Austenitic and Ferritic Stainless Steel Joints; A Brief Review

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Abstract: **Austenitic stainless steel (316L) and ferritic stainless steel (430) are the materials used in various production industries for the manufacturing of different equipments with specific requirements. They are used in production sectors like industrial, architectural and automobile due to their properties of good formidable strength, corrosion resistance at very extreme temperature. Different welding processes have been used to join these materials. These two materials have different compositions due to which it has become a challenge to join these materials via welding. Various companies have different requirements for their products due to which it is necessary to have data which have been analysed on these joints and use these data to increase growth and high production rate in industries. Various tests such as tensile, impact, hardness, corrosion and microstructure show us the rigidity, durability of the joints of these two materials. Because of these researchers are testing these joints which can be helpful in production companies.**

Keywords: Austenitic stainless steel, Ferritic stainless steel, Dissimilar welding, Different welding conditions

I. INTRODUCTION

Different compositions of stainless have been used in industries. Usually, austenitic stainless steel is used because of its strength and presence of chromium content in it. Due to high price of Austenitic stainless steel, it is not feasible to use in industries. For designer it is important to select suitable material for given requirement otherwise the weld engineer would have to face the problems while welding the joint. The ferritic stainless steel contains chromium content around 11 to 30 percent which makes it magnetic and corrosion resistance, so we can see that ferritic stainless steel has superior properties than austenitic stainless steel. Ferritic stainless steel has very low content of nickel due to which it is cost friendly to use in industries. Ferritic stainless steel has been used in various machines such as dishwashers, domestic appliances and washing machines. Welding joints of austenitic stainless steel and ferritic stainless steel is also used in oil and gas industries and petrochemical industries. These joints can be seen in nuclear power plant, evaporators and exchangers. The dissimilar joints have future scope because of advance technologies used due to their corrosion resistance properties. Different type of welding techniques such as friction welding, electron beam welding or cold metal transfer welding have been used to weld these joints. Various parameters are used in joining of dissimilar materials such as type of filler materials, welding speed, current, voltage is been considered while welding these two joints.

There is a huge requirement in biotechnology and pharmaceutical industries due to outstanding corrosion resistance property and clean ability to ensure pureness of drug. These material joints must withstand the temperature, pressure and corrosive nature of the medical environments. Also, joint materials must have good weldability and must be eligible of meeting the requirements of industry of surface finish. Also, austenitic stainless steels are hugely used for casting equipments in corrosive environments. Their popularity in industry is due to combination of corrosion resistance and mechanical properties. It also has high ductility and toughness in the temperature between +20 to -196 degree Celsius. The ferritic stainless steel are low cost and corrosion resistance steel. These steels have great future scope for application in construction industry.

II. DIFFICULTIES FACED DURING WELDING

Austenitic Stainless steel is used in industrial and production sects because it has very great strength, it is because it has nickel content present in it and also it is higher corrosion resistance. When welding these two joints we can see that ferritic stainless steel is little difficult to weld the austenitic stainless steel because we can see the excessive growth of grains in FSS, in heat affected zone we can see coarse grains and also, we can see heat affected zone in welding zone of fusion welding. Various authors state us that we can reduce the coarse grains by applying less heat while welding austenitic and ferritic stainless steel. In friction welding of 316L austenitic stainless steel, the distortion was limited to only 430 ferritic stainless steel. Usually, good grain size can be seen during high forge pressure. The grain growth in the heat affected zone is difficult infusion joining of these types of stainless steel. Generally, we can observe that the martensite formation along with grain boundaries in heat affected zone is seen when the carbon content of steel is present. Dissimilar joining of these materials is a tough process because of the different properties of these materials such as thermal, chemical and mechanical welded under same conditions. Also different difficulties can be faced during welding such as formation of cracks, residual stress and different kind of stress can be seen in materials.

III. WELDING TECHNIQUES

[2] Subodh Kumar et al., (2017) has done experimental investigation on dissimilar welding of austenitic stainless steel and ferritic stainless steel by MIG (Metal Inert Gas) welding, it is really a challenging process due to difference

in metals in thermal, mechanical and chemical properties welded in same conditions. [3] Aamir R. Sayed et al., (2019) has done a brief review on dissimilar metal weldments of stainless steel and mild steel by TIG (Tungsten Inert Gas) Welding process, TIG welding is relatively high strength welding technique. [6] Mr. K. V. Ganeshkumar et al., (2019) has studied gas tungsten welding of aluminium alloy 6063 and stainless steel 316. [9] Anhirav Mathur et al., (2015) studied Gas Tungsten Arc Welding of AISI 304 Austenitic stainless steel. [15] Jageshvar Verma et al., (2016) has done welding of dissimilar welding of 2205 Austeno-Ferritic and 316L Austenitic Stainless Steel where the welding is done by Shielded Metal Arc Welding (SMAW). [16] Faith Dokme et al., (2018) Has done Continues Current Gas Tungsten Arc Welding (CCGTAW) on Iconel 625 and AISI 316L. [17] C. R. Ashwin Kumar et al., (2016) has done welding of Gas Tungsten Arc Welded AISI 316LN Austenitic Stainless Steel. [18] P. Surendran et al., (2015) has done welding of Gas Metal Arc Welding on Austenitic Stainless Steel. [21] Md Razaullah Khan et al., (2016) has done welding of Metal Inert Gas on Ferritic Stainless Steel (AISI 430) Weldment using ER309L and ER430 electrodes.

IV. DIFFERENT OBSERVATION OF AUSTENITIC AND FERRITIC STAINLESS STEEL

1. Manninen et al., (2020) has studied on mechanical properties of ferritic stainless steel 430 at elevated temperatures. In which we can see that from range between 200 and 400 degree Celsius the strength of material remains constant although there was increase in temperature.
2. Subodh kumar and A. R. Ansari (2017) have studied on dissimilar welding of austenitic and ferritic stainless steel by MIG welding process in which we can see that at moderate current metal deposition rate increases. As the current value increases further, we can also see that metal deposition rate decreases. While there is increase in current, we can see that weld width also increases. Tensile strength of joint increases with increasing in current. The joint gets brittle with increase in current due to heat produced in it.
3. Aamir R. Sayed et al., (2019) studied dissimilar welds of stainless steel and mild steel by TIG welding process in which we can see that by welding of joints with TIG welding we can weld in all position and sound weld can be produced with less spatter.
4. Sujith Kumar SG and Dr. Hanumantha raju H G investigated on strength of stainless steel 316L and cobalt-chromium where we can see that there is not much difference if we applied pressure load for plastic deformation of stainless steel 316L and cobalt-chromium.
5. Mr. Anand Hegde et al., (2014) studied the corrosion behaviour of austenitic stainless-steel composites where microstructure showed large and irregular ores with the grain boundary area and as the amount of Tic increases the rate of corrosion decreases. Also, the particle size of the stainless-steel powder in first condition was found about 1200nm and after doing the reduction by ball milling for about 16hrs we can see that the size reduced to 600nm.
6. Mr. K.V. Ganeshkumar et al., (2019) studied on dissimilar welding of aluminium alloy 6063 and austenitic stainless steel 316 using different parameters and observed the mechanical properties in which tensile test result shows us yield load of 46.30 KN and yield strength of 331.85 N/mm^2 and tensile load of 64.76 KN where as in impact test we can see that impact value in joules is 77.5.
7. SM Hussaini et al., (2013) experimented on dynamic strain aging regime in austenitic stainless steel 316 where we can see that serrations has been occurred in range from 400 to 600 degree Celsius at the strain rate of $1x10^{-4}$ sec^{-1}. Also, as the DSA region decreases as there was increase in strain rate.
8. M. Alizadeh-Sh et al., (2013) studied resistance spot welding of AISI 430Ferritic stainless steel mechanical properties where we can see that energy absorption and peak load of the welded joints can be seen improved as there was increase in welding current. It is because of formation of larger FZ size at higher heat input.
9. Abhirav Mathur et al., (2015) studied on Gas tungsten arc welding of AISI 304 Austenitic stainless steel where we can see that tensile strength of base metal is greater than compared to weld blead and also the amount of ductility is significantly higher for base metal compared to weld bead, this may happen due to post heat treatment.
10. Musrafa Senol and Gurel Cam (2020) studied Mechanical Characterization of Gas Metal Arc Welded AISI 430 Ferritic Stainless-Steel joints where joints showed hardness in weld region. Also, the ductility performance was lower because of confined plasticity.
11. B. Kalandyk et al., (2015) studied impact strength of austenitic and ferritic-austenitic Cr-Ni stainless steel in -40 and +20 degree Celsius temperature in which we can see that at -40 and +20 degree Celsius fractures was observed in sample of ferritic-austenitic steel were ductile and brittle in nature.
12. Sridhar Atla and Mulugundam Siva Surya (2017) studied Influence of cutting fluids on tool wear and surface roughness during turning of Aisi 316 Austenitic stainless steel where coconut oil was found a better cutting fluid for austenitic stainless steel rather than conventional mineral oils.
13. Minakshi Vaghani et al., (2015) studied Structural Evaluation of Stainless steel as a Strengthening Material where it can be seen that increase in FRP width did not provide much improvement on the strength of ferritic stainless steel.
14. Jagesvar Verma et al., (2016) studied the effect of electrode on microstructure and mechanical properties of dissimilar welds of austeno-ferrritic and austenitic stainless steel where we can see that in tensile test data

both the weldments E2209 and E30 undergoes a ductile type fracture.

15. Faith Dokme et al., (2018) studied mechanical characterization of dissimilar metal welding of Inconel and Aisi 316L where Hardness and tensile test data showed us that PCGTA welding improves the mechanical properties of weldments.
16. C. R. Ashwin Kumar and Dr. S. Sathiyamurthy (2016) studied on Numerical analysis of Gas Tungsten Arc Welded AISI 316LN Austenitic Stainless Steel Joints using Response Surface Methodology and Finite Element Analysis where the optimized parameters were predicted and the results were validated using FEA and experimental method which shows good agreement.
17. R. Ramesh Babu et al., (2018) studied the optimisation of process parameters in weldments for stainless steel 316 austenitic stainless steel using taguchi method where with taguchi method the input parameters we get is MRR are pulse on 10 and pulse off is 5 and voltage is 25 v.
18. P. Surendran et al., (2015) studied Optimization of bead Geometry in Austenitic Stainless Steel Cladding using Taguchi's Method where wire feed rate gives more contribution to bead width, welding speed gives 27.32 % contribution to bead width whereas welding voltage gives 19.30 % and nozzle to plate distance gives 12.32 % contribution.
19. Musa Muhammed et al., (2020) studied Statistical Review of Microstructure-Property Correlation of Stainless Steel where tensile strength, hardness and corrosion current density showed a positive correlation and also a moderate correlation was exhibited in between tensile strength and hardness.
20. Razaullah Khan et al., (2016) studied Mechanical Properties of Ferritic Stainless Steel (AISI 430) where in tensile testing we can see that weldments broken outside the welded joints so we can consider the efficiency of the joints can be more than 100%.
21. N. V. Amudarasan et al., (2012) studied Tensile and Impact Properties of AISI 304L Stainless Steel Welded Joints Using Austenitic and Duplex Stainless Steel Filler Metal where the joints fabricated using austenitic stainless steel are superior compared to duplex stainless steel in yield strength, percentage of elongation, tensile strength, maximum displacement and impact toughness.
22. J. Charles et al., (2015) studied the ferritic stainless-steel family where ferritic stainless steel are alternative solution for 301, 304, 316 austenitic stainless-steel grades.
23. S. A. Cruz et al., (2015) studied Corrosion resistance of powder sintered ferritic stainless steels where we can see that high temperature corrosion experiments show the cermet 2% carbon Mirco fibres, will suffer strong oxidation because of absence of passive layer.
24. Mirza Pramudia and Khamdi Mubarok (2014) studied The Effects of The Degree of Deformation in The Work Hardening Process on Microstructure, Hardness, and Phase Transformation of The Material Structure of Nickel-Free Austenitic Stainless Steel where the degree of deformation in the work hardening process is able to increase the hardness of BioDur 108 without changing its chemical compositions nor the phase of its crystal structure.
25. K. R. Padmavathi et al., studied influence of process parameters on wire edm process for 316 stainless steel where the confirmation tests indicated that it is probable to augment MRR and diminish surface roughness appreciably by using the projected statistical technique.

V. RECENT TRENDS

1. The austenitic stainless steel is used in helicopter and military applications.
2. Medical requirements of austenitic stainless steel are used in hypodermic needles, surgical anvils, needle caps.
3. The magnetic properties of ferritic grades are a major benefit and enabler for many of their applications.
4. In FSS fastening parts and induction heating, for example, both make use of this property in the manufacture of induction cookers and magnetic fasteners.
5. Austenitic stainless steel has regular uses type of stainless steel because of resistance to corrosion and heat. It is used in industries counting the aerospace, automotive.

VI. CONCLUSIONS

1. Ferritic Stainless Steel has range between 200 and 400 degree Celsius the strength of material remains constant although there was increase in temperature.
2. In MIG welding process in which we can see that at moderate current metal deposition rate increases. As the current value increases further, we can also see that metal deposition rate decreases. While there is increase in current, we can see that weld width also increases.
3. TIG welding we can weld in all position and sound weld can be produced with fewer spatters.
4. Aisi 316 Austenitic stainless steel where coconut oil was found a better cutting fluid for austenitic stainless steel rather than conventional mineral oils.
5. Hardness and tensile test data showed us that PCGTA welding improves the mechanical properties of elements.
6. Austenitic and Duplex Stainless Steel Filler Metal where the joints fabricated using austenitic stainless steel are superior compared to duplex stainless steel in yield strength, percentage of elongation, tensile strength, maximum displacement and impact toughness.

REFERENCES

[1] Manninen, T. And Saynajakangas J. (2020) Mechanical Properties Of Ferritic Stainless Steels At Elevated Tempreature, T. Manninen & J. Saynajakangas, Outokumpu Stainless Oy

[2] Subodh Kumar, A. R. Ansari (2017) Experimental Investigation On Dissimilar Welding Of Austenite And Ferrite Stainless Steel By Mig Welding Process, International Journal Of Advance Research In Engineering, Vol. No.6, Issue No. 07, July 2017

[3] Aamir R. Sayed, Yogesh V. Kumbhare, Nikhil G. Ingole, Parvin T. Dhengale, Nainish R. Dhanorkar (2019) A Review Study Of Dissimilar Metal Welds Of Stainless Steel And Mild Steel By Tig Welding Process, International Journal For Research In Applied Science & Engineering Technology (Ijraset) Issn: 2321-9653; Ic Value: 45.98; Sj Impact Factor: 6.887 Volume 7 Issue Ii, Feb 2019- Available At Www.Ijraset.Com

[4] Sujith Kumar S G, Dr. Hanumantharaju H G (2013) An Investigation On Strength Of Ss316l And Cobalt-Chromium Used As Cardiovascular Stent Materials By Non Linear Fea, International Journal Of Engineering Research & Technology (Ijert) Vol. 2 Issue 12, December – 2013.

[5] Mr Anand Hegde, Mr Adarsh Patil And Mr Vijay Tambrallimath (2014) Corrosion Behaviour Of Sintered Austenitic Stainless Steel Composites, International Journal Of Engineering Research & Technology (Ijert), Vol. 3 Issue 12, December-2014.

[6] Mr. K. V. Ganeshkumar, Mr. J. David, Mr. P. Kenson, Mr. M. Magalingam (2019) Dissimilar Welding Of Aluminium Alloy 6063 And Stainless Steel 316 By Using Various Parameters And Evaluate The Mechanical Properties, International Journal Of Engineering Research & Technology (Ijert) Issn: 2278-0181 Published By, Www.Ijert.Org Etedm - 2019 Conference Proceedings.

[7] Sm Hussaini, S K. Singh, A K Gupta (2013) Experimental Investigation Of Dynamic Strain Aging Regime In Austenitic Stainless Steel 316, International Journal Of Engineering Research & Technology (Ijert) Vol. 2 Issue 8, August – 2013.

[8] M. Alizadeh-Sh , S.P.H. Marashi, M. Pouranvari (2013) Resistance Spot Welding Of Aisi 430 Ferritic Stainless Steel: Phase Transformations And Mechanical Properties, 0261-3069/$ - See Front Matter 2013 Elsevier Ltd. All Rights Reserved. Http://Dx.Doi.Org/10.1016/J.Matdes.2013.11.022.

[9] Abhirav Mathur, Md Areeb Muneer, S. S. Sricharan, K. Chandra Shekar (2015) Gas Tungsten Arc Welding Of Aisi 304 Austenitic Stainless Steels, International Journal Of Engineering Research & Technology (Ijert) Issn: 2278-0181 Ijertv4is120219 Www.Ijert.Org (This Work Is Licensed Under A Creative Commons Attribution 4.0 International License.) Vol. 4 Issue 12, December-2015.

[10] Mustafa Senol1, Gurel Cam (2020) Microstructural And Mechanical Characterization Of Gas Metal Arc Welded Aisi 430 Ferritic Stainless Steel Joints, All Content Following This Page Was Uploaded By Gürel Çam On 19 December 2020.

[11] B. Kalandyk, R. Zapała, Ł. Boroń, M. Solecka (2015) Impact Strength Of Austenitic And Ferritic-Austenitic Cr-Ni Stainless Cast Steel In -40 And +20◦C Temperature, Doi: 10.2478/Amm-2014-0190.

[12] Sridhar Atla1, Mulugundam Siva Surya (2017) Influence Of Cutting Fluids On Tool Wear And Surface Roughness During Turning Of Aisi 316 Austenitic Stainless Steel, International Journal Of Engineering Research & Technology (Ijert) Http://Www.Ijert.Org Issn: 2278-0181 Ijertv6is070119 (This Work Is Licensed Under A Creative Commons Attribution 4.0 International License.) Published By: Www.Ijert.Org Vol. 6 Issue 07, July – 2017.

[13] K. R. Padmavathi, S. Devaraj, I. John Solomon, A. Premkumar (2018) Influence Of Process Parameters On Wire Edm Process For Aisi 316 Stainless Steel, International Journal Of Engineering Research & Technology (Ijert) Issn: 2278-0181 Published By, Www.Ijert.Org Pecteam - 2k18 Conference Proceedings.

[14] Minakshi Vaghani, Dr. S.A. Vasanwala , Dr. A.K. Desai (2015) Structural Evaluation Of Stainless Steel As A Strengthening Material: A State Of A Review, Iosr Journal Of Mechanical And Civil Engineering (Iosr-Jmce) E-Issn: 2278-1684,P-Issn: 2320-334x, Volume 12, Issue 2 Ver. Vii (Mar - Apr. 2015), Pp 54-61

[15] Jagesvar Verma, Ravindra Vasantrao Taiwade, Rajesh Kisni Khatirkar And Anil Kumar (2016) A Comparative Study On The Effect Of Electrode On Microstructure And Mechanical Properties Of Dissimilar Welds Of 2205 Austeno-Ferritic And 316l Austenitic Stainless Steel, Materials Transactions, Vol. 57, No. 4 (2016) Pp. 494 To 500 ©2016 The Japan Institute Of Metals And Materials.

[16] Fatih Dokme, Mustafa Kemal Kulekci And Ugur Esme, Microstructural And Mechanical Characterization Of Dissimilar Metal Welding Of Inconel 625 And Aisi 316l, Metals 2018, 8, 797; Doi:10.3390/Met8100797.

[17] C. R. Ashwin Kumar, Dr. S. Sathiyamurthy (2016) Numerical Analysis Of Gas Tungsten Arc Welded Aisi 316ln Austenitic Stainless Steel Joints Using Response Surface Methodology And Finite Element Anlysis, International Journal Of Engineering Research & Technology (Ijert) Http://Www.Ijert.Org Issn: 2278-0181 Ijertv5is060210 (This Work Is Licensed Under A Creative Commons Attribution 4.0 International License.) Published By : Vol. 5 Issue 06, June-2016

[18] R. Ramesh Babu And S. Subhair (2018) Optimisation Of Process Parameters In Weldments For Stainless Steel 316 By Using Taguchi Method, Internal Journal Of Engineering & Technology (Ijert) Vol. 7 Issue 09, September-2018.

[19] P. Surendran, B. Senthilkumar, And T. Kannan. (2015) Optimization Of Bead Geometry In Austenitic Stainless Steel Cladding Using Taguchi’s Method And Multi Objective Genetic Algorithm, International Journal Of Engineering Research & Technology (Ijert) Issn: 2278-0181 Published By, Www.Ijert.Org Titcon-2015 Conference Proceedings.

[20] Musa Muhammed, Mazli Mustapha, Turnad Lenggo Ginta, Abdullah Musa Ali, Faizal Mustapha And Chima Cyril Hampo (2020) Statistical Review Of Microstructure-Property Correlation Of Stainless Steel: Implication For Preand Post-Weld Treatment, Processes 2020, 8, 811; Doi:10.3390/Pr8070811.

[21] Md Razaullah Khan, Umasankar Das, A. K. Pathak Professor, Dhirendra Tiwari (2016) Study Of Microstructure And Mechanical Properties Of Feritic Stainless Steel (Aisi 430) Weldment Using Er309l And Er430 Electrodes By Mig Welding Process, Nternational Journal Of Engineering Research & Technology (Ijert) Issn: 2278-0181 Ijertv5is010336 Vol. 5 Issue 01, January-2016.

[22] N.V. Amudarasan, K. Palanikumar And K. Shanmugam (2012) Tensile And Impact Properties Of Aisi 304l Stainless Steel Welded Joints Using Austenitic And Duplex Stainless Steel Filler Metal, International Journal Of Engineering Research & Technology (Ijert) Vol. 1 Issue 9, November- 2012.

[23] J. Charles1, J.D. Mithieux , P.O. Santacreu, L. Peguet (2015) The Ferritic Stainless Steel Family: The Appropriate Answer To Nickel Volatility ? , Article In Revue De Métallurgie • March 2009 Doi: 10.1051/Metal/2009024.

[24] S.A. Cruz, R. Poyato, A. Paul, J.A. Odriozola (2015) Corrosion Resistance Of Powder Sintered Ferritic Stainless Steels, All Content Following This Page Was Uploaded By L. Peguet On 18 August 2015.

[25] Mirza Pramudia., Khamdi Mubarok (2014) The Effects Of The Degree Of Deformation In The Work Hardening Process On Microstructure, Hardness, And Phase Transformation Of The Material Structure Of Nickel-Free Austenitic Stainless Steel, International Journal Of Engineering Research & Technology (Ijert) Vol. 3 Issue 7, July – 2014.