Dry Sliding Wear Behavior of AISI310 Stainless Steel with Low Temperature Salt Bath Nitriding and Gas Nitriding Processes

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Abstract*: *AISI 310 is an austenitic stainless steel that accomplished in high thermal applications like turbines, boiler parts etc. In this study AISI310 was treated with salt bath nit--riding for 60min, 120min and 150min and gas nitriding for 6hrs, 12hrs and 18hrs at the temperature of 570^{0}c respectively. Comparison study of nitrided specimens were performed under various metallographic tests like scanning electron microscope, X-ray Diffraction, pin on disc apparatus. Experimental results shown that when salt bath nitrided sample at 150min showed a white layer called "S-phase" layer which was detected. In gas nitriding also "S-phase" layer, an expanded austenite was observed, after 18 hrs, CrN phase was discovered after the decomposition of s-phase layer gas nitrided sample of 18hrs which showed the best corrosion resistance .Salt bath specimen 150 min showed minimum wear loss and gas nitrided sample of 18hrs showed more hardness, minimum wear and improved corrosion resistance compared to untreated sample.

Keywords: Wear Resistance, salt bath nitriding, gas nitriding, pin on disc, Scanning Electron Microscope (SEM).

I. INTRODUCTION

The majority of stainless steel studies and development remains to produce fresh thoughts for enhancing mechanical characteristics. Advancement of austenitic hardened steels with improved properties had turned out to be wide spread in 1980s. These materials are generally utilized utilizations of low temperature innovation, for example, sustenance handling gear, atomic reactors, sea innovation, petrochemical preparing and so on. Be that as it may, the use of this material superficially is seriously constrained by exceptionally poor wear conduct. A few surface medicines are accessible for improving the tribological execution, yet these are frequently of mind-boggling expense.The latter is the case with conventional gas, plasma and salt bath nitriding. At that point the expansion of nitrogen to these steels was made to improve the wear obstruction. Of the different surface solidifying strategies accessible, nitriding, as a low temperature treatment, offers the advantages of high dimensional dependabilityTempered steels are present day materials. As far back as they wound up accessible to ventures, their utilization has always stretched out into new applications. This procedure proceeds even today. To utilize the treated steels, in structure applications, it is important to know theproperties, their abilities with respect to erosion obstruction, the accessibility of item structures and surface completions tempered steels are being utilized for both consumption and the warmth opposing applications. Hardened steel is the conventional name for various steels utilized fundamentally for their protection from consumption. Stainless steel is definitely not a solitary material however the name for a group of consumption opposition steel. In metallurgy, tempered steel (inox) is characterized as a ferrous compound with at least 11% chromium content. The name starts from the way that stainless steel does not recolor, consume or rust as effectively as common steel. This material is likewise called erosion safe steel when it isn't gritty precisely to its composite sort and grade, especially in the flight.Grade AISI310 is a austenitic stainless steel which is used in high thermal applications like boiler parts, turbines.etc. It can withstand at high temperatures also. It also possesses excellent corrosion resistance. Because of their poor wear resistance and low hardness their usage is found to be an effective process in improving wear resistance and hardness. in engineering field applications. In order to improve their wear resistance and hardness, nitriding process. Salt bath nitriding process is the most common processes used nowadays in industries. The present study is about the wear behavior of salt bath specimens under various metallographic tests like scanning electron microscope, X-Ray Diffraction, Pin on Disc apparatus.

Table 1: Chemical Composition of AISI310 stainless steel

C% Max.	Mn% Max.	S% Max.	P% Max.	Si% Max.	Ni % Max.	Cr %Max	Fe %Max
0.06	1.56	0.023	0.03	0.4	19	24	Bal

Jun wang,yuan hua lin et.al (2017)[12] performed salt bath nitriding on AISI 321 steel at low temperature 430 c. Experimental findings indicated that a altered coating with a density varying from 3 µm to 32 µm with altering treatment period was created on the ground of the substratum after water pit nitriding. Scanning electron microscopy and X-ray diffraction indicates that in 321 stainless steel nitridized at such temperatures for less than 8 hours under

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complicated salt immersion.*Runbo huang, jun wang et.al (2013) [1] has* performed Surface alteration of 2205 duplex treated steel by low salt nitrocarburizing at 430 °C. Efficiently assessed the microstructure, hardness of the surface, and protection from disintegration erosion. At 430°C, salt nitrocarburizing can frame a nitrocarburized layer, and the thickness of the layer increments with delayed treatment time. Just expanded austenite (S phase) was made by nitrocarburizing inside 8 hours. With expanded treatment time, CrN slowly diffused before nitrocarburizing from the spots where ferrite grains were available in the layer. Likewise, with the nitrocarburized time, the profundity expanded and the layer developed roughly as per the allegorical rate law. Nitrocarburizing in the salt tub can effectively upgrade the 2205 DSS ground hardness.Xingwei wang, Zhongyu Liu (2019) [4] examined the rough obstruction of316L treated steel by gas nitriding. AISI 316 austenitic hardened steel tests were treated for a solitary extended austenite layer (S-stage) utilizing vaporous nitriding at low temperature (430 ° C). Both optical microscopy and X-beam diffraction characterized the authoritative stages. Small scale hardness and dry-sliding wear conduct were analyzed through electron microscopy filtering, microanalysis electron test, the wear of the AISI 316 steel substratum was extreme and portrayed by solid bond, scraped area and spallation, while the wear of the S-stage layer was gentle and slight scraped spot overwhelmed. What's more, the consumption qualities were investigated in 3.5NaCl option through potential powerful polarization tests. The discoveries demonstrate that the S-stage coats were produced with improved wear opposition and consumption obstruction at little nitrided temperature

II. EXPERIMENTAL PROCEDURE

The material used is grade AISI310 stainless steel and its chemical composition is shown in Table.1. Polished cylindrical pins were chosen and the dimensions were 40mm length and 12mm diameter. Before experiment, the specimens were ultrasonically polished. Three cylindrical pins were used and the samples was kept to 570^0c, dipped in a salt bath for 60 minutes, 120minutes and 150 minutes respectively. And for gas nitriding three samples are nitrided by passing ammonia gas for 6hrs,12 hrs and 18 hrs of soaking time. A Pin on Disc apparatus was accomplished for the wear test, shown in figure 2.2. With the disc rotated at 500 rpm, a load of 30N is applied for 5 minutes under the dry sliding conditions. Wear test readings were monitored. The weight loss is determined by monitoring the difference between, the test before wear and test after wear. Hence wear loss is determined. Microscopic observations are made using scanning electron microscope shown in fig.2.1.

Fig 2.1 Scanning Electron Microscope

III. RESULTS AND DISCUSSIONS

The microstructure of AISI310 obtained by the salt bath treatment is shown in figure 3.1(a, b, c, d).The etchant used was mild nitric acid solution. The nitrided modified layer is seen under higher magnification SEM. The modified nitrided layer was composed of α-ferrite and austenite for both 60 minutes and 120 minutes sample. After prolonging to 150 minutes, the sample of 150 minutes showed the expanded austenite phase(S-Phase) which showed better corrosion resistance than the other samples. For gas nitriding as shown in fig3.1 (d,e,f) S-phase appeared and late it decomposed to CrN when nitrided for 18 hrs. It was noted that, more peel of material were obtained from untreated AISI310 stainless steel material and less peel of material from treated stainless steel material.

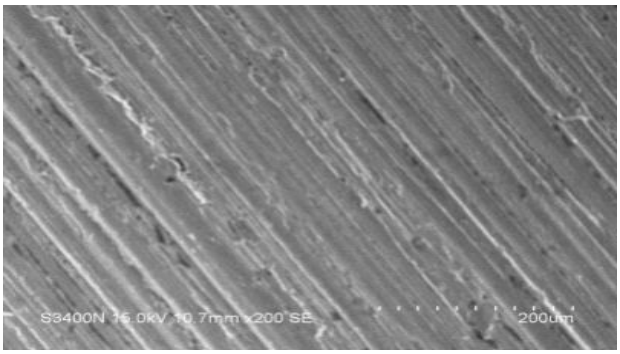

Fig.3.1 (a) Untreated Specimen of AISI 310 SS

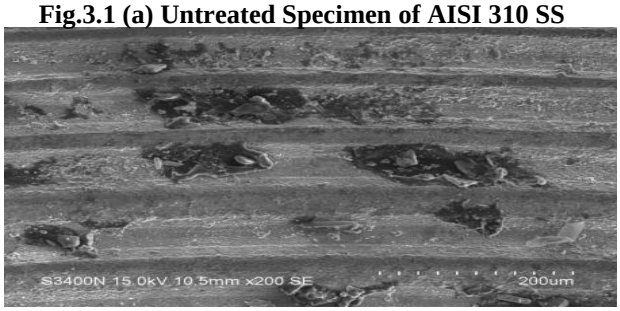

Fig.4.1 (b) Salt bath nitrided done at 60 min

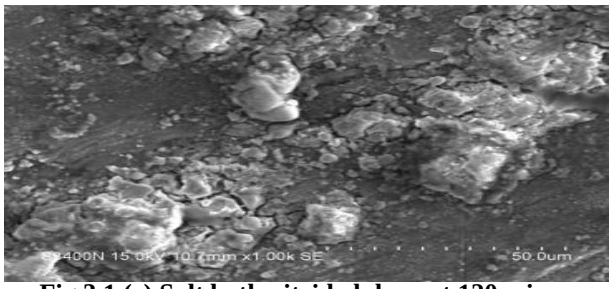

Fig.3.1 (c) Salt bath nitrided done at 120 min

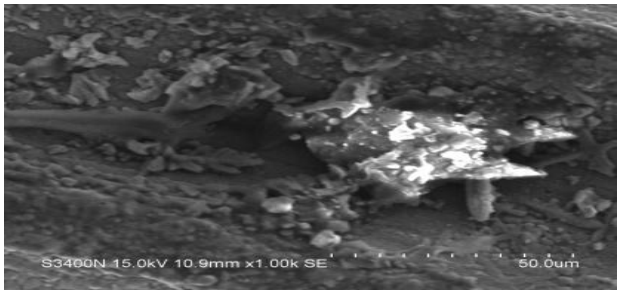

Fig.3.1 (d) Salt bath nitrided done at 150 min

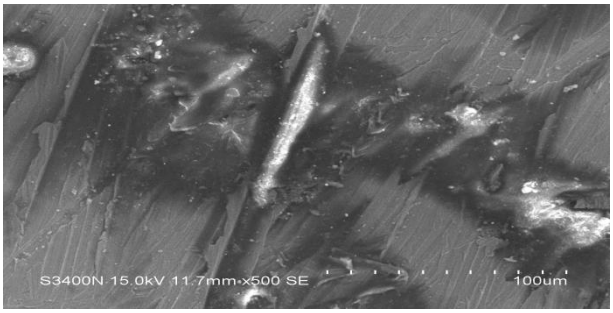

Fig.3.1 (e) Gas nitrided done for 6 hours

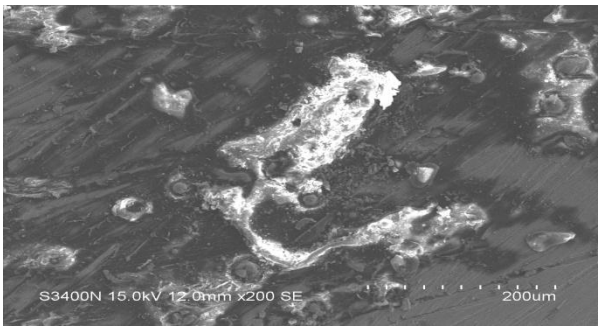

Fig.3.1 (e) Gas nitrided done for 12 hours

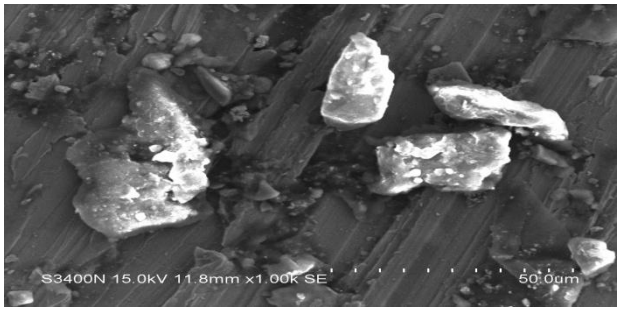

Fig.3.1 (f) Gas nitrided done for 18 hours

4.Hardness Behavior

The hardness for the untreated sample was found to be 26 HRC and there were no case depth found. The hardness for the salt bath nitriding sample subjected to 60 minutes was found to be 46 HRC and the case depth was found to 18µm. The hardness for the salt bath nitrided sample subjected to 120 minutes was found to be 58HRC and the case depth was found to be 22µm.The hardness for the salt bath nitrided sample subjected to 150 minutes was found to be 72 HRC and the case depth was found to be 28µm.For gas nitriding sample subjected to 6 hours hardness found to be 75HRC and the case depth found to be 46µm. For gas nitriding sample subjected to 12 hours hardness found to be 78HRC and the case depth found to be 52µm. For gas nitriding sample subjected to 18 hours hardness found to be 82HRC and the case depth found to be 58µm.

5.Wear Behavior

Wear loss was found by using pin on disc apparatus under the dry sliding conditions by applying the load of 30N, speed at 500 rpm the sliding distance of 80mm. Volume Wear loss was found to be minimum in salt bath nitriding subjected to 150 minutes because of the nitride precipitates in the ferrite matrix which makes the specimen more hard so that the wear loss is minimum, compared to salt bath nitrided 60 minutes and 120 minutes specimens.

For untreated specimen volume wear loss was very high due to the material softness. The wear loss for the untreated specimen was found to be as 0.5 grams and the volume wear loss was found to be as 6.25 mm^3. The wear loss for the salt bath specimen1 was found to be as 0.27 grams and the volume wear loss was found to be as 3.375 mm^3. The wear loss for the salt bath specimen2 was found to be as 0.23 grams and the volume wear loss was found to be as 2.87 mm^3. The wear loss for the salt bath specimen3 was found to be as 0.14 grams and the volume wear loss was found to be as 1.75 mm^3.

The wear loss for the gas nitrided specimen1 was found to be as 0.12 grams and the volume wear loss was found to be as 1.7 mm^3. The wear loss for the gas nitrided specimen2 was found to be as 0.9 grams and the volume wear loss was found to be as 1.4 mm^3. The wear loss for the gas nitrided specimen3 was found to be as 0.4 grams and the volume wear loss was found to be as 1.23 mm^3. Among all specimens gas nitrided sample 3 exhibits minimum wear loss.

VI. CONCLUSION

AISI 310 Stainless steel were subjected to salt bath and gas nitriding at low temperature 570^0c.The following conclusions are drawn.

1. From microstructure analysis, it was found that a white layer obtained called S-phase an expanded austenite. After further nitriding it was decomposed to CrN phase, which was very hard layer consists of ferrite and nitride mixtures.
2. The minimum wear loss was observed as 0.4 grams and the volume wear loss was found to be as 1.23 mm^3 in gas nitrided sample3 compared to all specimens.
3. The hardness for the salt bath nitrided sample subjected to 150 minutes was found to be 72 HRC and the case depth was found to be 28µm .For gas nitriding sample subjected to 18 hours hardness found to be 82HRC and the case depth found to be 58µm which was the highest compared to salt bath and untreated specimens.

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