Hardness, Wear and Corrosion Improvement techniques for Austenitic Stainless Steel SS316L - A Review

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Abstract: SS316L stainless steels have been broadly utilized in the extremely corrosive environment for the generation of power, oil, food, chemical, and fertilizers. They are also used in gas industries as well as petrochemical reactors. These materials are outstanding for their great erosion protection and their strength. However, as a result of its low hardness and wear protection, their applications are incredibly constrained. The Austenitic steel has an Austenitic structure which is steady at ambient temperature and portrayed by the presence of chromium, nickel, and low carbon content. Austenitic steels are utilized as a part of different forceful conditions and at high and low temperatures. The most widely recognized heat treatment for a wide range of austenitic steel is solution annealing. Research is going ahead extensively to diminish the wear either through utilizing another wear safe material or by enhancing the wear protection of the current material by the addition of a wear safe alloying component etc. In this paper, a study has been made to audit few of the strategies for enhancing the properties like corrosion, wear as well as hardness of austenitic stainless steel SS316L.

Keywords: **Austenitic stainless steel, SS316L, Corrosion, Wear, Hardness**

I. INTRODUCTION

Wear properties is the cardinal element that controls the life of any machine part or material. Metal parts regularly fail not on account of the fracture, but rather on the grounds that they wear, which makes them lose measurement and usefulness. Diverse classes of wear exist, however, the most common modes are – Abrasion, Corrosion, Impact, Metallic, Heat and so on. Most worn parts don't fail because of a single specific type of wear, like impact, but from a blend of modes, like, corrosion, impact and heat. Research is going from a long time to diminish the wear either through utilizing another wear safe material or by enhancing the wear protection of the current material by the addition of any wear safe alloying component and etc. The material of focus all through this task is austenitic stainless steel 316L. Austenitic stainless steels are iron alloys, have a FCC structure that is acquired by components, for example, Ni, Mn, and N. The SS316L of stainless steel has a composition [14] of Chromium 16-18 % (Wt), Nickel-2 %(Wt) and Manganese 2 %(Wt), C0.03 %(Wt) and minor measures of other components. These sorts of low carbon austenitic alloys are made to avoid the formation of chromium carbides which result in an exhaustion of chromium from the austenite matrix and a loss in the resistance against corrosion. These steels are for the most part soft in nature and because of this reason it might get numerous regular types of wear and contact damages. Because of this poor wear protection of these alloys, their application is constrained. "Surface Engineering" is a general expression that depicts an extremely wide scope of procedures which adjust a material's surface to enhance surface properties or change a materials connection with the present environment [15]. The most widely recognized surface engineering advances applied to steel alloys incorporate surface softening, melting, traditional carburization, traditional nitriding, hardening, and plating. So this paper surveys some of the techniques available to enhance the corrosion resistance, wear resistance and hardness properties of the austenitic stainless steel.

II. LITERATURE REVIEW AND DISCUSSION

S. A. Hassona [1] analyzed AISI 316L austenitic stainless steel to examine the impacts of gas nitriding process parameters on its erosion wear protection. Optical microscope, X-ray diffraction (XRD) and surface hardness measurements were utilized to examine the properties of the nitrided layers which were produced during gas nitriding by ammonia in the range of (400–600°C) nitriding temperature, (10– 50 hr.) nitriding time and an ammonia flow rate of (100-600 L/hr.). The results of this investigation demonstrated that gas nitriding of AISI 316L stainless steel produces nitrided layers that fluctuate in thickness, hardness, and composition as per the varying nitriding conditions. Contrasted with the untreated material, the consequences of the erosion test demonstrated a change in erosion resistance after gas nitriding that can be related to the nitrided layer properties. This change in erosion protection is reliant on the impact angle and could achieve, inside the scope of process parameters considered in this investigation, a value of around 93% in the 30 ° test and 54% in the 90° test.

Ram.Subbiah [2] utilized the case hardening techniques like nitriding and surface hardening processes which offer high corrosion protection along with, enhanced hardness and wear protection. The author contemplated the impact of gas nitriding on the properties like micro hardness, corrosion protection and wear protection of AISI316LN grade austenitic stainless steels. The author carried out the salt bath nitriding process at a temperature of 5000C for a period of 60, 90 and 120 minutes with a post-oxidation process for a time of 30 minutes and after that inter-metallic stages were investigated with an optical microscope and the micro-hardness was examined with the micro-hardness analyzer. The author inferred that that gas nitriding expands the micro-hardness to a significant amount. A greatest of 1410Hv could be acquired on the austenitic grade stainless steel samples and the purpose behind the increase in the micro-hardness could be the impact of Mo presence and the other alloying components in the solid solution. Additionally, it was noticed that the estimation of hardness at the surface level increments with the diffusion time, up to a specific level and over the specific level the hardness does not changes. The author additionally reasoned that post-oxidation has no significant impact on the hardness however it enhances the corrosion protection in comparison with the non-oxidized sample in a bigger factor and case depths were seen to be around 20 - 50 microns (µm).

Bo Wang [3] examined the annealing effect of the Bulk nanostructured 316L austenitic stainless steel (SS) tests with nano-scale twin groups inserted in nano-sized grains which were blended by utilizing dynamic plastic twisting (DPD). The author referred to the writing [11, 12] strategy for DPD The commercial grade SS316L. Material toughened to 1200 Dec C before DPD procedure to keep up the homogeneous coarse grains. After that DPD was performed. Some DPD 316L specimens tempered and a few examples left as DPD316L. After that the author analysed the microstructures of the as-annealed DPD and the as-strengthened DPD 316L SS samples were described by scanning electron microscopy (SEM) on a FEI Nova Nano-SEM system at a working voltage of 15 kV. At that point test have measured the hardness utilizing Vickers hardness machine. The author closed the outcome as - DPD 316L steel displays a little-upgraded wear protection under a heap of 10 N, and about indistinguishable wear protection under a heap of 30 N with respect to that of the first. The outcome demonstrates that the most astounding wear protection can be found in the DPD test strengthened at 750 ±C for around 20 min, which is over 46% higher than that of the CG steel test.Sulima [9] conducted the high temperature-high pressure (HT-HP) method to enhance the mechanical properties of AISI 316L material. Author utilized the two unique composites as AISI 316L stainless steel strengthened with 10 vol.% and 20 vol.% TiB2. The author delivered the composite by blending the powders in a turbula blender for 6 hours and the subsequent mixtures were framed into discs (15 mm in breadth, 5 mm high) by squeezing in a steel lattice under weight of 200 MPa. The author utilized high temperature-high pressure (HT-HP) Bridgman device for densification of materials and afterward, it was sintered at a temperature of 1200 deg C and weight of 7 ± 0.2 GPa for 60 seconds. Author Concluded that the addition of the TiB2 particles into the austenitic AISI 316L stainless steel is a decent course to enhance the mechanical properties of these materials and increasing Vickers hardness and Young's modulus of the composites with increasing the the TiB2 phase content was observed. Tribological estimations demonstrated that a contact coefficient of the composites increased with the expanding TiB2 content. The author reasoned that the most elevated properties were obtained for the austenitic AISI 316L stainless steel reinforced with 20 vol.% TiB2 ceramics. For this composite, the Young modulus, Vickers hardness, compression strength and coefficient of friction were 225 GPa, 460 HV1, 1350 MPa and 0.37, individually.

N. Chuankrerkkul [4] deduced that the Powder metallurgy method can be utilized for the manufacture of stainless steel tungsten carbide metal grid composites. The author utilized AISI 316L and Tungsten carbide (WC). The stainless steel powders were blended with Tungsten carbide with 5%, 10% or 15% by weight and compacted with 300MPa. Then this sample was sintered at 200 °C, 1250 °C or 1300 °C with a holding time of 30, 45 or a hour. Additionally, author utilized the samples of 316L stainless steel powder with no WC addition was likewise manufactured with a similar procedure. The author expressed that the composite samples had high porosity and hardness increased with increasing WC composition at all temperatures. Higher sintering temperature led to an increase in hardness and a decrease in porosity. Regardless, the impact of holding time on the hardness value did not demonstrate any huge contrast. The most astounding value of hardness was determined from examples, containing 15 wt% of WC, sintered at 1300 °C.

F.A.P. Fernandes [5] studied the method of Plasma nitriding and nitrocarburizing of austenitic stainless steels SS316L which can produce layers of expanded austenite.This is supersaturated in comparison to nitrogen and is portrayed by high hardness and wear protection. In this observation plasma nitriding and nitro carburizing on AISI 316Lstainless steel were led at 400, 450 and 500°C. Plasma nitriding (PN) and nitro carburizing (PNC) were performed by the author utilizing the dc technique with the accompanying gas mixtures: 80 vol. % H2 and 20 vol. % N2, for nitriding and 77 vol. % H2, 20 vol. % N2 and 3 vol. % CH4 for nitro carburizing. This was performed at a pressure of 500Pa for 5h at temperatures of 400, 450 and 500°C. The plasma-treated AISI 316L steel tests were described by optical microscopy, X-ray diffraction, and corrosion tests. Corrosion characterisation was performed by potentiodynamic polarization in 3.5% NaCl solution. After plasma treatment, it was observed that the layer thickness increases with temperature. The treatments at 400°C created homogenous and precipitate free S-phase layers while at 450 and 500°C X-ray diffraction demonstrates the nearness of iron carbide and/or chromium and iron nitrides. The potentiodynamic polarization curves demonstrate that corrosion protection is higher for the specimens treated at 400°C in respect to the untreated substrate. An adjustment in the prevailing corrosion system was additionally seen after nitriding or nitro carburizing from local pitting corrosion to general corrosion. The author reasoned that both nitriding and nitrocarburizing at 400°C significantly enhances the corrosion protection of ASS in 3.5% NaCl arrangement.

Sudjatmoko [6] carried out the nitrogen particle implantation method on 316 material to enhance the surface properties. The author utilized the AISI 316L stainless steel plate which was embedded with the ideal particle measurements of 5 1016 particle/cm2 for particle energy variation of 60, 80 and 100 keV. In light of the research the author presumed that the nitrogen ion implantation can adequately enhance the hardness and the erosion protection of AISI 316L SS. From the procedure utilizing SEM and EDX it was discovered that the boundaries appear on the top layer of embedded AISI 316L SS tests, and the white regions on boundaries because of nitride phases were formed. The nitride phases which were formed improve the hardness of the embedded specimens. XRD diffraction patterns were utilized to examine the surface morphology of embedded AISI 316L SS, and in light of the XRD diffraction patterns observed peaks of Fe2N, Fe3N and Fe4N. Iron nitride is the iron richest stable stage in the binary system Iron nitrogen. The author inferred that this iron nitride and other binary iron nitride phases have unique properties, for example, hardness, corrosion and wear safe properties on the top layer of iron and steel parts. The author reasoned that the assessment by utilizing a potentiostat PGS 201T demonstrated that there was a noteworthy change in the corrosion protection on account of nitrogen embedded specimens.

J.Suresh [7] performed experiments to determine the corrosion and wear attributes of the propeller shaft material as 316LSS with the increasing hardness properties. Stainless steels which generally depletes through the sensitization effect when it tries to get hardened through other high-temperature hardening techniques. The author found that increase in hardness and corrosion protection can be accomplished by Cryogenic treatment and updating the microstructure from austenite state to martensite state without any adjustment in chemical properties. In a Deep Cryogenic treatment the material is first permitted to cool from room temperature to a temperature of - 186 C by putting the test piece in Liquid Nitrogen (LN2) controlled flow chamber for up to 2-3 hours, then kept in a cooling chamber with the above temperature up to 24 hrs and then to room temperature, which takes around 6 hrs. Wear properties of the material are examined through Pin on Disk Test according to the (ASTM G 99) standard and the Corrosion properties are explored through the Ferric Chloride test according to the (ASTM G 48-03) standard. The outcome demonstrates that the Cryogenic medicines on AISI 316L Stainless steel enhances the wear properties by 24% with an assistance of Pin on Disc test and Ferric chloride test demonstrates that the corrosion properties enhanced by 37% against the untreated material. The hardness enhanced up to 16%.

P.M. Natishan [8] performed a novel low température (450°– 500 °C) Para equilibrium carburization method for bringing carbon into stainless steel surfaces without the formation of carbides. Usually, the case hardening does not utilize chromium-containing alloys, for example, stainless steels (SS), because of chromium carbide development that would essentially degrade the corrosion performance. Thus, the accessibility of case hardened alloys for applications in corrosive conditions was to a great degree, constrained. This strategy is additionally called Low-Temperature Colossal Super saturation (LTCSS). Para equilibrium refers to the idea that the diffusion of substitution solutes (metal atoms, for example, Cr and Ni in the alloy) is slower than the dispersion of interstitial solutes (atoms, for example, carbon that fit between metal alloy molecules). Substitution solutes are successfully stationary under LTCSS treatment conditions, while carbon can diffuse significantly into the alloy. These interstitially solidified surfaces constitute another branch of materials, in which improved corrosion protection is achieved along with an increase in wear and fatigue protection. The impact of LTCSS treatment on austenitic stainless steels 316 shows increment in surface hardness through leftover compressive surface stress. Carbon concentrations of up to 15 atomic percent can be produced in the closed surface area encasing the whole treated segment. The vast concentration of interstitial carbon instigates a lattice expansion that outcomes in surface compressive stresses which are more than 2 GPa. An increase in the surface hardness of the material increases wear protection. LTCSS treatment expanded pitting potential from +320 factory volts (mV) for untreated material to +950 mV for the LTCSS-treated material. The pitting potential is an electrochemical parameter utilized as a part of lab testing to look at the pitting protection of materials; a high positive value is desirable. This is a phenomenal increment in pitting corrosion protection with the end goal that under pragmatic conditions experienced in natural seawater (NSW) situations, LTCSS-treated 316 SS is basically resistant to pitting corrosion. Crevice corrosion test demonstrates that the corrosion protection of LTCSS-treated 316L was significantly improved contrasted with the untreated 316 and the more costly, high grade Ni alloy. Likewise, LTCSS-treated surfaces, by and large, have hardness more noteworthy than hard chrome and hence display a potential contrasting option to this naturally unwanted, poisonous, wear-safe and erosion safe covering.

V. Muthukumaran [9]performed the argon and oxygen Ion implantation method that changes the surface properties of solids, for example, corrosion and hardness on the SS316 material. The implantation of argon and oxygen particles was done on AISI316L SS at an energy level of 100 Key at a dosage of 1x1017ions/cm2, at 32°C temperature. Polarization test was completed to assess the corrosion response of the embedded specimens in the reproduced common tissue condition. The author presumed that the XRD and SEM outcomes were observed to be as per the corrosion test outcomes. The general corrosion behaviour demonstrated a critical change on account of both argon embedded and oxygen embedded when contrasted with the virgin AISI 316L SS. The pitting corrosion demonstrated a little change in argon embedded up 4% and no change in oxygen embedded. The surface hardness is observed to be 464% for argon embedded and 423% for oxygen embedded against the first material. Likewise found that the hardness of the argon and oxygen embedded specimens is observed to be increased by around 550% and 500% separately when contrasted with the first samples. Argon embedded specimens indicate better execution regarding corrosion protection and hardness when contrasted with those of the oxygen embedded samples.

M. Kulka [10] used the process of laser boarding to improve the wear properties of the material. The composite boride layer comprised of hard ceramic phases (borides and boro-carbides) and a soft austenitic matrix. The increment in wear protection of the laser-borided layer was compared with the initial untreated 316L steel. The transcendent abrasive wear was joined by adhesive and oxidative wear evidenced by shallow grooves and the presence of oxides. As per the two-hour wear test with an adjustment in the counter-specimen every 0.5 h, the examined layer was described by the roughly 15 times lower factor of mass wear intensity (1.70 mg cm−2 h−1) than that got for 316L steel (26.12 mg cm−2 h−1).

III. CONCLUSION

a) According to the survey, numerous techniques are available to improve the hardness, corrosion as well as the wear properties of the Austenitic stainless steel SS316L.
b) A very few techniques of metal composite and metal matrix are available to improve the hardness, corrosion and wear properties of the austenitic stainless steel SS316L.
c) Further study may be conducted incorporating metal matrix using welding technique to improve the hardness, corrosion and wear properties of austenitic stainless steel SS316L.

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