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Experimental Investigation of EN24 Steel Properties by Varying Flux Core Arc Welding Parameters

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Different type of welding used in joining the metals plays a major role in determining the change in properties. This research is about the after-effects of flux cored arc welding on EN 24 steel. This was chosen because of its high deposition rates and less skill required for operators to perform. In total 9 specimens were welded using flux core arc welding (FCAW) at 9 different parameters varying the welding current, arc voltage and gas pressure. Three different tests namely hardness, ultrasonic for flaw detection and tensile test for strength were performed to measure the deviation from the recorded values and the analysis of the obtained value shows that the parameters which are best suitable for EN24 FCA Welding are 180 amps, 20 volts, and 4 bar gas pressure. The three test results for all the parameter combinations are shown in further sections of the article.

1. Introduction

FCAW expanded as flux core arc welding commonly uses circular shaped wire filled with the flux material and is fusion welding process. FCAW have more benefits and it has been appreciated by the manufacturing industry from several years. As with other welding processes several Preheating and post weld heat treatment are required to ensure proper weld integrity and may even consist undesirable characteristics after weld, this process is always costly, requiring extra Equipment's, extra time and extra handling. Because of these reasons, FCAW process is better to use in order to avoid these cases. Most of the times ferrous metals like carbon steels, low alloy steels and stainless steels are welded using flux cored arc welding for various heavy and large structure. The mainly used method in this welding is direct current, positive electrode. Two types include self-shielded FCAW which is done in absence of gas and gas-shielded FCAW with a use of gas. Different fluxing agents in the electrodes mark the difference between the two types. The one which can use outdoors is the self-shielded one where the wind blows away the gas. The agents in electrode deoxidize the welding bed and also allow shielding of a pool and metal droplets from the atmosphere. The main applications revolve around buildings, bridges, and ships. Therefore, the metals welded with flux cored arc welding need to have high strength and corrosion resistant properties. The arc is developed between the base metal specimen and continuous wire electrode being used. The required heat to melt the base metal and electrode is drawn from this arc. Common ingredients include alloying gases, slag forming elements and flux materials. These elements only form a slag layer which builds a protective FCAW expanded as flux core arc welding commonly uses circular shaped wire filled with the flux material and is fusion welding process. FCAW have more benefits and it has been appreciated by the manufacturing industry from several years. As with other welding processes several Pre heating and post weld heat treatment are to be done in order to ensure proper weld integrity and will surely avoid undesirable characteristics after weld. And this process is always costly requiring extra Equipment's, extra time and extra handling. For these reasons only FCAW process to be desirable to avoid these cases. Most of the times ferrous metals like carbon steels, low alloy steels and stainless steels are welded using flux cored arc welding for various heavy and large structure. The mainly used method in this welding is direct current, positive electrode. Two types include self-shielded FCAW which is done in absence of gas and gas-shielded FCAW with a use of gas. Different fluxing agents in the electrodes mark the difference between the two types. The one which can use outdoors is the self-shielded one where the wind blows away the gas. The agents in electrode deoxidize the welding bed and also allow shielding of a pool and metal droplets from the atmosphere. The main applications revolve around buildings, bridges, and ships.

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Therefore, the metals welded with flux cored arc welding need to have high strength and corrosion resistant properties. The arc is developed between the base metal specimen and continuous wire electrode being used. The required heat to melt the base metal and electrode is drawn from this arc. Common ingredients include alloying gases, slag forming elements and flux materials. These elements only form a slag layer which builds a protective layer against atmospheric pollution and also improve weld shape and strength. High deposition rates and deeper penetrations cause this welding to be of superior than the manual metal arc welding and gas metal arc welding. Electrode selections do play a major role in welding performance. They must have properties similar to the base metal. They are designed in order to deposit carbon steel or low alloy steel weld metal in the joint. Low carbon steel welding is done with carbon steel electrodes. Low alloy electrodes are needed for higher strength requirements. Mostly self-shielded electrodes consist aluminum used in large amounts as a deoxidizer whereas gas shielded electrodes contain less aluminum because the required Deoxidation is obtained from the shielding gas. Similar to GMAW, FCAW uses constant voltage welder. Self-shielded FCAW uses direct current with straight polarity referred as DCEN (direct current electrode negative). Amperage used in welding determines the amount of heat in the arc. Electrode deposition rates and penetration are determined by the amperage, lack of which can cause porosity with self-shielded FCAW. Similarly, voltage too determines the quality of the weld having high spatter with high voltage and shallow penetration with low voltage. Therefore, varying weld parameters do affect the characteristics of the final weld joint and is defined in terms of mechanical properties, distortion etc. Most commonly used shielding gas used is carbon dioxide having advantages of low cost and deep weld penetration however at high temperatures it too forms carbon monoxide and oxygen causing porosity. In order to separate advantages of two or more gases, mixture is often used of argon (75 %) and carbon dioxide (25%). This ensures high tensile strength and yield strength than whole carbon dioxide used. In this paper, effects of change in parameters of welding are analyzed using different tests like hardness test, tensile test and ultrasonic test. The metal used for research was EN 24.

2. Problem identification

Usually, several precautions and pre-welding treatments have to be done in order to maintain the properties of the base metal steel. As most of the steel grades used in our manufacturing industries contain carbon in high quantity, therefore, welding these types of steels with any of the arc welding techniques like stick MIG or TIG, certain precautions have to be taken like preheating and slow cooling to prevent cracking or changing the strength characteristics of the steel.

3. Scope of the project

The main objective of the project is during welding process we have to get the minimum changes in the physical properties and no metallurgical defect is present.

Defect free welding process should be made. To achieve a good weldment of the different grades of carbon material. We will execute with many samples and quality checks with destructive testing in this experimental work.

4. Introduction of EN24 steel

EN 24 is that material which is mainly used for the parts bearing high loads and stress with a large cross section area. These parts may consist of aircraft components; automotive/mechanical components for example gear shafts, connecting rods, aircraft landing gear etc.

5. Experimental work

A rectangular block was chosen as a base metal specimen for welding with 10mm thickness. In total 9 blocks were taken for the experiment. Changes in different properties were tested while varying different parameters of welding like arc voltage, welding current, and gas pressure. The effects were analyzed using hardness, ultrasonic test, and tensile strength test. DC electrode positive with a programmable welding machine was used to conduct the experiments. The base metal of 10mm thickness was taken from low carbon content steel plate and its surface was ground. Electrode and base metal chemical composition is given in Table 1 while Table 2 shows the hardness value of EN24 steel. CO_2 gas at a constant flow rate was used for shielding. Movable carriage on a table was used as the experimental setup for the process for holding the specimens. The welding torch was held stationary in a frame mounted above the work table.

Table 1: Composition of EN24 Steel

No.	Elements	Minimum	Maximum
1	Carbon (C)	0.35	0.45
2	Manganese (Mn)	0.45	0.75
3	Silicon (Si)	0.1	0.35
4	Molybdenum (Mo)	0.2	0.35
5	Chromium (Cr)	0.9	1.4
6	Sulphur (S)	0	0.05

Table 2: Hardness Value of EN24 Steel

Material	Hardness Value (HRB)
EN24	104

6. Experimental procedure

The experimental design procedure used for this study is shown and important steps are briefly explained below. Identification of input factors and responses. Welding current, voltage, and pressure were chosen as the input factors for the procedure whereas the responses seemed through the tensile strength, hardness, and ultrasonic test. The range of welding current was set from 140 Amps to 180 Amps and that of arc voltage from 18 volts to 22 volts. Gas pressure was varied from 4 to 6 bar. Our chosen input and output parameters of FCAW are shown in Table 3.

Table 3: Welding parameters

Levels	Welding Current (A)	Arc Voltage (V)	Gas Pressure (Bar)
1	140	18	4
2	160	20	5
3	180	22	6

6.1 Designing of the Orthogonal Array

A basic factorial design was used to define the results got known as Taguchi orthogonal array which allows analyzing combinations of multiple parameters at multiple levels. Table 4 shows the formed orthogonal array.

Table 4: Orthogonal array

No.	Designation	Current (A)	Voltage (V)	Gas Pressure (Bar)
1	A1B1C1	140	18	4
2	A1B2C2	140	20	5
3	A1B3C3	140	22	6
4	A2B1C2	160	18	5
5	A2B2C3	160	20	6
6	A2B3C1	160	22	4
7	A3B1C3	180	18	6
8	A3B2C1	180	20	4
9	A3B3C2	180	22	5

6.2 Conduction of the Test

Three tests were performed after all the 18 test pieces had been welded to 9 joint welds. Hardness test was performed at Vinayaka metallurgical laboratory, Trichy. The ultrasonic test was done at Quality inspection services, Trichy whereas tensile test was performed at XL Engineering test services, Tiruchirappalli.

Figure 1: Procedure Process Flow

7. Results and discussion

Following are the results of the particular tests performed.

7.1 Hardness test

Rockwell hardness test (Major load 107.5 kgf.1/16'' ball intender) was performed with all 9 welded joints (18 pieces in total). It is the most commonly used type of test and is more accurate than any other method. This can be used in almost all metals. This measures the depth of indentation produced by a force on an indenter. The results of the above mentioned test is given in the Table 5. It consists different designations with different welding parameters and the resulting hardness is shown.

Table 5: Hardness test result

No.	Designation	Current (A)	Voltage (V)	Gas Pressure (Bar)	Hardness (HRB)
1	A1B1C1	140	18	4	103
2	A1B2C2	140	20	5	102
3	A1B3C3	140	22	6	102
4	A2B1C2	160	18	5	100
5	A2B2C3	160	20	6	102
6	A2B3C1	160	22	4	97
7	A3B1C3	180	18	6	96
8	A3B2C1	180	20	4	101
9	A3B3C2	180	22	5	107

7.2 Ultrasonic test

This was done to detect the flaws and discontinuity in the specimen. In this sound waves travel through the specimen with some loss of energy, reflected beam is displayed and then analyzed. This is done to detect the location of the flaws. UT Instrument – PX transducer angle – 70, 4MHz Technique, pulse echo size- 8*9 materials: 409, Thickness-10mm. Following is the test report of the ultrasonic test in Table 6.

Table 6: Ultrasonic test result

No.	Current (I)	Voltage (V)	Gas Pressure (Bar)	Indication
1	140	18	4	NI
2	140	20	5	ICP
3	140	22	6	Cr
4	160	18	5	ICP & Por
5	160	20	6	ICP & Por
6	160	22	4	EP
7	180	18	6	SI
8	180	20	4	NI
9	180	22	5	Cr

7.3 Tensile Test

The tensile test is performed to determine how a component will behave under different load conditions. It determines the max tensile load the material can withhold until fracture. Transverse tensile test – Model: UTE 60 M/c. SL No:6/2007-3672. Following are the test results in Table 7.

Table 7: Tensile test result

No.	Thick (mm)	Width (mm)	CSA (mm^2)	TL (KN)	TS (N/mm^2)	Fracture & Location
1	5.52	20	110.4	20.34	184.24	Brittle fracture / Weld metal
2	5.5	20	110	19.86	180.55	Brittle fracture / Weld metal
3	5.56	20	111.2	20.46	183.99	Brittle fracture / Weld metal
4	5.48	20	109.6	21.43	195.53	Brittle fracture / Weld metal
5	5.38	20	107.6	19.68	182.9	Brittle fracture / Weld metal
6	5.57	20	111.4	20.39	183.03	Brittle fracture / Weld metal
7	5.24	20	104.8	19.86	189.5	Brittle fracture / Weld metal
8	5	20	100	21.46	214.6	Brittle fracture / Weld metal
9	5.52	20	110.4	20.34	184.24	Brittle fracture / Weld metal

8. Conclusion

FCA Welding was performed on EN24 for 3 varying welding parameters which were welding current, voltage and gas pressure. As per the results are shown by the Rockwell hardness test, hardness increases with increasing welding current as well as voltage whereas gas pressure is in the medium range. So, as specimen 9 showed the maximum hardness of 107 HRB, we can say parameters of 180 amps and 22 volts with 5 bar gas pressure is a best-suited state. Considering the ultrasonic test results, no indication or flaw was found in only two specimens with parameters 140 amps, 18 volts, 4 bar pressure and 180 amps, 20 volts, 4 bar pressure. In the Tensile test, maximum tensile strength has been shown by specimen 8 which is 214.60 N/mm2. Thus, we can now say by observing and analyzing the above results that specimen 8 parameters have shown to be the most suitable for EN 24 welding.

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