International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-2S, December 2018

Optimization of Process Parameters in Robotic TIG Welding for High Pressure Valves

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ABSTRACT--- The valves form the main part of boiler assembly in order to control the pressure. The body and the yoke are the vital parts of the valve. Generally, in case of low and medium pressure valves, the body and yoke are bolted while in case of high-pressure valves, they are welded to withstand high pressure. During the welding process, defects such as porosity, blow holes, incomplete penetration, cracks, warm holes, lack of fusion, gas holes etc. are likely to occur in the welded components due to a number of reasons, viz., un-optimized process parameters, unskilled operator, working environment, equipment, raw material etc. This work has been done to establish the Optimization of Process parameters for High-Pressure Valve Welding machine to minimize the defects produced during the manufacturing of valve components.

I. INTRODUCTION

The body-yoke welding is a simple butt joining of body and yoke by using two welding process, TIG (Tungsten Inert Gas) Welding and MMAW (Manual Metal Are Welding). The former process forms the root while the latter completes the welding by filling the gap between the body and yoke. This body-yoke welding forms one process in the valve assembly. Further before the body-yoke welding is performed, there are certain preparations to be made. So before going to body-yoke welding, let us see about the parts of the valve in general.

Generally the parts of the valves are given below and figure 1.Body which is a heavy with sufficient wall thickness for maximum service life, provided with bosses for optional bypasses or drains. Yoke is made of same material as body and is welded or bolted to body depending on the applied pressure.Bonnet inside the yoke is a self-sealed one and bears more pressure.Stem, which is precision, ground and a reciprocating one ensures smooth operation and ensures leak tightness in gland.Wedges or Discs is a heavy pattern fully guided one, fitted to body seats for maximum shut off (Gate valves & Flap valves.). Eye bolts & Nuts facilitate easier maintenance and packing replacement.Stuffing Box provides maximum packing for stem seal.Hand Wheel is preferred for easier operation of stem and mostly valves will be available with gearing and motor actuators.

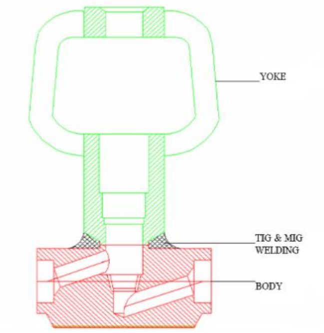

Figure 1- Parts of the valves

Welding of Valve

Generally In India welders who have obtained the certificate of Indian Boiler Regulation and ASME can do Body-Yoke welding. The valve body and yoke to be welded are first heated to a temperature of 150-200 degree Celsius in a furnace by passing producer gas. There are different capacity furnaces according to the size of the job. After heating, the body and yoke of same material is placed on the lathe for TIG welding. This welding just forms the root in one layer, which is strong enough with good penetration. The electrode used is non-consumable Tungsten electrode and Copper satellite is used as filler rod. The gas is used for shielding is Argon gas. Since the welding finish is not smooth it is subjected to grinding if necessary.

Manual Metal Arc Welding (MMA)

The TIG welded body-yoke is subjected to MMA Welding. Here the electrode used is a consumable flux coated carbon electrode. No gas is used for shielding as flux, which forms slag acts as a shielder preventing welded part from atmospheric contamination. This welding fills the gap between body and yoke in number of layers as decided by the diameter of the body. The welded body-yoke portion is again subjected to heat treatment to reduce the defects. This is Post heat treatment and for Alloy Steel are 250degree Celsius and for Carbon Steel it is nil.

Testing & Inspection

The portion welded by MMAW is then subjected to machining to get smooth finish. Then the body-yoke part is sent for NDT (Non Destructive Testing) also called X-Ray testing to check for defects like porosity, piping, incomplete penetration, slag holes, cracking etc., Once the piece

Manuscript published on 30 December 2018.
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satisfies the entire test, it is sent for assembly with other parts. Finally NTPC (National Thermal Power Corporation) will finalize the valves after entire assembly and then the valves are disposed.

Welding Defects

Despite process quality control tests which are normally carried out before production-welding operations, defective welds including may still be produced which can be metallurgical and result in loss of strength, ductility, etc. Welding defect data before optimization is given in the table 1.

Table 1 - Welding defect data

Date	Quantity	Accepted	Rejection	% of Accepted Pieces
Day 1	257	171	86	66.53
Day 3	307	192	115	62.54
Day 3	268	236	32	88
Day 3	310	253	57	81.67
Day 3	240	210	30	87.5
Day 6	269	154	115	57.24
Day 6	266	196	70	73.68
Day 7	251	172	79	68.52
Day 7	226	207	19	91.59
Day 7	285	187	98	65.61
Day 8	150	131	19	87.33
Day 11	300	240	60	80.33
Day 12	222	169	53	76.12
Day 12	167	90	77	54.12
Day 13	259	213	46	82.22
Total	3777	2821	956	74.68

II. NON-DESTRUCTIVE TESTING

Flaws and cracks can create havoc with the performance of structures, so that the destruction of defects in solids (body-yoke) is an essential part of quality control of engineering systems for a safe and successful use in practical situations. This is known variously as Non-Destructive Testing (NDT), Non-Destructive Evaluation (NDE), etc. NDT is the testing for defects without any damage to the specimen. Evaluation of various NDT methods are given in the table 2.

Table 2 - Evaluation of various NDT methods

Method	Characteristics Detected	Advantages	Limitations	Uses
Ultra sonic	Changes in acoustic impedance caused by cracks, non-bonds, inclusions or interfaces.	Can penetrate thick materials, excellent for crack detection, can be automated	Normally requires coupling materials either by contact to surface or immersion in a fluid such as water. Surface must be smooth.	Adhesive assemblies for bond integrity, laminations, hydrogen cracking.
Radiography	Changes in density from voids, inclusion, material variation, placement of internal parts.	Used for wide range of materials and thickness, film provides record of inspection.	Requires safety precautions, expensive, difficult to detect cracks unless perpendicular to x-ray films	Pipeline welds for penetration, inclusions, voids, internal defects in casting
Magnetic particle	Leakage of flux due to surface/near surface cracks, voids, inclusions, material or geometric changes.	Inexpensive, sensitive to surface and near surface flaws.	Limited to Ferro-magnetic materials, surface preparation and post-inspection, may require demagnetization.	Rail road wheels for cracks, large castings.
Liquid penetrant	Surface openings due to cracks, parasites, seams, etc.	Inexpensive, easy to use, portable, sensitive to small surface flaws.	Flaw must be open to surface, not used for porous or rough surfaces.	Turbine blades for surface cracks or porosity, grinding cracks.

G.M. Reddy, A.A. Goghale and K. Prasad Rao [11], analysed the process parameters of Gas Tungsten Arc Welding for car body frame welding. They vary the parameters and compare the surface roughness of welding. P.K. Giridaran and N.Murugan [3] had done an experiment on sensitive analysis of pulsed current Gas Tungsten Arc Welding process parameters on weld bead geometry. B.V.R. Ravikumar, Dr. J. S. Soni [10] had done an experimental study of welding characteristics of 65032 aluminium alloy weld aments using pulsed and non pulsed current Gas Tungsten Arc Welding. Natraj M, Arunachalam V P, Dhandaphani N [9] had done an experiment on risk analysis and Taguchi method to find the optimal conditions design parameters a case study. Taguchi parameter design requires fewer runs rather than traditional full factorial designs to optimize the process parameters. (International journal of advanced manufacturing technology-2000).Montgomery D C [7] recommended for each experimental run where the primary process variables are varied over certain range, varying environment factors that may affect the product performance have to be analyzed. A few runs of a follow up confirmation experiment is recommended in practice, when high factorial design is used. Many researchers suggested the use of Taguchi's standard OA instead of crossed arrays. Use of OA reduces the experimental runs and simplifies the confounding structure, especially to free the main effects of design variables of two factor interaction.

It is suggested by Natraj M, Arunachalam V P, and Dhandaphani N [9] in optimizing diesel engine parameters for low emissions using Taguchi. Natraj M, Arunachalam V P [9] had done an experiment on parameter optimization of electroplating process using Taguchi method. They used the larger the better characteristic of S/N ratio for quality checking. The objective of using the S/N ratio is a measure of performance to develop product and process insensitive to noise factor. The S/N ratio indicates the degree of predictable performance of a product or process in the presence of noise factor. Yang W H and Trang Y S [13], design optimization of cutting parameters for turning operations based on the Taguchi method.

Joshi K P, Pujari S A, Malik P [4] had done an experiment on parameter optimization of steam bluing process in electrical steels by Taguchi method. Taguchi method is a powerful tool to select and set the process parameter at optimum level and minimize the loss. Selection of three or more levels of process parameter will give more accurate results. Improper selection and deviation from process parameters results in quality loss. ANOVA gives the percentage contribution of each parameter. In this work TIG welding is optimized using Taguchi method. Taguchi method is widely used to optimize of process parameters [13-16].

III. EXPERIMENT AND RESULT

Optimization for TIG Welding

TIG welding process parameters are Shielding gas flow rate (Lit/min), Voltage (volts), Current (Ampere), Speed of weld (mm/min). A minimum of three levels is required to evaluate the factor's effect on a given quality characteristics. If several factors are under consideration, it is recommended to use 2 levels to keep the size of experiment to a minimum.

The selection of levels for factors depends on the type of system or process. It decides the number of experiments to be conducted. The welding process is more sensitive to the variation. The levels are limited to three. Parameters and levels are given in the table 3. Here Number of factors is 4 and Number of levels is 3. The degree of freedom is 9. So standard orthogonal array OA9 selected. Standard OA9 is shown in table 4.

Table 3 Parameters and levels

Parameter	level 1	level 2	level 3
Gas flow rate (lit/min)	10	12	14
Voltage (volts)	20	24	28
Current (amp)	160	180	200
Speed of weld (mm/min)	80	100	120

Table 4 Standard OA9

Gas flow rate (lit/min)	Current (volts)	Voltage (amp)	Speed of weld (mm/min)
1	1	1	1
1	2	2	2
1	3	3	3
2	1	2	3
2	2	3	1
2	3	1	2
3	1	3	2
3	2	1	3
3	3	2	1

Design of experiment and the accepted pieces out of 100 for all 9 treatment conditions are shown in the table 4. Treatment condition 5 produces 97% acceptance which is maximum value and treatment condition 8 produces 65% acceptance which least value.

Table 5. Design of experiment

Treatment condition	Gas flow rate (lit/min)	Current (volts)	Voltage (amp)	Speed of weld (mm/min)	Accepted pieces out of 100
1	10	20	160	80	80
2	10	24	180	100	83
3	10	28	200	120	75
4	12	20	180	120	71
5	12	24	200	80	97
6	12	28	160	100	68
7	14	20	200	100	85
8	14	24	160	120	65
9	14	28	180	80	89

Average of accepted pieces for each level and average of s/n ratio for each level are shown in table 6 and table 7 respectively.

Table 6 - Average of accepted pieces table for each level (A)

Parameter	1	2	3	▲	Rank
Gas flow rate (lit/min)	79.33	78.66	79.66	1	4
Voltage(volts)	78.66	81.66	77.33	4.33	3
Current(amp)	71	81	85.66	14.66	2
Speed of weld (mm/min)	88.67	78.67	70.33	18.34	1

Table 7 Average of s/n ratio table for each level

Parameter	1	2	3	▲	Rank
Gas flow rate (lit/min)	57.88	57.8	57.94	0.18	4
Voltage(volts)	57.89	58.12	57.65	0.47	3
Current(amp)	56.98	58.07	58.6	1.62	2
Speed of weld (mm/min)	58.86	57.87	56.92	1.94	1

Accepted pieces vs. parameter levels are plotted. Figure 2 shows accepted pieces vs. gas flow rate plot. When gas flow rate increases accepted percentage is increasing. Highest acceptance rate is at level 3 gas flow. Figure 3 shows accepted pieces vs. current plot. Highest acceptance rate is found at level 2 current. Figure 4 shows accepted pieces vs. voltage plot. Highest acceptance rate is at level 3 voltage. Figure 5 shows accepted pieces vs. speed of weld plot. When speed of weld increases accepted percentage is decreasing. Highest acceptance rate is at level 1 voltage.

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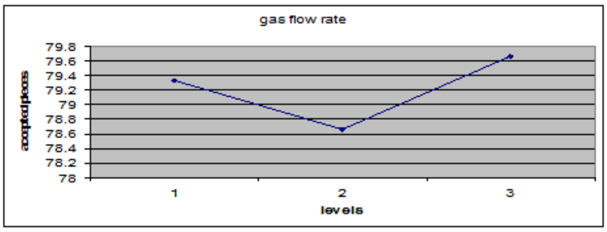

Figure 2 - Accepted pieces vs. parameter Gas flow rate

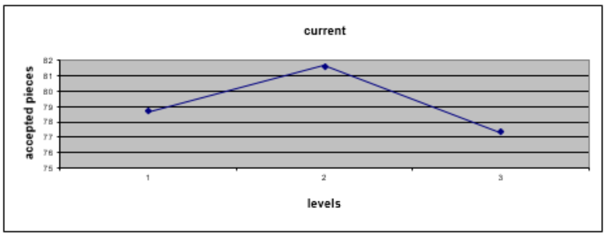

Figure 3 - Accepted pieces vs. Current

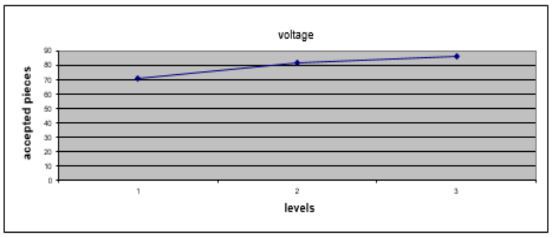

Figure 4 - Accepted pieces vs. Voltage

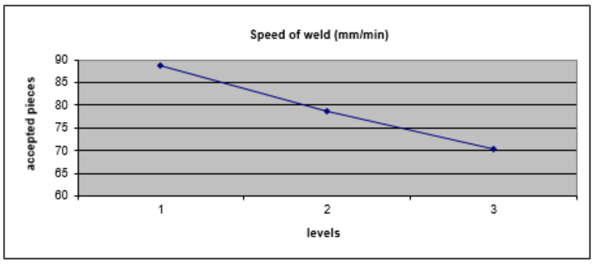

Figure 5 - Accepted pieces vs. Speed of weld

S/N ratio vs. parameter levels are plotted. Figure 6 shows S/N ratio vs. gas flow rate plot. S/N ratio is highest in level 3 gas flow. Figure 7 shows S/N ratio vs. current plot. Highest S/N ratio is found at level 2 current. Figure 8 shows S/N ratio vs. voltage plot. Highest S/N ratio is at level 3 voltage. Figure 9 shows S/N ratio vs. speed of weld plot. Highest S/N ratio is at level 1 voltage.

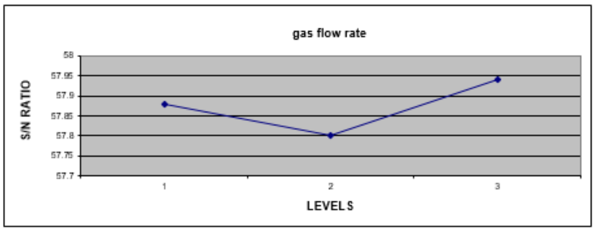

Figure 6 –S/N ratio vs. Gas flow rate

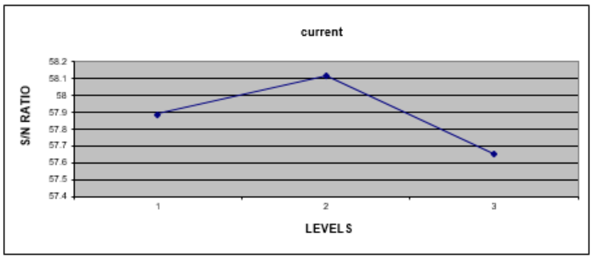

Figure 7 - S/N ratio vs. Current

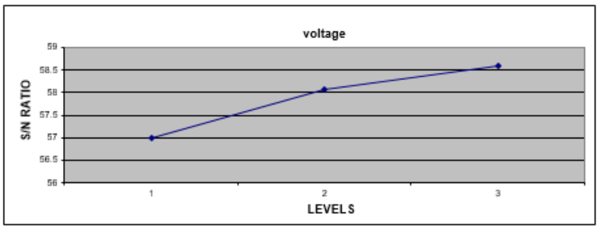

Figure 8 - S/N ratio vs. Voltage

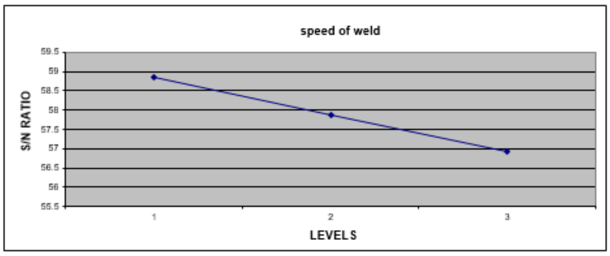

Figure 9 - S/N ratio vs. Speed of weld

ANOVA table is shown in table 8 and optimized parameters for TIG welding is shown in table 9.

Table 8 - ANOVA for TIG welding

Parameter	DFP	SS	MS	F0	SS'	%
Gas flow rate (lit/min)	2*	1.55*	0.775*	-	-	-
Voltage (volts)	2	29.55	14.775	19.06	28	3.2
Current (amp)	2	336.88	168.44	217.44	335.33	38.39
Speed of weld (mm/min)	2	505.55	252.775	326.16	504	57.7
Error (pooled)	2	1.55	0.775	-	6.2	0.71
Total	8	873.53	-	-	873.53	100

Table 9 - Optimized parameters for TIG welding

Parameter	Level	Value
Gas flow rate (lit/min)	3	14
Voltage (volts)	2	24
Current (amp)	3	200
Speed of weld (mm/min)	1	80

Conformation test is conducted and the results are shown in table 10. After optimization, rejection is reduced to 5.49%.

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Table 10 - Confirmation test

Quantity welded	Accepted pieces	Rejection	% Rejection
300	287	13	4.33
267	253	14	5.24
284	269	15	5.28
294	278	16	5.44
300	281	19	6.33
256	242	14	5.47
289	269	20	6.92
310	295	15	4.83
210	198	12	5.73
2510	**2372**	**138**	**5.49**

IV. CONCLUSION

The optimization of process parameters in Robotic welding (TIG) for high pressure valves to minimize the welding defects is analyzed by using Taguchi Optimization techniques.

TIG welding Process parameters, gas flow rate, current, voltage, speed of weld is optimized using Taguchi's design of experiments, S/N ratio, ANOVA.

The significance and contribution of each parameter are checked by using the S/N ratio, ANOVA and response curve. Once the optimum choice has been made, it is tested by performing a confirmation run. In the confirmation test, the defects are about 5.49 %. So the defect rate is reduced from 25.32 % to 5.49 % using Taguchi optimization techniques.

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