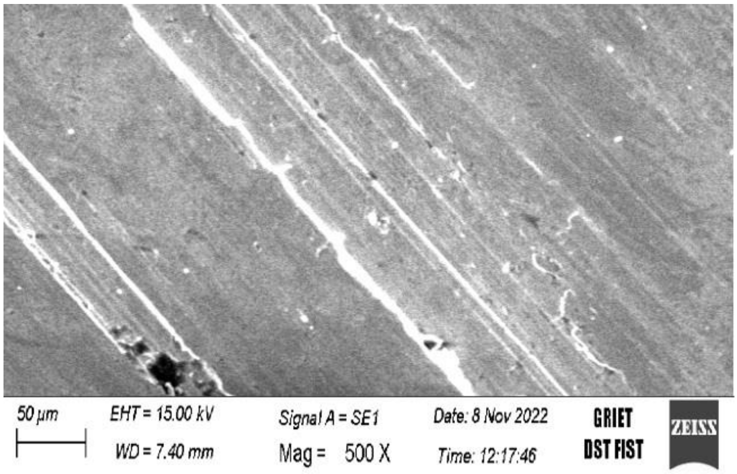

Fig.5. Microstructure of sample nitrided at 240 Minutes

Fig.5 revealed, the specimen treated to 240 minutes and the solid layer made up of the nitrogen, iron and carbon with the combination of alloying elements were deposited on the surface. Comparison with other treated specimens; it was found that there were fewer material peels and cracks. Wear loss decreased throughout the wear test as treatment time increased. The case dept were found to be as 30 microns and high level of nitrogen, carbon atom were diffused which results in excellent wear resistance. The layer made of carbon and nitrogen had a strong concentration, offering exceptional wear resistance. This exhibited a fine grain structure compared to other treated and untreated specimen.

4 Conclusion

Investigations have been made on austenitic stainless steel that has been nitrided at 550 °C for various durations. Very few researchers have made salt bath nitriding on AISI 309 stainless steel. The following are the conclusions made from this research work:

1. On the surface, modified layers with a thickness of up to 30 microns were obtained. Moreover, the case depths increased as the time of nitriding were increased.

2. According to electron scanning microscopy AISI 309 stainless steel that had been treated to salt bath, the expanded austenite comprised with Chromium nitride precipitated phase were obtained. The surface hardness of the specimen was increased.

3. As the wear loss is reduced, the case's depth improves from 14 microns to 30 microns. The sample treated to 240 minutes offered a significant improvement in case depth and wears resistance over the other nitrided samples and had better durability. The expanded austenite content had the highest hardness, provides excellent wear resistance.

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