International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-3, Issue-1, March 2014

Effect of Nitrogen on Stainless Steel Material at Low Temperature Salt Bath Solution Applicable to Ship Propeller Blades

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Abstract: ***Energetic nitrogen implantation into 316LN stainless steels or nickel-chromium alloys leads to the formation of a very hard and wear resistant surface layer with an expanded lattice. Austenitic stainless steels can be hardened at temperatures around 450-5500C using energetic nitrogen into ion implantation while retaining the corrosion resistance. The expanded austenite is characterized by a concentration dependent diffusion coefficient, strongly increasing at higher nitrogen concentrations.***

A comparison of the phase formation under identical process conditions at 4500C were nitrided and investigated at different time parameters. Low temperature salt bath nitriding of austenitic stainless steels can produce a specified nitrided layer with high hardness and good corrosion resistance. In this study, various austenitic stainless steel specimens were low temperature salt bath nitrided. As the application goes behind the ship propeller blades, these blades are always under salt waters. Due to this, these blades get corrode easily and loss its life in a very short period of time.

In order to improve the corrosion resistance and wear resistance of these blades, salt bath nitriding is done on the blades and the effect of nitrogen on the specimens were investigated by various analyzing techniques using an optical microscope, scanning electron microscope analysis. Wear test were carried out by a pin on disc machine. The thickness of the nitrided layers increased with an increase in the process temperature, and the thickness of the layer formed on AISI 316LN steel is thickest in all substrate steels. The wear resistance of every stainless steel was obviously improved by nitriding treatment.

Keywords: Liquid Nitriding, Ship Propeller Blades, Scanning Electron Microscope.

I. INTRODUCTION

Austenitic stainless steels, well known for its good corrosion resistance, have not been used for industrial components exposed to severe friction because of low hardness and poor friction and wear properties. A salt bath surface treatment has been used widely for various industrial applications for many years. However the technology is able to be applied in mass production in manufacturing of large ship propeller blades. Salt bath nitriding is a thermo chemical treatment which involves the diffusion addition of nitrogen to the surface of ferrous metals. Usually carried out at temperatures within the ferrite phase field of the Fe-Cr-Ni below 450^0C. The treatment involves the resistance to scuffing through the development of a compound layer at the surface consisting of nitrided layer. The treated components also exhibit the enhanced fatigue properties on account of the diffusion zone where nitrogen is held in solid solution beneath the compound layer. Research works were carried out in a low temperature, non polluting salt bath treatments which are superior to traditional treatments. The accelerated salt bath treatment consists of nitrogen accelerated salts containing high amount of nitrogen.

Chosen for this research work on the basis of their wide application and commercial availability, salt bath nitriding is chosen for improving the wear resistance of stainless steel material which was exhibited in ship propeller blades. By virtue of their operating mechanisms, salt bath nitriding does not require prior treatment for removal of passive oxide film. Nitriding of ferrous alloys involves the temperature dependent interaction of substitutional solutes with interstitial nitrogen.

Revised Manuscript Received on 30 March 2014.

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II. EXPERIMENT PROCEDURE

2.1 Specimen Preparation

The stainless steels examined were prepared in the following forms. Polished cylindrical specimens measuring 10mm diameter, 20 mm long were used for metallographic examination. Specimens for wear testing machine were produced in accordance with the falex pin on disc machine.

2.2 Treatments

A disc material of austenitic stainless steel which was nitrided to the saturated limit and three pin specimens were nitrided to various time parameters. Prior to all treatments, specimens were cleaned ultrasonically, rinsed and dried, with care taken to avoid further finger contact. Before nitriding, the specimens were additionally sand blasted and just prior to treatment, pickled in 10% sulphuric acid for 10 minutes. The specimens were preheated to 450^0C, immersed in a salt bath for 60 minutes, 80 minutes and 100 minutes respectively.

2.3 Wear testing

Using a standard falex machine, with the test pin rotating at 800 rpm, a constant load of 15 kg was applied for a period of 2.5 minutes under dry conditions. The wear rate was calculated by determining the weight loss or if the specimen seized, the time to seizure was recorded.

III. RESULTS

Microscopy study showed the surface layers produced after nitriding stainless steel to be different from those observed on other nitride stainless steel materials. Three distinct layers were found clearly on the AISI316LN grade stainless steel material. The first layers was found to be austenite together with FCC austenite phase, the second layer was found to be austenite, ferrite and chromium nitride and the third layer was found to be FCC structure corresponding to the austenite.

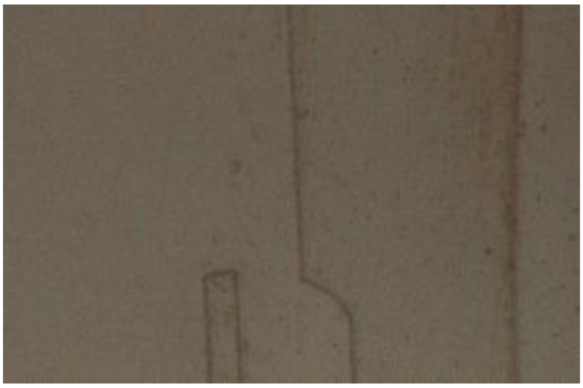

Fig 3.1 Optical Microscope with No Case Depth

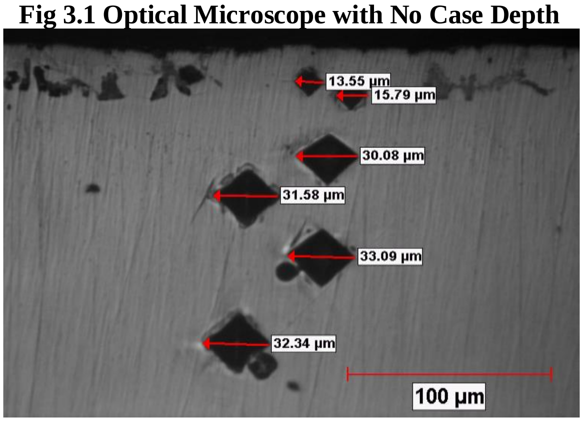

Fig 3.2 Optical Microscope Results with 32.3 µm

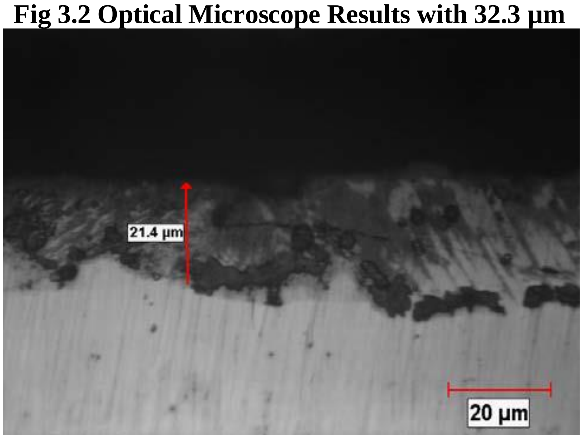

Fig 3.3 Optical Microscope Results with 21.4 µm

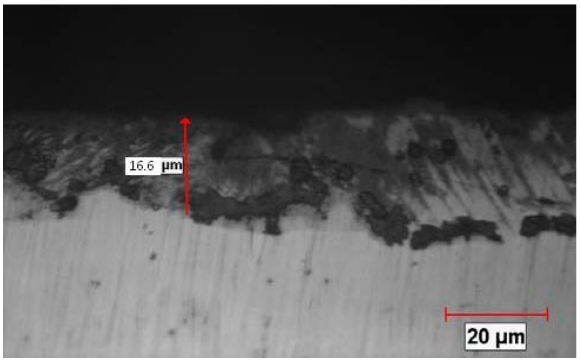

Fig 3.4 Optical Microscope Results with 16.6 µm

From the Fig 3.1, the diagram shows that no case depth was found in an untreated specimen. The specimens which was nitride to 100, 80 and 60 minutes exhibited case depth which was found to be 32 µm, 21 µm and 16 µm respectively.

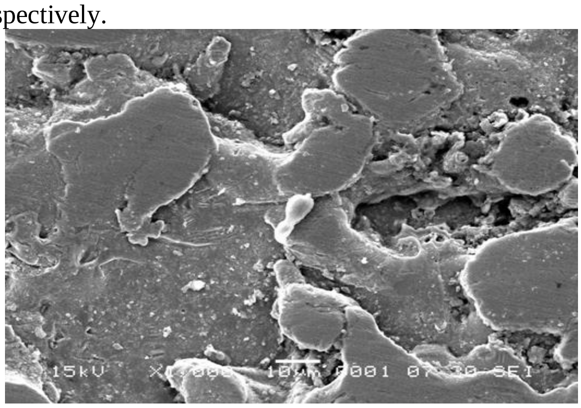

Fig 3.5 SEM Image for Untreated Specimen

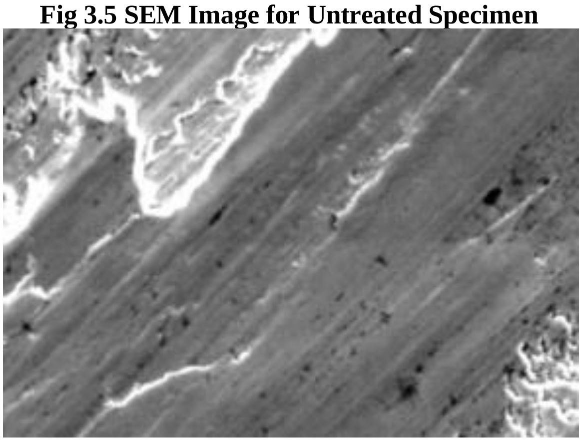

Fig 3.6 SEM for treated Specimen – 100 min

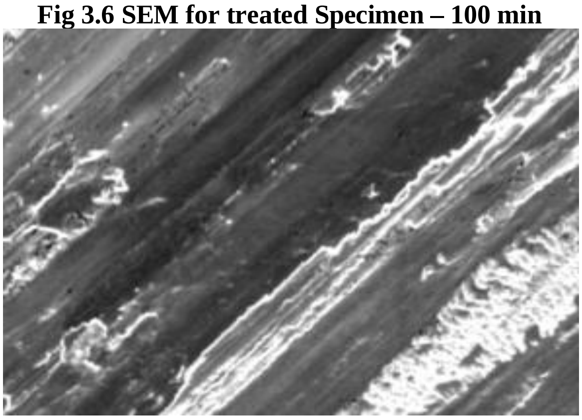

Fig 3.7 SEM for treated Specimen – 80 min

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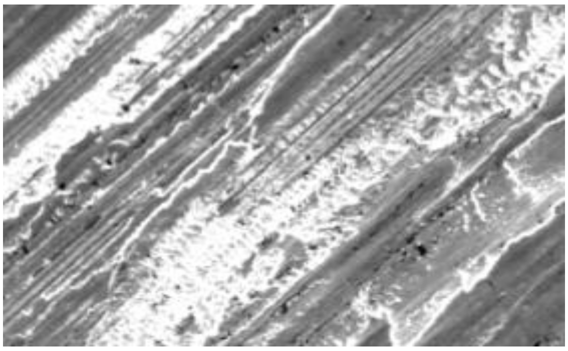

Fig 3.8 SEM for treated Specimen – 60 min

From the scanning electron microscope results, it was found to be wear in untreated specimen was found to be high. The peels of material in an untreated specimen were obtained in large grams and the wear loss is also high. As the nitriding time increases, wear decreases. The peel of material gets reduced as per the nitriding treatment time increases. It could be seen in the fig 3.6, low peel of material was found in 100 min nitrided specimen. Fig 3.7 shows moderate peel of material, as the specimen was treated less than 100 minutes. Fig 3.8 shows, more peel of material in as the specimen was nitrided to the lowest time period. The wear was found to be high. Therefore as the time of nitriding increases, case depth increases, wear decreases.

IV. HARDNESS PROFILE

Comparative hardness profiles for the different grades of stainless steels and the various nitriding treatments were investigated. Salt bath nitriding imparted a good surface hardness with values as high as 1450 H_v for the AISI steel. In an untreated specimen, the hardness was found to be 330 $H_{v.}$ The value of hardness was improved 10 times greater when compared to an untreated specimen.

V. CONCLUSIONS

As expected, the specimens salt bath nitrided at higher temperatures exhibit deeper nitrided cases than those treated at the low temperature. The diffusivity of nitrogen in the FCC matrix of austenitic stainless steel is very low and the alloying elements are not mobile enough to combine with the nitrogen to form the nitrides readily. However, stainless steel salt bath nitride at this temperature, has a surface hardness as high as 1040 H_v. This low temperature salt bath nitriding imparts better corrosion resistance than the other nitriding methods. It is generally believed that the passivity untreated stainless steel is due to the protective surface which consists of chromium oxide. Nitriding results in the precipitator chromium nitrides, depleting the matrix of chromium providing a hard surface layer. This improves the wear resistance and also improves the life of the turbine/ propeller blades providing good surface finish.

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