STM JOURNALS

Trends in Mechanical Engineering & Technology
ISSN: 2231–1793 (Online), ISSN: 2347-9965 (Print)
Volume 7, Issue 3
www.stmjournals.com

Minimization of Distortion during Gas Metal Arc Welding Process used for Hydraulic Shearing Machine Pressure Plate Square

Shashin M. Vyas[1,]*, Sagar I. Shah[2], G.D. Acharya[3]
[1]Research Scholar (Production Engineering), Atmiya Institute of Technology and Science (affiliated to Gujarat Technological University), Rajkot, Gujarat, India
[2]Assistant Professor, Atmiya Institute of Technology and Science (affiliated to Gujarat Technological University), Rajkot, Gujarat, India
[3]Principal, Atmiya Institute of Technology and Science (affiliated to Gujarat Technological University), Rajkot, Gujarat, India

Abstract
The Gas Metal Arc Welding process is widely used in many appliances because of its versatility. The change of shape and dimensions that occur after welding is known as distortion that leads to undesirable results. And to overcome this, it requires reducing the distortion within the limits. A large number of resources are used recently for reworking the weld. But it causes higher cost of production and delay for completing the work. Higher amount of residual stresses may generate if the distortion is controlled physically during welding. This work is aimed to predict and reduce distortion with optimization of GMAW process parameters such as welding current, welding speed and wire feed rate. Using three levels three factors full factorial method, effects of process parameters can be determined and the parameters can be optimized. Simufact Welding V6.0 Software is used in this work for finite element analysis of welding distortion. A confirmatory test has also been performed for validation of the result obtained by Simufact Welding V6.0. Prediction helps mitigate the cost of experiments and provides better accuracy for obtaining the results such as, temperature, heat distribution, stress distribution and distortion.

Keywords: *Gas metal arc welding, distortion, optimization, finite element analysis, simufact welding*

****Author for Correspondence*** E-mail: vyassameer654@gmail.com

INTRODUCTION
Welding is the most important process among different joining processes; it is used for large structures and industrial applications [1]. And it is considered one of the most efficient, dependable, and economical means of fabrication to join metals permanently. Gas metal arc welding (GMAW) is one of the popular arc welding processes that has been applicable in a wide range of plate thicknesses due to its high productivity and ease of operation [2].

Mild Steel – IS 2062 material is used in this work (Table 1).

This work is aimed to predict distortion and minimize it using optimization method. Distortion takes place during welding of a Hydraulic shearing machine pressure plate square (Figure 1).

DISTORTION IN WELDING
Distortion in welding takes place if the thermal expansion and contraction are nonuniform caused by nonuniform distribution of temperatures and localized heating [3].

Table 1: *Chemical Composition of IS 2062 [9].*

Elements	Contents
Carbon, C	0.22
Manganese, Mn	1.40
Silicon, Si	0.40
Sulphur, S	0.045
Phosphorous, P	0.045
C.E. Value	0.41

The nonuniform distribution of temperature during welding results in increase in strains that generate self-residual stresses which are self-balancing. The stress distribution presents in the structure even after cooling down to atmospheric temperature [4].

Welding residual stress and distortion are strongly linked together [5]. The excessive weld distortion deteriorates the dimensions and performances of the structures and influences the appearance of the finished products [6]. Distortion and residual stresses in base metal get generated. Because during welding, high amount of heating takes place and further it cools down rapidly.

DESIGN OF EXPERIMENTS

In the last few decades, many researches have been done in order to control process parameters of welding for minimizing deformations and residual stress. Structural, welding parameters and material parameters highly affect distortions [7].

Reduction of the computational time and complexity of transient nonlinear problems such as the welding process is one of the active research areas in engineering fields. Numerous studies have been published in this area of study [8]. Optimization is required for reducing the weld simulation parameters cost incurred and time consumption. It is necessary to choose appropriate parameters in order to obtain the required weld bead shape [9].

Three level three factors general full factorial design is implemented for optimizing the existing parameters. Three parameters: Current, Welding speed, and Wire feed rate have been considered (Tables 2 and 3).

Fig. 1: *Pressure Plate Square.*

SIMULATION AND ANALYSIS

The finite element method has been proven to be a very suitable tool for the thermo-mechanical analysis of welding and to estimate the resulting residual stresses and distortions (Figure 2) [10]. The name FEA comes from the way, a complicated model is divided into a model that is built by small elements [11]. However, it is difficult to obtain a complete analytical solution to predict angular distortion that may be reliable over a wide range of processes, materials, and process control parameters so as to reduce the angular distortion in the welded plates [12].

Table 2: *Range of Parameters.*

	Current (A)	Welding Speed (mm/s)	Wire Feed Rate (mm/s)
Lower	170	35	75
Medium	180	40	80
Higher	190	45	85

Table 3: *Design of Experiments.*

Experiments	Current	Welding Speed	Wire Feed Rate
1	180	40	80
2	190	40	85
3	190	45	85
4	190	40	80
5	170	35	85
6	180	35	80
7	190	45	80
8	180	45	85
9	170	45	80
10	180	40	75
11	180	45	75
12	180	45	80
13	170	40	85
14	170	40	80
15	170	40	75
16	170	45	75
17	170	35	75
18	170	45	85
19	180	35	75
20	190	40	75
21	180	40	85
22	170	35	80
23	190	35	80
24	190	35	85
25	190	45	75
26	190	35	75
27	180	35	85

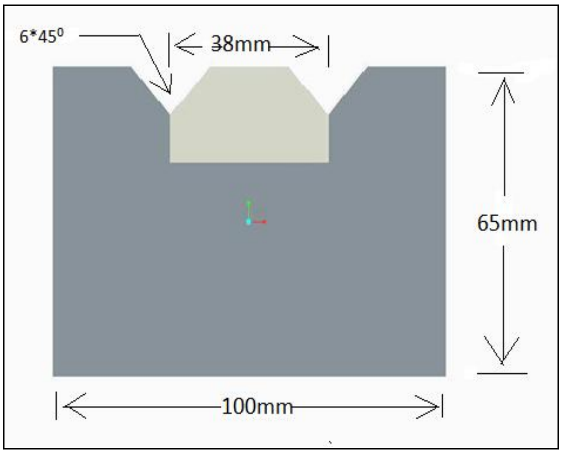

Fig. 2: *Hydraulic Shearing Machine Pressure Plate Square.*

The trial-and-error experimental methods were generally used for establishment of conventional manufacturing processes. There are many disadvantages of trial-and-error methods like, requirement of higher amount of material, energy, fumes and emissions, labours, procedure significant waste [13].

FEM simulation is a method with respect to experimental techniques incorporated for determining the interaction effects between complex physical phenomena in welding process [14].

Conventional numerical techniques proved to be highly time consuming and thereby prohibitively expensive in real life welding situations [15]. The predictions are helpful in order to control welding deformations. Thus, it is very important to develop a very effective method for accurately predicting welding deformations [16]. In weld simulation, computational software like ANSYS, ABAQUS and SYSWELD are popular. ANSYS and ABAQUS require complex subroutines programming, whereas SYSWELD is specifically designed for various heat treatment and welding processes [17].

Welding simulation program is a commercial FE-based welding simulation program named Simufact welding. It executes the welding simulation based on input file and stores the desired output results. It has the ability to simulate welding process models with multiple welding robots working at the same time or different times, flexibility to define or modify welding parameters, paths, directions and simple automatic batch running option useful for simulation-based numerical optimization [18-20].

Step: 1: 3D Modelling
Length: 2500 mm
Thickness: 65 mm
Width: 100 mm
Strip Thickness: 10 mm
Strip Width: 38 mm
Material: IS 2062

Step: 2: Meshing
Meshing was done using MSC MARC Mentat Student Edition and Gmsh Softwares (Figure 3).

First, the pressure plate square and the strip were meshed using MSC MARC Mentat, and then for fine meshing, they were meshed in Gmsh (Figure 4).

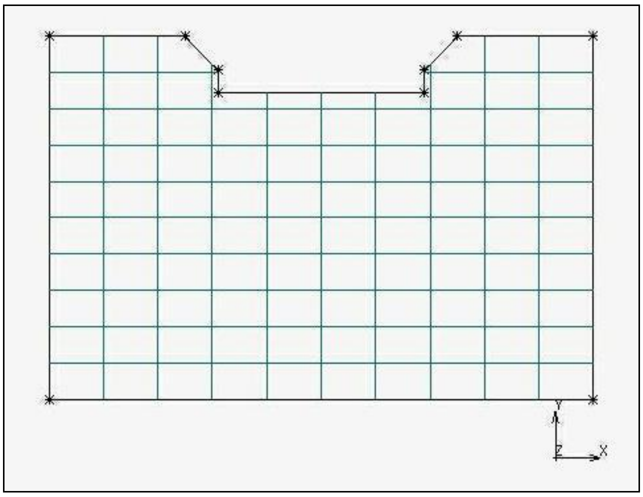

Fig. 3: *Meshing Pressure Plate Square using MSC Marc.*

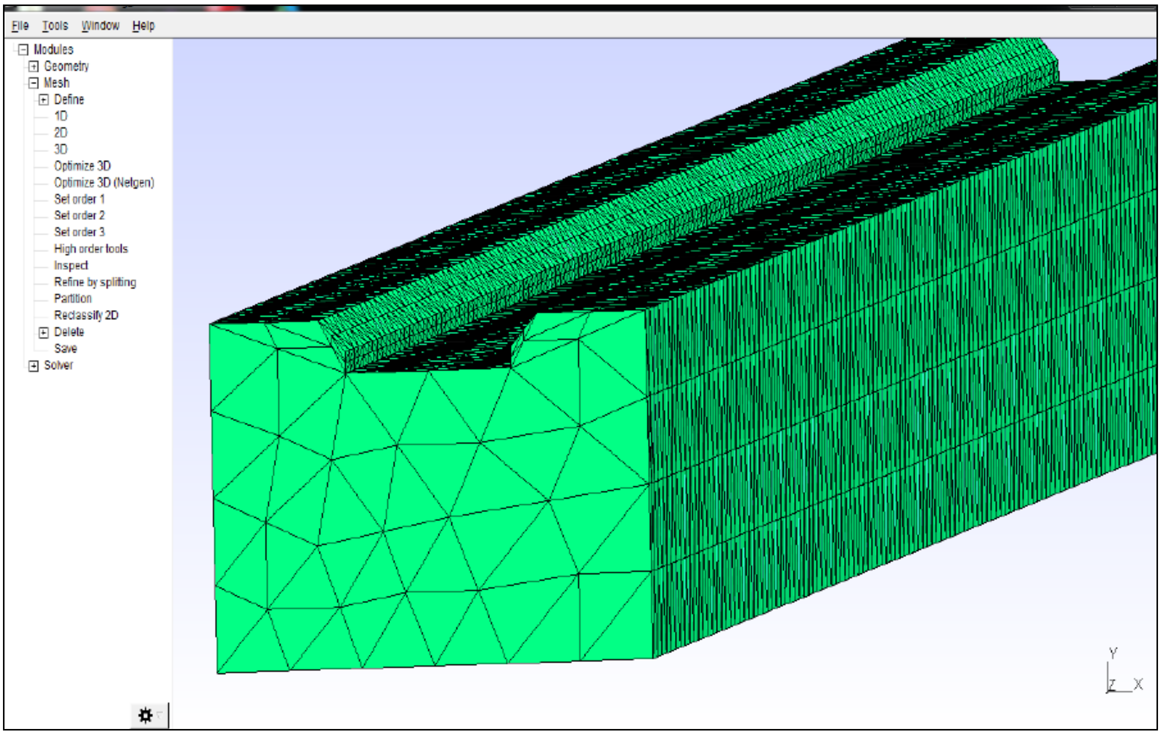

Fig. 4: *Re-meshing the Pressure Plate Square using Gmsh.*

Step: 3 – Simulation and Assembly in Simufact Welding (Figure 5)

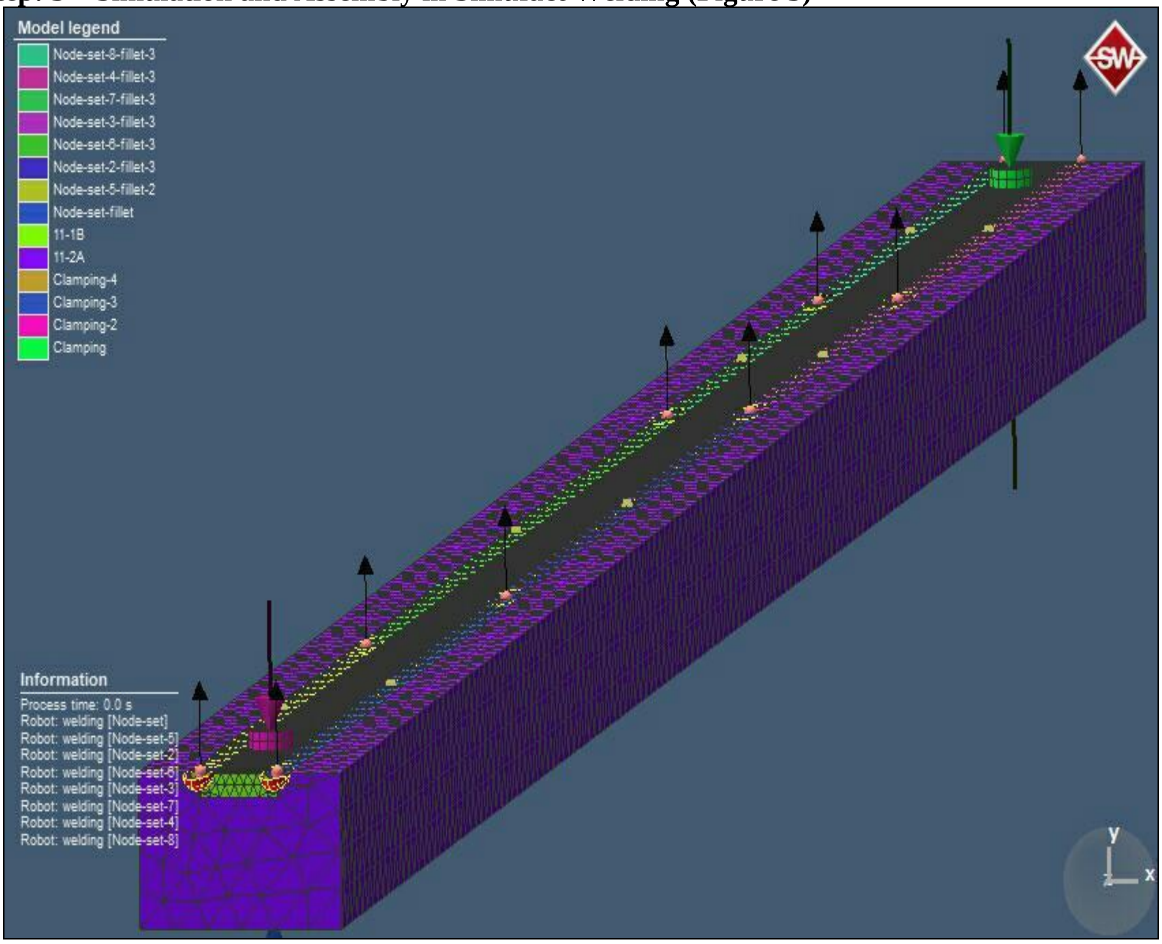

Fig. 5: *Assembling the Components and Setup in Simufact Welding.*

Step: 4 – Distortion Analysis in Simufact Welding

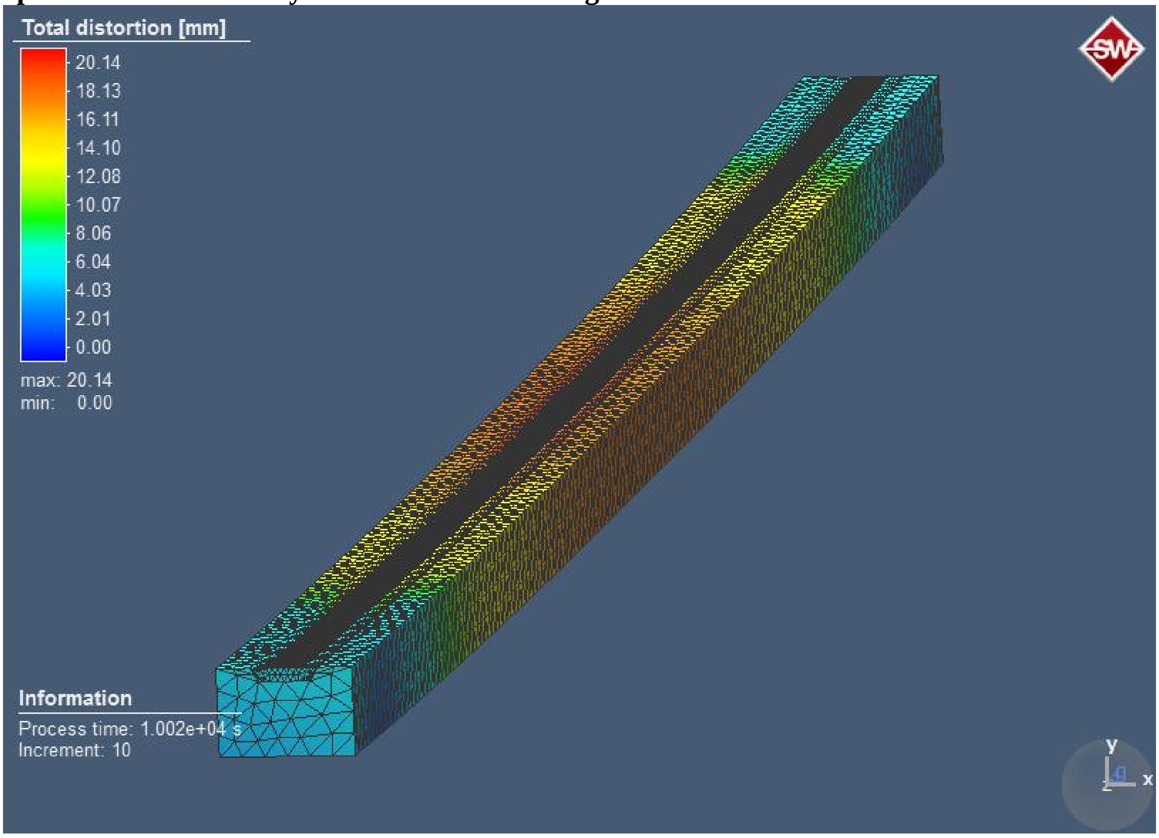

Fig. 6: *Result of Analysis.*

After analysis, the minimum amount of distortion is 20.14 mm (Figure 6).

EXPERIMENTAL SETUP

As shown in Figure 7, the experiment was performed with optimum process parameters for validation of results obtained by Simufact welding.

Fig. 7: *Experimental Setup.*

The Optimum Parameters are:
Current: 170A
Wire Feed Rate: 75 mm/s
Welding Speed: 45 mm/s.

For obtaining uniform velocity during the process, a setup was established as shown in Figure 8. The welding torch was moved with a uniform speed of 45 mm/s. Where, current and wire feed rate are set 170A and 75 mm/s, respectively.

Fig. 8: *Experimental Setup for Validation.*

MEASUREMENT OF DISTORTION

The distortion after validation of experiments was measured using vernier height gauge as shown in Figure 9.

The maximum amount of distortion in pressure plate square was found in the center of its length.

The measure of distortion is 22.76 mm by performing experiment at optimum process parameters.

Fig. 9: *Measurement of Distortion.*

RESULTS AND DISCUSSION

The minimum amount of distortion is found to be 20.14 mm after analysis using Simufact welding (Table 4).

It is observed from the results (Table 4) that the Optimum Parameters, i.e., current, welding speed and wire feed rate are 170A, 45 and 75 mm/s.

The effect of each parameter on distortion is shown in Figure 10.

It can be observed that, current has the maximum effect on distortion, where welding speed has less effect than current and wire feed rate has comparatively minimum effect than the other parameters.

- Distortion increases with increase in current, thus it is directly proportional to current.
- Distortion decreases with increase in welding speed, thus it is inversely proportional to welding speed.
- Distortion increases with increase in wire feed rate, thus it is directly proportional to wire feed rate.

After comparing the results obtained by experiments and simulation, it is observed that the minimum amount of distortion was 20.14 mm using SIMUFACT WELDING and 22.76 by performing experiments.

The amount of percentage similarity between simulation result and experimental result is 87.00% which shows that the predicted amount of distortion is very close to experimental result.

Table 4: *Results of Analyses.*

Experiments	**Current (A)**	**Welding Speed (mm/s)**	**Wire Feed Rate (mm/s)**	**Distortion (mm)**
1	170	35	75	**22.90**
2	180	40	85	**23.20**
3	170	40	80	**22.65**
4	170	45	75	**20.14**
5	180	45	75	**22.73**
6	180	35	80	**23.36**
7	180	45	80	**23.22**
8	190	45	80	**24.06**
9	180	35	85	**23.93**
10	170	45	85	**21.83**
11	190	35	75	**24.23**
12	190	35	85	**26.20**
13	190	45	85	**24.30**
14	190	45	75	**22.50**
15	190	40	85	**25.32**
16	190	35	80	**25.40**
17	170	40	85	**23.00**
18	170	45	80	**21.00**
19	190	40	80	**24.32**
20	180	40	80	**22.63**
21	170	40	75	**21.50**
22	170	35	80	**23.29**
23	180	40	75	**21.80**
24	180	45	85	**22.95**
25	190	40	75	**23.79**
26	180	35	75	**23.03**
27	170	35	85	**23.96**

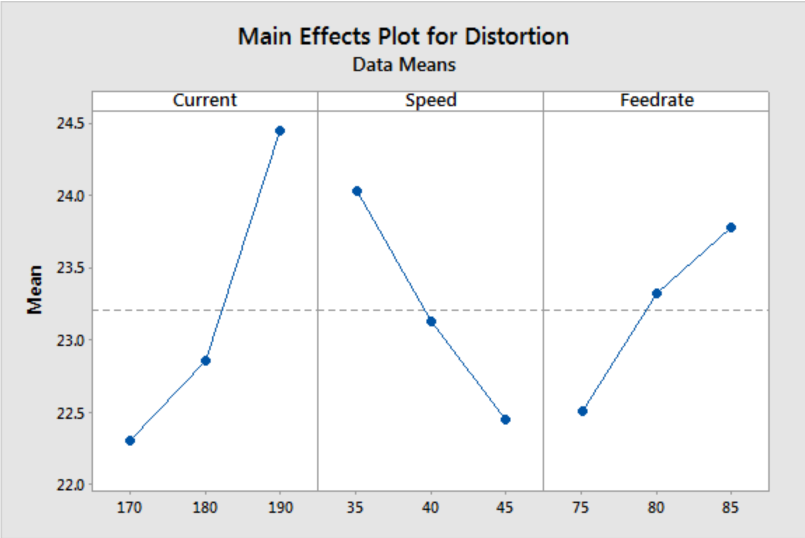

Fig. 10: *Main Effect Plots.*

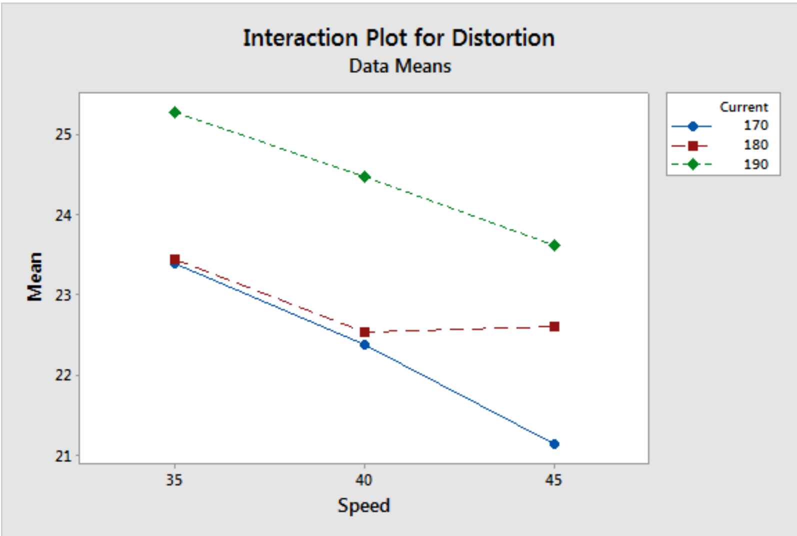

Fig. 11: *Interaction Plot of Current and Welding Speed.*

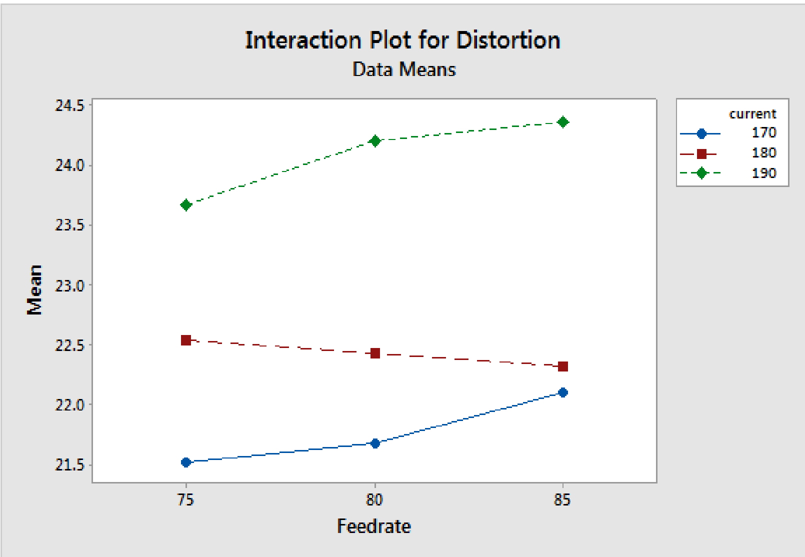

Fig. 12: *Interaction Plot of Current and Wire Feed Rate.*

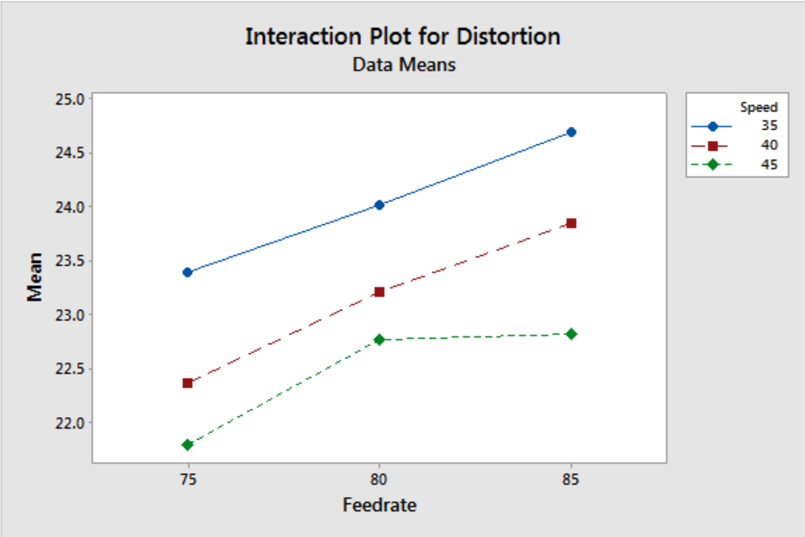

Fig. 13: *Interaction Plot of Welding Speed and Wire feed Rate.*

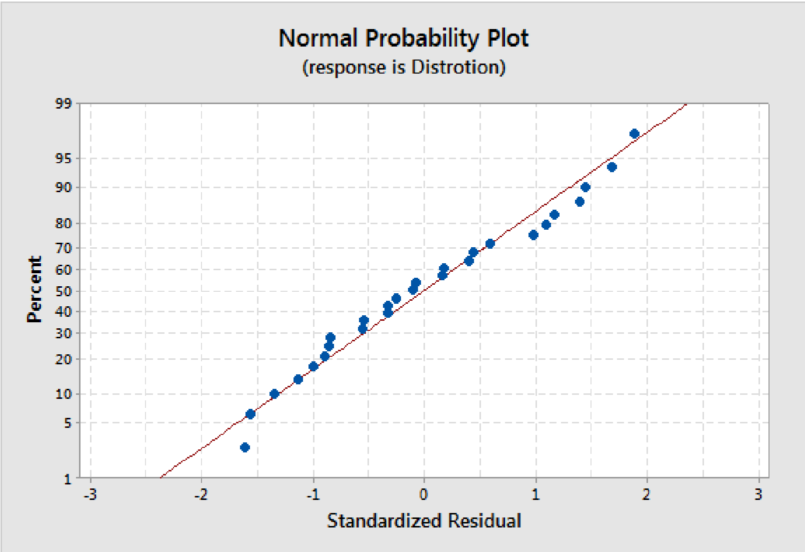

Fig. 14: *Normal Probability Plots of the Residuals.*

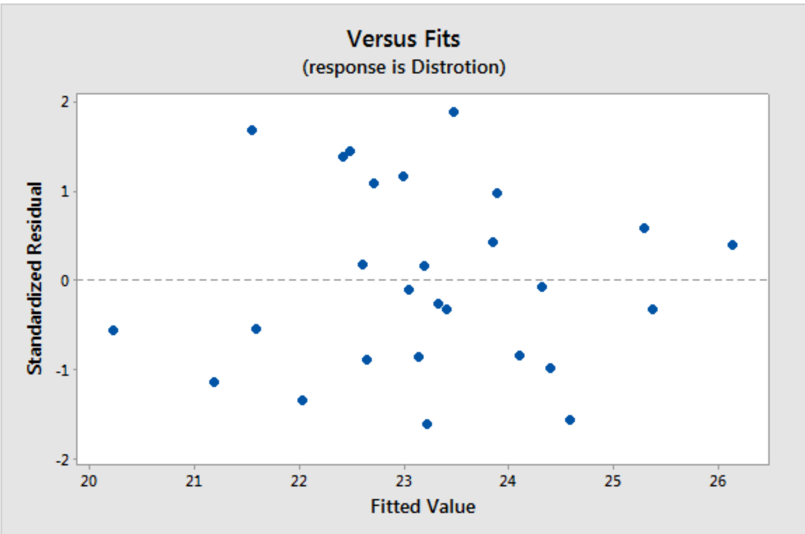

Fig. 15: *Residuals versus the Fitted Values.*

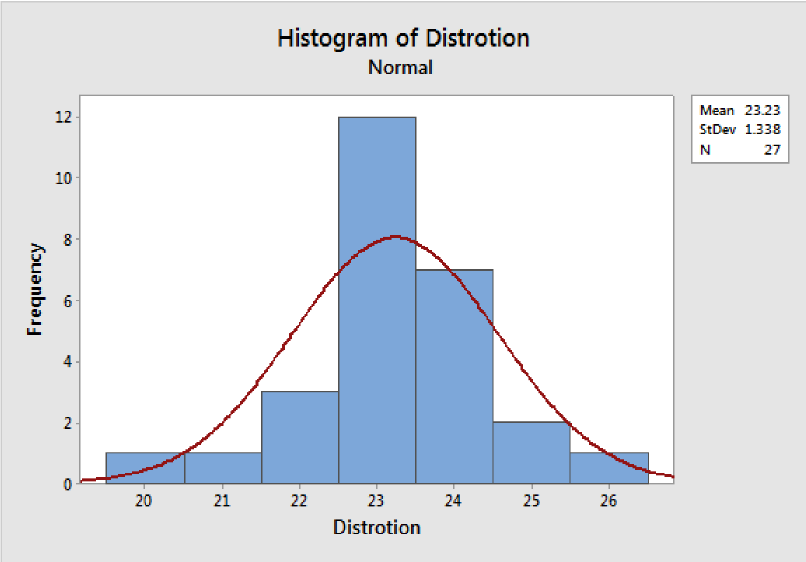

Fig. 16: *Histogram of Distribution of Results.*

From the interaction plot (Figure 11), it can be observed that,

- When the current is 170A and the welding speed increases from 35 to 45 mm/s, the amount of distortion decreases significantly.
- When the current is 180A and the welding speed increases from 35 to 45 mm/s, the amount of distortion decreases during 35 to 40 mm/s and then slightly increases during 40 to 45 mm/s. When the current is 190A and welding speed increases from 35 to 45 mm/s, the amount of distortion decreases significantly.
- Thus the interaction effect of current and welding speed will result in decreased amount of distortion.
- When the current is 170A and the wire feed rate increases from 75 to 85 mm/s, the amount of distortion increases (Figure 12).
- When the current is 180A and the wire feed rate increases from 75 to 85 mm/s, the amount of distortion increases. When the current is 190A and the wire feed rate increases from 75 to 85 mm/s, the amount of distortion increases.
- Thus the interaction effect of current and wire feed rate will result in increased amount of distortion.
- When the wire feed rate is 75 mm/s and the welding speed increases from 35 to 45 mm/s, the amount of distortion decreases.
- When the wire feed rate is 80 mm/s and the welding speed increases from 35 to 45 mm/s, the amount of distortion decreases. When the wire feed rate is 85 mm/s and the welding speed increases from 35 to 45 mm/s, the amount of distortion decreases (Figure 13).
- Thus the interaction effect of wire feed rate and welding speed will result in decreased amount of distortion.

From the above graphs, it can be observed that the observed values of distortion and the predicted values are having good similarity.

From Figure 14, the normal probability plot shows that the obtained results are very close to the straight line, it can be said that the observed data of distortion is normally distributed around the mean line.

Figure 15 represents residuals versus the fitted values. The observations range from 20.14 to 26.20 mm. From the graph, it can be observed that there is no particular pattern generated for the results. Hence, the observations are almost equally distributed around the residual mean line.

Figure 16 represents the frequency of observations for the range of 20.14 to 26.20 mm. The maximum amount of observations was found between 22.5 and 23.5 mm.

CONCLUSION

The optimum values of current, wire feed rate and welding speed are 170A, 75 mm/s and 45 mm/s, respectively. This gives minimum amount of distortion, i.e., 22.76 mm.

The percentage similarity between simulation result and experimental result is 87.00% which indicates that SIMUFACT WELDING is beneficial for predicting and minimizing distortion with accurate results.

By performing ANNOVA, it was found that the current has maximum effect on distortion, where welding speed has less effect than current and wire feed rate has the minimum effect on distortion than these above parameters.

Using finite element analysis method, it becomes more beneficial for predicting distortion to improve weld quality. The combination of design of experiments and finite element method leads to high reduction in cost of experiments and time consumption.

REFERENCES

1. Adak M, Mandal NR. Numerical and experimental Study of mitigation of welding distortion. *Applied Mathematical Modelling*. 2010; 34: 146–158p.
2. Pazooki AMA, Hermans MJM, Richardson IM. Control of welding distortion during gas metal arc welding of AH36 plates by stress engineering; *Int J Adv Manuf Technol.* May-2016.
3. Damale AV, Nandurkar KN. Thermo-Mechanical Finite Element Analysis and Experimental Validation of Weld Induced Angular Distortion in MMAW Butt Welded Plates. Aug-2012; 1(6): 1–8p.
4. MatoPeric´, ZdenkoTonkovic´, Alan Rodic´, *et al.* Numerical analysis and experimental investigation of welding residual stresses and distortions in a T-joint fillet weld. *Mater Design.* 2014; 53: 1052–1063p.
5. Dean Deng, Yijun Zhou, Tao Bi, *et al.* Experimental and numerical investigations of welding distortion induced by CO2 gas arc welding in thin-plate bead-on joints. *Mater Design.* 2013; 52: 720–729p.
6. Amudala Nata Sekhar Babu, Lakshmana Kishore. T. Finite Element Simulation of Hybrid Welding Process for Welding 304 Austenitic Stainless Steel Plate. *Int J Res Eng Technol*. Nov-2012; 1(3): 401–410p.
7. Islam M, Buijk A, Rais-Rohani M, Motoyama K. Simulation-based numerical optimization of arc welding process for reduced distortion in welded structures. *Finite Elem ental Des.* 2014; 84: 54–64p.
8. Zubairuddin M, Albert SK, Mahadevan S, Vasudevan M, *et al.* Experimental and finite element analysis of residual stress and distortion in GTA welding of modified 9Cr-1Mo steel. *J Mech Sci Technol.* 2014; 28(12): 5095–5105p.
9. Yupiter HP. Manurung, Robert Ngendang Lidam, *et al.* Welding distortion analysis of multipass joint combination with Different sequences using 3D FEM and experiment. *Int J Pres Ves Pip.* 2013; 1–10p.
10. Hsuan-Liang Lin. The use of Taguchi method with grey relational analysis and a neural network to optimize a novel GMA welding process. *Int J Manuf.* 2012; 26: 1671–1680p.
11. Robert Ngendang Lidam, Yupiter HP. Manurung, Esa Haruman. Angular distortion analysis of the multi pass welding process on combined joint types using thermo-elastic–plastic FEM with experimental validation. *Int J Adv Manuf Technol.* 2012.
12. Ganesh KC, Vasudevan M. Balasubramanian KR, *et al.* Modeling, Prediction and Validation of Thermal Cycles, Residual Stresses and Distortion in type 316 LN Stainless Steel Weld Joint made by TIG Welding Process. *Procedia Eng.* 2014; 86: 767–774p.
13. Akshay Nighot, Anurag A. Nema, Anantharma A. Finite Element Analysis and Optimization of Weld Distortion in Automobile Chassis; *Int Res J Eng Technol.* Aug-2016; 3(8): 656–661p
14. Arunkumar Ap, Ravichandran Sp Theoretical and Experimental Analysis Of T-Joint in Tig Welding Process; *Int J Sci Eng Appl Sci (IJSEAS).* June-2016; 2(6): 237–247p.
15. Youmin Rong, Jiajun Xu, Yu Huang, *et al.* Review on finite element analysis of welding deformation and residual stress; *Sci Technol Weld Join.* 2017; 1–11p.

16. Chougule MN, Somase SC. Experimental and Analytical Study of Thermally Induced Residual Stresses for Stainless Steel Grade Using GMAW Process. *All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014)*. December 12th-14th, 2014, IIT Guwahati, Assam.
17. Lohate MS, Damale AV. Fuzzy Based Prediction of Angular Distortion of Gas Metal Arc Welded Structural Steel Plates. *Int J Innovation Eng Res Technol*.1–10p.
18. Tapas Bajpei, Chelladurai H, Zahid M. Ansari. Experimental investigation and numerical analyses of residual stresses and distortions in GMA welding of thin dissimilar AA5052-AA6061 plates; *J Manuf Process*. 2017; 25: 340–350p.
19. Shigetaka Okano, Masahito Mochizuki. Engineering Model of Metal Active Gas Welding Process for Efficient Distortion Analysis; *ISIJ International*, 2017; 57(3): 511–516p.
20. Hashemzadeh M, Garbatov Y, Guedes Soares C. Analytically based equations for distortion and residual stress estimations of thin butt-welded plates; *Eng Struct*. 2017; 137: 115-124p.

Cite this Article
Shashin M Vyas, Sagar I. Shah, Acharya GD. Minimization of distortion during gas metal arc welding process used for hydraulic shearing machine pressure plate square. *Trends in Mechanical Engineering & Technology*. 2018; 7(3): 33–43p.