THINK INDIA JOURNAL

ISSN:0971-1260
Vol-22-Issue-37-December -2019

Investigation and comparison of the mechanical and metallurgical properties of sensitized and cryogenic treated weldments of austenitic stainless steel by TIG

Ranjit Singh[1*], Mandeep Singh Rayat[2], Guravtar Singh Mann[3]
[1,2,3] *School of Mechanical Engineering, Lovely Professional University*
** Corresponding author, ranjitsaraal@gmail.com*

Abstract

Stainless steels are having very important role in the industries, because of its good mechanical properties, better corrosion resistance and good weld ability. Samples of 304 austenitic stainless steel welds which were fabricated by TIG welding, are subjected to the sensitization heat treatment in the Muffle furnace at 690°C for 4 hours followed by cooling in furnace. Cryogenic treatment is done by dipping the weld bead into liquid nitrogen at -193°C. The soaking time and the temperature effects the mechanical properties, due to these significant changes appear in the mechanical properties of the austenitic stainless steel. Sensitization heat treatment shows the 4.6% increase in impact energy and considerable 6% decrease in hardness after treatment along with ditch type of structure which is observed after oxalic acid etching and in microstructural studies annealing twin are observed. On the other side, Cryogenic treatment results 22.14% increase in hardness of sensitized sample as well as 29.53% increases in non-sensitized sample. However, impact energy 22.3% is decreased in sensitized and non-sensitized sample is decreased by 27.7%. Isolated ferrite pools are observed on sensitized cryogenic treated sample and dual type structure is observed on non- sensitized cryogenic treated sample. Martensite and carbides are also observed in microstructural studies.

Keywords: *sensitization, Cryogenic, TIG welding, 304 Austenitic stainless steel*

1. Introduction:

During the welding of stainless steels chromium carbides forms. As a result, the steels develop susceptible to intergranular corrosion at the joint. Among all welding processes fusion welding operation shows maximum effect of heat, because in fusion welding operations joint is fabricated by the diffusion of atoms together and weld pool will be in liquid state for a long time during this time freely available carbon try to make reaction with chromium for obtaining stable condition, result of this chromium carbides will form along the grain boundaries and these grain boundaries are the more probable sites for nucleation and growth of pits [1,3,6]. During the weld of austenitic stainless steel plates experiences the different temperature distribution at different sections [2]. In this some of sections stand in critical temperature range, at this place chromium carbides formation take place along grain boundary. Sensitization effect is maximum in fusion welding over other non-fusion welding [4]. Worked on sensitization of 21% Cr FSS weld joints contrived without or with austenitic steel due to use of austenite interlayer prevent the microstructure of weld bead form

ISSN:0971-1260
Vol-22-Issue-37-December -2019

coarsening and grain refinement is achieved by using optimum duration of sensitization time which helps to regain corrosion resistance of the weldbead [5,7,8]. In addition, deep subzero treatment of alloys and metals is a process of stress relieving method. When materials are exposed to enormously low temperatures over a long period of time, it leads to ironing effect of defects in the material [10]. Due to this ironing effect grain size and shape get refined and is uniform and also defects as well as inter atomic spacing is reduced [14]. Compaction of the crystal structure results too much superior adhesive, abrasive, wear resistance, corrosion resistance, resilience and fatigue [9-10].

2. Objectives

- The main objective of the study is to find out the mechanical and metallurgical effect of cryogenic treated and sensitized weldments which are perpared by TIG welding operation.
- To study the effect of cryogenic treatment of sensitized stainless steel on corrosion resistance.

3. Experimentation

Four plates of AISI 304 Austenitic stainless steel of 200 X 30 X 10 mm with double V groove having 60° angle is used for the present work as it is the most commonly used material in the various industries due to its higher corrosion resistance. Filler rod of 304L with 1.4 mm diameter was used. AISI 304 ASS weldment material and filler material composition is shown in table 1.1 and 1.2 respectively.

Table 1.1: Chemical composition of AISI 304 ASS material

%C	%Mn	%Si	%P	%S	%Cr	%Ni
0.056	1.35	0.49	0.034	0.025	18.19	8.04

Table 1.2: Chemical composition of 304L filler

%C	%Mn	%Si	%P	%S	%Cr	%Ni
0.025	1.8	0.35	0.026	0.025	18.32	10.40

Weldments were welded with direct current electrode negative polarity, 170A current and 27 voltage. All prepared samples are categorized into four Sample groups on the basis of treatment given is listed in Table 1.3.

ISSN:0971-1260
Vol-22-Issue-37-December -2019

Table 1.3: Classification of samples

Sample	Type of treatment given	Treatment Parameters
G1	As-weld	170A and 27 V
G2	Sensitized	After weld samples were treated at 690°C for 4 h and then it is cooled in furnace
G3	Sensitized + Cryogenic Treatment	After Sensitization samples were cryogenically treated at -193°C with 24 hours of ramp down, 15 hours of socking and 8 hours of ramp up time.
G4	Cryogenic Treatment	Only cryogenic treatment given at -193°C with 24 hours socking time

3.1. Testing

Vicker's hardness, Charpy impact test, Intergranular corrosion and microstructure were examined for all the samples to make any conclusion. For The susceptibility to IGC was estimated according to standard procedures of the ASTM A262 Practice A. the samples were dipped in the solution which is contains 10% oxalic acid solution and 90% of distilled water mixed equally. This uniformly mixed solution were taken in stainless steel beaker which is made as anode. By using this solution the samples were etched for 4 min. the specimen which is going to be tested is made as cathode and the solution container is made as anode. Power source for the test is 4 volts DC supply battery with 3 amp current. The etch surfaces are observed on inverted metallurgical microscope (DMI crown) with 200X to 400X.

4. RESULTS AND CONCLUSIONS

4.1. Hardness test

Following results were obtained from the different tests. Table 1.4 shows the hardness of weld bead, HAZ and base plate. From the results it shows that considerably decrease in hardness at weld metal when it is compared with the base metal and HAZ. The sensitized specimen (Group 2) shows the least hardness in the weld metal. And cryogenic treated (Group 4) specimen shows the high hardness in weld zone. The hardness of the specimens at HAZ and base metal shows almost same, but slight increase in HAZ. The hardness of metals depends on the percentage of carbon present in it. Due to the sensitization phenomenon carbide precipitates are forming along the grain boundaries in HAZ. Along grain boundaries amount of carbide precipitates is higher, due to this hardness of HAZ is higher than base metal.

Table 4.1: Vickers hardness of samples

S No	Treatment given	Weld	HAZ	Base
G1	As-weld	149	176	178
G2	sensitized	140	175	170
G3	sensitized + cryogenic	182	212	211
G4	Cryogenic	193	222	218

ISSN:0971-1260
Vol-22-Issue-37-December -2019

4.2. Impact test

Table 1.5 shows the results of Impact test as well as figure 1.1 depicts the broken specimen after the test. Group 2 specimen shows highest impact energy of 272 J, which was subjected to sensitization heat treatment. Same specimen shows decrease in hardness at Heat Affected Zone. The cryogenic treated group 4 is shows low impact energy of 188 J. This is because of the presence of brittle in the samples after cryogenic treatment. Impact energy of the both groups cryogenic treated are reducing from 202 to 188 J. Which means that the samples have the less energy absorbing capacity before the fracture. As compared sensitized sample with cryogenic treated the impact energy is slight increase due to presence of the small plastic deformation in the material. Only cryogenic treatment decreases the impact energy. Due to pre – sensitization, the group 3 samples shows slight increase in the capacity of absorbing impact energy as compared with group 4 even it is cryotreated. This is because of presenting the annealing structure before cryogenic treatment. But in case of group 4 the samples shows least capacity of absorbing impact energy.

Table 1.5: Charpy impact test results

S No	G1	G2	G3	G4
Impact Energy, J	260	272	202	188

Figure 1.1: Specimens after impact test

4.3. Intergranular corrosion test

From the microstructural studies it is obtained that the sepcimen which is subjected to sensitization heat treatment shows the higher intergralur attack along the grain boundaries and it shows the ditch type structure after ASTM A262 Practice A test. Due to welding operation the carbides formation is very less as comapred with Group 2, beasuce in welding operation metals are subjected to critical temperature range for very few seconds only. But incase of group 2 the samples are subjected to 4 hr in critical temperature range. Group 3 smaples shows isolated ferrite pools are observed but the grain size of the samples is decresed. Due to the reduction in grain sizes and refinement of the carbides the width of the deplection layer is reduced by small amount as compared to group 2.Gorup 1 and group 4 sample shows dual type structure of carbides after the IGC testing. For Intergranular corrosion test Oxalic acid etching process was used and figure 1.2 portrays the process.

ISSN:0971-1260
Vol-22-Issue-37-December -2019

Figure 1.2: Oxalic acid etching

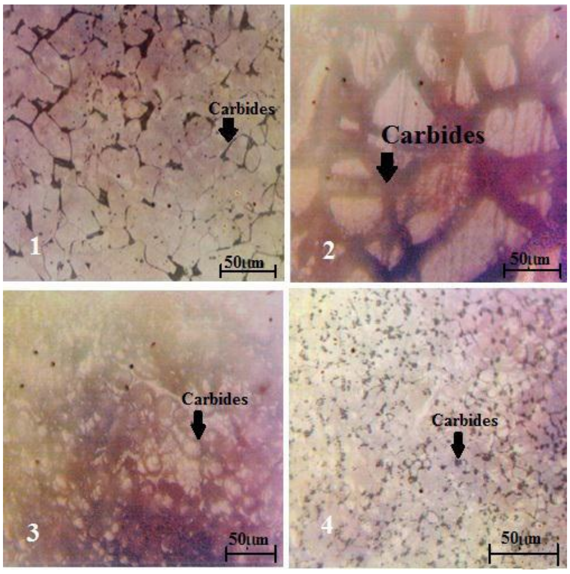

Figure 22: IGC results

4.4. Microstructure study

Microexaminations reveals that due to the sensitization heat treatment of the sample (Group 2) is shows the annealing twins. Because of sensitization heat treated samples were cooled in furnace to maximize the carbide precipitation formation on samples so that effect of cryogenic treatment is easily analysed. Group 1 specimen show that it having ferritic structure after welding, this is cooled at room temperature. Group 4 and Group 3 specimen shows that martensitic structure which was converted from austenite to twinned martensite through cryogenic treatment.

ISSN:0971-1260
Vol-22-Issue-37-December -2019

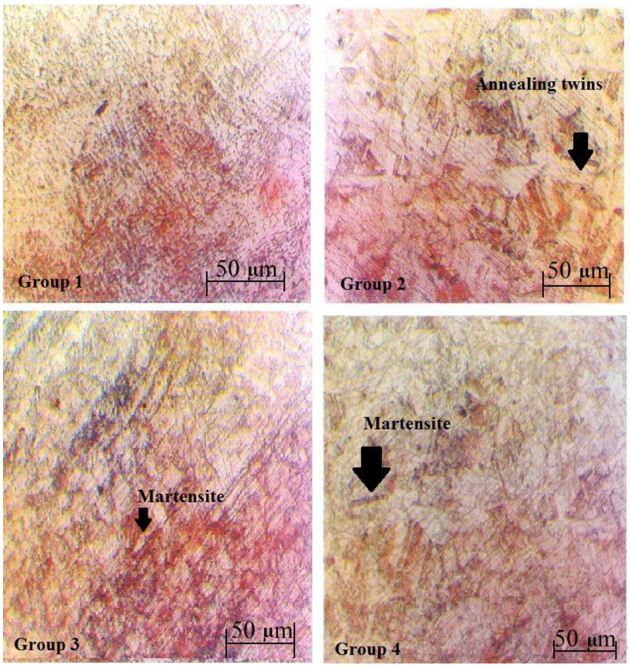

Figure 4.13: Microstructure of four specimen group samples

5.

6. Conclusions

- It has been observed that the ditch type structure on sensitized sample after Intergranular corrosion test. But in sensitized cryo treated sample due to the pre – sensitization treatment the formation of the carbide precipitations in cryogenic treated sample shows the isolated ferrite pools and also fine carbides are observed. As - weld and cryogenic treated samples shows the dual type structure. It means that the cryogenic treatment is shows very little effect on sensitized cryo treated sample and slight changes were observed on the cryogenic treated samples regarding carbide formations.

- Due to sensitization heat treatment the impact energy of sensitized sample is increased by 4.6% than the As–weld. And cryogenic treated is decreased by 27.7% than as-weld. Sensitized cryo treated specimen shows considerably increase in impact energy by 7% with cryogenic treated and it is decreased by 22.3% with as-weld. From this it is concluded that the microstructure before cryogenic difference shows difference in impact energy absorption after cryogenic treatment.

- The hardness test results shows that in all group specimens the hardness of the weld metal is reduced. The hardness of weld is decreased by 6% in sensitized sample, increased by 22.14% in sensitized cryo treated sample and 29.53% in cryogenic treated when compared with as-weld. Sensitized cryo treated sample shows after cryogenic treatment considerably increase in hardness even it is annealed before cryogenic treatment. But remaining base metal and HAZ shows almost same hardness in each group with slight variations.

- Microexaminations reveals that due to the sensitization heat treatment of the sensitized sample is shows the annealing twins, because of sensitization heat treated samples was cooled in furnace. As-weld samples shows ferritic structure. Cryogenic and sensitized cryo treated samples shows that martensitic structure along with carbides. The formed martensite is which

ISSN:0971-1260
Vol-22-Issue-37-December -2019

was converted from austenite to twinned martensite through cryogenic treatment.

References

[1] Chetan, S. Ghosh, and P. V. Rao, "Comparison between sustainable cryogenic techniques and nano-MQL cooling mode in turning of nickel-based alloy," *J. Clean. Prod.*, vol. 231, pp. 1036–1049, 2019.

[2] R. Saluja and K. M. Moeed, "ScienceDirect Experimental Investigation Of Solidification-Mode And Response Surface Modeling Of Ferrite-Content In Grade 304L Pulse GMA Welded Plates," *Mater. Today Proc.*, vol. 18, pp. 3876–3890, 2019.

[3] G. Suresh, P. K. Parida, S. Bandi, and S. Ningshen, "Effect of carbon content on the low temperature sensitization of 304L SS and its corrosion resistance in simulated ground water," *Mater. Chem. Phys.*, vol. 226, no. November 2018, pp. 184–194, 2019.

[4] J. Singh and A. S. Shahi, "Weld joint design and thermal aging influence on the metallurgical, sensitization and pitting corrosion behavior of AISI 304L stainless steel welds," *J. Manuf. Process.*, vol. 33, no. May, pp. 126–135, 2018.

[5] I. Taji, M. H. Moayed, and M. Mirjalili, "Correlation between sensitisation and pitting corrosion of AISI 403 martensitic stainless steel," *Corros. Sci.*, vol. 92, pp. 301–308, 2015.

[6] R. Singh and R. Singh, "Effect of Cryogenic Treatment on Sensitization of 304 Stainless Steel in TIG Welding," *J. Inst. Eng. Ser. C*, 2015.

[7] B. Lee, H. Lee, and Y. Shin, "Intergranular Corrosion Characteristics of Super Duplex Stainless Steel at various Interpass Temperatures," vol. 10, pp. 7535–7547, 2015.

[8] V. Kumar, P. Joshi, and S. Dhakad, "Analysis of the Effect of Sensitization on Austenitic Stainless Steel 304L Welded by GTAW Process," vol. 14, no. April, pp. 1–12, 2015.

[9] T. C. Scalise, M. C. L. de Oliveira, I. J. Sayeg, and R. A. Antunes, "Sensitization Behavior of Type 409 Ferritic Stainless Steel: Confronting DL-EPR Test and Practice W of ASTM A763," *J. Mater. Eng. Perform.*, vol. 23, no. 6, pp. 2164–2173, 2014.

[10] M. O. H. Amuda and S. Mridha, "Exploratory Study of Sensitization in Cryogenically Cooled Ferritic Stainless Steel Welds," vol. 2014, 2014.

[11] A. K. Lakshminarayanan and V. Balasubramanian, "Use of DL-EPR test to assess sensitization resistance of AISI 409M grade ferritic stainless steel joints," *J. Mater. Eng. Perform.*, vol. 22, no. 8, pp. 2293–2303, 2013.

[12] M. O. H. Amuda and S. Mridha, "Grain refinement and hardness distribution in cryogenically cooled ferritic stainless steel welds," *Mater. Des.*, vol. 47, pp. 365–371, 2013.

[13] M. W. A. Rashid, M. Gakim, Z. M. Rosli, and M. A. Azam, "Formation of Cr23C6 during the sensitization of AISI 304 stainless steel and its effect to pitting corrosion," *Int. J. Electrochem. Sci.*, vol. 7, no. 10, pp. 9465–9477, 2012.

[14] P. I. Patil and R. G. Tated, "Comparison of effects of cryogenic Treatment on different types of steels: A review," *IJCA Proc. Int. Conf. Comput. Intell.*, vol. ICCIA, no. 9, pp. 10–29, 2012.