Experimental Investigation of the Effect of Vibration on Mechanical Properties of DSS2205 during TIG Welding

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Abstract— This research provides the information about the problem of tensile strength reduction of DSS due to welding. To overcome this problem different vibratory stress relief techniques are used. We have used mechanical vibration technique that uses low frequency vibrations to relieve residual stresses in weldment. The optimization of TIG of DSS 2205 using taguchi method has been done. Nine experimental runs (L9) based on orthogonal array taguchi method was performed. The welding parameters to be varied are Welding current, Torch tilt angle and Motor speed. As a response Tensile strength & Hardness are being investigated. As a result this research provided the best combination of welding parameters to produce mechanically defect free and sounds welds.

Key words: Welding, TIG, Vibration, Mechanical Properties, Grain Structure

I. INTRODUCTION

Arc welding is a technique to melt and join different materials that is widely used in the industry. To make a weld, either the edges of the metal must melt and flow together by themselves or filler metal must be added directly into the molten pool. Filler metal is added by dipping the end of a filler rod into the leading edge of the molten weld pool. Most metals oxidize rapidly in their molten state. This review concentrate about one of the recently developed techniques of stress relieving and reducing the defects in arc welding. Vibration: generally taken as unwanted parameter, but if it introduced properly in the system it can be a better option of thermal heat energy input.

II. PRINCIPLE

Heat is vibration, according to physics. When metal is heated, its molecules vibrate faster. When a vibration is induced into the part, the part responds as if it has the same molecular action when the part is heated up for heat treatment. Thermodynamically it's a cold process, but internally, there is a movement. At a certain frequency during welding, it supplements the weld heat that vibrates the weld pool at the molecular level. The vibration level is very specific: in the lower, or sub harmonic, portion of the harmonic curve, just before the amplitude get rises and reaches the part's natural resonance. The device induces vibration into the workpiece and monitors the work piece’s reaction.

In recent time, the vibratory equipment is applied after welding to relieve stress, essentially replacing PWHT. But recent studies shows that it also can be applied during welding to improve weld quality through grain refinement and stress reduction. In fact, applying the right vibration during welding can eliminate the need for PWHT completely, unless tempering of the heat affected zone is required. By inducing vibration, we reveal thermal stress. In certain applications, Hebel said, it can replace low temperature preheating requirements, between 250 and 300 degrees F.

III. LITERATURE REVIEW

Pravinkumar Singh, et. al. [1] has designed vibratory setup of frequency 300 Hz & amplitude of 0.5 mm to stir the molten weld pool before solidifies during SMAW operation. They used Taguchi’s analysis technique to optimize process parameters & the response values for analysis are yield strength and micro hardness. The auxiliary vibration is able to increase micro hardness and the yield strength of the welded joints. Because of the orientation of the crystal and refinement of grains took place. By ANOVA analysis frequency is termed as most significant factor for Hardness and Yield strength. Frequency is contributing 90% in increasing Hardness and 95% in increasing Yield strength.

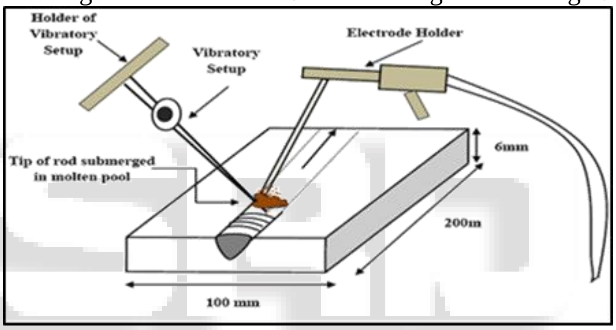

Fig. 1: Vibration setup for MIG welding

Prof. S.D. Ambekar & Sunil R. Wadhokar [2] has investigated the effect of welding parameters on the penetration. The optimization for GMAW of martenstic stainless steel workpiece AISI 1410 using taguchi method is done. ANOVA and S/N ratio is used to identify the most significant factor and predicted optimal parameter setting. They have formed % contribution of various parameters for MIG welding found to be welding speed 46.61%, welding current 21.24% and wire diameter is 24.75% and the error is found to be 4.90%.

S.P. Tiwari and A. Shanker, [3] “Effects of Longitudinal Vibration on Tensile Properties of Weldments”. This paper conclude that increase frequency resulted in better tensile properties but the Percentage elongation was reduced with an increased frequency. By experiments they showed that excellent properties were found in the range of 0-400 Hz and amplitude from 5-30 µm.

Munish Kainth, et. al. [4] “Experimental Investigation of the effect of Vibration on Mechanical Properties of AISI 1018 mild/low carbon steel welded joint using SMAW”. This article shows that finer grain structures can be produced during the welding of metals along with mechanical vibration. During general conditions long dendrites are formed which shows uniform solidification while with vibratory system long dendrites break and form a new nucleation sites which shows non-uniform solidification.

The oscillatory system increase the cooling rate thus increases the grain size effects in better mechanical properties. Tensile strength, elongation & force bearing capacity of AISI 1018 during vibration by 18.25%, 39.34% & 29.17%. Reduction in area is approx. 50% more in vibration effected test piece.

Govindrao P., et. al. [5] Analyzed effect of vibration during MMA welding of 5 mm thick mild steel plates Butt joints. They showed that due to vibration, as the weld pool solidifies, grains are not only limited in size, but dendrites growing perpendicular to the fusion line are restricted. While the process is going on dendrites can be broken up before they grow to become large in size. So that the microstructure of the weld metal is improved and welded plates found to be high hardness, without any considerable loss in its ductility.

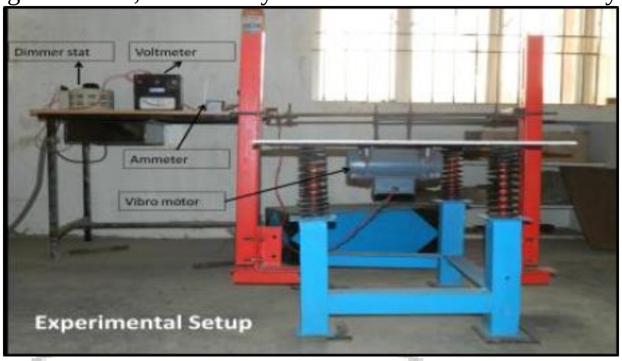

Fig. 2: Vibration setup used by Govindrao P.

P. Sakatvel and P. Shivkumar [6] has studied effects of vibration on TIG and ARC welding OF aisi216 stainless steel. Studies have revealed that due to vibration, depth of penetration increases and stress relieved in weld metal. The experiment reveals that the stress is relieved when the combination of the residual stress and the vibration stress exceeds the yield strength of the material. They have derived that due to vibration effects hardness and percentile elongation increases as the vibration increases.

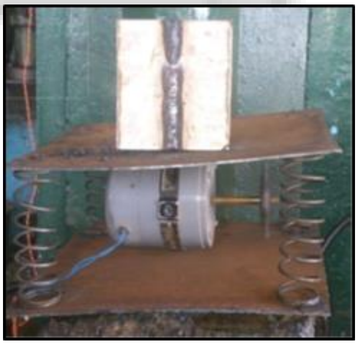

Fig. 3: Vibration setup for 3G welding position

M. Saravanan, et. al. [7] compared macro & micro properties of AISI 304 plates with and without vibration during SMAW process. They showed that with vibratory condition cross section of weldment has a cup like structure with its axis symmetrical, shorter dendrite arm of 4 µm-5µm and a fine grain microstructure. Due to vibration the tensile strength increases to 26% and impact strength increases to 17% as compared to plain weldment. While the hardness increases slightly and remain uniform over its length. Where as in plain welding hardness varied across its length. The penetration level & fusion of weld specimen also increases due to vibration.

Garcia & Lopezet. al. [8] have studied the effect of Microstructure and mechanical properties of 2205 DSS plate by applying EMS during GMAW. The study revealed that Acceptable weld beads are obtained up to 12 mT AMT. Larger intensity lead to welds with undercuts due to the instability of the electric arc and 3 mT magnetic field yielded best microstructure & mechanical behaviour.

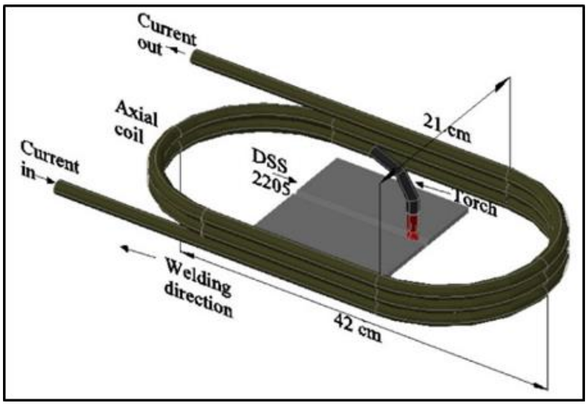

Fig. 4: Vibration by Axial Magnetic Field

Tong WEN, et. al. [9] developed a device capable of transmitting both horizontal & vertical vibration of 15 kHz during TIG welding. They used AZ31 magnesium ALLOY SHEETS OF 1 & 3 MM and find out that grain size decreases due to vibration. The micro hardness, tensile strength & elongation of weldment increases due to wave energy transferring in the melt with the help of vibration. They find out that mechanical properties are highest at groove angle of 20° under vertical vibration.

Jaskirat Singh et. al. [10] have designed a stirrer that produce a disturbance in weld pool during solidification. After completion of nucleation, the solidification process will continue with nucleus growth. Increasing the growth rate will reduce the grain size of metal. Due to auxiliary mechanical vibrations long dendrites break and forms a new nucleation sites. This review shows that the weld joints fabricated with vibratory condition were found to have relatively high yield strength (YS) and high ultimate tensile strength (UTS), with minor loss in the ductility.

IV. EXPERIMENTAL WORK

A Vibration table has a vibratory motor attached below it is joined with Variac which is helpful in changing input Voltage of the motor. A multimeter is coupled with variac so that exact voltage input to the motor can be seen digitally and accurately. The variac is connected to the AC supply lines. TIG welding used in our experiment has a argon gas supply and its pressure is maintained constant to 8 bar during all experiments. Motor voltage is adjusted and RPM has been measured by tachometer. Different experiment has been performed by changing motor RPM, Torch tilt angle and Welding current.

Fig. 5: Experimental setup

Tungsten Electrode with pointed tip is used for better heat concentration. C-clamp is used to fix the weld plates with Table top. Moreover, wooden sheets are used to isolate the welding current from table top so that the motor may not damage. A steel table top is fixed in notch such that it may not vibrate to amplitude more than 1 mm. With the help of variac, based on the TAGUCHI, for 3 different factors and 3 levels, 9 experimental run is carried out and the responses ultimate tensile strength and hardness has been tested. The TIG welding carried out on vibration table is as shown in Figure:6.

It is noted that welding with vibration is difficult task and when vibration amplitude is higher it is difficult to stabilize arc. After successful welding the 9 test pieces are welded as shown in Figure:7.

Fig. 6: TIG welding done on vibration table

Fig. 7: Welded plates with different parameters

The 9 Welded test pieces after tensile testing fractured at weld when Ultimate load is applied are as shown in figure 8.

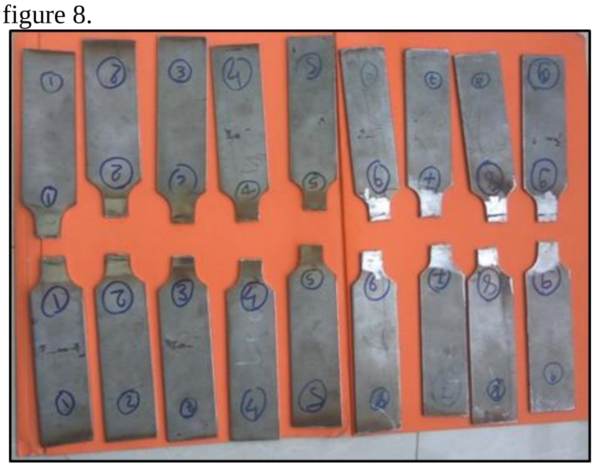

Fig. 8: Fractured welded plates after Tensile test

The results from tensile testing and Vickers hardness test has been shown. Tensile and Hardness testing has been carried out as per ASME IX and the results are as shown in table 1.

V. FEM SIMULATION

A tensile test specimen as per ASME IX is generated in Ansys Workbench 17.2. Meshing is done for accurate simulation results. There after Displacement Boundary conditions are applied such that one of its side is fixed and the other is displaced in X-direction while Y & Z direction have no displacements. The simulation was run and the test results shows that the tensile strength of specimen is higher as compared to experimentation. The P- δ curve generated by Simulation is compared with experimentation results for validation purpose.

	current (A)	angle (°)	RPM (RPM)	UTS (MPa)	Hardness (HV)
1	80	60	1400	804	237
2	80	75	1450	843	238
3	80	90	1500	855	240
4	90	60	1450	646	241
5	90	75	1500	780	243
6	90	90	1400	570	244
7	100	60	1500	783	242
8	100	75	1400	655	244
9	100	90	1450	670	247

Table 1: Experimental runs and their responses

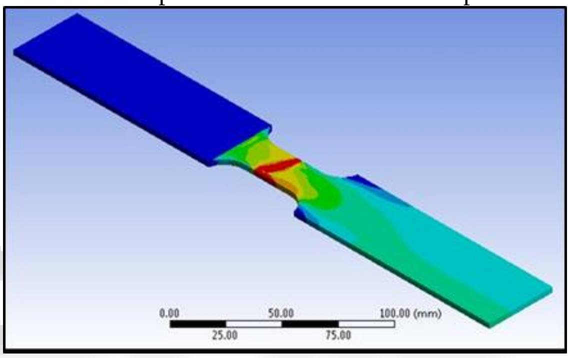

Fig. 9: Stresses generated in Test piece

The Stress strain diagram generated by FEM is quite similar to the graph generated by Experimental method. The maximum value of stress generated is at Weldment and HAZ. So test pieces have more tendency to crack at this places.

VI. RESULTS & DISCUSSION

while the values for a third variable are represented by shaded regions, called contours. A contour plot is like a topographical map in which X, Y and Z values are plotted instead of longitude, latitude and altitude. The contour plots of different combinations are as shown in below fig:

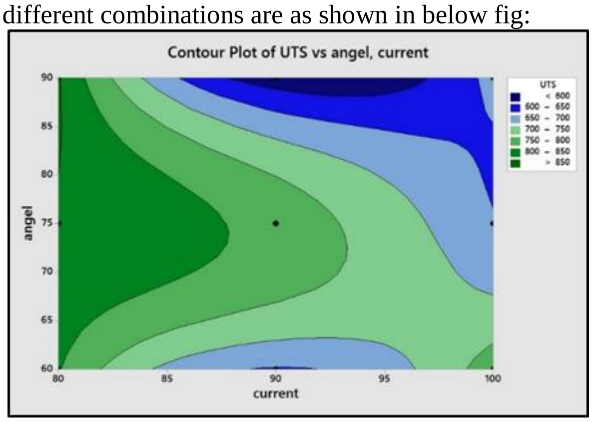

Fig. 10: Contour plot of UTS vs angle, current

Figure 10 shows a contour plot of ultimate tensile strength vs torch tilt angle in degrees and welding current in ampere. The maximum tensile strength has occurred when the current minimum and torch tilt angle is maximum. As the figure shows that for a tensile strength greater than 850 MPa we need to have a torch tilt angle in the range of 80º to 90º approximately and the current of 80A which is calculated approximately from the graph.

Figure 11 shows a contour plot of ultimate tensile strength vs vibration motor RPM and welding current in ampere. The maximum tensile strength has occurred when the current minimum and motor RPM is maximum. As the figure shows that for a tensile strength greater than 850 MPa we need to have motor RPM in the range of 1470 to 1500 RPM approximately and the current of 80A which is calculated approximately from the graph.

Figure 12 shows a contour plot of ultimate tensile strength vs torch tilt angle in degrees and vibration motor RPM. The maximum tensile strength has occurred when torch tilt angle is average and motor RPM is slightly higher than average.

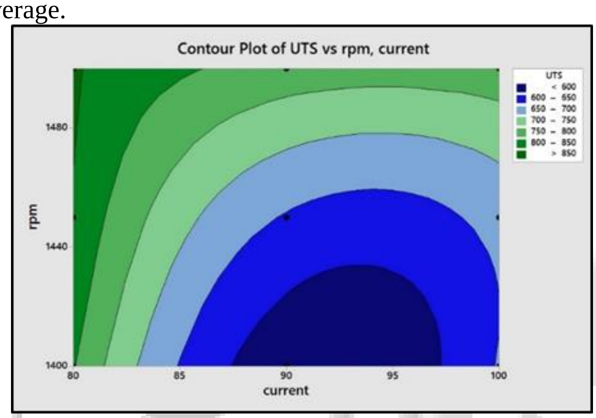

Fig. 11: Contour plot of UTS vs rpm, current

As the figure shows that the for a tensile strength greater than 850 MPa we need to have a torch tilt angle in the range of 75º to 78º approximately and the motor RPM in the range of1460 to 1470 RPM which is calculated approximately from the graph.

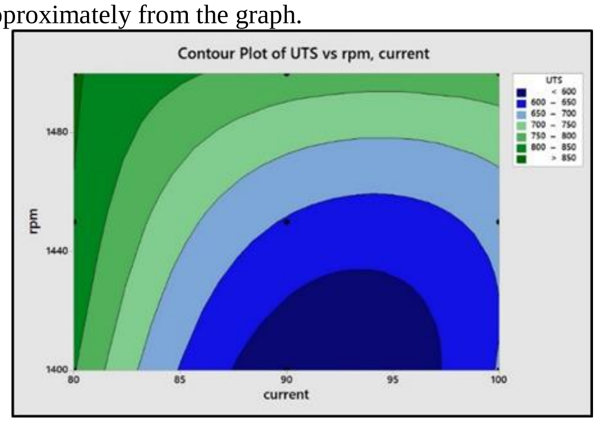

Fig. 12: Contour plot of UTS vs rpm, angle

ANOVA was used to identify the optimal welding parameter levels so as to maximize the Ultimate Tensile Strength. Figure 13 clearly suggests a dominant influence, in a quantitative sense, of the Welding current, Torch tilt angle and Motor RPM. The result of ANOVA represented in response diagrams shown in Figure 13 suggest that the optimal combination of welding parameter levels, which gives the highest value of the UTS is C1A2R3.

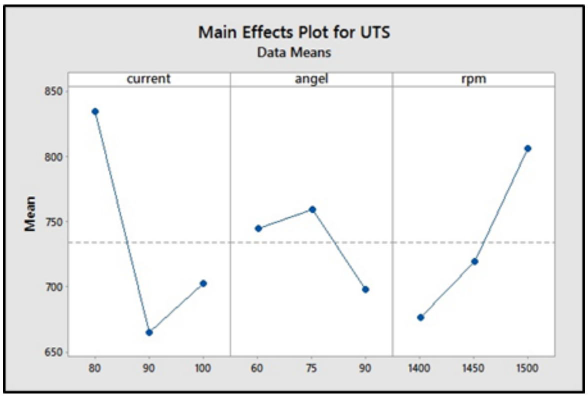

Fig. 13: Main effects plot for UTS

Figure 14 clearly suggests a dominant influence, in a quantitative sense, of the Welding current, Torch tilt angle and Motor RPM. The result of ANOVA represented in response diagrams shown in Figure 14 suggest that the optimal combination of welding parameter levels, which gives the highest value of the Hardness is C3A3R2.

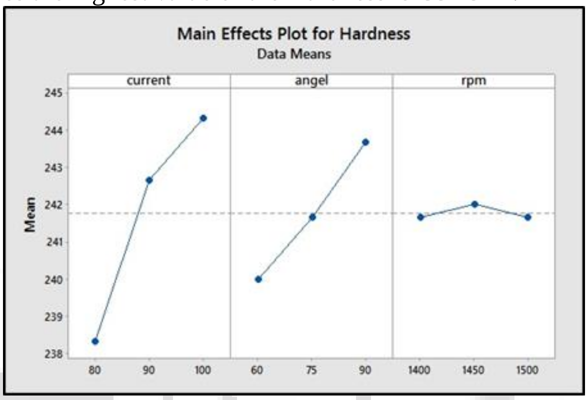

Fig. 14: Main effects plot for UTS

VII. Conclusion

The auxiliary vibrations induced into the weld pool resulted in increased hardness and the yield the welded joint which indicates the orientation of the crystal and refinement of grains took place. RPM of vibration motor is varied during the welding so that weld pool could be mechanically stirred in order to induce favorable micro structural effects. The tensile strength of the weld with vibration was larger than that without vibration. Especially, the tensile strength was remarkably increased when the combination of certain parameters takes place. Taguchi method is a very effective tool for process optimization under limited number of experimental runs. Taguchi optimization method was applied to find the optimal process parameters for Tensile Strength. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance were used for the optimization of welding parameters. Here largest value of tensile strength is number three results shows highest value 855 MPa of tensile strength with lowest current (80 A) Maximum torch tilt angle (90°) and maximum RPM of vibration motor (1500 RPM).

VIII. Future Scope

Experiment can be carried out with purging so that the common defects found in steel can be reduced. Different vibration setups can be designed to produce better effects on weldments. A change in vibration setup can be made in structure so that it can be used in steel structures in real conditions. Experiment can be carried out with different base material thickness and different Filler metal. So that the best fit filler material can be determined. Different welding methods like Arc, MIG, SAW can also be analyzed with this principle. Other emerging Duplex grade and Super Duplex grade steels can be used in experimentation. Since this material used in pipes, welding of pipe joints can be analyzed.

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