Effect of Nitrogen on Low Temperature Nitrided Stainless Steels for Steam Turbine Blades

Ram.Subbiah, P.Karthick, R.Ilavarasan, T.Prasanth, R.Manjunath, R.Rajavel

Abstract: In the last few years, an increasing interest has been taken in AISI 300 series austenitic stainless steels for use in industrial applications. In these steels nickel is partly replaced by other austenite stabilizing elements like manganese, chromium, nitrogen. However, their chromium content is usually lower than that of largely used Fe-Cr-Ni based other grade of stainless steels, so that their corrosion resistance may be lower. For these AISI 300 series of stainless steels, low temperature nitriding treatments have been successfully employed to increase the corrosion resistance, due to the formation of modified surface layers consisting of chromium-nickel layers. In this research, a low nickel AISI 316LN austenitic stainless steels was subjected to gas nitriding treatments in the range of 450-5500C. The applications was found to be in steam turbine blades. The specimens were characterized by optical microscope results and scanning microscope results. The treatments produce modified surface layers having a double layer structure. When the treatments are carried out at these temperatures, the outer layer was modified by iron chromium nitrides, and their amount increases as the treatment time goes higher.

Keywords: Gas Nitriding, steam turbine blades, chromium-Nickel, scanning electron microscope.

I. INTRODUCTION

Nitriding is a thermochemical treatment used to improve wear, fatigue and sometimes corrosion resistance of materials. Generally a modified layer on the top and a diffusion layer beneath it forms after nitridng treatment. These layers exhibit different hardness, phase structure and wear behaviors in terms of the applied process parameters. When 316LN stainless steel is nitrided, a single modified layer forms on the surface but the diffusion layer cannot be found under the surface. On the other hand, both modified and diffusion layers have different effect on mechanical and tribological properties of the material.

Modified layer improves the wear resistance while the diffusion layer increases the load bearing capacity and the fatigue strength. Delay of the fatigue crack initiation of the nitride materials is widely investigated by different research groups. Common opinion for the fatigue behavior of many nitrided materials is that modified layers has no effect on the fatigue life. The application falls behind on steam turbine blades. When high pressurized steam from the boiler, hits the blades of steam turbine, which is made up of an untreated austenitic stainless steel material, the water vapour gets deposited as it starts corroded slowly.

At the same time, adhesive wear occurred by sudden impact also affects the life of the material. In order to improve the wear resistance, corrosion resistance and life of the material, it is been undergone gas nitrided process.

The wear resistance of a nitrided material depends on the modified layer formed on the surface after nitriding. In this study, it has been aimed to get detailed information about wear behaviors of the layers on the surface of 316 LN stainlesssteel. This surface heat treatment method is usually employed at temperature of about 550^{0}C to the components made of low alloy steels composed of Cr, Al, Ni, Mo to cause strengthening effect by the formation of alloy nitrides in nitrogen diffusion zone.

Austenitic stainless steel is Fe-Cr-Ni based alloys with chromium composition from 16-20% and nickel with 8%. This is the most widely used among the stainless steel grades due to its good ductility and weldability during fabrication along with its inherent corrosion resistance in acid solutions. This type of stainless steels is widely used in chemical and oil gas industries as components for eample: heat exchangers, piping and tanks or containers. However, this material has poor tribological properties due to inherent austenitic structure and low hardness. Earlier attempts on nitriding on this material which aims to improving its surface hardness and thus enlarging a possible wider application resulted in appreciable loss of its corrosion resistance.

These lead to development of the low temperature nitriding process, which is carried out at temperatures less than 500^{0}C. At such low processing temperatures, it was found that the nitriding layer is free from chromium nitride precipitation, and is super saturated with nitrogen in solid solution. Such a layer is expanded in austenite phase. Alternatively the strengthening effect will be replaced by super saturation of the interstitial nitrogen species in austenite matrix which leads to the hardening of surface region. This precipitation free nitrogen layer not only exhibits high hardness but also possesses good corrosion resistance due to the availability of retaining chromium in solid solution for corrosion protection.

II. EXPERIMENTAL PROCEDURE:

The material used in this study was AISI 316LN austenitic stainless steel material with the chemical composition shown in table 1. Samples were cut from hot rolled bars of 10 mm diameter to 30 mm length.

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The disc diameter was found to be 80mm with 10 mm thickness. The ammonia gas was constantly throwed at a pressure of 66.6Pa. The timing parameters of the specimen nitrided were 8 hrs, 40 hrs and 72 hours respectively. In the same chamber, the samples were nitrided at different oxidation temperature of 400, 450 and 500^0C. Tribological properties of samples were evaluated using a pin on disc machine. During the test, the 316LN disc which was nitrided to a saturated limit, were evaluated using a pin on disc machine, which was rotated against a stationery aisi 316ln pin. With 4.5mm hemispherical tip radius at a speed of 1200 rpm. The sliding distance were 1000m and all the tests were conducted in air and without lubrication. The applied loads were 10 kg and the friction force was monitored continuously by means of a force transducer.

Composition of AISI 316LN stainless steel in %

Fe	C	Mo	Ni	Cr	S	P	Mn	Si
Balance	0.03	2	11	18	0.01	0.03	1.35	0.45

After the tribological tests, the wear track were characterized by scanning electron microscopy of the surface and the cross section.

III. RESULTS AND DISCUSSIONS

3.1 Microstructural Characterization

The optical and SEM micrographs from cross section of gas nitrided sample for 8 hrs at 400^0C, 40 hrs at 450^0C, 72 hrs at 500^0C. The nitrided layer was found to be 14, 26 and 41 microns. This microstructure is known to be related to the formation of a homogenous nitrogen super saturated phase.

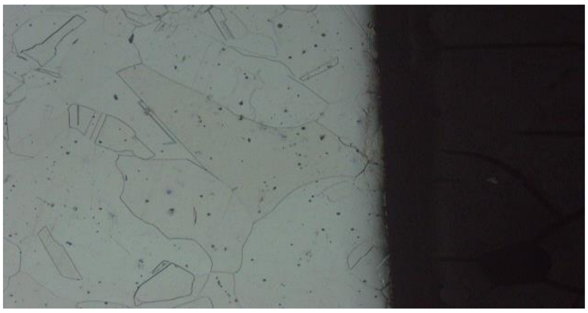

Fig 3.1 – Optical Microscope Image for Untreated

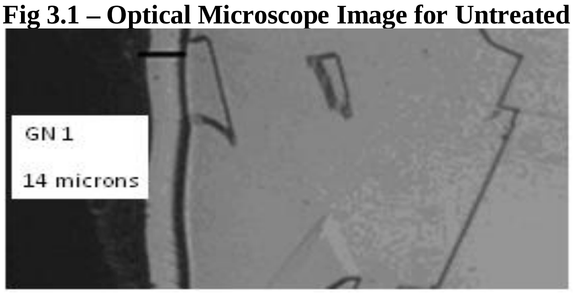

Fig 3.2 – Optical Microscope Image for GN 1

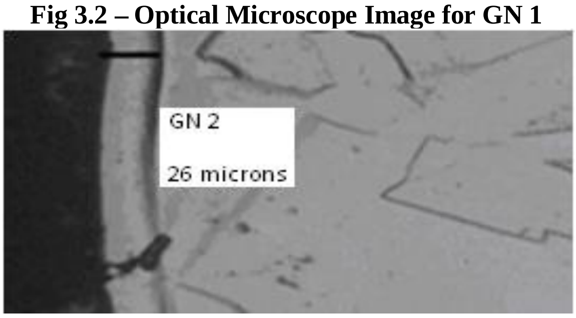

Fig 3.3 – Optical Microscope Image for GN 2

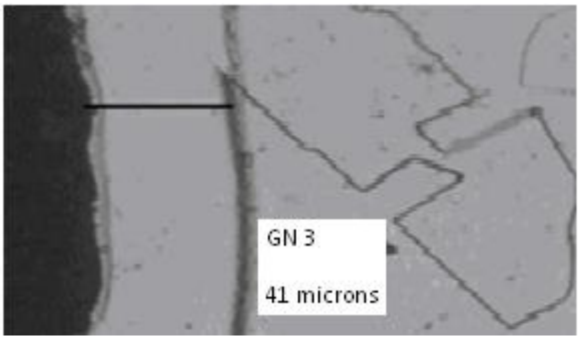

Fig 3.4 – Optical Microscope Image for GN 3

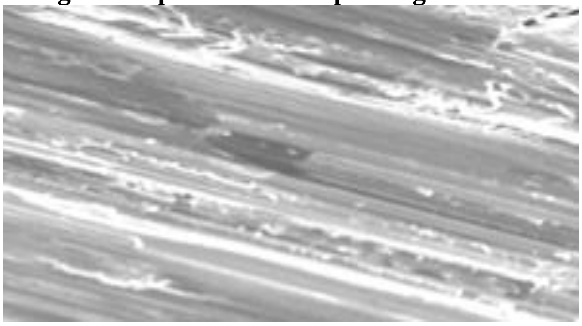

Fig 3.5 – SEM Image for Untreated Specimen

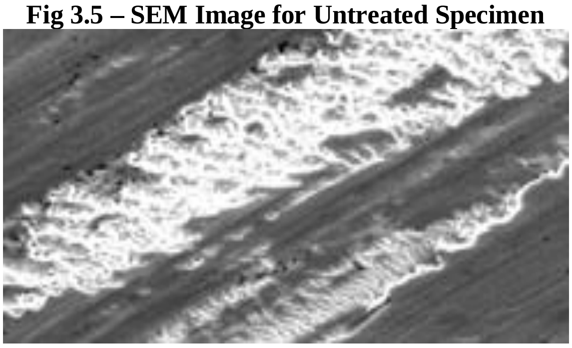

Fig 3.6 – SEM Image for GN 1 Specimen

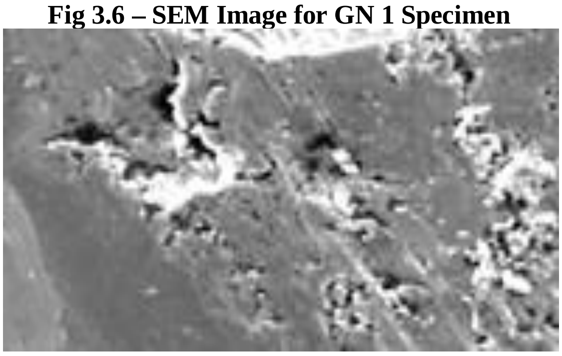

Fig 3.7 – SEM Image for GN 2 Specimen

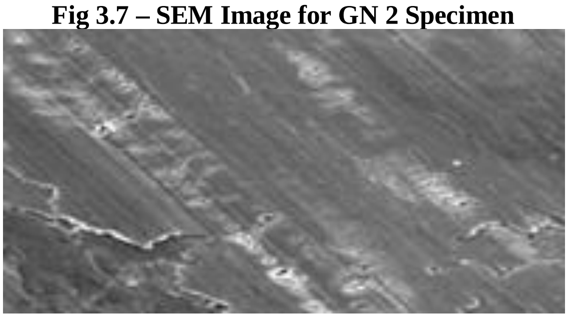

Fig 3.8 – SEM Image for GN 3 Specimen

From the above figure, it was incurred that there was no case depth found in an untreated specimen Fig 3.1. From the figure 3.2, 3.3, 3.4

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it was found that case depth occurred in the specimen with 14 microns, 26 microns and 41 microns respectively. From figure 3.5, scanning electron microscope image, it was found that peel of material is very high as of in the case of fig 3.6, fig 3.7, fig 3.8, the peel of material rate starts to decrease. In GN 3, the wear rate of the material tends to be very low, as it improves the wear resistance.

3.2 Surface Hardness

Surface micro hardness were measured using vickers hardness machine which was carried out in a Vickers hardness machine using a diamond indentor. The load applied was 25 kg and a loading time of 20 seconds. The hardness of the untreated sample was found to be 330 H_v. The nitrided samples were undergone hardness tests and the hardness was found to be 1110 H_v, 1180 H_v, 1269 H_v respectively.

IV. CONCLUSIONS

Gas nitriding at 500^{0}C with the gaseous mixture of ammonia and hydrogen leads to the formation of S-phase as the nitride layer. Nitrided samples show excellent resistance to scuffing. The load to failure in the wear test increases with the increase in compound layer thickness achieved in austenitic nitrided treatments. The compound layer thickness can be increased by increasing the nitriding temperature treatment. When compared to untreated specimen, the specimen which is nitride to 72 Hrs, provides a better wear resistance and improves the life of the material.

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