International Journal of Engineering Research and Reviews **ISSN 2348-697X (Online)**
Vol. 2, Issue 4, pp: (18-23), Month: October - December 2014, Available at: www.researchpublish.com

A Review Paper on Methods of Improvement of Wear, Corrosion and Hardness Properties of Austenitic Stainless steel 316L

P.Elango

PG Student, Department of mechanical Engineering, Bharath University, Chennai –India

---

Abstract: **SS316L stainless steels have been widely used in highly corrosive environments for power generation, chemical, fertilizer, marine, food, oil and gas industries and petrochemical reactors. These materials are well known for their good corrosion resistance and mechanical properties like strength etc. However, because of its low hardness and wear resistance their applications are greatly limited .The Austenitic steel has an Austenitic structure is stable at ambient temperature and characterized by the presence of chromium and nickel and low carbon content Austenitic steels are used in various aggressive environments and at high and low temperatures. The most common heat treatment for all types of austenitic steel is solution annealing. Research is going on over years to reduce the wear either in the form of using a new wear resistant material or by improving the wear resistance of the existing material by addition of any wear resistant alloying element etc. In this paper an study has been made to review few of the methods of improve the properties like wear, corrosion and hardness on austenitic stainless steel SS316L**

Keywords: **SS316L, Wear, corrosion, hardness.**

I. INTRODUCTION

SS316L stainless steels have been widely used in highly corrosive environments for power generation, chemical, fertilizer, marine, and food and petrochemical reactors. These materials are well known for their good corrosion resistance and mechanical properties like strength etc. However, because of its low hardness and wear resistance their applications are greatly limited .The Austenitic steel has a Austenitic structure is stable at ambient temperature and characterized by the presence of chromium and nickel and low carbon content [13]. Austenitic steels are used in various aggressive environments and at high and low temperatures. The most common heat treatment for all types of austenitic steel is solution annealing [13]. Research is going on over years to reduce the wear either in the form of using a new wear resistant material or by improving the wear resistance of the existing material by addition of any wear resistant alloying element etc. In this paper an study has been made to review few of the methods of improve the properties like wear, corrosion and hardness on austenitic stainless steel SS316L

Wear properties is the predominant factor that controls the life of any machine part material and. Metal parts often fail their intended use not because they fracture, but because they wear, which causes them to lose dimension and functionality. Different categories of wear exist, but the most typical modes are – Abrasion, Impact, Metallic (metal to metal), Heat, Corrosion etc. Most worn parts don't fail from a single mode of wear, such as impact, but from a combination of modes, such as abrasion and impact etc. Research is going on over years to reduce the wear either in the form of using a new wear resistant material or by improving the wear resistance of the existing material by addition of any wear resistant alloying element etc. The material of focus throughout this project is austenitic stainless steel 316L. Austenitic stainless steels are iron based alloys have a FCC structure that is obtained by elements such as Ni, Mn, and N. The SS316L of stainless steel has a general composition [14] of Chromium 16-18 % (Wt), Nickel-2 %(Wt) and Manganese 2 %(Wt), C0.03 %(Wt) and minor amounts of other alloying elements and remaining Fe Element. These types of low carbon austenitic alloys are formulated to avoid the formation of chromium carbides which result in a depletion of chromium from the austenite matrix and a loss in corrosion resistance. These steels are generally soft in nature and due to this reason it may get many common forms of wear and contact damage. Due to this poor wear resistance of these alloys application is limited. So hardening the surface of stainless steels to improve wear and hardness resistance of the material and also without change any other desirable properties. “Surface Engineering” is a general phrase that describes a very broad range of processes which alter a materials surface to improve surface properties or modify a materials interaction with the surrounding environment [15]. The most common surface engineering technologies applied to steel alloys include transformation hardening, surface melting, conventional carburization, conventional nitriding, coating, and plating. So this paper deals with reviews of few methods available to improve the wear, corrosion and hardness properties of the austenitic stainless steel.

II. LITERATURE REVIEW AND DISCUSSION

J.Suresh [1] performed the corrosion and wear characteristics of the propeller shaft material as 316LSS with increasing the hardness properties. Stainless steels which usually depletes through the sensitization effect when tries to harden through other high temperature hardening methods .Author found that increase in hardness and corrosion resistance can be achieved by Cryogenic treatment and upgrading the microstructure from austenite state to martensite state without any change in chemical properties. In a Deep Cryogenic treatment the material is first allowed to cool from room temperature to a temperature of -186 C by introducing the test piece in Liquid Nitrogen (LN2) controlled flow chamber up to 2-3 hours duration to take, then maintained in a cooling chamber with the above temperature up t0 24 hrs and retain back to room temperature, it takes 6 hrs. Wear properties of the material is investigated through Pin on Disc Test as per the (ASTM G 99) standard and the Corrosion properties are investigated through the Ferric Chloride test as per the (ASTM G 48-03) standard. The result shows that the Cryogenic treatments on AISI 316L Stainless steel improve in wear properties up 24% with a help of Pin on disk test and Ferric chloride test shows that the corrosion properties improved to 37% against the untreated material. The hardness improved up to 16%

P.M. Natishan [2] performed a new low-temperature (450°–500 °C) paraequilibrium carburization technique for introducing carbon into stainless steel surfaces without formation of carbides. Generally, the case hardening is not using in chromium-containing alloys such as stainless steels (SS), due to chromium carbide formation that significantly degraded corrosion performance. As a result, the availability of case-hardened alloys for applications in corrosive environments was extremely limited. This technique also called as Low-Temperature Colossal Supersaturation (LTCSS). Paraequilibrium refers to the concept that the diffusion of substitutional solutes (metal atoms, such as Cr and Ni in the alloy) is slower than the diffusion of interstitial solutes (atoms such as carbon that fit between metal alloy atoms). Substitutional solutes are effectively immobile under LTCSS treatment conditions, whereas carbon can diffuse considerable distances into the alloy. These interstitially hardened surfaces constitute a new branch of engineered materials, in which improved corrosion resistance is attained alongside improvements in wear and fatigue resistance. The effect of LTCSS treatment on austenitic stainless steels 316 shows increase in surface hardness through residual compressive surface stress. Carbon concentrations of up to 15 atomic percent can be generated in the near-surface region encasing the entire treated component. The large concentration of interstitial carbon induces a lattice expansion that results in surface compressive stresses greater than 2 GPa. Increasing the surface hardness of the material increases wear resistance. LTCSS treatment increased pitting potential from +320 mill volts (mV) for untreated material to +950 mV for the LTCSS-treated material. The pitting potential is an electrochemical parameter used in laboratory testing to compare the pitting resistance of materials; a high positive value is desired. This is a dramatic increase in pitting corrosion resistance such that under practical conditions experienced in natural seawater (NSW) environments, LTCSS-treated 316 SS is virtually immune to pitting corrosion. Crevice corrosion test shows that the corrosion resistance of LTCSS-treated 316L was greatly increased compared to the untreated 316 and the more expensive, high-grade Ni alloy. In addition, LTCSS-treated surfaces, in most cases, have hardness values greater than hard chrome and thus present a potential alternative to this environmentally undesirable, toxic, wear-resistant and corrosion-resistant coating

V. Muthukumaran [3]performed the argon and oxygen Ion implantation technique that alterations in surface properties of solids such as corrosion and hardness on the SS316 material The implantation of argon and oxygen ions was done on AISI316L SS at an energy level of 100 KeV at a dose of 1x1017ions/cm2, at 32°C temperature. Polarization test was carried out to evaluate the corrosion behaviour of the implanted samples in the simulated natural tissue environment. The author concluded that the XRD and SEM results were found to be in accordance with the corrosion test results. The general corrosion behaviour showed a significant improvement in the case of both argon implanted and oxygen implanted when compared to the virgin AISI 316L SS .The pitting corrosion showed a small improvement in argon implanted up 4%

and no improvement in oxygen implanted showed no improvement. The surface hardness is found to be 464% for argon implanted and 423% for oxygen implanted against the original material. Also found that the hardness of the argon and oxygen implanted samples is found to be increased by about 550% and 500% respectively, when compared to the original samples. Argon implanted samples show better performance in terms of corrosion resistance and hardness when compared to those of the oxygen implanted samples.

Sudjatmoko,[4] performed the nitrogen ion implantation technique on 316 material to improve the surface properties. Author used the AISI 316L stainless steel plate was implanted with the optimum ion dose of 5 1016 ion/cm2 for ion energy variation of 60, 80 and 100 keV. Based on the research the author concluded that the nitrogen ion implantation can effectively improve the hardness and the corrosion resistance of AISI 316L SS. From the analytical technique using SEM and EDX it was found that the boundaries appear on the surface layer of implanted AISI 316L SS samples, and the white areas on boundaries due to nitride phases were formed. The nitride phases which formed enhance the hardness behaviour of the implanted samples. XRD diffraction patterns were used to analyze the surface morphology of implanted AISI 316L SS, and based on the XRD diffraction patterns observed peaks of Fe2N, Fe3N and Fe4N. Iron nitride is the iron-richest stable phase in the binary system iron-nitrogen. Author concluded that this iron nitride and other binary iron nitride phases have special properties such as hardness, corrosion and wear resistant properties on surface layer of iron and steel components. Author concluded that the evaluation by using a potentiostat PGS 201T showed that there was a significant improvement in the corrosion resistance in the case of nitrogen implanted samples.

F.A.P. Fernandes [5] studied the technique of Plasma nitriding and nitro carburizing of austenitic stainless steels SS316L can produce layers of expanded austenite .This is supersaturated with respect to nitrogen and is characterized by high hardness and wear resistance. In this study plasma nitriding and nitro carburizing on AISI 316Lstainless steel were conducted at 400, 450 and 500°C. Plasma nitriding (PN) and nitro carburizing (PNC) were performed by author using the dc method with the following 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. All this were performed at a pressure of 500Pa during 5h at temperatures of 400, 450 and 500ºC. The plasma treated AISI 316L steel samples were characterized by optical microscopy, X-ray diffraction and corrosion tests. Corrosion characterization 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 produced homogenous and precipitate-free S-phase layers while at 450 and 500°C X-ray diffraction indicates the presence of iron carbide and/or chromium and iron nitrides. The potentiodynamic polarization curves show that corrosion resistance is higher for the samples treated at 400°C relative to the untreated substrate. A change in the dominant corrosion mechanism was also observed after nitriding or nitro carburizing from localized pitting corrosion to general corrosion. The author concluded that both nitriding and nitro carburizing at 400°C considerably improves the corrosion resistance of ASS in 3.5% NaCl solution.

Y. Sun[6], analyzed the response of carburized stainless steel to combined actions by wear and electrochemical corrosion. Author experimented tribocorrosion behaviour of low temperature plasma carburized AISI 316L stainless steel, under unidirectional sliding in 1 M H2SO4 solution, using a pin-on-disk tribometer integrated with a potentiostat for electrochemical control. Author performed the Sliding wear tests were conducted under potentiodynamic and potentiostatic conditions at a wide range of applied potentials. It is found that the carburized layer exhibits much better tribocorrosion resistance than the untreated specimen at anodic potentials, but is not effective in improving wear resistance at cathodic potentials. The author described that, at a anodic potentials, the carburizing treatment can significantly improve the tribocorrosion resistance of 316L steel by up to 10 times, due to different tribocorrosion mechanisms. At anodic potentials, the untreated specimen suffers from wear-accelerated corrosion and corrosion-accelerated wear; while material removal from the carburized specimen is dominated by chemical wear in the form of repeated removal and re-growth of the oxide film during the sliding process. Mechanical wear of the underlying carburized layer is reduced at anodic potentials under the present testing conditions. The principal tribocorrosion mechanism of the carburized layer thus changes from pure mechanical wear at cathodic potentials, to mixed mechanical and chemical wear with mechanical dominance at open circuit, and then to mixed chemical and mechanical wear with chemical dominance at anodic potentials. The much enhanced tribocorrosion resistance of the carburized layer at anodic potentials (and thus in more aggressive environments) is derived from its high hardness and good corrosion resistance such that both mechanical wear and chemical wear are reduced. Depending on the anodic potential, low temperature carburizing can reduce the mechanical wear component by 30 to 55 times and the chemical wear component by 3 times under the present testing conditions

Uílame Umbelino Gomes[7], used the technique of metal matrix composite to improve the density and hardness. Author was carried out with starting powders of water-atomized stainless steel 316L. Pure sample and samples with addition of up to 3% of NbC and with 3% of TaC , it were mechanically milled in a conventional ball mill for 24 hours and axially cold pressed in a cylindrical steel die at 700 MPa. Sintering was carried out in vacuum. Samples were heated up to 1290°C with heating rate 20°C/min and isothermally held for 30 and 60 minutes. Sintered samples were characterized by x-ray diffraction, scanning electron microscopy and density and hardness were measured. Author analyzed the effects of nanosized particles of refractory carbides (NbC and TaC) on the sintering mechanism, denseness and hardness of stainless steel .It shows that the action of hardening mechanisms owed differences in fine particles size (10-20nm) results in great increase in the hardness values of the samples reinforced with carbides, especially for NbC. Author explained the Great influence on the hardness that increase from 76.0 HV up to 115HV and even to 140HV, for the samples with nanosized reinforcement, was observed, owing to dispersion and precipitation of fine carbides in metallic matrix. Author explained the addition of carbides increases significantly the hardness of the stainless steel due to grain size reduction of the metallic matrix during sintering. Thus, the hardness does not increase only as a function of the density but mostly due to nanosized particles segregation on grain boundaries in the sintered microstructure.

N. Chuankrerkkul [8] performed the Powder metallurgy technique can be employed for a fabrication of stainless steel tungsten carbide metal matrix composites. Author used AISI 316L and Tungsten carbide (WC). The stainless steel powders mixed with Tungsten carbide with 5%, 10% or 15% by weight and compacted with 300MPa then this specimen was sintered at 200 °C, 1250 °C or 1300 °C with a holding time of 30, 45 or 60 minutes. Also author used the Specimens of 316L stainless steel powder without any WC addition was also fabricated with the same process. Author stated that the composite specimens had high porosity and Hardness increased with increasing WC contents at all temperatures. Higher sintering temperature led to an increase in hardness and a reduction of porosity. Nonetheless, the effect of holding time on the hardness value did not show any statistically significant difference. The highest value of hardness was gained from specimens, containing 15 wt% of WC, sintered at 1300 °C.

I. Sulima [9] performed the high temperature-high pressure (HT-HP) technique to improve the mechanical properties of AISI 316L Material. Author used the two different composites as AISI 316L stainless steel reinforced with 10 vol.% and 20 vol.% TiB2. Author produced the composite by mixing the powders in a turbula mixer for 6 hours and the resulting mixtures were formed into discs (15 mm in diameter, 5 mm high) by pressing in a steel matrix under pressure of 200 MPa. Author used high temperature-high pressure (HT-HP) Bridgman type apparatus for densification of materials and then it were sintered at temperature of 1200 deg C and pressure 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 good route to improve the mechanical properties of these materials and increasing Vickers hardness and Young's modulus of the composites with increasing the TiB2 phase content was observed. The experiment proves the resulting composite showed the increase in the compression strength when compared to the unreinforced alloy. Tribological measurements showed that a friction coefficient of the composites increased with the increasing TiB2 content. Author concluded that The highest 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 friction coefficient achieved values of: 225 GPa, 460 HV1, 1350 MPa and 0.37, respectively.

Bo Wang studied [10] the annealing effect of the Bulk nanostructured 316L austenitic stainless steel (SS) samples with nano-scale twin bundles embedded in nano-sized grains were synthesized by using dynamic plastic deformation (DPD).The author referred the literature [11, 12] method for DPD The commercial grade SS316L Material annealed to 1200 Dec C before DPD process to maintain the homogeneous coarse grains. After that it was performed the DPD. Some DPD 316L samples annealed and some samples left as in the form of DPD316L.After that author analyzed the microstructures of the as-DPD and the as- annealed DPD 316L SS samples were characterized by scanning electron microscopy (SEM) on a FEI Nova Nano-SEM system at an operating voltage of 15 kV. Then sample were measured the hardness using Vickers hardness machine. Author concluded the result as -DPD 316L steel exhibits a little enhanced wear resistance under a load of 10 N, and nearly identical wear resistance under a load of 30 N relative to that of the original. Author also concluded after annealing, the wear resistance roughly follows the Archard equation under a load of 10 N and also the wear resistance increases with increasing hardness, and decreases with a further increase in hardness under a load of 30 N. The result shoes that the highest wear resistance can be found in the DPD sample annealed at 750 ±C for about 20 min, which is more than 46% higher than that of the CG steel sample.

Ram.Subbiah [11] used the case hardening techniques like nitriding and surface hardening processes offer high corrosion resistance in addition to, improved hardness and wear resistance. Author studied the effect of gas nitriding on the properties like micro hardness, corrosion resistance and wear resistance of type AISI 316LN grade austenitic stainless steels were investigated. Author performed the salt bath nitriding was carried out at a temperature of 5000C for durations of 60, 90 and 120 minutes with a post oxidation process for a period of 30 minutes and then inter metallic phases were analyzed with optical microscope and micro hardness tested with micro hardness tester. Author concluded that that gas nitriding increases the micro hardness to a considerable amount. A maximum of 1410Hv could be obtained on the austenitic grade stainless steel specimens and reason for the increase in the micro hardness could be effect of Mo presence and the other alloying elements in the solid solution. Also noticed that the value of hardness at the surface level increases with the diffusion time up to a certain level and after that above the certain level the hardness changes not happened. Author also concluded that post- oxidation has no significant effect on the hardness but improves the corrosion resistance in comparison with non-oxidized specimen in a larger factor and case depths were observed to be about 20 -50 microns (μm).

III. CONCLUSION

a) As per the survey Lot of Methods available to improve the wear, corrosion and hardness properties of the austenitic stainless steel SS316L

b) As per the survey Very few methods of metal composite and metal matrix are available to improve the wear, corrosion and hardness properties of the austenitic stainless steel SS316L

c) Further study may be conducted the overlay technique and metal matrix using welding technique to improve the wear, corrosion and hardness properties on austenitic stainless steel SS316L

REFERENCES

[1] J.Suresh, S.Suthagar, A STUDY ON WEAR AND CORROSION CHARACTERISTICS OF MARINE PROPELLER SHAFT MATERIAL - AISI 316L STAINLESS STEEL SUBJECT TO CRYOGENIC TREATMENT, Proceedings of ICSEM"14 - 2nd International conference on science, Engineering and management

[2] P.M. Natishan,Carbon Surface Modification for Enhanced Corrosion Resistance, MATERIALS SCIENCE AND TECHNOLOGY, 2008 NRL REVIEW

[3] V. Muthukumaran, V. Selladurai, S. Nandhakumar, M. Senthilkumar, Corrosion and Hardness Behaviour of AISI 316L SS Implanted with Argon and Oxygen Ions, Journal for Engineering,Design and Technology, ISSN: 1726-0531

[4] Sudjatmoko, Lely Susita R.M., Wirjoadi, Bambang Siswanto "BATAN,CORROSION RESISTANCE IMPROVEMENT OF AISI 316L STAINLESS STEEL USING NITROGEN ION IMPLANTATION " Ganendra Journal of Nuclear Science and Technology Vol. 16 No. 2 Juli 2013: 67-75

[5] F.A.P. Fernandes1*, J. Gallego2, G.E. Totten3, C.A. Picon2, L.C. Casteletti1, CORROSION RESISTANCE OF PLASMA NITRIDED AND NITROCARBURIZED AISI 316L AUSTENITIC STAINLESS STEEL, www.feis.unesp.br

[6] Y. Sun, E. Haruman, Effect of electrochemical potential on tribocorrosion behaviour of low temperature plasma carburized 316L stainless steel in 1 M H2SO4- solution Surface & Coatings Technology 205 (2011) 4280–4290- www.elsevier.com/ locate/surfcoat

[7] N. Chuankrerkkul1*, C. Lorchaiyanunt2, S. Tansittipan2 and S. Polsilapa2, POWDER METALLURGY OF STAINLESS STEEL - TUNGSTEN CARBIDE COMPOSITES, www.iccm-central.org

[8] Uílame Umbelino Gomes, José Ferreira da Silva Jr. And Gislâine Bezerra Pinto Ferreira- Effect of the Additives of Nanosized Nb and Ta Carbides on Microstructure and Properties of Sintered Stainless Steel- www.intechopen.com

[9] Sulima a,*, L. Jaworska a,b, P. Wyżga b, M. Perek-Nowak c, The influence of reinforcing particles on mechanical and tribological properties and microstructure of the steel-tib2 composites, Jpurnal of Achivement in material and manufacturing engineering -Volume-48, Issue1 september2011

[10] Bo Wang, Bin Yao and Zhong Han, Annealing Effect on Wear Resistance of Nanostructured 316L Stainless Steel Subjected to Dynamic Plastic Deformation- J. Mater. Sci. Technol., 2012, 28(10), 871{877.

[11] N.R. Tao and K. Lu: J. Mater. Sci. Technol., 2007, 23, 771.

[12] Y.S. Li, N.R. Tao and K. Lu: Acta Mater., 2008, 56, 230.

[13] Ram.Subbiah, S.Satheesh, Shoan C.Sunny, G.Kishor, K.Fahad, R.Rajavel, “Assessment of Properties on AISI 316LN Austenitic Stainless Steel Material under Low Temperature Liquid Nitriding Processes”, International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-3, Issue-9, February 2014

[14] “stainless steel”, Lucefin S.p.A. I-25040 Esine (Brescia) Italy ,www.lucefin.com

[15] “www.bssa.org.uk/topics.php?Article=183

[16] LUCAS J. O’DONNELL, “TRIBOLOGY OF 316L AUSTENITIC STAINLESS STEEL CARBURIZED AT LOW TEMPERATURE”, Department of Materials Science Engineering -CASE WESTERN RESERVE UNIVERSITY.