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Dissimilar Weld of Austenitic and Ferritic Stainless Steel: A Review

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Abstract: This paper deals with the various investigations of austenitic and ferrite stainless steel welding carried out by the various researchers. Across various industries including chemical, petrochemical and shipbuilding industries, austenitic stainless steel is used. In most sectors, austenitic stainless steel is used, but its cost has a major impact on manufacturers and end users. So for these, the ferrite stainless steel can be used instead of austenitic stainless steel.But the whole replacement of austenitic stainless steel with the ferrite stainless steel is not possible in industries. Therefore welding of austenitic withferrite gives strength and reduces the cost of material. So, this review paper systematically highlights the effects of microstructure, mechanical properties and corrosion resistance of 316 austenitic stainless steel with 430 ferritic stainless steel welding processes and conditions.
Keywords:-Welding, austenitic and ferritic , parameters.

I. INTRODUCTION

Welding of Austenitic and Ferrite steel studies has been extensively carried out and is well documented. These two types of steel can be readily welded by all standard methods. After welding, the investigation can be done on the heat affected zone where the mechanical, metallurgical and corrosion properties changes takes place. The heat affected zone of welding two materials is used for studying temperature distribution across heat affected zone. For welding the two materials there are different parameters which are current, voltage, welding speed, energy input and types of filler materials used in welding. These parameters have to be studied and for welding two materials which parameters have to be chosen are important criteria for investigation. After carrying out which parameters are to be chosen we have to carry out their significance in welding. The effect of welding on mechanical ,metallurgical and corrosion property have been the basic part of an investigation where by means of X-ray diffraction, optical microscope and Scanning Electron Microscope we can get the crystal and micro structural view of the heat affected zone in welding. The preliminary literature review reveals that the studies on welding of austenitic stainless steel with ferritic stainless steel have been useful in many chemical industries, petrochemical and shipbuilding industries.

Literature Review:

The various input parameters are welding current, Voltage, Welding Speed, Heat input and Welding Processes. The proper selection of input parameters results in proper welding of austenitic and ferrite steel. The different input parameter ranges used by the various researcher affects the heat affected zone of the welding.

- WichanChuaiphan et.al (2012) investigated the behavior of nitrogen on dissimilar joint of AISI 304 and AISI 316 austenitic stainless steel using gas tungsten arc welding process. The relations between nitrogen content of dissimilar weld metal and the welding parameters such as welding current, welding speed, welding arc length and penetration area of weld metal were evaluated and it was found that nitrogen content of dissimilar metal decreases with an increasing welding current and penetration of weld metals, it increases with the increase in welding speed and it hardly depends on the welding arc length.

- M.M.A Khan et.al(2013) used AISI 440 C martensitic and AISI430F ferritic stainless steel . The input parameters are (Laser Power :- 600 to 1000 W,Welding Speed :- 2.0 to 4.0 m/min ,Energy input :- 9.0 to 30.0 kJ/m). Laser Beam Welding is used to find out most significant welding parameters, crack path of weld, microstructure determination. Software, Leica IM500 and optical microscope are used. Combined welding and pre-and post weld treatment technique is able to overcome the crack formation, laser power and welding speed are the most significant laser welding input factors and have opposite effects, weld penetration depth determines the minimum crack path of the weld, laser power of 790 to 810 W and a welding speed of 3.6 to 4.0 m/min are the optimal parameters to obtain excellent weld.

- Mahmud SarkariKhorrami et.al (2014) used plain carbon steel and AISI 430 ferritic stainless steel for study .The microstructure and mechanical properties of plain carbon steel and AISI 430 ferritic stainless steel are carried out. GTAW is used in autogenous and by using ER309L austenitic filler metal was used. Optical microscopy (OM), Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) and X-ray diffraction are used for study. The welding parameter during GTAW process with ER309L filler rod and Autogenous welding are (Welding Current :-85 A and 130 A, Arc Voltage :- 12 and 12 V, Welding speed:- 2mm/s and 4.27 mm/s, Gas flow rate:- 12 and 12 lit/min)respectively.Fully ferritic

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microstructure are formed for autogenous weld and duplex ferritic-martensitic microstructures for filler added welds.Ultimate tensile strength increased from 662MPa to 910MPa,hardness increases from 140Hv to 385Hv and absorbed energy increases from 53.6 J/m^3 to 79 J/m^3 by addition of filler metal.The weld heat input strongly affects grain growth phenomenon along with amount and composition of carbides and intergranular martensite. Ductile fracture is observed in specimen welded with filler metal while mainly cleavage fracture occurs in autogenous weld metal.

- MadduruPhanindra Reddy et.al (2014) used dissimilar joint of AISI 4140 and AISI 316 by means of Gas Tungsten Arc Welding Process with and without filler metal. Scanning electron microscope and Energy Dispersive Spectroscopy are used to found out microstructural structure of welds. Hardness and Tensile strength were evaluated. It was found that martensite formation is observed at the HAZ of AISI 4140 in both the cases. In AISI 316 metal tensile failure occurred for both the cases. The strength of the welds are found to be higher and comparable with AISI 4140/AISI 304 candidate metals.

- JeswinAlphy James et.al (2016) friction welded austenitic stainless steel 304 and medium carbon steel AISI 1040 and compared the properties of weld with and without interlayer at different welding parameters. The nickel is selected for study the interlayer materials. The welding parameters such as forging pressure, rotational speed and friction time are optimized by choosing three input parameters and three input level. Taguchi Orthogonal array is used for design of experimentation. The microstructure, tensile strength, micro hardness and FESEM-EDS results are compared and analysed for weld with nickel interlayer and without interlayer to study the effect and found that the Ultimate tensile strength of welds without using interlayer was directly depend on the forging pressure. But when nickel interlayer was introduced highest strength was achieved at highest burn off length of 8 mm. Micro hardness results showed a decrease in peak hardness at the interface which was 454 Hv. The Micro hardness shows decrease in peak hardness at the interface (391 Hv) which was 454 Hv when welded without using interlayer which is due to the reduction in the precipitation of chromium carbide at the interface due to presence of nickel.

- R. Neissi, M. Shamanian, and M. Hajihashemi (2016) studied dissimilar 316L austenitic stainless steel/2205 duplex stainless steel (DSS) joints were fabricated by constant and pulsed current gas tungsten arc welding process using ER2209 DSS as a filler metal. Microstructures and joint properties were characterized using optical and electron scanning microscopy, Charpy V-notch impact and micro-hardness tests, and cyclic polarization measurements. Microstructural observations confirmed the presence of chromium nitride and delta ferrite in the heataffected zone of DSS and

316L, respectively. In addition, there was some deviation in the austenite/ferrite ratio of the surface welding pass in comparison to the root welding pass. Besides having lower pitting potential, welded joints produced by constant current gas tungsten arc welding process, consisted of some brittle sigma phase precipitates, which resulted in some impact energy reduction. The tensile tests showed high tensile strength for the weld joints in which all the specimens were broken in 316L base metal.

- N.Hara et.al, (2017) used Ferritic/Martensitic and 316 austenitic steel. The input parameters used are (accelerating Voltage: 150kV; beam current:- 20 mA and welding speed:- 1000 mm/min).Post Weld Heat Treatment have been done at 750^0C for 1 hour. Electron beam welding is used to find mechanical properties by Scanning Electron Microscope, Energy dispersive spectroscopy and Transmission electron microscope. Mechanical Properties was improved by the optimization of electron beam position in the welding, smaller irradiation hardening than 316L was observed in the Weld metal 316L dissimilar weld after PWHT at 750^0 C for 1 hour where the electron beam was shifted 0.2 mm on 316L side, though the formation of voids and dislocation loops occurred in the Weld Metal.

- SaeidGhorbania , Reza Ghasemib, Reza Ebrahimi-Kahrizsangia, Akbar Hojjati-Najafabadid (2017) investigated dissimilar metals austenitic stainless steel (304 L) and ferritic stainless steel (430) by GTAW with two types of fillers (316 L and 2594L). The effect of heat treatment on the microstructure, mechanical properties and corrosion properties of welded joints were studied. Scanning Electron Microscope (SEM) was used for microstructure, fracture cross section and corrosive areas of sample. For Metal (304L and 430) filler metal used was 2594 and 316L, range of heat treatment temperature is 860 to 9600 C. With increasing the heat treatment temperature from 860 °C to 960 °C, the more austenite phase stabilized at HAZ area of 430 ferritic steel. The corrosion current density values reduced at 860 °C in comparison to 960 °C for all of the samples. The main factors for increasing corrosion resistance were residual stress and presence of precipitation in grain boundaries due to quenching.

- Nabendu Ghosh, Pradip Kumar Pal, Goutam Nandi (2017) studied and analysed the effects of welding parameters: welding current, gas flow rate and nozzle to plate distance, on ultimate tensile strength (UTS) and Yield Strength (YS) in MIG welding of AISI409 ferritic stainless steel to AISI 316L Austenitic Stainless Steel materials. The welding current (100 to 124 A, Gas flow rate (10 to 20 l/min) and Nozzle to plate distance (9 to 15 mm). Experiments have been conducted as per L9 orthogonal array of Taguchi method. The observed data of UTS and YS have been interpreted, discussed and analyzed with use of Taguchi Desirability analyses. The optimal parameter combination is (Welding current-112A, Gas flow rate-15 l/min and Nozzle to plate distance-15 mm).

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- Manuel Thomas, Raghu V. Prakash, Ganesh Sundara Raman S and Vasudevan, M. (2018) used 316 LN for study. The Conventional Multipass Tungsten Inert Gas Welding (MP-TIG) and Activated TIG (A-TIG) welding process is used. Fatigue tests were carried out to characterize the crack growth rates of base metal, HAZ and Weld Metal for A-TIG and MP-TIG configurations. Scanning Electron microscopy is used to help better understand the fatigue crack propagation modes during high temperature testing. The analysis of HAZ crack growth rate showed that the MP-TIG process is the process to improve the fatigue crack growth rate resistance to materials.

- JagesvarVerma, Ravindra V. Taiwade,RavinderKataria , Anil Kumar (2018) studied stainless steel UNS 32205 and AISI 430 welded by arc welding process with the help of Mo based austenitic and duplex electrodes .The analysis of X-Ray diffraction suggests the existence of carbide phase in the welds due to the presence of more carbon.Electron backscatter diffraction showed strong texture of both welded zone. Higher ferrite content was measured in duplex electrode weld. Higher degree of sensitization was measured in AISI 430 base metal and duplex weld. Higher pitting corrosion and film resistance were measured in duplex base metal and duplex electrode weld. More intergranular corrosion was observed in the heat affected zone of AISI 430.

- Nabendu Ghosh et.al (2018) used 316 L Austenitic Stainless Steel for study. The parameters used are (Welding Current-100 to 124 A,Gas flow rate-10 to 20 l/min, Nozzle to Plate Distance-9-15 mm). Taguchi ,X-ray radiographic testis used and MIG Welding is used. Ultimate strength, yield strength and percentage of elongation have been evaluated. Butt joints between austenitic stainless steel 316L being done under welding and X-ray Radiographic test. The best result For Current-100A,flow rate-20l/min,and nozzle to plate distance -15 mm the Yield strength=322.7427 MPa,ultimate tensile strength=591.1774 MPa and percentage of elongation=54.539 and the worst result are for current-124A,gas flow rate-10 l/min and nozzle to plate distance-15 mm . Yield Strength=242.42773, ultimate tensile strength=426.23343 MPa and percentage of elongation=19.524.

- Rong Chen et.al(2018) used austenitic stainless steel 316L for study. To find magnetic field intensity 4 kW fiber laser and 4000 digital arc power. Laser-MIG hybrid welding is used. Fatigue life (strength and ductility) and crack deflection. Having Magnetic field having 4-kW fiber laser and 4000 digital arc power were used as sources for bead-on plate weld. Magnetic field promotes formation of skeletal ferrite with diverse orientations, plastic deformation transferring at phase boundary

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consumes more energy and contributes to crack deflection in grain interior, Semi-coherent interface between δ-γ with non-K-S OR not only impedes transmission of the dislocation slip but also accommodates a considerable amount of plastic strain by continual loss of coherency. Thus, it can improve both strength and ductility of the welds.

- Ranjit Singh et.al (2018) used 316 Stainless Steel for study. They used 10 mm thick AISI 316 L stainless steel plates were welded using GMAW process.3 pass weld and 5 pass welding procedure is used for butt joint. GTAW and GMAW to find Impact Toughness. 5-weld pass technique resulted into higher impact toughness than the 3-weld pass technique. Thermal aging resulted into loss of toughness in both the welds.Aging condition of 750o C/12 hours resulted into higher loss of impact toughness as compared to 750o C/2 hours condition. Weld metal in both the cases showed higher impact toughness as compared to Heat Affected Zone (HAZ) of these welds under aging conditions. Loss of toughness was more when testing temperature was cryogenic.

- I.A.Segura et.al (2018) used 316 L austenitic stainless steel for investigation. EBM (Electron Beam Melting), Selective Laser Melting (SLM), X-Ray Diffraction and TEM (Transmission electron microscopy) technique are used to find out tensile and ultimate strength of the material. The study compared the micro structural and mechanical properties of 316 L claddings produced by EBM AM to those of the wrought 316 L material highlighting the potential for using this AM technique in the fabrication or repair of components with enhanced corrosion resistance and decreased sensitization susceptibility including those that can be used in nuclear reactor and other corrosive environment applications. The tensile tests indicate that the EBM produced components exhibited yield strength and ultimate tensile strength values roughly 76% and 29% greater than wrought 316L stainless steel.

- Diego Silva et.al (2018) used AISI 316L austenitic stainless steel and AISI 1020 low carbon steel for study. Welding Current:-13 KA,Welding time:-1 s and constant pressure. Spot Welding technique is used to find thermal Energy,Q. Three thermocouples are used. The first thermocouple placed in HAZ, second 1 cm distance from HAZ and third thermocouple placed at 2 cm distant from HAZ. The temperature curves obtained show that the materials undergo different thermal cycles, this is expected because the steels have different chemical compositions and thermal properties. The Coefficient of determination R2 obtained in 1020 carbon steel and 316L stainless steel have values very close to 1,that is the fit of the model was good .Except the third thermocouple of stainless steel sheet (R2 = 0.7308).

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- Amir Torabi et.al (2018) used Nd:YAG laser beam welding to weld AISI 316L austenitic stainless for study. The input parameters are Peak Power(Pp)=1650 to 1850 Watt ,Pulse duration(Δt)=3.5 to 5.5 ms ,Pulse frequency(fr)=3 to 5 Hz, Welding Speed (V)=0.2 to 0.6 mm/s. Ultimate Tensile Strength was found out by means of Simulated Annealing (SA) algorithm and desirability function of RSM in Minitab Software. Main effect in frequency and peak power are more significant with effects of 32.2% and 27.7% than pulse duration and welding speed. The RSM is a good statistic method to analyze the interaction between factors in this study. The optimization in two methods of RSM and SA was done. Results indicate that both the SA and RSM methods are very good compatibility with experimental results. An average Maximum UTS of 607 MPa with near 96% UTS in base metal (630 MPa) was obtained by setting the optimized process parameters. The residual plots and surveying the correlation coefficients (R2 =97.99%, R2(adj) = 96.46% and R2(pre) = 91.43%) prove the claim. The two validation tests prove the reliability of the model.

- Suman Saha et.al (2018) used 6 mm, 316L Austenitic Stainless Steel ,butt joint for study. Welding Current:-90A,100A,110A, 120A and 130A.Flux used:-No flux,TiO2,Fe2O3 and Cr2O3. Tungsten Inert Gas Welding (TIG) welding is used. Depth of penetration, width of weld bead, reinforcement, Reinforcement Form Factor (RFF), and Penetration Shape Factor (PSF). Five different current values (90,100,110,120 and 130A) for TIG and A-TIG welding with TiO2,Fe2O3 and Cr2O3 as flux for bead-on-plate as well as for butt joining. For both TIG and A-TIG welding (with TiO2, Fe2O3 and Cr2O3 as fluxes) joining can be achieved with heat input values higher than 1.4 KJ/mm except Cr2O3 flux having 1.9KJ/mm.TiO2 flux is effective in reducing weld bead width.Fe2O3 flux is used for increase in penetration (90%) with higher heat input, effective in reducing weld bead width.Cr2O3 flux is non effective in reducing weld bead and penetration rather it decreases penetration achievable by TIG welding.

- AbdeljlilHdhibi et.al (2018) used 316L austenitic stainless steel as a material for study. Welding Speed:-15 cm/min, Welding Current:-(150-180-200) Amp, Arc Length:-2mm, Electrode Tip Angle:-600 ,Shield gas on workpiece:-Argon with flow rate 12l/min, Shield gas Back side:-Argon with flow rate 5l/min, Welding Mode:-Direct current electrode negative. Activated TIG Welding (ATIG) is used. TIG welding with flux, X-ray Photoelectron Spectroscopy (XPS). XPS analysis show that the percentage of oxygen in the welds decreases with the increase of current welding intensity. Oxide fluxes with high thermodynamic stability and high melting points are not advisable to use for austenitic stainless steel. Tensile strength of ATIG is high than that of TIG because of delta ferrite. Except for TiO2, the weldment using other fluxes exhibits worse withstanding to sudden shock compared to those of TIG welding. This is due to oxygen content in welds and delta ferrite formation.

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CONCLUSION

The research of the dissimilar joint of Austenitic stainless steel 304L and ferritic steel 430 was performed and welded by Fusion welding process such as tungsten arc welding (GTAW), electron beam welding (EBW) and friction welding process. However, there is still no dissimilar joint of Austenitic stainless steel 316 and ferritic stainless steel 430 and it is the area to be studied. The investigation area was the dissimilar joint with the help of friction welding. The Finite Element Analysis (FEM) of the heat-affected area of 316 and 430 dissimilar joint is not yet completed and further investigation is needed for FEM analysis. We can use the dissimilar joints in chemical, petrochemical and ship building industries. So there is a scope of investigation in these area, where austenitic stainless steel can be welded for ferritic stainless steel.

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