DOE FOR WELDING

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ABSTRACT

This paper presents a method for designing an experiment for welding pins to rotary joints. Design of experiments (DOE) is used for analyzing the controllable parameters working in Gas Metal Arc Welding (GMAW). Taguchi's method of orthogonal array is used to formulate the number of experiments. The goal of this experiment is to determine which set of parameters provides a sound weld. In a series of experiments conducted nine pins were welded to a round component and subjected to various tests. Continuing the study further six more pins were welded to a plate. These weldments were sectioned and analyzed. Based on root penetration, convexity and fusion, optimum parameters for obtaining a sound weld were arrived at.

Keywords: DOE, welding, root penetration, convexity, orthogonal array.

Introduction

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is an arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. Originally developed for welding aluminum and other non-ferrous materials in the 1940s, GMAW was soon applied to steels because it allowed for lower welding time compared to other welding processes. Today, GMAW is the most common industrial welding process, preferred for its versatility and speed. The objective of this exercise is to develop the parameters to give a sound weldment to fasten pins to shaft. There were some field failures of pins. This created a sense of urgency to get to the depth of this issue.

The experiments were conducted by M/s Hycom Engineering by using DOE. DOE is a structured, organized method that is used to determine the relationships between different factors affecting a process and the output of that process. DOE is widely used in research and development, where a large proportion of the resources go towards solving optimization problems. The key to minimizing costs is to conduct as few experiments as possible. DOE requires only a small set of experiments and thus helps to reduce costs. Nine experiments were done by welding pins to a round component. These weldments were subjected to various tests. Continuing the study, six experiments were conducted on a plate. The joints were sectioned to know the fusion. On the basis of the experiments conducted, visual observtion of welds, study of sections of welded areas and discussion with welding specialists, the ranges of current and voltage were selected to be ideal for the parts.

Step-by-step procedure in designing an experiment

1. Selection of problem

In order to design an experiment, a problem has to be selected and phrased. It is the selection and the phrasing of the problem that will direct the design and outcomes of an experiment. In our case, the problem was to determine the optimum parameters for welding the pin.

2. Determining dependant variables

The dependent variables are the variables that are being measured throughout the experiment. There can be many different dependent variables measured during an experiment.

The dependent variables are divided into two different sub-categories, system level and individual level. A system level dependent variable is how many experimenters are used during a certain task. On an individual level, the dependent variables are measurements of a particular subject. Individual level dependent variables are those that are analyzable and can be measured. In this case the dependant variables are root penetration, convexity and fusion.

3. Determining independent variables

Independent variables are variables that are manipulated in the experiment. Independent variables in this case are current, voltage and gas flow.

4. Determining the number of levels of independent variables

The number of levels of independent variables determines the number of experimental conditions to be varied. This is important in determining the extent of the scope of the experiment.

The parameters chosen for experimentation can take the following values.

Current: 180,184,186,188,192,194,196,198,200 Amps

Voltage: 20.8,21, 21.4, 22, 22.4, 22.4, 22.8, 23, 23.2 Volts

Gas Flow: 16 Lpm (with permitted variation of ±1 Lpm)

Parameters: Current, Voltage, Gas Flow = 3

Levels: 9 9 1 = 3

		Parameters																				
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number of Levels	2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32	L32	L32	L32	L32	L32	L32
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36	L36	L36	L36	L36	L36	L36
	4	L16	L16	L16	L16	L32	L32	L32	L32	L32												
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50										

In this case, it is appropriate to have 9 levels (L9), Accordingly the number of pins to be welded to the shaft is 9.

5. Determining the possible combinations

The types of combinations between the independent variables have to be established in order for the experiment to be valid. The possible types of combinations are current, voltage and gas flow.

Experiment	Current in Amps	Voltage in Volts	Gas Flow in Lpm
1	180	20.8	16
2	184	21	16
3	186	21.4	16
4	188	22	16
5	192	22.4	16
6	194	22.4	16
7	196	22.8	16
8	198	23	16
9	200	23.2	16

Table 1 Values of experiments

6. Determining the number of observations

Depending on the desired analysis, there are certain factors that need to be taken into consideration when deciding on the number of observations. The number of trials is 9.

7. Data collection

The data collection portion of experiment design must make sure that the experiment is supported by factual data. This involves collecting raw data while adhering to the experimental conditions.

Material

Shaft: IS 1875 (C45), Heat treated to 230-260BHN

Pin: IS 1875 (C45), Heat treated to 200-220BHN

Tests conducted

- Lateral impact
- Visual check
- Checking for soundness of welding
- Fusion test
- Measurement of convexity

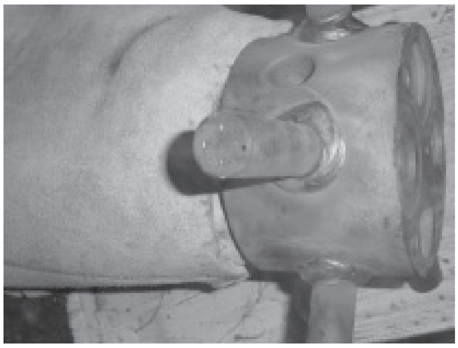
The initial experiment was conducted by welding pins to a plate as shown in Fig 1 with current in the range of 180-188 Amps and voltage in the range of 23.6-24volts. The pin was press fitted in to the plate and it was pre-heated to 80-100°C, checked with thermo pen. The pins were laterally hit with the 5kg hammer.

Fig 1: Pin bent after hammering

Observation

The pin bent, but the weldment did not give way, which indicated that the weld was capable of withstanding the load.

In the next stage a further series of 9 experiments were done as per the values given in Table 1. The pin was press- fitted into the shaft and the joint was pre-heated to 80-100°C, checked with thermo pen. The machined surface was covered with leather to avoid welding spatter contamination.



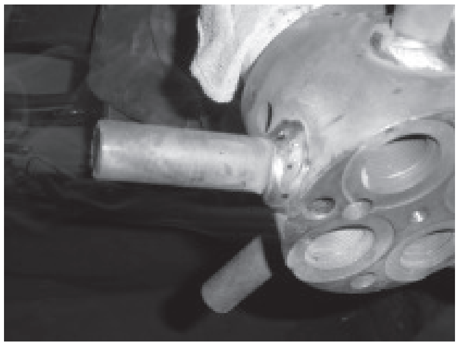


Fig 2: Pin welded to shaft

Observation

Based on the visual checks, it was found that, there was no pin holes/porosity and surface cracks; hence, soundness of the weld was found to be good

The experiments were continued further as a result of which, six more pins were welded to a plate. The procedure followed was similar to that of previous experiment. The weldments were sectioned and analyzed.

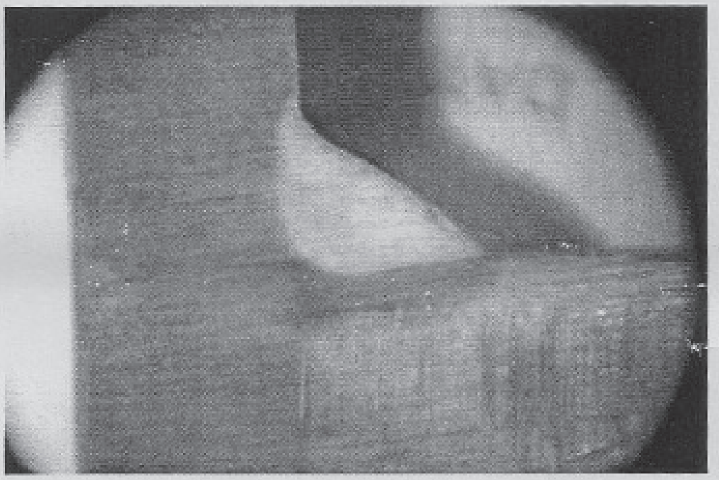
Fig 3: Pin welded to flange

The above Fig 4 shows the cross-section of the weld. The sectioned pieces were polished and etched to perform macro analysis on them. The tests were done with reference to ASME Sec. IX: 2004.

Observation

- Fusion was good
- There were no cracks or pores
- There was no slag entrapment and undercuts
- Soundness of the weld was good
- Root penetration was found ok
- Convexity was within the limit

Results and Discussion



Parameters	Observations
Leg length, L1 (mm)	7.85
Leg length, L2 (mm)	8.20
|L1-L2|, mm	0.35
Convexity (mm)	0.6
Root penetration (mm)	0.8

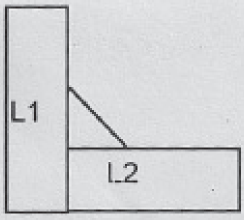


Fig 4: Cross-section of the weld

Conclusion

In this paper, we presented an example for designing an experiment for welding a pin to a shaft. Taguchi method of orthogonal array (L9) was used for deciding the number of experiments. Different tests were conducted on samples. The weldments were sectioned and analyzed. The following optimum parameters for obtaining the sound weld were arrived upon based on root penetration, convexity and fusion.

Current: 188 - 196 Amps

Voltage: 22 - 23Volts

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