A Study on Non-Destructive Testing of Welding Defects using Radiography Inspection

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Abstract— This paper reports non-destructive testing conducted on similar MIG welds between mild steel plates. The MIG welds of ms plates were produced at different current, voltage and welding speed. The current was varied between 100,120 and 140 amp while the voltage was varied between 20, 25 and 30volts and welding speed is varied between 1.5,2 and 2.5mm/s. The radiographic testing techniques were employed to conduct the tests; these tests were conducted on the welds to ascertain the joint integrity before characterization to have an idea of the quality of the welds. Radiography technique revealed the presence of incomplete penetration defects and discontinuities in some of the welds. It was found that the welds produced at 140amp, 20volts and 2.5mm/s were the best quality weld.

Key words: Mild Steel plate, Welding Defects, MIG welding, Welding Parameters optimization, Taguchi method, Non-Destructive Testing, Radiography inspection

I. INTRODUCTION

Metal Inert Gas welding is one of the most widely used processes in industry. A wide range of materials may be joined by MIG welding—similar metals, dissimilar metals, alloys, and nonmetals. In the present scenario demand of the joining of similar materials continuously increases due to their advantages, which can produce high yield strength, deeper penetration, continuous welding at higher speed and small welding defects. The input parameters play a very significant role in determining the quality of a welded joint. In fact, weld geometry directly affects the complexity of weld schedules and thereby the construction and manufacturing costs of steel structures and mechanical devices. Therefore, these parameters affecting the arc and welding should be estimated and their changing conditions during process must be known before in order to obtain optimum results; in fact a perfect arc can be achieved when all the parameters are in conformity. The welding parameters are current, arc voltage and welding speed. These parameters will affect the weld characteristics to a great extent. Because these factors can be varied over a large range, they are considered the primary adjustments in any welding operation. Their values should be recorded for every different type of weld to permit reproducibility

MIG welding is basically a semi-automatic process, in which the arc lengths of electrode and the feeding of the wire are automatically controlled. A schematic diagram of the MIG welding process is presented in Fig. 1.

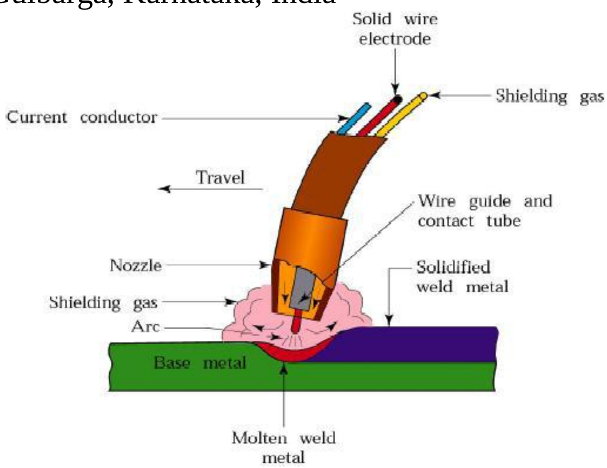

Fig. 1: A schematic diagram of the MIG welding process

The process is sensitive to the effects of wind, which can disperse the shielding gas, and it is difficult to use in narrow spaces due to the torch size. Problems such as lack of shielding, irregular wire feeding, unstable arc, burn-back or even weld discontinuities (porosity, incomplete penetration, excessive melt-through, undercutting or cracks) can occur during welding. A major weld quality aspect in question is how to be able to detect the internal defect formed in the weld and a Non-Destructive Testing (NDT) technique is most appropriate in this regard. Non - _Destructive Testing rose from the necessity to detect flaws within components to avoid detrimental and repetitive failures. NDT is a wide group of analysis techniques used in science and industry to evaluate the characteristics of a material or component without causing damage to it. The techniques used are non-invasive. Because NDT does not permanently alter the article being inspected, they are highly valuable techniques that can save both money and time. Many different types of NDT methods exist, the most commonly used ones being ultrasonic testing, magnetic particle testing, liquid penetrant inspection, radiographic testing and eddy current testing. NDT is used in almost every field of engineering and can be applied to any types of materials including metals, ceramics, coatings and polymers of different plastics and composites. The detection of these flaws is critical for the safety criteria of all designs. These flaws include cracks, internal voids, surface cavities, delamination, defective welds and any sort of imperfection in the welds that could be detrimental to the performance of the welds. Successful attempts have been made on non-destructive testing techniques on mig welds of mild steel plates. Non-destructive testing for defects is the most effective method of determining the integrity of a mig weld, hence research studies into non-destructive techniques of similar joints between ms plates will ultimately lead to achieving optimised setting to produce quality welds and increase material performance in this regard. The aim of this paper therefore, is to present results of non-destructive testing techniques on similar mig welds of ms plates.

II. TAGUCHI'S DESIGN METHOD

Taguchi Technique is an experimental design process called the Taguchi design method. Taguchi design, developed by Dr. Genichi Taguchi. The Taguchi method has become a influential tool for improving output during research and development, so that better quality products can be produced quickly and at minimum cost. Taguchi has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter.

A. Design of Experiments:

Design of experiment is scientifically setup of the different involved parameters in various combinations to do particular operation but generally as the no. Of factors increases the no combination also increase. It becomes difficult to try all possible combination as it consumes money time and effort .Therefore Taguchi based DOE design of experiment is designed using the OA orthogonal array. Taguchi optimization procedure begins with selection of orthogonal array (OA) with distinct number of levels (L) defined for factor (l) such as welding current(C), voltage(V), welding speed(S). Minimum number of trials in the array is

$Na = (L-1)F + 1$,
$= (3-1)3+1$
$= 7 \approx 9$

Where F = number of factors = 3

Therefore we take Orthogonal array of L9, experiment set up is designed for three levels of welding current, welding voltage, welding speed.

III. EXPERIMENTATION SETUP

The experiments were conducted at Pitti Laminations Limited, Telangana on Mild steel plates of 6mm thickness. The dimensions of the work piece length 100mm, width of 65mm, thickness 6mm. CO_2 and argon mixture is used as a welding gas.

Fig. 2: A Schematic drawing of Mig Welding Samples

Element	C	Si	Mn	P	S	Fe
Weight%	0.06	0.09	0.37	0.063	0.065	99.05

Table 1: Chemical Composition of Base Metal Mild Steel

Parameters	Welding Current(C)	Welding Voltage(V)	Welding Speed(S)
Units	Amp	Volt	mm/s
Level1	100	20	1.5
Level2	120	25	2
Level3	140	30	2.5

Table 2: Welding parameters and their levels

A. L9 Level Taguchi Orthogonal Array:

Taguchi's orthogonal design uses a special set of predefined arrays called orthogonal arrays (OAs) to design the plan of experiment. These standard arrays stipulate the way of full information of all the factors that affects the process performance (process responses). The corresponding OA is selected from the set of predefined OAs according to the number of factors and their levels that will be used in the experiment. Below Table shows L9 Orthogonal array.

Expt.No	Welding Current(C)	Welding Voltage(V)	Welding Speed(S)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3:Level9 Orthogonal Array

Expt.No	Welding Current(C)	Welding Voltage(V)	Welding Speed(S)
1	100	20	1.5
2	100	25	2
3	100	30	2.5
4	120	20	2
5	120	25	2.5
6	120	30	1.5
7	140	20	2.5
8	140	25	1.5
9	140	30	2

Table 4: Matrix With Actual Values Of Parameters

IV. RESULTS AND DISCUSSION

A. Radiography Inspection:

Fig. 3: A Schematic drawing of Radiography Inspection

Radiography is based on the differential absorption of short wavelength radiations such as X-rays and gamma rays on their passage through matter because of differences in density and variations in thickness. The gamma ray source used in this project is Ir-192. The radiography test procedure specification follows ASME Section V.

Description	
Source to film distance	13.0 inches
IQI Type	Set B,ASTM
Radiation Source	Ir-192
Lead Screen	Front:0.15mm Back:0.15mm
IQI Placement	Source side

Film Size	16*4 inches
Source Strength	11.0 Ci
Density	2.0-4.0
IQI Sensitivity	2.0%
Exposure Time	115 sec
Specimen Thickness	6mm

Table 5: Radiography Test Description

The results of the radiographic tests conducted on all the welds produced at 100Amp, voltage of 20, 25 and 30V and welding speed of 1.5,2 and 2.5mm/s are hereby presented in Table 6. This includes the gamma ray radiographs and the comments on each sample examined.

100Amp,20V ,1.5mm/s	100Amp,25V, 2mm/s	100Amp,30V, 2.5mm/s
		
Comments Incomplete penetration, Spatter,Root Concavity, Poor Start & Stop,Slag inclusion are observed	**Comments** Incomplete penetration, External Undercut, Spatter,Poor Start&Stop, RootConcavity	**Comments** Incomplete penetration, Excessive penetration, Spatter,Poor Start&Stop, Slag Inclusion,Root concavity

Table 6: Photographs and radiographs of welds 100 Amp, Voltage of 20,25 and 30V and Welding speed of 1.5, 2 and 2.5mm/s

From the gamma-ray radiographs presented in Table 6, it was observed that these welds are characterized with incomplete penetration, root concavity, poor start and stop, slag inclusion, spatter of both materials joined and undercut defect was also noticed.

The results of the radiographic tests conducted on all the welds produced at 120Amp, voltage of 20,25 and 30V and welding speed of 2,2.5 and 1.5mm/s are hereby presented in Table 7.

120Amp,20V ,2mm/s	**120Amp,25V ,2.5mm/s**	**120Amp,30V, 1.5mm/s**
		
Comments Incomplete penetration, Poor start & stop,Root concavity	Comments Slag inclusion, Root concavity, Excessive penetration	Comments Incomplete penetration, Excessive penetration, Spatter, External undercut,Poor start & stop

Table 7: Photographs and radiographs of welds 120 Amp, Voltage of 20,25 and 30V and Welding speed of 2, 2.5 and 1.5mm/s.

With reference to Table 7, it was found that welds produced at a constant current of 120Amp at varying voltage of 20, 25 and 30V and varying welding speed of 2,2.5 and 1.5mm/s has a evidence of incomplete penetration, excessive penetration, root concavity, poor start and stop or defects at the joint interface.

The results of the radiographic tests conducted on all the welds produced at 140Amp, voltage of 20,25 and 30V and welding speed of 2.5,1.5 and 2mm/s are hereby presented in Table 8.

To verify the testing accuracy of the NDT system after using the proposed method, we made nine samples of varied parameters and then use the NDT system to detect the defects, the results are: the NDT using the proposed method has detect all defect, and the NDT using other methods has detect only surface and sub-surface defects. With the help of radiography testing we can detect surface and sub-surface flaws, and can also detect varieties of internal flaws, its size and shape. Numerous experiments are conducted on the various sample of mig welding .We see Most of the samples has lack of penetration defects. Lack of penetration is usually caused by the use of too low welding current and can be eliminated by simply increasing the amperage. Other causes can be the use of too slow welding speed and an incorrect torch angle.

Undercut is found in second, sixth and eight specimens, this type of defect is most commonly caused by improper welding parameters, particularly the welding speed and voltage. When the welding speed is too high, the weld bead will be very peaked because of its extremely fast solidification. The forces of surface tension have drawn the molten metal along the edges of the weld bead and piled it up along the center. Melted portions of the base plate are affected in the same way. However as the voltage is a raised to excessive level, undercutting may again appear. We evaluate these samples by radiography testing the first, second, third, sixth, eighth and ninth samples have maximum defects and in fourth and fifth samples minimum defects are seen where as in sample seventh we find no significant defect are observed. Hence sample seven is the best quality.

V. CONCLUSION

In present study parametric analysis has been carried out for identifying the defect on mild steel plate of length 100mm, width 65mm and thickness 6mm . Experiments are carried out using tagouchi Method by varying welding current, welding voltage and welding speed for 6mm thickness of mild steel material. Radiographic testing technique successfully detected the defects present in the welds and can be said to be appropriate in this regard. Current is varied between 100 to140 Amps, voltage is varied between 20 to 30 volts and welding speed is varied between 1.5 to 2.5mm/s .by conducting radiography ndt system We have concluded that at welding current(100Amp),welding voltage (20,25&30V)and welding speed(1.5, 2&2.5mm/s), we measure the maximum defects and at welding current

(120Amp), welding voltage(20,25V)and welding speed(2,2.5mm/s) we measure the minimum defects and also at the welding current(140Amp),welding voltage (25&30V), welding speed(1.5&2mm/s), we measure the maximum defects and at welding current (140Amp), welding voltage(20V), welding speed (2.5mm/s),there are no any significant defects.

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