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Experimental Study on Turbine Blade Material

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Abstract
This experimental study investigates the nitriding effects on microstructure of wrought 17-4 PH stainless steel. Nitriding was carried out at 560 °C for 2 hours, resulting in significant improvements in hardness. Nitriding improves the hardness on the surface of the 17-4 PH steel and remains constant in the core. As a result of nitriding the harness increased 3.5 times the hardness of the wrought alloy. Microstructural analysis of both untreated and nitrided samples using a scanning electron microscope (SEM) equipped with energy-dispersive X-ray spectroscopy (EDS) revealed the formation of a nitride layer. The results show a relationship between nitriding temperature and nitride layer thickness, with higher temperatures leading to thicker layers.
Keywords: *17-4 PH steel, Nitriding, Surface hardness, Precipitate Hardened.*

1. Introduction
Turbine blade is a crucial part of the aircraft which undergoes a high temperature and high pressures. It should withstand hot gases that release from the combustion chamber. If there is any small damage in it, then is causes a lot of damage to the engine. So, the material should be non-corrosive and withstand high temperatures and pressure. It should have a long durability. Most of the failure occurs in the turbine blade, so it should be high corrosive resistant, tear resistant, and yield more harness. Most of the turbine blade use nickel-based super alloys as a material. We are using 17-4 ph steel as a material in our experimental analysis. 17-4 PH steel have many applications such as oil industry, Paper industry, aerospace industry, chemical industry etc. we are using this material for aircraft turbine blade material. Many people like Kazior, Aripin et.al discussed about the materials used for the additive manufacturing of the 17-4 PH stainless steel and the effect of microstructure on 17-4 ph steel [1-3]. Steel surface treatments are essential for improving the lifetime and performance of steel components in a variety of industries. [4 – 6] These treatments comprise a variety of procedures, including as plating, nitriding, carburizing, and galvanizing, among others. Applying a layer of zinc to prevent corrosion is known as galvanizing, whereas plating such as nickel or chrome plating improves both corrosion resistance and aesthetics. Carburizing includes adding carbon to the steel surface to increase surface hardness, whereas nitriding adds nitrogen to the surface to increase hardness and wear resistance. Every treatment tackle certain issue including wear, corrosion, and hardness, enhancing the overall robustness and dependability of steel components in a range of applications. Adding nitrogen to stainless steel enhances its mechanical and corrosion resistance characteristics were said by Carlos [8]. They also discussed about nitrogen bearing stainless steel, high temperature gas nitriding, and low temperature plasma nitriding in their research work. Lorena [9] said, due to its superior corrosion resistance and biocompatibility, AISI 316L stainless steel is frequently used in medical implants, including internal fixation devices and prosthetic knee or hip joints. It is possible to increase the hardness of AISI 316L without sacrificing its resistance to corrosion by using ion nitriding, a tried-and-true steel hardening technique. This study compares nitrided and untreated circumstances using electrochemical tests such as potentio dynamic polarization and linear polarization to investigate the effect of ion nitriding on the corrosion performance of AISI 316L in a

0.9% sodium chloride solution. Yetim [10] discussed that 316L austenitic stainless steel was subjected to a plasma nitriding treatment in an 80% H2-20% N2 gas mixture for 1, 4, and 8 hours. At 400°C, the majority of s-phase and small chromium nitride precipitates formed, and at higher temperatures, there was an increase in the amount of CrN and γ-Fe4N nitrides, which produced the highest hardness at 500°C for 8 hours. According to Fraczek [11], the study contrasts two placement methods—directly on the cathode and with an active screen—and covers ion nitriding of 316L austenitic steel research in order to increase process efficacy. In addition, it examines how process variables affect the depth of nitrogen diffusion and proposes an ionizing nitriding mechanism to be used in conjunction with the active screen technique. Based on our literature study it is observed that the researchers done their work mainly on AISI 316L steel only [9]. There is a lack of research on nitrided wrought alloy 17–4 PH steel, and study of the microstructure and its properties. Our study explains the detailed report on nitrided 17-4 PH steel and its properties along with sem analysis.

2. Materials And Methods

2.1. Material Used

17–4 ph steel, is chosen for our study. It is a wrought alloy of cylindrical shape with dimensions of 100 mm in length and 30 mm diameter. It consists of 17% chromium and 4% of nickel in it. It also consists of many elements. The chemical composition of the 17 – 4 ph steel is given below.

Table 1 The Chemical Makeup Of 17-4PH Steel

Element Name	Weight Percentage
Chromium	15.00 – 17.50
Nickel	3.00 – 5.00
Copper	3.00 – 5.00
Manganese	1.00
Silicon	1.00
Phosphorous	0.040
Sulfur	0.030
Carbon	0.07
Nb + Ta	0.15 – 0.45
Iron	Balance

2.2. Process of Nitriding

The salt bath nitriding process is now being used to nitride the cylindrical sample of 17-4 PH steel. 560° C is the temperature that is maintained for nitriding [14]. This process took two hours to finish. This temperature will greatly improve the nitriding process's efficacy.

2.3. Hardness

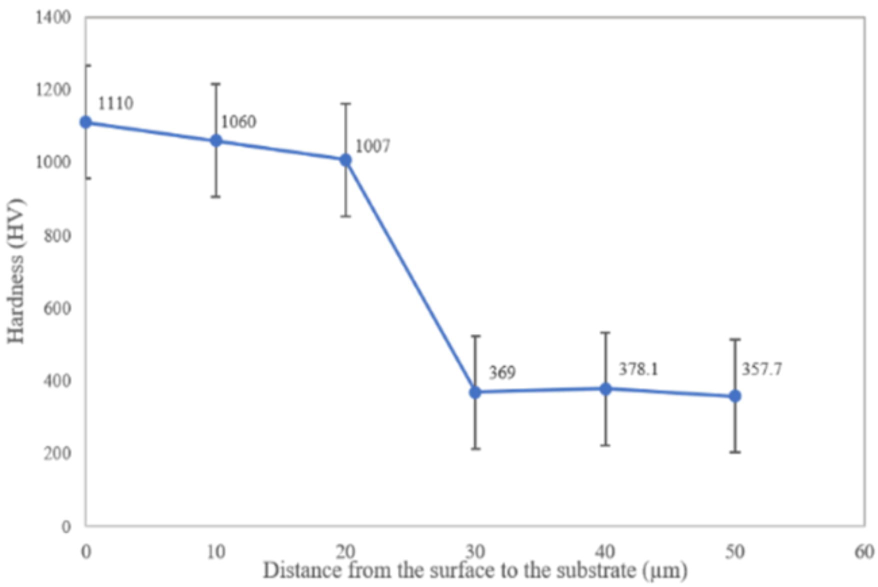

Figure 1 Hardness Value of Nitride 17-4 PH Stainless Steel

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In accordance with ASTM standard E384, the microhardness of both as-built and nitrided 17-4PH steels was assessed using a Shimadzu HMV G-series Vickers Microhardness tester [14]. A diamond-shaped indenter weighing 500 g was used to evaluate the microhardness of the sample's top surface and cross-section, and it was left in place for ten seconds.

2.4.Sem Analysis

The nitrides sample's cross-section was first examined using a scanning electron microscope (SEM). To provide a more precise measurement of the nitride layer thickness, line mapping of nitrogen was performed using Energy Dispersive X-ray Spectroscopy (EDS).

3. Results and Discussion

a. Effect of Nitriding Process on Hardness Value

The top surfaces and cross-sections of the as-built and nitrided samples of 17-4PH steel were tested for microhardness using a diamond-shaped indenter. A table summarizing the measured top-surface microhardness values of the 17-4PH steel along with values from literature [14–15] indicates that the as-built material has superior microhardness compared to the sintered/wrought material and that the nitriding process significantly enhances surface hardness compared to the as-built material. These outcomes concur with those of the wrought 17-4PH steels. Moreover, a small correlation has been seen between high nitriding temperatures and high microhardness values. The microhardness values of 17-4PH steels, both as-built and nitrided, differ from the surface into the core, as seen in the figure. The hardness was measured in ten-millimeter stages from the surface to the core. The material has remarkably constant microhardness values from the surface to the middle of the core. The microhardness value, however, is greater near the surface after nitriding and progressively decreases to a value that approaches the as-built case as it gets closer to the core.

b. Micro Structural Analysis

The SEM cross section of nitride 17-4 PH steel is displayed in the figure. The substrate, diffusion layer, and compound layer are all clearly apparent by the SEM investigation. The nitrogen concentration of the diffusion layer is lower than that of the compound layer, which has the greatest nitrogen percentage. The nitride layer has an average thickness of 25 µm.

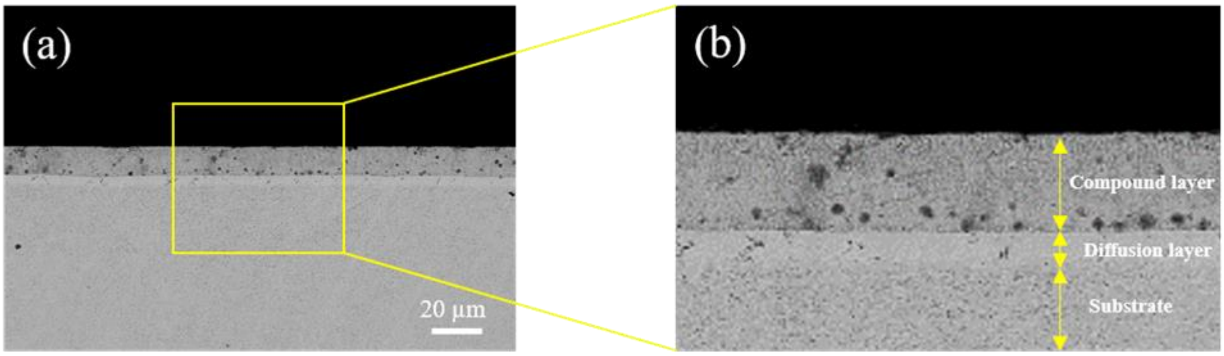

Figure 2 (a) Sem Image of Nitrided 17-4 Ph Steel At 560 °c for 2 Hours (b) Magnified Image of (a)

Summary

The nitriding procedure used in this study is applied to a 17-4 PH steel for two hours at 560°C. It demonstrates how much the hardness value is improved by the nitriding procedure. The hardness of the wrought alloy is lower than that of the nitrided alloy. The micro-vicker harness is examined, and a hardness graph is created. We came to know the presence of compound layer, diffusion layer, and the substrate through the SEM image. We can say that 17-4 PH steel will be a good alternate for the nickel based super alloys, which are currently used in aircraft turbine blade material. 17-4 PH steel is very cost effective when compared to other materials.

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References

[1]. Kazior, J., Szewczyk-Nykiel, A., Pieczonka, T., Hebda, M., & Nykiel, M. (2013). Properties of precipitation hardening 17-4 PH stainless steel manufactured by powder metallurgy technology. Advanced Materials Research, 811, 87-92.

[2]. Aripin M. A., Sajuri, Z., Jamadon, N. H., Baghdadi, A. H., Syarif, J., Mohamed, I. F., & Aziz, A. M. (2022). Effects of Build Orientations on Microstructure Evolution, Porosity Formation, and Mechanical Performance of Selective Laser Melted 17-4 PH Stainless Steel. Metals, 12(11), 1968.

[3]. Rosso, M., Peter, I., & Gobber, F. S. (2015). Overview of heat treatment and surface engineering, influences of surface finishing on hot–work tool steel. International Journal of Microstructure and Materials Properties, 10(1), 3-30.

[4]. Thelning, K. E. (2013). Steel and its heat treatment. Butterworth-heinemann.

[5]. Totten, G. E. (Ed.). (2006). Steel heat treatment: metallurgy and technologies. CRC press.

[6]. Totten, G. E. (Ed.). (2006). Steel heat treatment handbook-2 volume set. CRC press.

[7]. Tang, D., Zhang, C., Zhan, H., Huang, W., Ding, Z., Chen, D., & Cui, G. (2023). High-efficient gas nitridation of AISI 316L austenitic stainless steel by a novel critical temperature nitriding process. Coatings, 13(10), 1708.

[8]. Tschiptschin, A. P., & Pinedo, C. E. (2022, June). Surface hardening of stainless steel. In Stainless Steels. IntechOpen.

[9]. Gil, L., Brühl, S., Jiménez, L., Leon, O., Guevara, R., & Staia, M. H. (2006). Corrosion performance of the plasma nitrided 316L stainless steel. Surface and Coatings Technology, 201(7), 4424-4429.

[10]. Yetim, A. F., Yildiz, F., Alsaran, A., & Celik, A. (2008). Surface modification of 316L stainless steel with plasma nitriding. Kovove Materialy, 46(2), 105.

[11]. Fraczek, T., Ogorek, M., Skuza, Z., & Prusak, R. (2020). Mechanism of ion nitriding of 316L austenitic steel by active screen method in a hydrogen-nitrogen atmosphere. The International Journal of Advanced Manufacturing Technology, 109(5-6), 1357-1368.

[12]. Borgioli, F., Galvanetto, E., & Bacci, T. (2016). Low temperature nitriding of AISI 300 and 200 series austenitic stainless steels. Vacuum, 127, 51-60.

[13]. Wang, L., Ji, S., & Sun, J. (2006). Effect of nitriding time on the nitrided layer of AISI 304 austenitic stainless steel. Surface and Coatings Technology, 200(16-17), 5067-5070.

[14]. Michla, J. J., Ravikumar, B., Prabhu, T. R., Siengchin, S., Kumar, M. A., & Rajini, N. (2022). Effect of nitriding on mechanical and microstructural properties of Direct Metal Laser Sintered 17-4PH stainless steel. Journal of Materials Research and Technology, 19, 2810-2821.

[15]. Riazi, H., Ashrafizadeh, F., Hosseini, S. R., & Ghomashchi, R. (2017). Influence of simultaneous aging and plasma nitriding on fatigue performance of 17-4 PH stainless steel. Materials Science and Engineering: A, 703, 262-269.