Assessment of Properties on AISI430 Ferritic Stainless Steel by Nitriding process

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Abstract. AISI 430 Ferritic Stainless Steel is well known for its good corrosion resistance applicable for high resistance to pitting and stresses. But it lacks in its wear resistance and hardness in order to improve the mechanical properties of AISI 430 Ferritic Stainless-Steel materials Nitriding Heat Treatment is chosen in this project. The samples are taken in the form of cylindrical shapes with diameter 10mm and length 40mm respectively. The specimen is subjected 4 numbers being the highest treated to saturated limit. One specimen is kept as untreated for comparison purpose. Wear test will be carried out under constant speed and with variable load by pin on disk wear testing apparatus. Finally, all the specimens are subjected to various metallographic tests like SEM (Scanning Electron Microscope) and EDAX (X-ray Despresive Analysis) or XRD (X-ray Diffraction) and the results are compared.

1 Introduction

The best and a cheap process for enhancing the properties of metals or their alloys is Heat Treatment or treatment of metals through thermal process. This is a process usually happens on various materials by keeping them at a same temperature over a period of time which depends on the type, thickness and the output required out of the process and this helps in changing the internal microstructures and which is followed by changing the mechanical or physical properties of the alloys. By improving the structure of the crystals and their alignment, we can improve the properties. This can also be done to stainless steels to improve their hardness along with ductility, durability and machinability and even other mechanical properties. [1-6]

There are various heat treatment processes in the market but Nitriding process is the most used process as it is the cheapest and extensively improves wear resistance, corrosion resistance, hardness and other mechanical properties through surface treatment. There are different nitriding processes available like salt bath nitriding, plasma nitriding, gas, laser, and so on. Nitriding process is generally carried at high temperatures like near to 773°C for a longer span of time which is equal to 20-80 hours. This is sufficient to alter and enhance the mechanical properties of the material. [7-12]

Stainless steel is a composite whose significant segment consists of Iron along with Carbon in the range of 0.02-1.7 % which varies according to grade as well. It is also known that at least 10.5-11 % Chromium is present. Not only these, but normal Ferritic Stainless Steels contains some amounts of Mo, Al, Si, Ti and Nb too. Due to this, it is referred as Consumption safe steel and preferred in flight business programs. They depict larger protection from oxidizing agents in atmosphere just as martensitic steels do. They show magnetic behavior along with formability when they are impression forged at lower temperature by becoming fragile. These steels are to be welded in the form of slim segments to ensure no loss of grain development in microstructure which may end up with properties diminishment when thicker segments are employed. [13-16]

2 Experimental procedure

Table 1. Chemical Composition

Metals	Composition (%)
Chromium (Cr)	16-18%
Nickel (Ni)	0.19%
Carbon (C)	0.048%
Manganese (Mn)	1.0%
Phosphorous (P)	0.025%
Sulphur (S)	0.3%
Silicon (Si)	0.31%

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Iron (Fe)	Remaining%

All the experiments are performed in a Salt bath nitriding furnace maintained at 650°C constant temperature by varying time of experimentation for detailed comparison purpose. For performing the heat treatment operation on AISI 430 Ferritic stainless samples, four specimens of 40mm length and 10mm diameter are cut and surface finished from long stainless-steel rod. These samples are subjected to turning to get bullet shape so that the tip of specimens would completely touch the pin on disc during wear test, which would generate better wear on specimen surface for SEM and XRD analysis. After setting up the furnace to required conditions, the Ammonia salts are introduced into container. This salt solution is allowed to dissolve completely in furnace so that no scale formation takes place on the walls. The AISI 430 specimens are tightly held together in a cage and placed in Salt bath furnace. As the temperature constantly increases, the specimens are allowed to develop a nitrided layer. Now, the experimentation timing is varied accordingly for all four samples by taking out sample from furnace after every 45minutes. Therefore, the time of heat treatment is varied by 45minutes, 90minutes and 150minutes accordingly for three specimens while one is left untreated for comparing SEM and Wear test results. The main objective of developing a case depth of nitrogen is achieved which varies between samples due to time variation. The longest treated specimen develops a large case depth while the least treated specimen develops smaller case depth. After completing heat treatment process, the specimens are prepared for wear test on pin on disc apparatus. The sample is held in the pin position by fixtures with help of suitable mechanical tightening tools. The diameter of disc is 110mm which is made up of high-speed stainless-steel material. The speed of rotation is set to 600rpm and a load of 10N is applied constantly on disc by pin. When apparatus is switched on, the pin is allowed to make contact with disc vertically such that the specimen tip entirely touches it. The elastic pivoted arm enables to vary the pin position on disc by moving in three-dimensional plane. The disc is rotated for a time period of two minutes for all specimens. First the untreated specimen is subjected to wear test, subsequently the remaining specimens i.e., 45min treated specimen, 90min treated specimen and 150min treated specimen are subjected to wear test on pin on disc equipment. A graph is plotted between applied frictional force(N), Wear generated(mm) and time(s) for all the samples during the experiment. The maximum wear developed in specimen is depicted in graph along with track diameter and load applied. Further, the SEM analysis is done on the samples before and after wear test to compare the mechanical properties, microstructure and case depth developed.

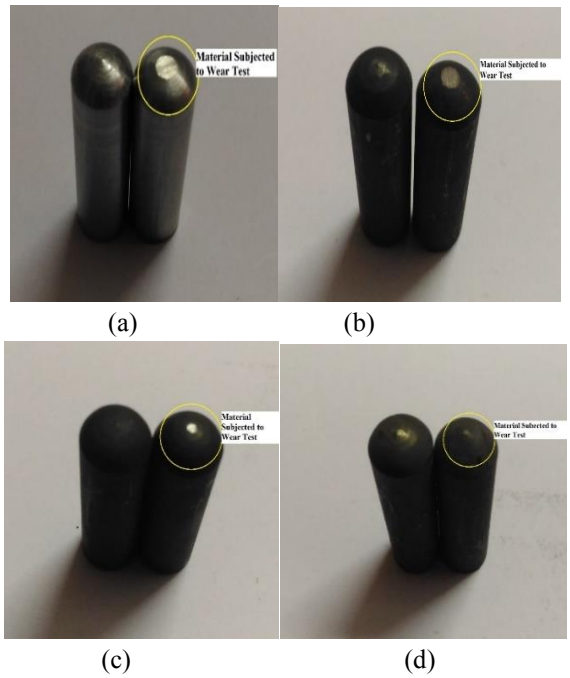
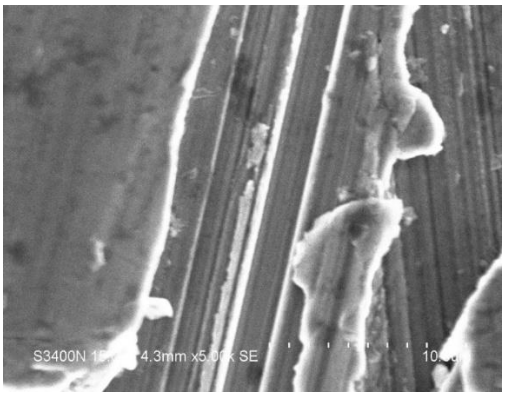


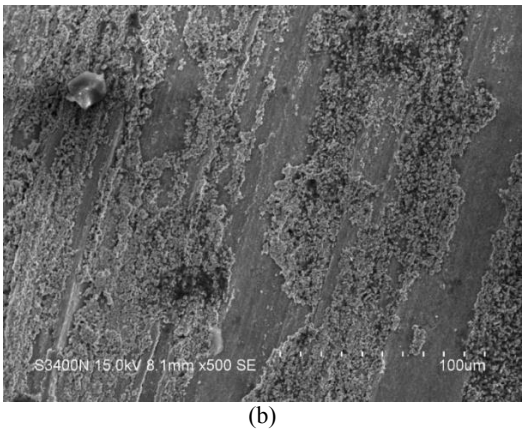
Fig. 1. (a) Untreated Sample (b) 45 Minutes Nitrited Sample (c) 90 Minutes Nitrided Sample (d) 120 Minutes Nitrided Sample

3 Results and discussions

AISI 430 material has undergone the microstructural analysis which was completed for getting information about surface morphology. SEM analysis is used for the specimen which was tested after and before the nitriding surface treatment process. In Untreated material, there will be only base metal austenitic phase. More wear is occurred with so much of peel off material because of poor hardness and poor strength.

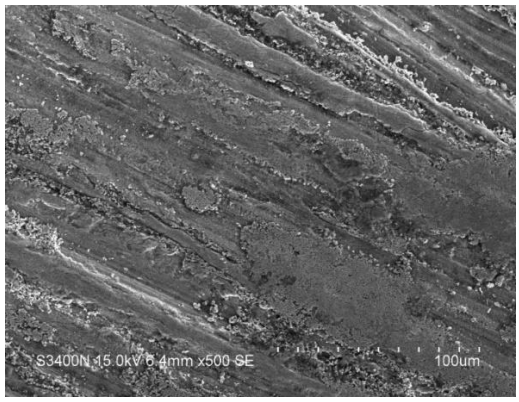


(a)

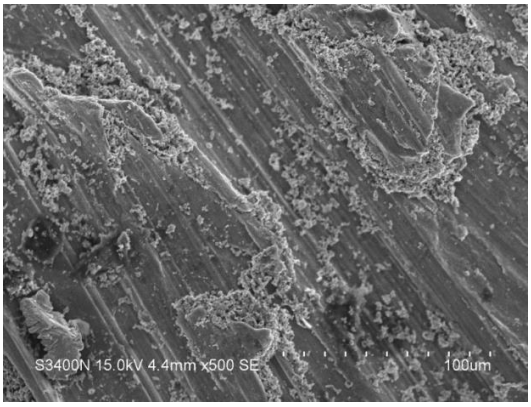


(b)

Apart from the base metal and the austenitic phase, chromium nitride layer is added because of the Nitriding process. The smoothness is increased by increasing the time of the nitriding process and can be seen in the pictures below. The chips or powder formed during the wear testing of the surface treated samples is very less when compared to the untreated sample. The more the nitrided time, the less is the powder formation during the wear testing process.



(c)



(d)

Fig. 2. Microstructure of (a) Untreated Sample (b) 45 minutes Nitrided Sample (c) 90 minutes Nitrided Sample(d) 120 minutes Nitrided Sample

When compared to all other sample SEM pictures, the peel off material was smoothened in the last picture and the smoothness have been increased gradually from untreated sample to 120minutes nitrided sample.

3 Conclusion

In this work, wear behavior of AISI 430 grade stainless steel was experimented under nitrided and normal conditions. From this experiment, we can prove that as the time of nitriding increases from 45-120 minutes, the case depth increases with decrease in wear loss. The 120 minutes treated sample has more wear resistance and higher case depth compared to other two nitrided samples. However, the untreated samples give a comparative study of mechanical properties with the nitrided samples. The life or durability of final treated specimen is improved. From electron microscope results, third specimen shows maximum hardness that is case depth. As compared to Untreated specimen, third specimen has high wear resistance along with increase in durability.We can observe from the wear test on pin on disc apparatus that the wear resistance has been improved from 17.375 cm^3 for untreated sample to 13 cm^3 for 45 minutes nitrided sample, 0.125 cm^3 for 90 minutes nitrided sample to 0.05 cm^3 for 120 minutes nitrided sample.

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