ISSN: 2455 - 1597

ijergs
Open Access

International Journal of Engineering Research and Generic Science (IJERGS)
Available online at: https://www.ijergs.in

Volume - 7, Issue - 6, November - December - 2021, Page No. 09 - 21

Optimization of MIG Welding Process Parameters for AISI-4340 (34CrNiMo6) Steel Test Specimen Using Composite Desirability Function

[1]Nishant Kumar, Research Scholar, Department of Mechanical Engineering, Jaipur Engineering College, Kukas, Jaipur

[2]Prashant Kumar, Assistant Professor, Department of Mechanical Engineering, Jaipur Engineering College, Kukas, Jaipur

[3]Pinky Mourya, Assistant Professor, Department of Mechanical Engineering, Jaipur Engineering College, Kukas, Jaipur

Abstract

Purpose: The purpose of the present investigation was to optimize the process parameters of the MIG welding for AISI-4340 (34CrNiMo6) steel object. The reason to select the MIG welding research area is the small scale industries and road side shops where MIG is widely used for joining the materials. There was various operational drawbacks during performing the operation, so present investigation help the welder who use MIG machine for joining the high grade steel.

Research Methodology: Research methodology adopted for present study was that, first of all a small survey conduct by researcher to find the drawbacks of the MIG welding operation in local area where these welding machines are used widely, then a deep literature review conduct by researcher to find the proper research gap. After adopt the proper DOE technique for conducting the experiment and in last analysis was performed for selective response parameters. The tools required for analysis of the data was Signal to Noise ratio analysis, Interaction plots, Regression modeling, ANOVA analysis, CD function optimization

Research Findings: The conclusion of the research study was that the effect of process parameters on the response parameters are crucial for some parameters like welding speed and welding gas pressure are more crucial then other process parameters. Optimal cases are also found by using CD function methodology.

Limitations: Like other research works, present investigation was also have some limitations. The work was concluded for two response parameters welding time and Micro hardness, whereas some advance micro mechanical properties analysis can also possible but not select for present investigation.

Importance of present work: MIG welding process was one the most used welding technique for industries specially when other techniques are not feasible. The present research work help the scientific research community to find the effect of the process parameters of MIG welding on cylindrical object of the test materials. This type of research work was contribute effective part when any one goes for welding on cylindrical object. Another advantage of the research work was to show the importance of the design of experiment methods like Taguchi method, Regression modeling, ANOVA analysis, Multi Objective Optimization.

Keywords: Six Sigma, DMAIC methodology, Small Scale Industries, Oil Filled Transformers, Customer Complaints

Introduction

Joining is the one the common and important part for the assembly products for most of the industries. Joining became crucial when leakage was one common issue in industries. Various joining techniques available in market like riveted joints, bolted joints, welding joints and many more. Welding joints was considered as most common and better

techniques for assembly products where leakage was one of the common issues. Welding joining method has various advantages over other techniques like

Permanent Joint among base objects which increase durability for long time spam

Joint was free from corrosion defects, Seasonal defects and other strength related issues

Welding process was classified into two separations which was called as Plastic welding process and Fusion welding process. In plastic welding process (High Pressure welding), pressure and temperature was created on the base objects and then joining operation was performed. In fusion welding process extensive heat was generated near the welding area of the base metals and joining was performed. In general contrast, four types of welding process was used for joining the metals objects which are following:

MIG WELDING

TIG WELDING

SHIELDED METAL ARC WELDING

FLUX-CORED ARC WELDING

The present investigation was on the application of MIG welding techniques to find the effect of the process parameters on the selective response parameters. The four type of welding methods was shown in figure 1.

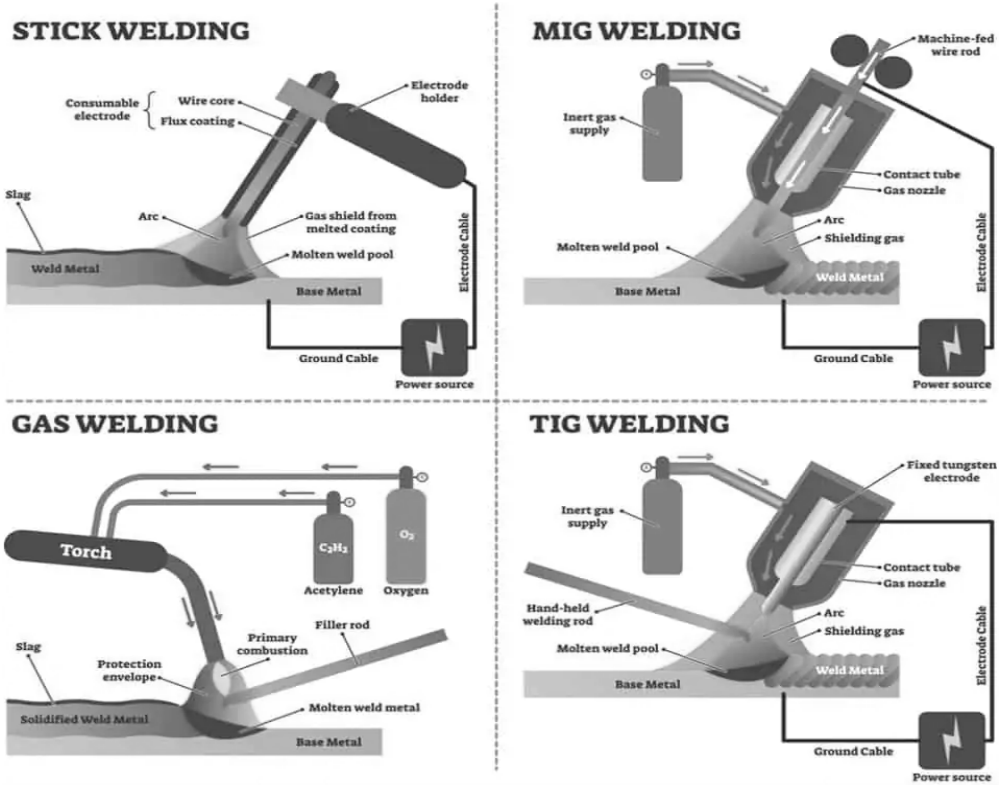

Figure 1: Welding Methods (Source: https://toolshaven.com)

To find the research gap for the present investigation total 20+ sci research papers are identified and conduct literature review. The research gap was following:

A. After conduct literature review on the MIG related papers, it was found that very less research work available in which cylindrical object was selected for welding research, so in present investigation cylindrical objects was selected as test specimen.

B. Like other research works, multi objective optimization (MOO) was conduct in the present study, but the technique adopted was quite new for MOO which was CD function optimization.

Scope of the Present Investigation: The aim of the present investigation was to optimize the MIG welding process parameters for AISI-4340 steel object using CD function multi objective optimization for two response parameters welding time and micro hardness. Taguchi method was selected for generated experiments for present investigation.

Research work Methodology: The research work methodology for the present study was that, first of all selection of the scope of the research work was identified and then plan for the research work was selected and then experiment was conduct on the work pieces. Then data recording for the present investigation was conduct using Mini-tab software. In last conclusion was finalize for the present investigation. The research flow diagram for present study was shown in figure 2.

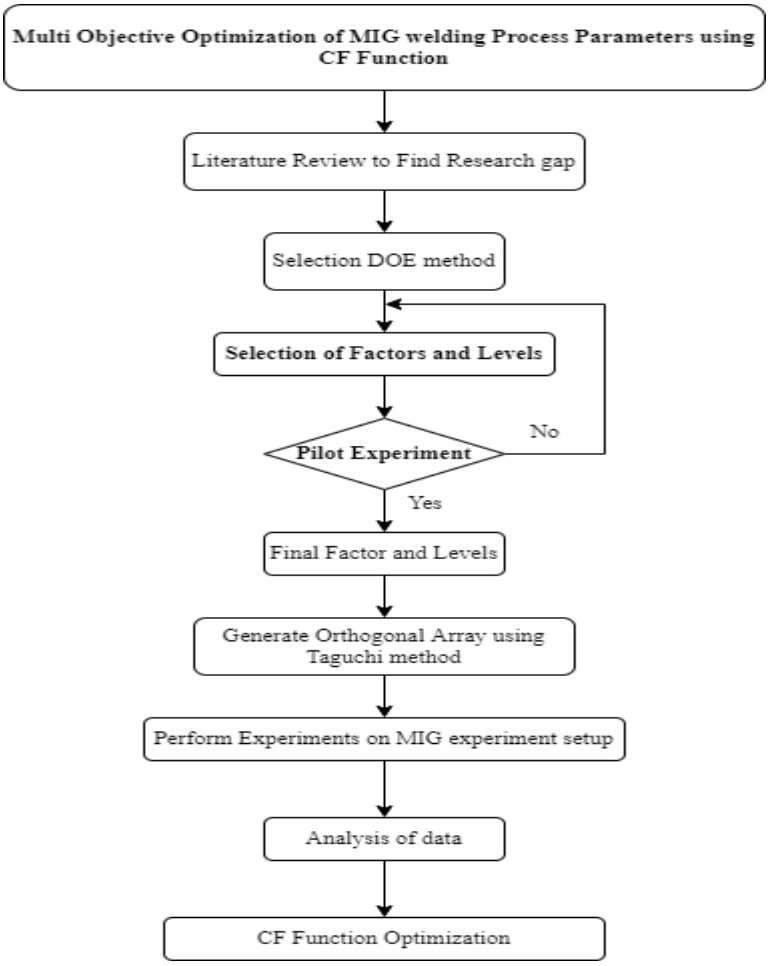

Figure 2: Research Flow Diagram

MIG machine Technical Specification

The machine selected for present investigation was available in college workshop and made by Koko-Tawa-Mig-mag series. The machine used for investigation was shown in figure 3.

Figure 3: MIG machine used for experiment work

The machine used present study have facility to change the voltage and current facility for better welding options. The options available in machine was shown in figure 4.

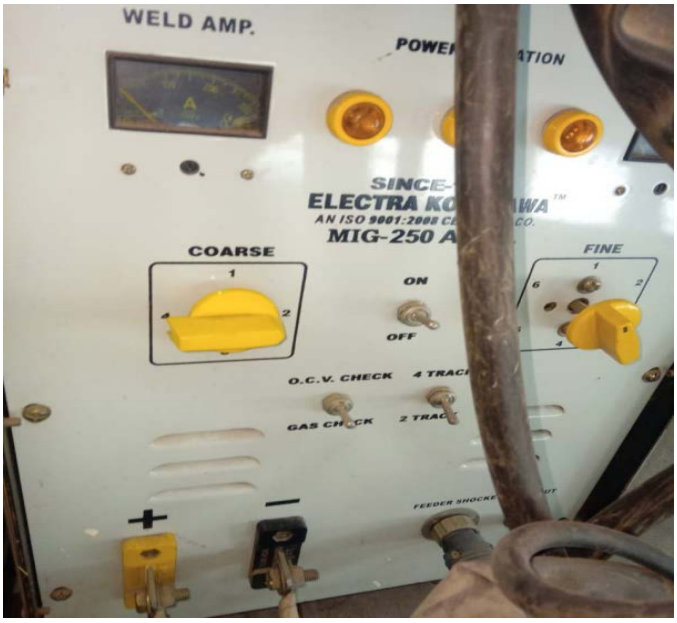

Figure 4: Machine control panel required for present study

Factor and Levels

In present investigation three input parameters are selected for investigation which are gas flow rate, gap among work pieces and feed rate of filler materials wire. The selection of the levels is conduct using pilot experiments which was shown in figure 2. The final factors and levels for present investigation was present in table 1.

Table 1: Factors and levels for MIG research work

Factors/Levels	**Feed Rate**	**Gas Flow Rate**	**Distance**
	Inch/sec	PSI	mm
I	3	2.0	0.0
II	4	2.5	0.2
III	5	3.0	0.4
IV	6	3.5	0.6

These factors and levels are required to select the experiment table for present investigation. The selection of experiment runs are done by using Taguchi method and the final orthogonal array was present in table 2. The distance calculation was done by using vernier caliber device. The reason to select this as input parameter was that research want to find the strength of welded joint when base metals are not in contact with each other. In present study two response parameters welding time and Micro hardness was selected. Welding time was measured by using stop watch and micro hardness was measured by hardness tester machine. Both testing machines was available in college laboratory.

Table 2: Orthogonal Array developed for present experiment work

Run	**FR**	**GFR**	**Distance**
1	3	2	0
2	3	2.5	0.2
3	3	3	0.4
4	3	3.5	0.6
5	4	2	0.2
6	4	2.5	0
7	4	3	0.6
8	4	3.5	0.4
9	5	2	0.4
10	5	2.5	0.6
11	5	3	0
12	5	3.5	0.2
13	6	2	0.6
14	6	2.5	0.4

Run	FR	GFR	Distance
15	6	3	0.2
16	6	3.5	0

Test Specimen and Dimensions

As discussed in previous sections, in present study cylindrical objects are selected for MIG welding process study. The material select for present study was AISI-4340, the reason to select the material for present investigation was its high application for industrial purpose. The raw work pieces are shown in figure 5.

Figure 5: AISI-4340 work piece material

Welded joint required to made by MIG welding machine was shown in figure 6 in which proper welding design was shown.

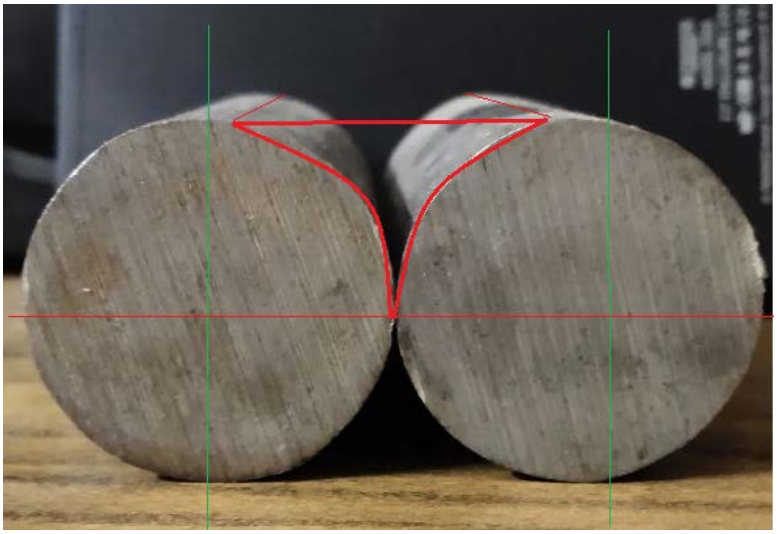

Figure 6: Welding bead required to make for present investigation

The length of the work piece was 70 mm and diameter was 30 mm. Bead was made from center point matching for both cylindrical objects.

Data Recording

As seen in table 2 total 16 experiments are required to run on MIG machine with desired boundary conditions. The data was recorded for welding time and micro hardness and present in table 3.

Table 3: Final response table for present investigation

Run	FR	GFR	Distance	Welding Time	Micro Hardness
1	3	2	0	56.24	515
2	3	2.5	0.2	53.68	517
3	3	3	0.4	53.62	489
4	3	3.5	0.6	62.51	428
5	4	2	0.2	52.37	460
6	4	2.5	0	54.61	507
7	4	3	0.6	61.82	491
8	4	3.5	0.4	60.37	532
9	5	2	0.4	51.56	469
10	5	2.5	0.6	58.94	523
11	5	3	0	49.37	519
12	5	3.5	0.2	55.86	562
13	6	2	0.6	59.36	541
14	6	2.5	0.4	56.81	483
15	6	3	0.2	52.28	491
16	6	3.5	0	45.88	553

Result and Discussion

In present study two major sections of the analysis was divided which was following: in fist section signal to noise ratio analysis and optimal solutions are discussed but in second section regression modeling and optimization was performed.

Signal to Noise ratio calculation for welding time and Micro hardness

For welding time calculation smaller is better option was selected for signal to noise ratio analysis. The first step was to calculate the individual S/N ratio then by using this S/N ratio values delta parameter was calculated, which help to find the rank among input parameters. The final S/N ratio table for welding time was present in table 4 and for micro hardness the final S/N ratio results are present in table 5.

Table 4: S/N ratio analysis for Welding Time

Level	**FR**	**GFR**	**Distance**
1	-35.03	-34.77	-34.21
2	-35.14	-34.96	-34.57
3	-34.62	-34.66	-34.88
4	-34.54	-34.93	-35.65
Delta	0.6	0.3	1.44
Rank	**2**	**3**	**1**

Table 5: S/N ratio analysis for Micro hardness

Level	**FR**	**GFR**	**Distance**
1	55.36	55.5	55.89
2	55.52	55.67	55.65
3	55.81	55.52	55.46
4	55.8	55.8	55.48
Delta	0.45	0.3	0.44
Rank	**1**	**3**	**2**

As seen in tale 4, the crucial parameter for welding time was distance among test specimen and least crucial parameter was gas flow rate. And for Micro hardness the crucial parameter was feed rate and least crucial parameter was gas low rate. The same analysis for both response parameters are present in figure 7 and figure 8.

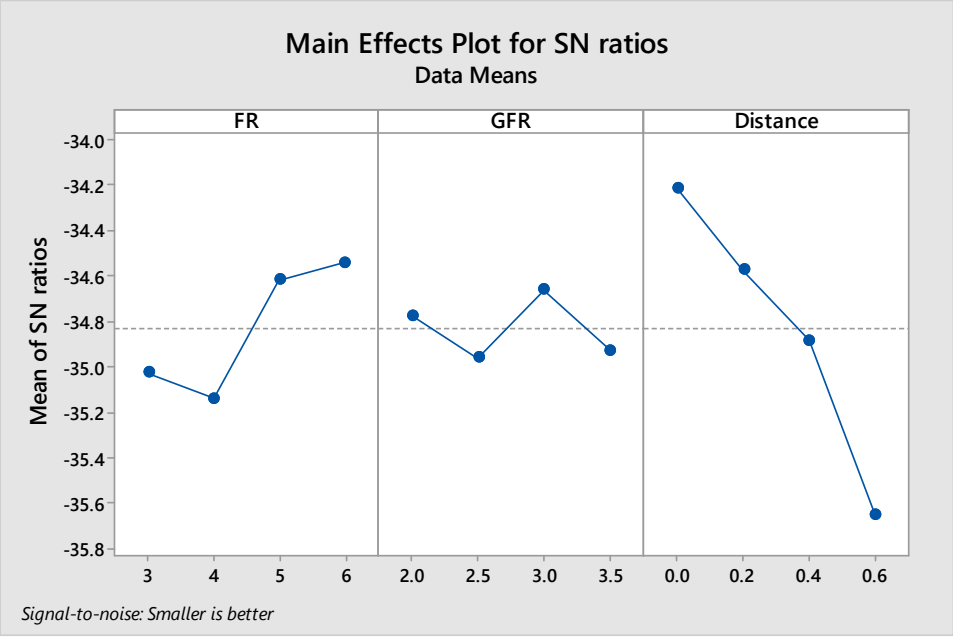

Figure 7: S/N ratio analysis for welding time

As seen in figure 7, the best optimal solution for welding time was, 6 inch/sec feed rate, 3.0 PSI for gas flow rate, and zero mm gap among two object work piece.

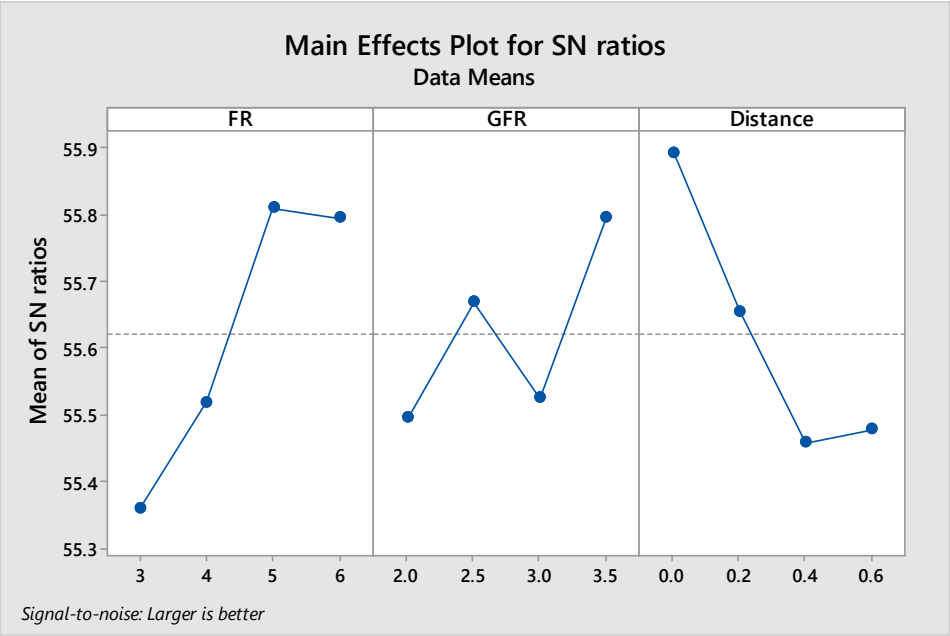

Figure 8: S/N ratio analysis for welding time

As seen in figure 8, the best optimal solution for welding time was, 5 inch/sec feed rate, 3.5 PSI for gas flow rate, and zero mm gap among two object work piece.

Regression equations for Welding time and Micro hardness

In this section regression modeling was adopt for both response parameters. The selection of right modeling equation was quite experience and for present investigation linear and interaction model was adopted and the final equations with

Welding Time = 63.7 - 2.02 FR + 0.55 GFR - 99.5 Distance - 0.401 FR*GFR + 12.56 FR*Distance+ 20.64 GFR*Distance

Table 5: ANOVA analysis for Welding Time

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Model	6	297.08	49.5133	24.99	0
Linear	3	99.578	33.1926	16.75	0.001
FR	**1**	**2.906**	**2.9055**	**1.47**	**0.257**
GFR	1	42.929	42.9286	21.67	0.001
Distance	1	53.744	53.7437	27.13	0.001
2-Way Interaction	3	93.388	31.1292	15.71	0.001
FR*GFR	**1**	**0.355**	**0.3546**	**0.18**	**0.682**
FR*Distance	1	55.55	55.5496	28.04	0
GFR*Distance	1	37.483	37.4833	18.92	0.002

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Error	9	17.831	1.9812		
Total	15	314.911			

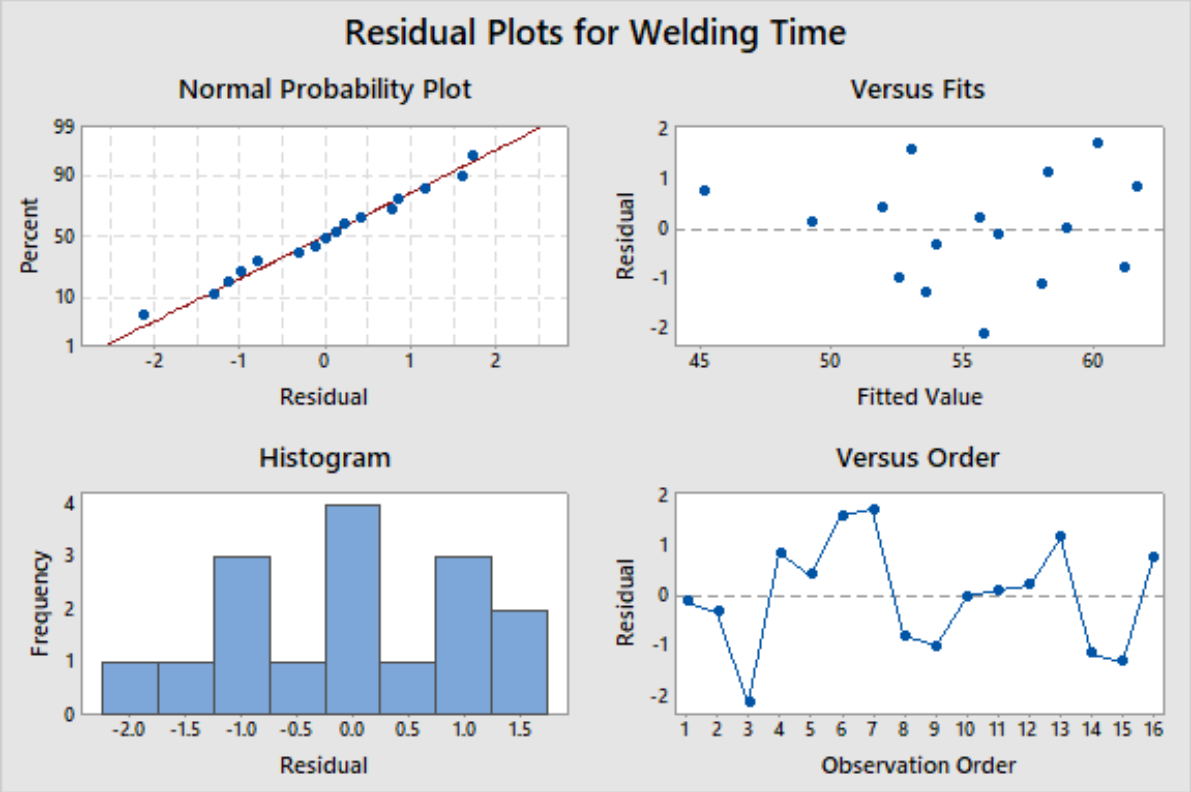

Figure 8: Residual Plot for welding time

Table 6: Model Summary for Welding Time

S	R-sq	R-sq(adj)	R-sq(pred)
1.40757	94.34%	90.56%	80.17%

Hardness = 745.6 - 111.7 FR + 36.6 GFR - 56 Distance + 21.14 FR*GFR + 148.3 FR*Distance- 222.7 GFR*Distance

Table 7: ANOVA analysis of Micro hardness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	6	18071.8	3011.97	41.31	0.000
Linear	3	7986.4	2662.15	36.51	0.000
FR	1	576.0	576.01	7.90	0.020
GFR	1	7410.0	7410.02	101.63	0.000

Distance	1	0.4	0.40	0.01	0.943
2-Way Interaction	3	13089.3	4363.11	59.84	0.000
FR*GFR	1	982.8	982.84	13.48	0.005
FR*Distance	1	7741.0	7741.02	106.17	0.000
GFR*Distance	1	4365.5	4365.45	59.88	0.000
Error	9	656.2	72.91		
Total	15	18728.0			

Table 8 Model Summary for micro hardness

S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**
8.53868	96.50%	94.16%	88.41%

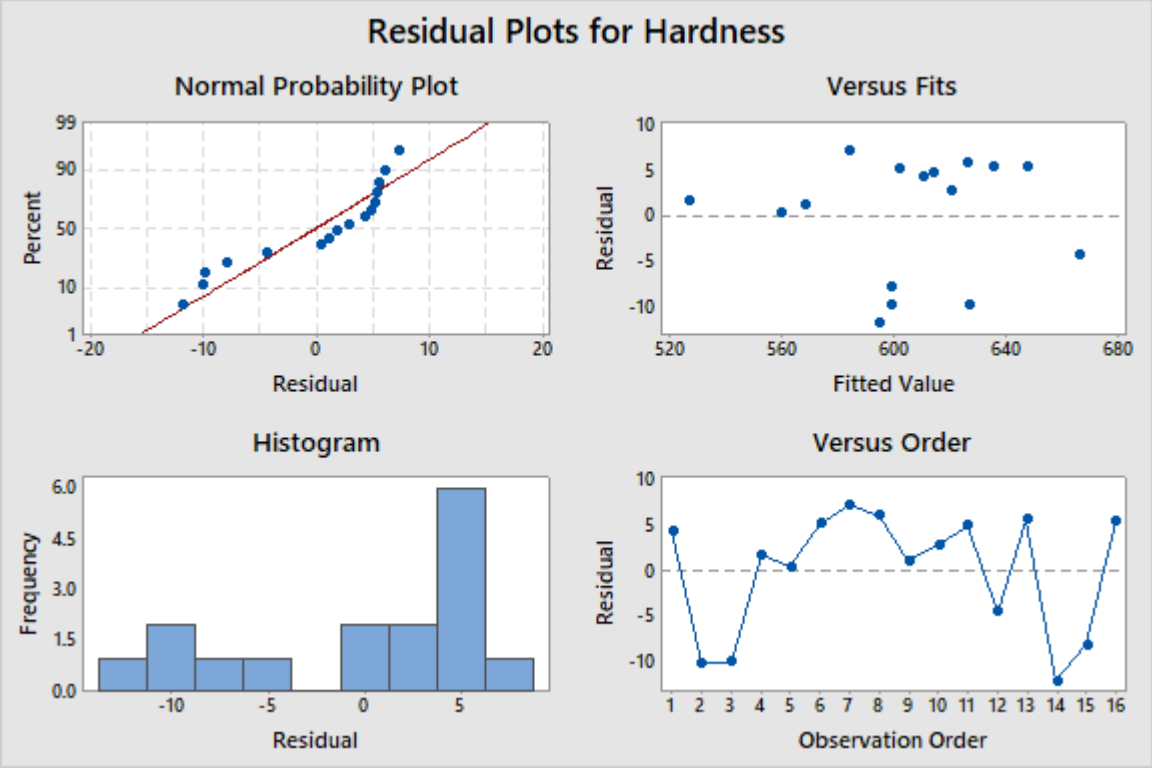

Figure 9: Residual Plot for micro hardness

CD Function optimization

Table 9: Goals criteria for CD function optimization

Response	Goal	Lower	Target	Upper	Weight	Importance
Welding Time	Minimum		45.88	62.51	1	1
Hardness	Maximum	528	662.00		1	1

Table 10: Final Solution for MIG welding process

Solution	FR	GFR	Distance	Welding Time Fit	Hardness Fit	Composite Desirability
1	5.63636	3.5	0	46.3515	661.316	0.983204

Conclusion

MIG welding process was one the most used welding technique for industries specially when other techniques are not feasible. The present research work help the scientific research community to find the effect of the process parameters of MIG welding on cylindrical object of the test materials. This type of research work was contribute effective part when any one goes for welding on cylindrical object. Another advantage of the research work was to show the importance of the design of experiment methods like Taguchi method, Regression modeling, ANOVA analysis, Multi Objective Optimization. The conclusion of the research study was that the effect of process parameters on the response parameters are crucial for some parameters like welding speed and welding gas pressure are more crucial then other process parameters. Optimal cases are also found by using CD function methodology.

References

1. Shanping Lu, Hidetoshi Fujii, Kiyoshi Nogi. Sensitivity of Marangoni convection andweld shape variations to welding parameters in O2-Ar shielded GTA welding. ScriptaMaterialia. 2004; 51: 271-277.
2. Janez Grum, Matjaz znidarsic. Microstructure, Microhardness, and Residual StressAnalysis of Laser Surface Cladding of Low-Carbon Steel. Materials and ManufacturingProcesses. 2004; 19(2): 243-258.
3. Palani P K, Murugan N. Development of mathematical models for prediction of weldbead geometry in cladding by flux cored arc welding. Int. J. Adv. Manuf. Technol. 2006;30: 669676.
4. Saurav Datta, Asish Bandyopadhyay, Pradip Kumar Pal. Modeling and optimisation offeatures of bead geometry including percentage dilution in submerged arc welding usingmixture of fresh flux and fused slag. International Journal of Advanced ManufacturingTechnology 2008; 36: 1080-1090.
5. Serdar Karaoglu, Abdullah Secgin. Sensitivity analysis of submerged arc weldingprocess parameters. Journal of Materials Processing Technology. 2008; 202: 500-507.
6. Balasubramanian M, Jayabalan V, Balasubramanian V. Optimizing pulsed currentparameters to minimize corrosion rate in gas tungsten arc welded titanium alloy. InternationalJournal of Advanced Manufacturing Technology 2008; 39: 474–481.
7. Kamal Pal, Sandip Bhattacharya, Surjya K Pal. Prediction of metal deposition from arcsound and weld temperature signatures in pulsed MIG welding. International Journal ofAdvanced Manufacturing Technology 2009; 45: 1113-1130.
8. Ghosh P K, Lutz Dorn, Shrirang Kulkarni, Hofmann F. Arc characteristics and behaviourof metal transfer in pulsed current GMA welding of stainless steel. Journal of MaterialsProcessing Technology. 2009; 209: 1262-1274.

9. Kamal Pal, Sandip Bhattacharya, Surjya K Pal. Optimisation of weld depositionefficiency in pulsed MIG welding using hybrid neuro-based techniques' InternationalJournal of Computer Integrated Manufacturing. 2011; 24(3): 198-210.
10. Kannan T, Yoganandh Y. Effect of process parameters on clad bead geometry and itsshape relationships of stainless steel claddings deposited by GMAW. Int. J. Adv. Manuf. Technol. 2010; 47: 1083- 1095.
11. Wang J F, Yu H D, Qian Y Z, Yang R Z, Chen S B. Feature extraction in weldingpenetration monitoring with arc sound signals Proceedings of the Institution ofMechanical Engineers-Part B: Journal of Engineering Manufacture. 2011; 225: 1683- 1691.
12. Kamal Pal, Sandip Bhattacharya, Surjya K Pal. Optimisation of weld depositionefficiency in pulsed MIG welding using hybrid neuro-based techniques' International Journal of Computer Integrated Manufacturing. 2011; 24(3): 198-210.