OPTIMIZATION OF WELDING PARAMETERS FOR SHIELDED METAL ARC WELDING IN METAL FABRICATION INDUSTRIES BY SIMUFACT SOFTWARE

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Abstract-*Shielded metal arc welding (SMAW) is the commonly used welding process in the metal fabrication industries. Shielded metal arc welding uses electrode rods consisting of a core with external protected coating. This coating melts and forms as a protective slag in the weld area which helps us to protect the weld area form oxygen and other atmospheric gases. The weld quality is affected by various input parameters like welding voltage, welding current, welding speed etc. The present study is to optimize the input parameters which majorly affect the yield strength of the weld using Simufact simulation software. The optimum value can be calculated by S/N ratio technique in mini tab software from the noted yield strength value. The regression equation was generated in mini tab software based on the yield strength value which was determined from Simufact simulation software.*

***Key Words*: Shielded Metal Arc Welding, Optimization, Simufact Software**

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1. INTRODUCTION

The metal-based construction is developing in the present days instead of brick construction. Durability, affordability, flexibility, safety and cost efficient are the major advantages of metal fabrication. Joining of metals plays a major role in metal fabrication and repair, and they are classified into two, permanent and temporary joints. In the construction of metal fabrication, permanent joint such as welding is mostly used.

Shielded metal arc welding is one of the most employed processes in the fabrication of metals. In this process, coalescence of the metals is achieved from an electric arc between electrode and the work. The welding quality can be determined by the welding parameters including welding current, welding voltage, welding speed, electrode diameter etc [1-2].These parameters should be optimized to get the most efficient weld with reduced distortion and higher yield strength in the weld joint. The ideal value of the parameters is commonly obtained by trial and error and it is not feasible, because of labour shortage, labour wages and material cost involved. The output of the trail is not consistent because of deficiency of skilled labours. Hence computer-based software helps us to simulate the number of trials for several input parameters. Gokulakrishnan et al studied the finite element simulation of temperature distribution and residual strength in single bead on plate weld trial using double ellipsoidal heat source model using SYSWELD software [3]. Few researchers used simulation of welding using MSC MARC software [4].

Apart from the usage of above software, introducing a software named Simufact in the welding process, which saves lot of time in optimizing parameters instead of doing trial and error. Based on the input parameters such as welding current, welding voltage, weld speed, arc length etc; Output such as displacement, strain, strength can be obtained after simulation. In this paper, the welding parameters are examined and optimized for shielded metal arc welding by Simufact software to achieve maximum yield strength.

2. MODELLING AND MESHING OF WELDING COMPONENTS

In this study, two square plates of same size 305mm in length and breadth and 25mm in height were used and it was modelled using Solid works software. Both the plates are modeled separately in part modeling and assembled the plates exactly where the weld should occur.Fig-1 shows the model of the work piece. The exact model was obtained and exports the file in bit distribution format (.bdf).
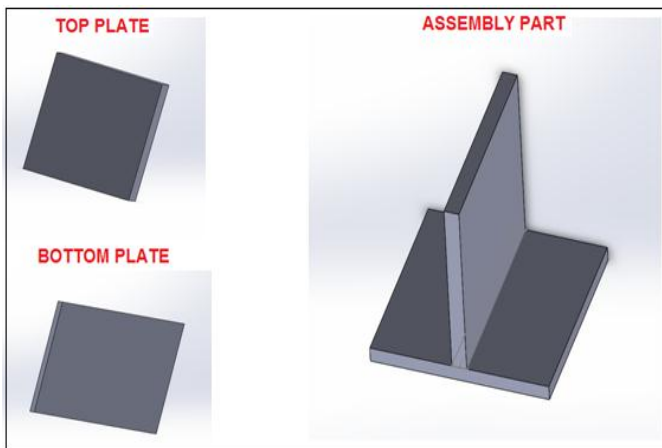
Fig -1: Model of the work piece

Finite element method reduces the entire domain from infinite to finite nodes and elements with the help of meshing. Meshing should be done to analyze the result accurately obtained by the Simufact simulation. Meshing can be done in various size and shape based on our study. The modelled work piece is meshed using MSC Apex Software. The meshed model is shown in Fig -2.
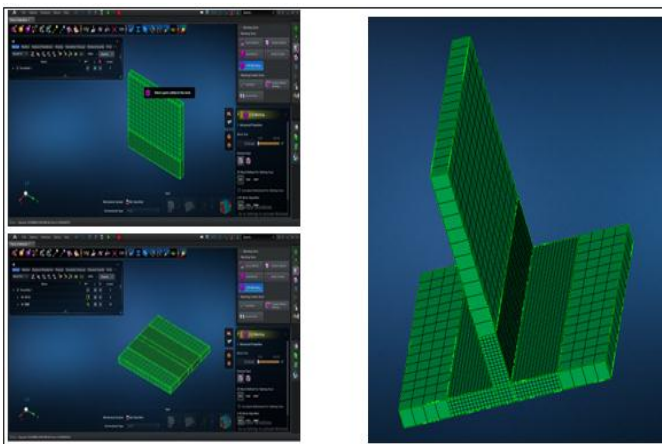

Fig -2: Model of the work piece after mesh

3. SIMULATION OF WELDING COMPONENT

Simufact welding is finite element-based software for welding simulations for different types of welds. It helps us to calculate the welding sequences efficiently and to predict yield strength of the component realistically. This predicts the final contour of the component and helps to produce parts in series with precise tolerance. Before simulate the weld components, process settings were entered in the software.

3.1 Process Parameters Settings

Two meshed geometry of the component to be weld in this study. Hence number of components to be weld is two. Bearing is the component which helps us to rest our work piece over there. Two clamping were used to clamp the work

piece and robot is the arm which is attached to the welding holder of the electrode. Each robot contains its weld path, trajectory configuration, sequences etc. Single weld and one trajectory path were used in this study. Fig -3 shows the input process parameters settings window.
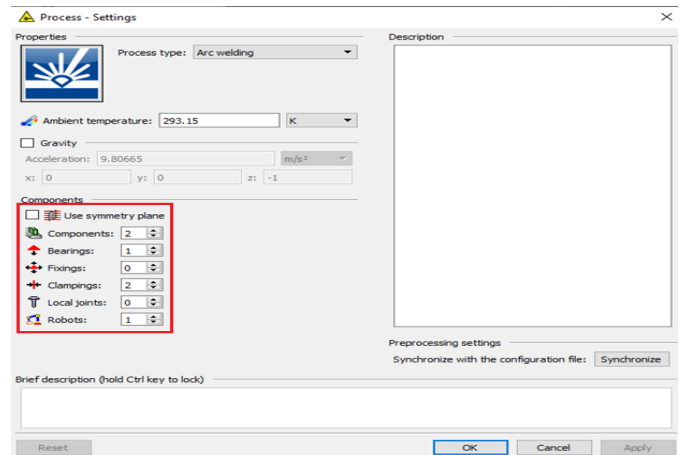

Fig -3: Process parameters settings

Ambient temperature was set at room temperature, by changes of room temperature, the output value may differ which gives different output compares to the simulation output. The components given in the process settings except the work piece geometry should be designed in the Simufact. The geometry of the Simufact component is based on the dimensions of the work piece. In this study the material of the work piece is STKM13A was chosen and the study of this material was selected from the existing research work done by Daniyan et al [5] and the material of the electrode is G2SiL.The shape of clamping and bearing can be cuboid or cylinder. In this work the clamping is designed in cylindrical shape and was positioned exactly where the clamping locates and the bearing is designed in cuboid. Fig-4 shows the model of the components, clamp and bearing.
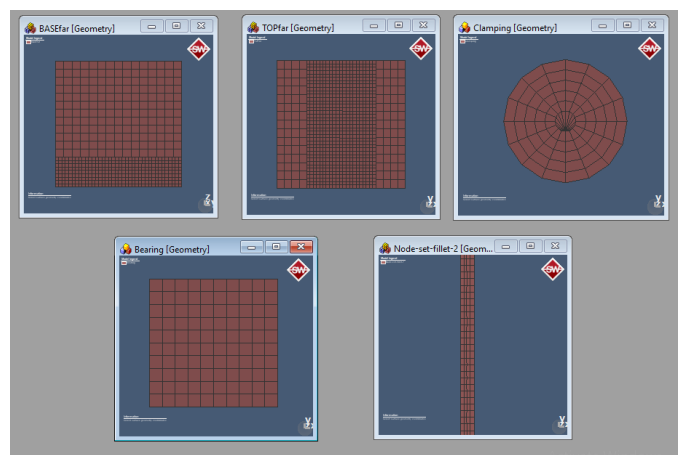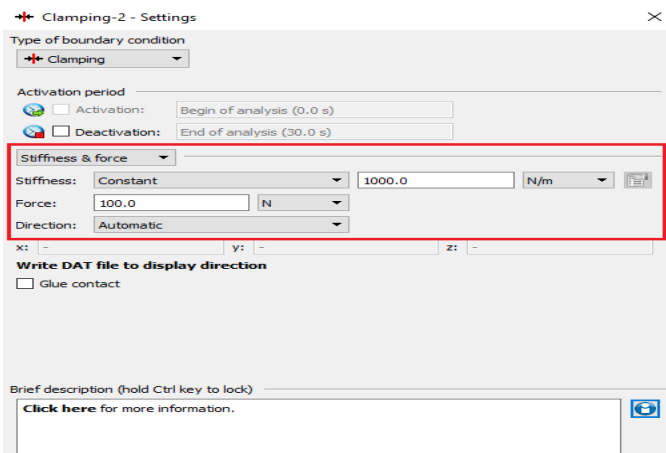

Fig -4: Model of the simufact components
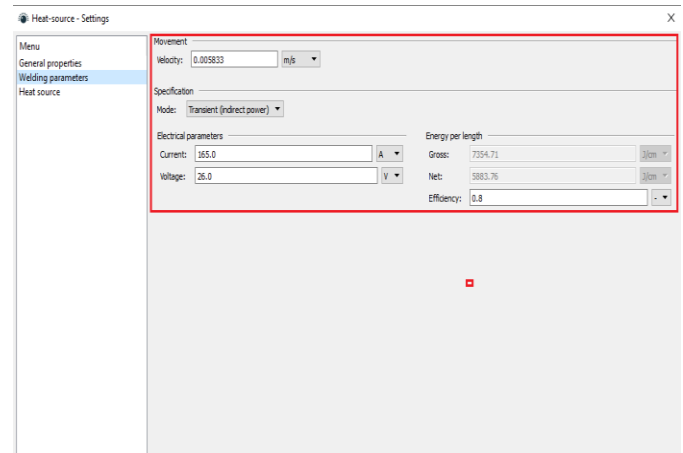
Fig -5: Clamping settings

The force applied to arrest the motion of the work piece is the clamping force. Clamping which helps to arrest the work piece to avoid misplacement during welding, Force applied in this study is 100Nas shown in Fig-5.Stick rod size as 1.5mm diameter and feed velocity as 4.5m/min was entered in the general settings of the software which is shown in Fig-6.

Fig -6: General Settings for heat source

3.2 Welding Parameters

In order to obtain the high-quality weld, the ideal values of the welding parameters to be obtained. In this study, the most affecting parameter such as welding current, welding voltage, and weld speed were optimized in order to get the maximum yield strength. The input parameter for the shielded metal arc welding was given in the Simufact software. The range of input parameters was extracted from existing research work done by Ugur et al [6]. The range of input parameters is voltage– 24V to 28 V, current -165A to205A and weld speed - 0.180 m/min – 0.240 m/min. Fig-7 shows the welding parameter settings.

Fig -7: Welding Parameter Settings

The trajectory path of the robot should be selected to obtain the weld bead. This was performed by selecting the nodes on the meshed geometry. This also helps to calculate the robot process time based on this, end time of the robot was chosen.Fig-8 shows the trajectory path of the weld.
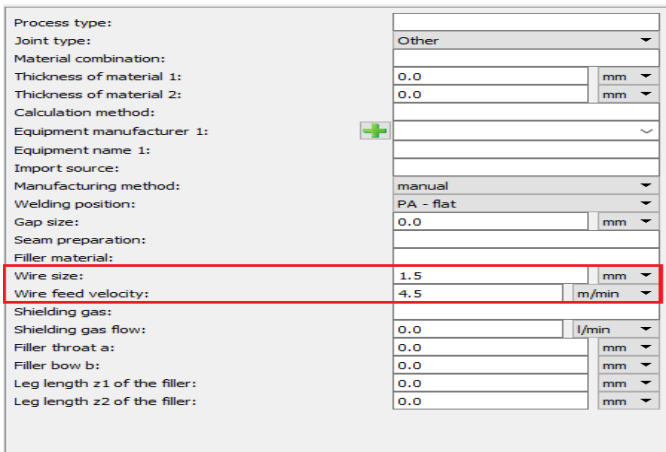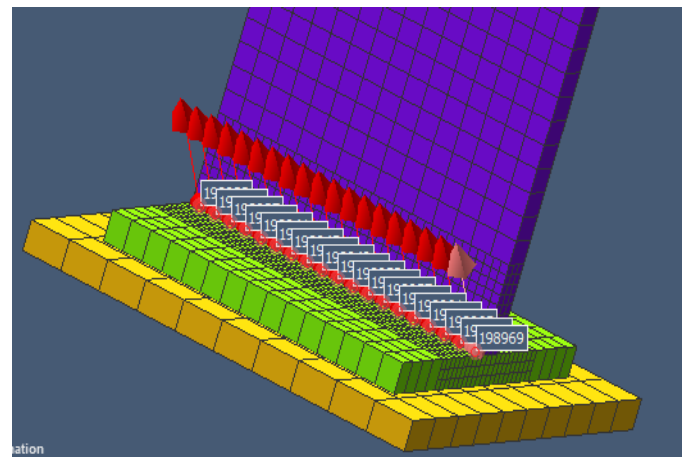

Fig -8: Trajectory path of the weld

The start time, pause (start) time, lead time, follow up time, pause (end) time to be given in the window shown in Fig-9. Start time: 0.0s–It was manually defined for the robot. This has direct impact on delaying all trajectories. Pause (start): 0.2s - There is no heat input despite already initiated the trajectory within this time interval. Lead Time: 0.1s -The robot has arc opened; heat input starts but there is no movement. Follow up time: 0.1s- The robot has still an open arc but ceases the movement. Pause (end): 0.2s - There is no heat input and no movement in this time interval.
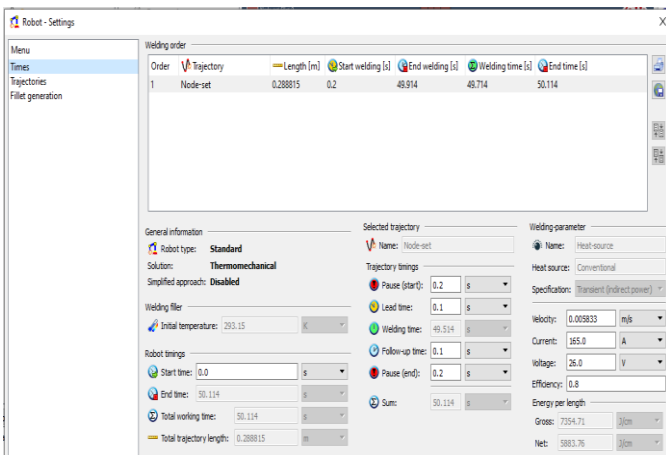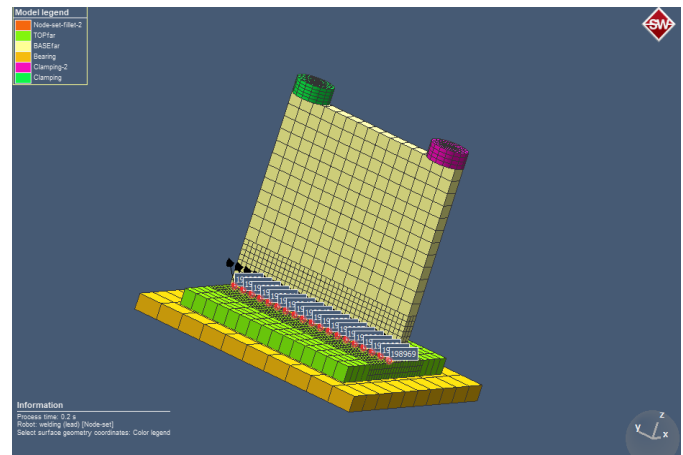
Fig-9: Robot Time Settings

The dimension of the filler is to be given in the window shown in Fig-10. This dimension is based on the application of the work piece. Where, Throat a - The height of the cross section; Bow b - The concavity of the fillet; $LegZ_1$: Leg of the fillet; $ToeZ_2$- Toe of the fillet. This dimension was chosen based on the work piece application. The final Simufact weld component is shown in Fig-11 after entering the setting parameters.
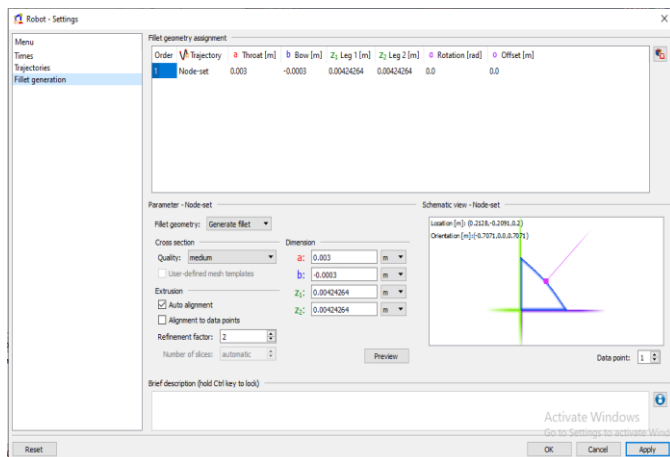

Fig-10: Fillet generation window

Fig -11: Final simufact component

4. GENERATION OF ORTHOGONAL ARRAY

The input range of parameters was divided into three level three factor matrix method. This helps us to develop a design of experiments (DOE) to minimize the number of trails. DOE is the mathematical tool used to define the importance of specific processing and product variables, and how to control them to optimize the system performance while maximizing properties. DOE uses statistical methodology to analyze data and predict product property performance under all possible conditions within the limits selected for the experimental design. For DOE, 3level 3 factors are considered which is shown in the Table -1.

Table -1: 3 Level 3 Factor Parameters

| Parameter	Level 1	Level 2	Level 3
Welding Voltage (V)	24	26	28
Welding Current (A)	165	185	205
Weld speed (m/min)	0.180	0.210	0.240

Taguchi method involves identification of proper control factors to obtain the optimum results of the process. Orthogonal arrays are used to conduct the set of operations. Taguchi design of experiments is recommended to generate possible outcomes for three level three factor matrix to reduce the number of trails [7]. This can be done with the help of Minitab software. These 3 level 3 factor matrices should be given in the Minitab worksheet window. For the 3 Level 3 factor L9 and L27 combinations are possible in Taguchi DOE. In this study L9 combination was chosen to reduce the number of trails. Table-2 shows the orthogonal array generated by Taguchi DOE.

Table -2: Orthogonal Array Generated by Taguchi DOE

Sample	Welding Voltage (V)	Welding Current (A)	Welding Speed (m/min)
1	24	165	0.18
2	24	185	0.21
3	24	205	0.24
4	26	165	0.21
5	26	185	0.24
6	26	205	0.18
7	28	165	0.24
8	28	185	0.18
9	28	205	0.21

5. RESULT FROM SIMULATION SOFTWARE

The required output for this study from the Simufact software is maximum yield strength. Hence the yield strength for each sample was noted and the noted yield strength was given in the Minitab software to find the signal to noise ratio. In the Taguchi method the term signal represents the desirable value (mean) for the output characteristics and the term noise represents the undesirable value for the output characteristics [8]. Based on the input (Yield Strength) given in the Minitab, S/N ratio can be calculated by the Taguchi method based on higher the value higher the efficiency and the calculated S/N ratio will be displayed next to the yield strength column in the Minitab worksheet shown in Fig-12.

	C1	C2	C3	C4	C5
	VOLTAGE	CURRENT	SPEED	Y STR	SNRA3
1	24	165	0.18	245.84	47.8131
2	24	185	0.21	239.85	47.5988
3	24	205	0.24	247.19	47.8606
4	26	185	0.24	252.45	48.0435
5	26	205	0.18	231.96	47.3083
6	26	165	0.21	247.65	47.8768
7	28	205	0.21	236.45	47.4748
8	28	165	0.24	268.21	48.5695
9	28	185	0.18	233.51	47.3661

Fig-12: S/N ratio obtained from the Taguchi method

The graph which contains mean of S/N ratios to the corresponding three parameters is also displayed in the S/N ratio window. From the graph shown in Chart-1, higher the value higher the efficiency, the ideal value for the three parameters can be obtained and listed in Table -3.
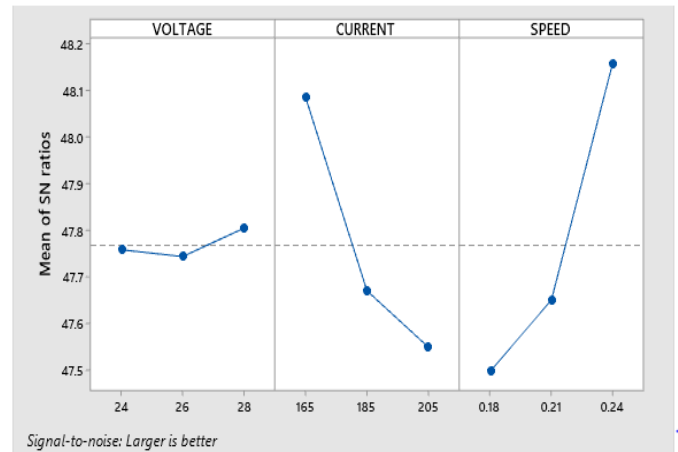
Chart -1: S/N ratio graph

Table -3: S/N Ratio to Parameters

Level	Voltage	Current	Speed
1	47.76	48.09	47.50
2	47.74	47.67	47.65
3	47.80	47.55	48.16

The Ideal value of the parameters can be obtained from Fig-12 and Chart -1. Level 3 of the welding voltage (28V) resulting 47.80 S/N ratio is the optimum condition in terms of high yield strength while variation of the voltage is the only consideration. Level 1 of the welding current (165A) resulting 48.09 S/N ratio is the optimum condition in terms of high yield strength while variation of current is the only consideration. Level 3 of the welding speed (0.24m/min) resulting 48.16 S/N ratio is the optimum condition in terms of high yield strength while variation of the weld speed is the only consideration. The optimum values of welding parameters are listed in Table -4.

Table -4: Optimum Values of Welding Parameters

Parameter	Optimum Value
Welding voltage (V)	28
Welding current (A)	165
Weld speed (m/min)	0.24

The regression equation for the yield strength generated by mini tab software is

238.4+0.441 (V) -0.3842 (C) +314.1 (S) (i)

Where, V is Welding voltage (V); C is Welding current (A); S is Welding Speed (m/min)

This regression equation helps to calculate the yield strength without simulation of welding parameters. This equation was generated in mini tab software based on the yield strength value which was determined from Simufact simulation software.

6. CONCLUSION

The optimization of the welding parameters for shielded metal arc welding in the metal fabrication industries by Simufact software is successfully performed. The efficiency of the welding is high and it helps to achieve higher yield strength by optimizing the parameters. Simufact allows designers, process planners and manufacturing practitioners to validate the material characteristic and residual strength of the work piece. The design of experiments (DOE) helps to reduce the number of trails of simulation. Taguchi's Technique and S/N ratio obtained for the L^9 combination assists in determining the best optimum process parameters values for the maximum yield strength. The usage of Simufact welding simulation software and by planning of experiments helps us to reduce the material wastage, time and investment on the manufacturing of welding joints.

ACKNOWLEGMENTS

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