Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 6, June -2015

EFFECT OF PROCESS PARAMETER ON MECHANICAL AND METALLURGICAL PROPERTIES OF DISSIMILAR METAL WELDS USING GTAW PROCESS

Jigar R. Parasiya[1], Ketan Sathavara[2], Parthiv T. Trivedi[3]

[1]*ME AMS Student, VICT, Gandhinagar,*
[2]*Asst Prof, Mechanical Department, VICT, Gandhinagar,*
[3]*Asst Prof, Mechanical Department, SVBIT, Gandhinagar,*

Abstract - *The aim of this research work is to obtain optimum process parameters for dissimilar metals (AISI 304 Stainless Steel and CP- Copper) welding using Gas Tungsten Arc Welding (GTAW) process. Study the mechanical and metallurgical properties of weld joint and optimizing process parameters so as to achieve optimum weld strength and microhardness. The experimental setup consists of semi-automatic welding machine with control over welding parameters such as root gap, joint angle, welding current. The DOE (Design of Experiment) method applied for the experiments is Response Surface method (RSM) with Central Composite Design (CCD). The DOE will be prepared using MINITAB software. The experimental readings will be then taken like ultimate tensile strength and microhardness of the weld joint. Moreover microstructure will be performed to examine microscopic description of the individual constituent of material, and macrostructure inspection will be performed to examine of weld quality. Optimization of process parameters will be been carried out using the Response Surface Methodology (RSM). This will be done using the soft computing tool MINITAB.*

Keywords - *Gas Tungsten Arc Welding (GTAW), AISI 304 Stainless Steel, CP- Copper, Mechanical and Metallurgical properties, Response Surface method (RSM)*

I. INTRODUCTION

Welding is a materials joining process in which two or more parts are coalesced at their contacting surfaces by a suitable application of heat and/or pressure. The necessary heat for Gas Tungsten-Arc Welding (GTAW) or Tungsten Inert Gas (TIG) is produced by an electric arc maintained between a non-consumable Tungsten electrode and the part to be welded.

The GTAW process is used for a wide variety of applications and similar and dissimilar metals, particularly stainless steel, copper and copper alloy, aluminum, magnesium, titanium, and refractory metals, and it is especially suitable for thin metals.

Welding of dissimilar metals is the joining of metals by different welding processes which has different chemical, physical and metallurgical properties. During welding of dissimilar metals, there are many interesting features that are not completely understood. Physical properties of the two metals being very different from each other lead to complexities in weld pool shape, solidification microstructure and segregation patterns. The Industry needs construction of advance equipment and machinery. Different kinds of metals feature with different chemical, physical, and metallurgical properties. Some are more resistible to corrosion, some are lighter, and some are stronger, so this area got priority among the engineering industry.

II. LITERATURE REVIEW

Madduru Phanindra Reddy, etc. presented investigation the weldability of AISI 4140 and AISI 316 by Gas Tungsten Arc Welding process with and without filler metal. The filler material employed for joining dissimilar metal was ER309L. The process parameter employed such as voltage, current, shielding gas flow and filler wire diameter. Tensile studies were conducted on the ASTM E8 standard samples to assess the strength and ductility of the weldments. The hardness studies, the lower hardness values are found be at the parent metal side of AISI 316. Successful welds of AISI 4140 and AISI 316 could be obtained by GTA welding process employing with and without filler wire [1].

Savyasachi Pandit, etc. was investigates the weldability of dissimilar metals (Monel 400 and Hastelloy C276) by Gas Tungsten Arc Welding technique employing ERNiCrMo-3 filler wire. The studies were carried out to characterize the weldments of mechanical and metallurgical properties. The input parameter used to voltage current and filler wire diameter. The weldments were characterized to determine for any macro/microscopic defects using X-Ray radiographic technique. Overall defect free welds of parent metal could be obtained by GTAW process employing ERNiCrMo-3 filler metal [2].

I. Hajiannia, M. Shamanian, M. Kasiri present study of microstructure and mechanical properties of AISI 347 austenitic stainless steel/ ASTM A335 low alloy steel dissimilar joint were investigated. Employed two filler metals including ER309L and ERNiCr-3 were selected to be used during the gas tungsten arc welding process. The welding process parameters including current, voltage, welding speed, heat input to calculated elongation ratio, tensile strength and yield strength. The microstructure was examined by optical microscopy (OM) and scanning electron microscopy (SCM). ERNiCr-3 filler material presented the optimum mechanical properties [3].

Palani.P.K, Saju.Mapplied investigate the effect of TIG welding process parameters are welding speed, current and gas flow rate. Response Surface Methodology was used to conduct the experiments. Strength of weld and percent elongation was calculated. From the results of the experiments, mathematical models have been developed to study the effect of process parameters on tensile strength and percent elongation. Optimization was done to find optimum welding conditions to maximize tensile strength and percent elongation of welded specimen [4].

Prachya Peasura, Anucha Watanapab studying types of shield gas and gas flow rate which affect to mechanical properties and microstructures of HAZ and fusion zone on gas tungsten arc welding (GTAW) in aluminum alloy AA 5083. The factors of AA 5083 weld used in the study types of shielding gas in argon and helium, gas flow rate. The factorial experiment was designed for this research. Then the results were using microstructure and Vickers hardness test. Experimental results showed that the argon condition provided smaller grain size, suitable size resulting in higher hardness both in weld metal and HAZ. They also indicated that the grain size and precipitation Mg affect the hardness of sample [5].

III. EXPERIMENTAL DETAILS

Selection of base metal:

GTAW is capable of joining dissimilar materials that are precise and difficult to joining such as stainless steel and their alloys, mild steel, aluminum, copper and their alloys, etc. I have selected the dissimilar material AISI 304 Stainless Steel and Cp-Copper as it is been widely used in the industrial application in the field of food processing and vessel industries to utilize high strength and corrosion resistance of stainless steel with high electrical and thermal conductivity of copper. The Table 1 and Table 2 show the chemical composition of the base material and Table 3 show the chemical composition of the filler material.

Table 1 Chemical Composition of CP-Copper [wt. %]

Material	Tin	Phosphorus	Iron	Copper
Copper base	0.004	0.041	0.003	99.931

Table 2 Chemical Composition of AISI 304 Stainless Steel [wt. %]

Material	C	Cr		Fe		Mn	Ni		P	S	Si
	Max	Min.	Max.	Min.	Max.	Max	Min.	Max.	Max	Max	Max
AISI 304	0.08	18	20	66.3	74	2	8	10.5	0.045	0.03	1

Table 3 Chemical Composition of Super Bronze [wt. %]

Material	Tin	Lead	Zinc	Iron	Phosphorus	Copper
Copper filler (Super bronze)	6.477	0.092	0.049	0.041	0.057	93.196

Design of Experiment based on Response Surface Methodology:

In this study three parameters have been chosen for analysis. They are welding current, root gap and joint angle. Trial experiment and research papers were referred to deciding the range of these parameters.

Table 4 Factor and their levels

Factors	Notation	Levels

		-1	0	+1
Root Gap (mm)	RG	1.5	2	3
Joint Angle (°)	JA	60	75	90
Welding Current (Amps)	I	150	185	220

Experimental results:

Table 5 Experimental Results

Std Order	Run Order	Pt Type	Blocks	Input Parameter			Output Parameter	
				Root Gap (mm) (1.5-3)	Joint Angle (°) (60°-90°)	Welding Current (Amps) (150-220)	Ultimate Tensile Strength (MPa)	Micro-hardness (HV)
15	1	0	1	2	75	185	205.000	148.125
5	2	1	1	1.5	60	220	219.563	139.256
12	3	-1	1	2	90	185	208.300	142.587
18	4	0	1	2	75	185	205.000	148.125
7	5	1	1	1.5	90	220	212.300	140.353
8	6	1	1	3	90	220	229.600	135.142
1	7	1	1	1.5	60	150	205.200	135.141
19	8	0	1	2	75	185	205.000	148.125
10	9	-1	1	3	75	185	214.700	141.021
2	10	1	1	3	60	150	208.100	138.032
13	11	-1	1	2	75	150	199.600	145.719
11	12	-1	1	2	60	185	213.951	142.480
20	13	0	1	2	75	185	205.000	148.125
4	14	1	1	3	90	150	210.800	134.214
16	15	0	1	2	75	185	205.000	148.125
17	16	0	1	2	75	185	205.000	148.125
3	17	1	1	1.5	90	150	196.300	137.745
9	18	-1	1	1.5	75	185	205.851	141.214
6	19	1	1	3	60	220	229.600	142.154
14	20	-1	1	2	75	220	215.300	149.012

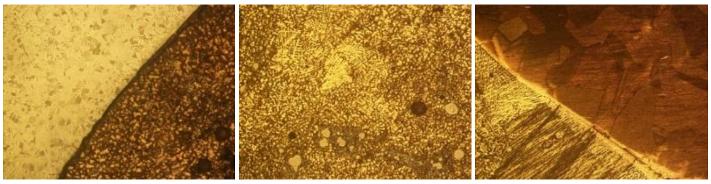
Macrostructure test:

All the specimens will be subjected to macro structure testing for checking external quality defects, if any like porosity, shrinkage, etc. The testing was performed at Accurate Metal Test Services, Ahmedabad. Initially samples were cut from the welded specimens, they were polished on a polishing machine and etchant 100 ml Distilled Water, 5gm Ferric Chloride and 50 ml HCL. The macrostructure was studied at 10X zoom level with a "Stereozoom Microscope" and the photographs of macrostructure were recorded. Photograph of a typical micro structure is shown below.

Figure 1 Macrostructure

Microstructure Test:

All metallographic specimens were prepared by mechanical grinding paper, polishing, followed by etching with Stainless steel- Aqua Regia+1 ml HCL+2 ml HNo_3 and with Copper- 50 ml HCL+5 gm $FeCl_3$+ 50 ml Water solution by swabbing it on the transverse side of the specimen for the microstructure development. Microstructure specimens' 100X magnify to preparation and characterization is carried out at M/S ERDA, Baroda.



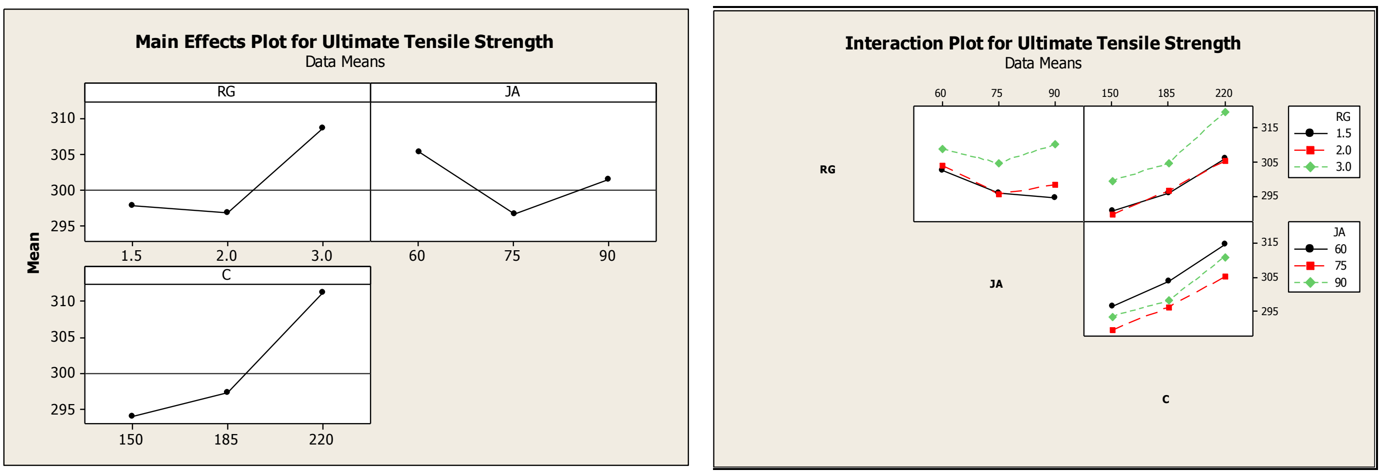
(a) (b) (c)
Figure 2 Microstructure of Maximum UTS Sample (a) HAZ of SS side, (b) Weldment, (c) HAZ of Cu side

(a) (b) (c)
Figure 3 Microstructure of Minimum UTS Sample (a) HAZ of SS side, (b) Weldment, (c) HAZ of Cu side

The microstructures of fusion zone produced by Super bronze filler material at the copper and stainless steel sides are show in Figure 2 and Figure 3. These zones were free of microscopic defects like cracks, pores, etc. Figure 2 indicates maximum strength due to the fine grain and steel globular in the weld zone. Figure 3 indicates minimum strength due to the course grain in the weld zone. There were some steel globules in the fusion zone and delta ferrite phase in the austenite grain boundaries at the stainless steel side Figure 2 (a,b). The presence of these globules led to the formation of a steel-copper composite in this region. Showing Figure 3 (a) some copper penetration into the stainless steel heat affected zone grain boundaries.

III. ANALYSIS, OPTIMISATION AND VALIDATION

Effect of process parameters on Ultimate Tensile Strength (UTS):



(a) (b)
Figure 4 (a) Main effect of process parameters on Ultimate Tensile Strength,
(b) Interaction effect of process parameters on Ultimate Tensile Strength

Figure 4 (a) shows the main effect plot of process parameters on ultimate tensile strength at different parameters like root gap, joint angle and welding current in GTAW process of for dissimilar welding between 304 stainless steel and commercial pure copper (CP-Copper). From the figure, it can be seen that:-

Effect of root gap: There is a slight decrease with increase in ultimate tensile strength with the increase in root gap.
Effect of joint angle: There is a decrease with increase ultimate tensile strength with increase in joint angle.
Effect of welding current**:** Ultimate tensile strength increase with increase in current.

The interaction plot in Figure 4 (b) suggests interactions. As the lines are not parallel; meaning the change in any one parameter will have effect on other parameters.

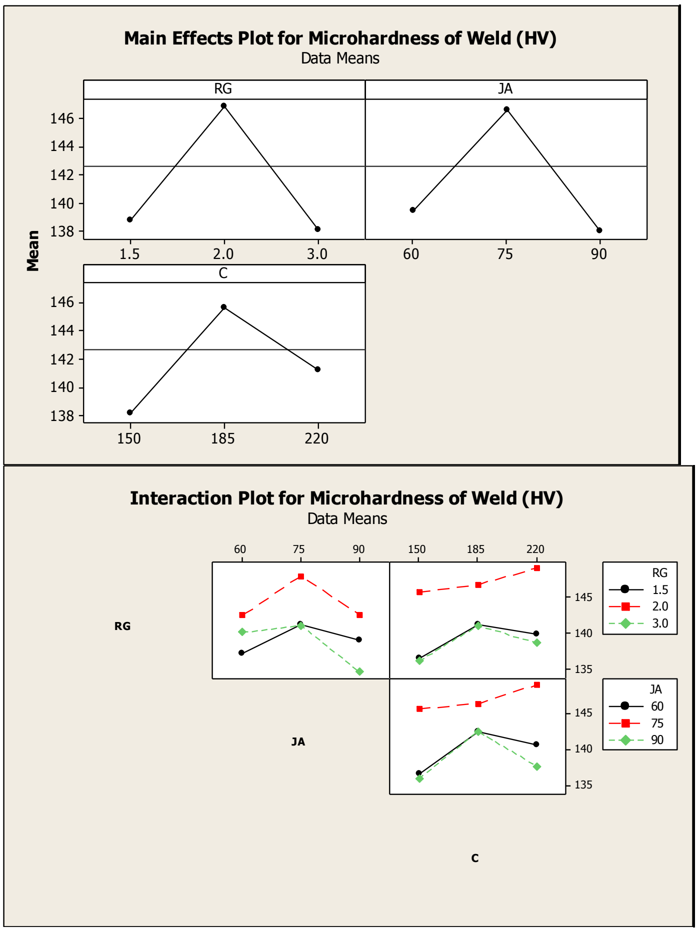
Regression Model analysis for Ultimate Tensile Strength (UTS):

Table 6 Estimated Model Co-efficients

Predictor	Coef	SE Coef	T	P
Constant	350.50	23.81	14.72	0.000
RG	-33.053	8.225	-4.02	0.002
JA	-3.4376	0.5365	-6.41	0.000
C	-0.0413	0.2406	-0.17	0.867

S = 1.25670 R-Sq = 98.9% R-Sq(adj) = 97.9%

Effect of process parameters on Microhardness of Weld (HV):



(a) (b)

Figure 5 (a) Main effect of process parameters on Ultimate Tensile Strength,
(b) Interaction effect of process parameters on Ultimate Tensile Strength

Figure 5 shows the main effect plot of process parameters on microhardness of weld (HV) at different parameters like root gap, joint angle and welding current in GTAW process of for dissimilar welding between 304 stainless steel and commercial pure copper (CP-Copper). From the figure, it can be seen that:-
Effect of root gap: There is a increase with decrease in microhardness of weld with the increase in root gap.
Effect of joint angle: There is a increase with decrease microhardness of weld with increase in joint angle.
Effect of welding current: There is a increase with decrease microhardness of weld with increase in current.

The interaction plot in Figure 6.5 suggests interactions. As the lines are not parallel; meaning the change in any one parameter will have effect on other parameters.

Regression Model analysis for Microhardness of Weld (HV):

Table 7 Estimated Model Co-efficients

Predictor	Coef	SE Coef	T	P
Constant	-63.41	12.80	-4.95	0.001
RG	65.704	4.424	14.85	0.000
JA	3.5231	0.2885	12.21	0.000
C	0.0463	0.1294	0.36	0.728

S = 0.675890   R-Sq = 99.0%   R-Sq(adj) = 98.2%

Results of optimization:

One of the most important aims of experiments related to welding is to achieve optimum value of Ultimate Tensile Strength and Microhardness. The Response Surface optimization is a technique for determining best welding parameter combination. Here the goal is to maximize UTS and minimize Microhardness. RSM optimization result for UTS and Microhardness is shown in Figure 6. Optimum parameters obtained are shown in Table 8.

Table 8 Composite Response Optimization for process parameter

Parameters	Goal	Optimum Combination			Lower	Target	Upper	Predicted Response
		Root Gape	Joint Angle	Current				
Ultimate Tensile Strength	Maxi-mum	1.5	60	220	196.3	229.6	229.6	220.551
Micro-hardness	Mini-mum	1.5	60	220	134.214	134.214	149.012	139.188

Composite Desirability = 0.695318

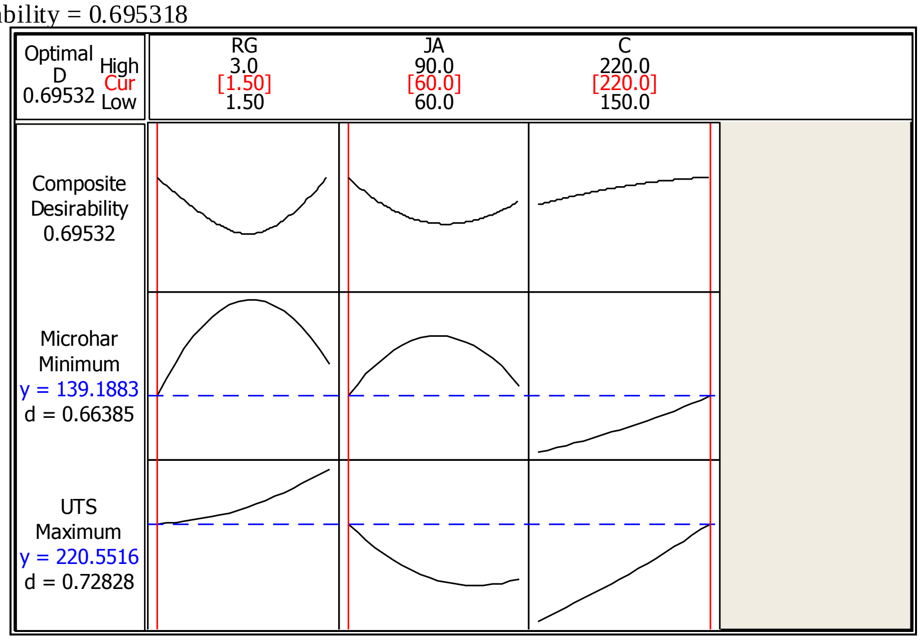


Figure 6 Composite Optimization Plot of UTS, Microhardness

Validation through practical experiment:

The results obtained through optimization had to be validated. This was done through practical performance of the experiment in the same manner as the practicals performed earlier as per DOE. The results are tabulated as under:

Table 9 Validatory Experiment

Input Parameters	Value	Predicted values of output parameters		Actual obtained values of output parameters		% Error
		UTS (Mpa)	Microhardness (HV)	UTS (MPa)	Microhardness (HV)	
Root Gap	1.5 mm	220.552	139.188	229.6	134.214	4%
Joint Angle	60°					
Current	220 Amps					

V. CONCLUSIONS

After conducting the experiments and analysis, the following conclusions were derived.

- Successfully welds of copper and AISI 304 Stainless Steel could be obtained satisfactory value. Such as UTS is 229.600 and Microhardness is 134.214.
- RSM was able to reach the optimal solution. This was validated in present work practically, after performing a confirmatory experiment as per process parameters optimized by RSM. Maximum error of 4% was found between the predicted values and the actually measured values.
- The formation of steel globules in copper matrix and copper globules in steel matrix in the fusion zone. Some steel globules in the fusion zone and delta ferrite phase in the austenite grain boundaries at the stainless steel side.

VI. FUTURE SCOPE

Although the Gas Tungsten Arc Welding has been thoroughly investigated for dissimilar CP-Copper and 304 Stainless Steel work material, still there is a scope for further investigation as following suggestions:

- The effect of process parameters such as welding speed, gas flow rate, voltage, heat input, filler wire dia. etc. may also be investigated.
- This method will be also used for other machining process.
- This experiment will be done by other DOE method or other optimization techniques.
- SEM/ EDX/ X-RD analysis will be also used for GTAW dissimilar weld joints.

REFERENCES

[1] Madduru Phanindra Reddy, A. Aldrin Sam William, M. Mohan Prashanth, S.N. Sabaresh Kumar, K. Devendranath Ramkumar, N. Arivazhagan, S. Narayanan, "Assessment of Mechanical Properties of AISI 4140 and AISI 316 Dissimilar Weldments", *7th International Conference on Materials for Advanced Technologies*, Procedia Engineering 75 (2014) 29 – 33

[2] Savyasachi Pandit, Vaibhav Joshi, Meghna Agrawal, M. Manikandan, K. Devendranath Ramkumar*, N. Arivazhagan, S. Narayanan, "Investigations on Mechanical and Metallurgical Properties of Dissimilar Continuous GTA Welds of Monel 400 and C-276", *7th International Conference on Materials for Advanced Technologies*, Procedia Engineering 75 (2014) 61 – 65

[3] I. Hajiannia, M. Shamanian b, M. Kasiri, "Microstructur and Mechanical Properties of AISI 347 Stainless Steel/ A335 Low Alloy Steel Dissimilar Joint Produced by Gas Tungsten Arc Welding", *Materials and Design 50 (2013) 566 – 573*

[4] Palani. P.K, Saju.M, "Modelling and Optimization of Process Parameters for TIG Welding of Aluminium-65032 Using Response Surface Methodology", *International Journal of Engineering Research and Applications*, Vol. 3, Issue Issue 2, March -April 2013, pp.230-236

[5] Prachya Peasuraa, AnuchaWatanapab, "Influence of Shielding Gas on Aluminium Alloy 5083 in Gas Tungsten Arc Welding", *2012 International Workshop on Information and Electronics Engineering (IWIEE)*, Procedia Engineering 29 (2012) 2465-2469

[6] Sajjad Gholami Shiri1, Mohsen Nazarzadeh1, Mahmood Sharifitabar2, Mehdi Shafiee Afarani, "Gas tungsten arc welding of CP-copper to 304 stainless steel using different filler materials", Transaction of Nonferrous Metal Society of China 22(2012) 2937−2942

[7] Chethan Roy, Vipin V Pavanan, Vishnu G, Hari P R, Arivarasu M, Manikandan M, Devndranath Ramkumar,Arivazhagan N, "Characterization of Metallurgical and Mechanical Properties of Commercial Pure Copper and AISI 304 Dissimilar Weldments", Procedia Materials Science 5 (2014) 2503-2512

[8] BALDEV RAJ, V. SHANKAR, A.K.BHADURI, "Welding for Engineers", Narosa Publishing House, India. pp 97-116

[9] V.M.RADHAKRISHNAN, "Welding Technology and Design" Revised Second Edition, New Age International Publishers 2005, pp 103-107

[10] DR. R. S. PARMAR, "Welding Processes and Technology", Khanna Publishers

[11] O. P. KHANNA, "A textbook of Welding Technology", Dhanpat Rai Publications

[12] METALS HANDBOOK VOLUME 2, "Properties and Selection: Nonferrous Alloys and Special-Purpose Materials", American Society for Metals (ASM)

[13] METALS HANDBOOK VOLUME 6, "Welding, Brazing and Soldering", American Society for Metals (ASM), 1993

[14] ADOR WELDING LIMITED, "Modern Arc Welding Technology", Oxford & IBH Publishing Co. Pvt. Ltd

[15] A. RAVINDRAN, K. M. RAGSDELL, G. V. REKLAITIS, "Engineering Optimization – Methods and Application", John Wiley & Sons, Inc. Publication

[16] RAYMON H. MYERS, DOUGLAS C. MOTGOMERY, CHRISTINE M. ANDERSON - COOK, "Response Surface Methodology – Process and Product Optimization Using Designed Experiments", John Wiley & Sons, Inc. Publication

