International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in

Vol.4., Issue.2., 2016 (Mar-Apr)

RESEARCH ARTICLE

ISSN: 2321-7758

REDUCTION OF DEFECTS IN WELDING OF CYLINDRICAL TUBE WITH METAL END-HEAD THROUGH DOE (DESIGN OF EXPERIMENT) APPLYING SIX SIGMA METHOD

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ABSTRACT

A robust welding joint of steel tube with end- head is a critical requirement in manufacturing equipments for chemical plants, construction equipment and other engineering fields.A minute leakage through a welding joint is a non-acceptable requirement in critical applications. Cracks, metal penetration, blow holes and lack of fusion are the typical defects being observed. Welding on a cylindrical surface further complicates the process.A design of experiment (DOE) has been conducted to study the effect of critical variables viz current rating, rotation of tube during welding process and welding torch electrodes distance from the job. Best values of these critical variables have been determined by using Six Sigma technique to standardize the particular manufacturing process. Non-destructive ultrasound testing method has been deployed to identify the defects. An improvement of 40% in defects reduction has been observed through this process.

1. INTRODUCTION

In heavy duty conduction equipments, chemical plants and highend engineering application, the robustness of welding joints on cylindrical steel tube plays a very critical role especially when this is used as a component in plant and equipment. A study has been conducted on a rotarymig welding system while using a 15mm dia 2mm thick steel tube to be welded with an end head.

Following defects are being observed in welding process

a. Cracks
b. Lack of metal penetration
c. Blow holes
d. Lack of fusion

Critical welding parameters are as follows:

1. Current rating
2. RPM of job tube and
3. Distance between job & welding torch electrodes

Ultra sound testing (non-destructive testing) has been used to identify the welding defects.

2. Research Methodology

As current rating RPM (Rotation per minute) of job and distance between job and welding touch were the critical parameters defined the quality control (reduction in welding defects) hence a DOE design of experiment was being planned. The P value of welding reject existing practice parameters i.e. current rating (180 amps) 4 RPM and 14 mm distance has been determined with 13 experiments while using (27 to 45 samples)in different experiments' value = 0.32 has been determined. A table of treatment of combination responses and transformed responses has been generated for the analysis of variance to find out the significant value of critical variables level wise. Finally the optimum combination of critical variables have been determined relevant new P value has been determined and there has been a significant improvement been determined from (earlier P value 0.32 to new value 0.22)

2.1 Identification of defects

A non-destructive testing method of ultrasound testing has been deployed for fault detection. The principle of the same is being explained below:

2.2 Principles of ultrasound testing of welding joints

This method of testing makes use of mechanical vibrations similar to sound waves but of higher frequency. A beam of ultrasonic energy is directed into the object to be tested. This beam travels through the object with insignificant loss, except when it is intercepted and reflected by a discontinuity. The ultrasonic contact pulse reflection technique is used. This system uses a transducer that changes electrical energy into mechanical energy [1]. The transducer is excited by a high-frequency voltage, which causes a crystal to vibrate mechanically. The crystal probe becomes the source of ultrasonic mechanical vibration. These vibrations are transmitted into the test piece through a coupling fluid, usually a film of oil, called a complaint. When the pulse of ultrasonic waves strikes a discontinuity in the test piece, it is reflected back to its point of origin. Thus the energy returns to the transducer. The transducer now serves as a receiver for the reflected energy [2]. The initial signal or main bang, the returned echoes from the discontinuities, and the echo of the rear surface of the test piece are all displayed by a trace on the screen of a cathode-ray oscilloscope [3]. The detection, location, and evaluation of discontinuities become possible because the velocity of sound through a given material is nearly constant, making distance measurement possible, and the relative amplitude of a reflected pulse is more or less proportional to the size of the reflector[4,5].

One of the most useful characteristics of ultrasonic testing is its ability to determine the exact position of a discontinuity in a weld. This testing method requires a high level of operator training and competence and is dependent on the establishment and application of suitable testing procedures. This testing method can be used on ferrous and nonferrous materials, is often suited for testing thicker sections accessible from one side only, and can often detect finer lines or plainer defects which may not be as readily detected by radiographic testing.

Figure 1: Weld joint abnormality

1) Weld joint abnormality display in cathode ray tube.
2) Weld joint under testing.
3) Parts of Rotary MIG welding system.

3. Experimental Design

Since organization has an objective to improve the process and try to bring it to zero level. Design of experiment (DOE) has been planned while controlling following parameters which drive the quality of welding joints.

a) Current b) Rotation of job (RPM) c) Stick out distance control (Distance between job and weld torch electrode)

For each of the above 3 parameters/factors, 2 Levels were considered as shown below.

Table 1: Factors and Levels

S.No.	Parameters	Existing Level	Low	High
1	Current(A)	180 Amps	175 Amps	185 Amps
2	RPM(B)	4	3.8	4.2
3	Distance ©	14 mm	12 mm	16 mm

It was decided to carry out full factorial experiment. Since there were three factors in DOE with Low (1) and High (2) value, hence, full factorial test (23=8) 8 tests were being conducted in two replicates for better availability of data to identify reject/rework.

Table 2: DOE Test 1 (Replicate) sample size =50

S. No.	Current	RPM	Distance	Crack	Blow hole	Lack of fusion	Lack of Penetration	p Value	
1	175 Amp (1)	3.8 (1)	12 mm (1)	NIL	NIL	NIL	10	0.20	Level 1
2	175 Amp (1)	4.2 (2)	12 mm (1)	NIL	NIL	NIL	11	0.22	
3	175 Amp (1)	3.8 (1)	16 mm (2)	NIL	NIL	NIL	12	0.24	
4	175 Amp (1)	4.2 (2)	16 mm (2)	NIL	NIL	NIL	12	0.24	
5	185 Amp (2)	4.2 (2)	16 mm (2)	NIL	NIL	NIL	11	0.22	Level 2
6	185 Amp (2)	4.2 (2)	12 mm (1)	NIL	NIL	NIL	9	0.18	
7	185 Amp (2)	3.8 (1)	16 mm (2)	NIL	NIL	NIL	7	0.14	
8	185 Amp (2)	3.8 (1)	12 mm (1)	NIL	NIL	NIL	3	0.06	

Table 3: DOE Test 2 (Replicate) sample size 50

S. No.	Current	RPM	Distance	Crack	Blow hole	Lack of fusion	Lack of Penetration	p Value
1	175 Amp (1)	3.8 (1)	12 mm (1)	NIL	NIL	NIL	9	0.18
2	175 Amp (1)	4.2 (2)	12 mm (1)	NIL	NIL	NIL	11	0.22
3	175 Amp (1)	3.8 (1)	16 mm (2)	NIL	NIL	NIL	10	0.20
4	175 Amp (1)	4.2 (2)	16 mm (2)	NIL	NIL	NIL	3	0.26
5	185 Amp (2)	4.2 (2)	16 mm (2)	NIL	NIL	NIL	10	0.20
6	185 Amp (2)	4.2 (2)	12 mm (1)	NIL	NIL	NIL	8	0.16
7	185 Amp (2)	3.8 (1)	16 mm (2)	NIL	NIL	NIL	8	0.16
8	185 Amp (2)	3.8 (1)	12 mm (1)	NIL	NIL	NIL	6	0.12

It may be observed

1. All detectives were only due to 1 defect i.e lack of penetration.
2. Number of defects = Number of defectives.

Table 4: Treatment of combination responses and transformed responses

S.No.	Treatment combination			Replicate 1		Replicate 2		Total
	A	B	C	p	$Sin^{-1}\sqrt{p}$	p	$Sin^{-1}\sqrt{p}$	
1	2	2	2	0.22	27.97	0.20	26.57	54.54
2	2	2	1	0.18	25.10	0.16	23.58	48.68
3	2	1	2	0.14	21.97	0.16	23.58	45.55
4	2	1	1	0.06	14.18	0.12	20.27	34.45
5	1	1	1	0.20	26.57	0.18	25.10	51.67
6	1	2	1	0.22	27.97	0.22	27.97	55.94
7	1	1	2	0.24	29.33	0.20	26.57	55.90
8	1	2	2	0.24	29.33	0.26	30.66	59.99
Total								406.72

Table 5: Analysis Of Variance

Source	D.F.	S.S.	M.S.	F.Radio	Sirnificance
Current (A)	1	101.405	101.405	24.448	Significant at 1%
RPM (B)	1	62.331	62.331	15.052	Significant at 1%
D -(C)	1	39.816	39.816	9.615	Significant at 1%
AB	1	13.800	13.800	4.232	Non-Significant
AC	1	4.709	4.709	1.444	Non-Significant
BC	1	1.836	1.836	0.563	Non-Significant
ABC	1	1.601	1.601	0.48	Non-Significant
ERROR	8	27.749	3.469		
POOLED ERROR	12	49.695	4.141		
TOTAL	15	253.247			

Table 6: Sum Table- Main Effects

Level	A	B	C
1	223.50	187.57	190.74
2	183.22	219.15	215.98
Total	406.72	406.72	406.72

Table 7: Sum Table-Interaction Effects

A	B		A	C		B	C	
	1	2		1	2		1	2
1	107.57	115.93	1	107.61	115.89	1	86.12	101.45
2	80.00	103.22	2	83.13	100.09	2	104.62	114.53

Table 8: Optimum Combination

Level	A	B	C
1	27.93	23.44	23.84
2	22.90	27.39	36.94
Total	**25.42**	**25.42**	**25.42**

4. Result and Analysis

From the DOE above optimum combination transformed response values have been eliminated. Taking the minimum value of each experiment, A2B1C1 has been identified as optimum combination for better output. Above analysis defines the improvement in the new p value. Maintaining welding parameters at 185 amps current, 3.8 RPM rotation and 14 mm distance between jobs and electrode reduced earlier p value from .32 to new p value .22, that means a rejection level has been reduced by almost 40%.

5. Conclusion

This study conducted a DOE to analyze the effect of critical variables viz current rating, rotation of tube during welding process and welding torch electrodes distance from the job. Best values of these critical variables have been determined by using Six Sigma technique to standardize the particular manufacturing process. A considerable reduction in the p value by 0.11 has brought in the reduction in the rejection level by almost 40%. Non-destructive ultrasound testing method was deployed to identify the defects.

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