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The effect of welding fixtures on welding distortions

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ABSTRACT

Purpose: of this paper is to examine the effect of welding fixture used to prevent the distortions during cooling process utilizing a robot controlled gas metal arc welding method on cooling rate and distortions of welded structures.

Design/methodology/approach: Using a specially designed welding fixture for a welded steel structure, six different types of AISI 1020 steel specimens are tested in three different welding speeds and two different cooling conditions either at fixture or without using fixture.

Findings: designed fixture is reduced amount of distortions. The preheating effect of previous weld on the next weld has increased distortions on the other side of part. Increase in distortions is directly proportional to the increase in welding speed which affects the weld heat input.

Research limitations/implications: the study can be repeated on more complex structures and fixtures.

Practical implications: the study has shown that the fixture design has an important effect on cooling rate of the welded parts.

Originality/value: most of papers in literature is about fixture design methodology, but this paper is an example of demonstration for a practically applied welding fixture.

Keywords: Welding distortion; Welding fixture; Weld sequence; Welding speed; GMAW

1. Introduction

As product design, to optimize a product, process design is also considerable. The product obtained after process must be at target in terms of value of geometry, size, tolerance etc. to be acceptable. For this reason, a product which is not affected by uncontrolled parameters must be planned on, in process design. When these expectations mentioned to achieve standard production and continuous challenge are considered, the importance of automation in manufacturing processes come into existence. However, when product variety is considered deficiency of hard automation and necessity to flexible manufacturing systems are stand in the forefront [1, 2].

Although, human factor seems as the main reason of faults in manufacturing, many present automation systems cause to face troubles in response to unpredicted modifications. Despite the decrease of human factor, full automation is still discussed as a difficult topic [3, 4].

In welding to achieve the target values and obtain repeatability, fixtures are used as in some other manufacturing methods [5, 6]. The main idea of designing a flexible manufacturing cell, producing hollow sections, discussed in this paper is depend on welding process that cause high manufacturing cost in comparison with product quality because of low manufacturing volume. The problems experienced during gas metal arc welding process of mentioned sections, used in automotive industry, are the basis of this study. Various defects were detected on manually welded parts at previously designed welding fixture and an improvement study was done to remove them.

In preliminary work, low weld quality, geometrical tolerance faults and aesthetic defects were detected after manual welding.

This study speeds up welding process of the part and also for aesthetic and strength properties stable quality level is achieved. By stable quality level problems would occur in next processes are eliminated [7].

For this purpose, a welding fixture is designed and welding parameters, affecting distortions and residual stresses, such as welding speed and reverse distortion are taken into consideration. An industrial robot that can give response to modifications in manufacturing and feasible for process was chosen and integrated to test setup with suitable welding equipments.

2. Experimental studies

2.1. Material

Square shaped hollow sections made from AISI 1020 steel are used for the material. According to calculated shrinkage values, in tests reverse distortion is given to parts to be welded. By applying reverse distortion, at the end of the process nominal geometric sizes are provided. Inspections after welding indicated, the tested parts are in required tolerance range. The part obtained after these studies is shown in Figure 1.

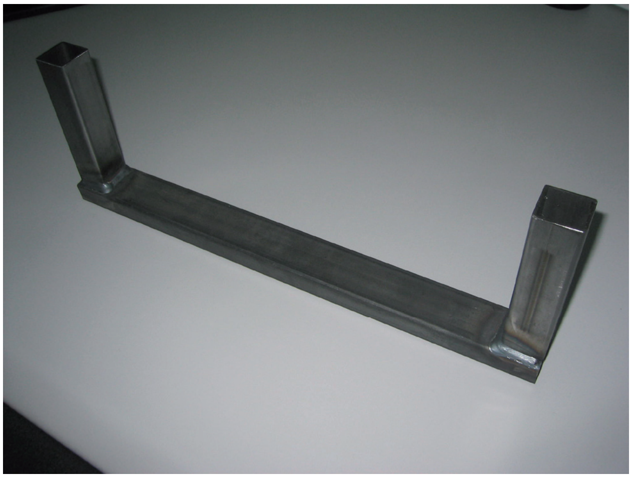

Fig. 1. A welded Part

2.2. Experimental setup and fixture design

Characteristics of a fixture can be summarized as providing proper position and rigidity of work piece, providing ease and safety of operation, increasing productivity and low manufacturing cost itself.

Basically there are three main structural components in a fixture. These are, respectively, locator, clamp and support. Locator is generally an immobile unit and it determines the position of part on the fixture by constraining freedom. Locators can be pin or surface. Clamps constitute mobile part of fixture. Forces to grab the work piece are applied by clamps. Support is mostly stable on fixture, it holds the work piece and it facilitates to work piece keeping its geometry under thermal stresses arise because of welding process.

In the initial stage to locate part with required rigidity and in proper position, locating surfaces are determined.

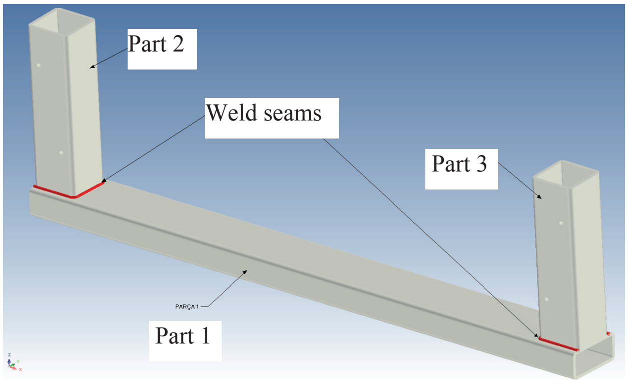

Fig. 2. Components of the U-shaped part

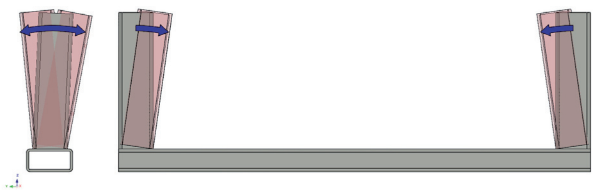

Fig. 3. Possible dirtontions

In Figure 2 three components to be welded to form the U-shaped part and welds are shown. As seen from figure to form welds electrode must follow a U-shape path. In Figure 3 possible directions of distortions caused by thermal stresses of welding process, are shown. However, assuming stress effects of parallel arms of U-shape path compansate each other, expected distortions are as both parts close up. In Figure 4 determined loacting surfaces and pressure force points are shown. Part 1 is constrained in x and y axes by atachments and in z axis by pressure force. Part 2 and part 3 are constrained in y and z axes by upper surface of part 1 and attachments, in x axis by pressure force.

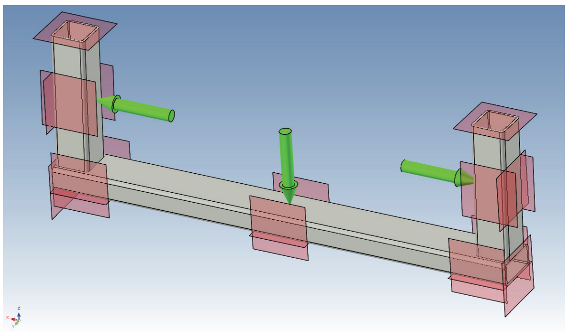

Fig. 4. Locating surfaces and forces

To remove, the work part constrained in all axes, from fixture, side and up attachment groups of part 2 and part 3, must be movable. In x axis attachments locating part 2 and part 3 each from three surfaces must be capable of linear motion.

Completed fixture is shown in Figure 5. Before test stage the robot is adapted to the test setup and system are prepared for tests. Assembled test setup is shown in Figure 6.

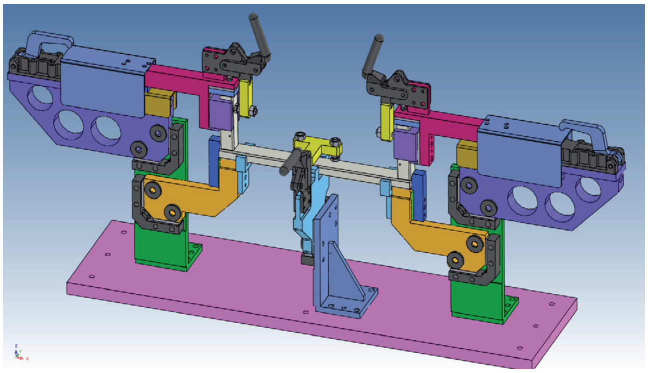

Fig. 5. Assembled fixture

Fig. 6. Test setup

2.3. Wedling parameters

The power source used in experiments can generate 16 – 400 A current and provide 100% duty cycle up to 250 A. The solid wire was EN 440-G3Si1 with 0,8 mm diameter. Shielding gas was 80% Ar+20%CO_2 with 12 liter/min flow rate. Cooling rate measurements are done by a infrared temperature measuring test equipment capable of between -20^oC and +500^oC. Room temperature was 18^oC during experiments. Six different specimens were obtained with three different welding speeds while current and voltage were kept constant. For each welding speed two specimens are welded, one was cooled on fixture and the other outside of the fixture. In this way, effects of welding speed and fixture on distortions are determined. Experiment installation is shown in Table1.

Table 1.
Welding conditions applied in experiments.

Specimen No.	Welding speed (%) 80	100	120	Cooling on fixture	Cooling without fixture
Specimen 1		X		X	
Specimen 2		X			X
Specimen 3			X	X	
Specimen 4			X		X
Specimen 5	X			X	
Specimen 6	X				X

Welding voltage and current with welding time and filler metal consumption are given in Table 2. After all parts are welded, distortion rate is measured at a point of 100 mm above the weld. Distortion rates are given in Table 3.

Table 3.
Measured distortions at welded specimens.

	Specimen No.	Distortions (mm) Part 2	Part 3
Cooling on fixture	1	-0,15	0,15
Cooling outside of fixture	2	0,20	0,25
Cooling on fixture	3	-0,10	0,20
Cooling outside of fixture	4	0,35	0,40
Cooling on fixture	5	-0,20	0,05
Cooling outside of fixture	6	0,15	0,20

Table 2. Welding parameters used to obtain test specimens.

				Part 2	Part 3	Part 2	Part 3
	Average voltage (V)	Average current (A)	Average power (kW)	Arc time (s)	Arc time (s)	Filler metal consumption (gr)	Filler metal consumption (gr)
Specimen 1	18,58	110,55	2,04	15	15	7	7
Specimen 2	18,54	113,06	2,09	15	15	7	7
Specimen 3	18,63	113,13	2,09	19	19	9	9
Specimen 4	18,58	114,03	2,10	19	19	9	9
Specimen 5	18,57	111,41	2,06	13	13	6	6
Specimen 6	18,58	110,55	2,04	13	13	6	6

2.4. Experimental results

After analysis of six specimens, inversely proportional to weld speed, distortions are increased by increasing heat input, as expected.

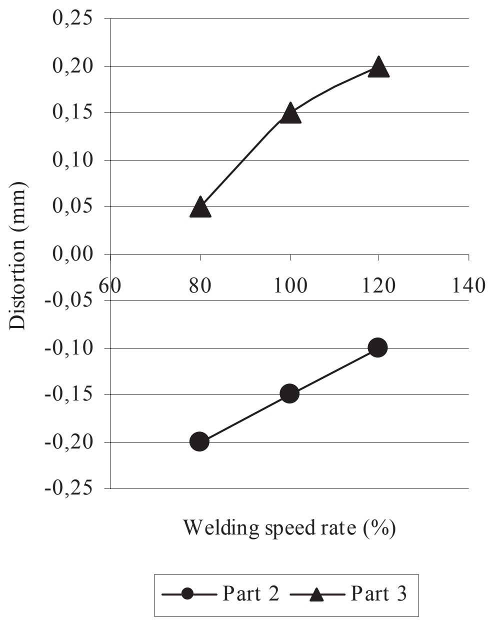

Fig. 7. Distortions measured at cooling in fixture

In Figure 7, distortions of specimens cooled on the fixture are graphically shown. Figure 8 shows distortions observed outside of fixture. To determine effect of fixture on distortions comparing distortions of part 3 on specimen 1 (cooling on fixture) and specimen 2 (cooling outside of fixture), or specimen 3 and 4 or specimen 5 and 6 would be useful.

3. Conclusions

In this study, a welding fixture is designed and welding parameters, affecting distortions and residual stresses, such as welding speed and reverse distortion are taken into consideration

Weld sequence is effective on distortions. First weld seam on the part creates preheating effect on the next weld seam and increases distortions. After analysis of six specimens, inversely proportional to weld speed, distortions are increased by increasing heat input, as expected.

Reverse distortions applied to see how they effect the main distortion arising from the welding process.

Although reverse distortions are applied to part 3 of the specimens, they presented a positive distortion characteristic because of being preheated while part 2 was being welded. This characteristical based on decreasing of yield strength by heating. This results can be used to predict the amount of reverse distortions.

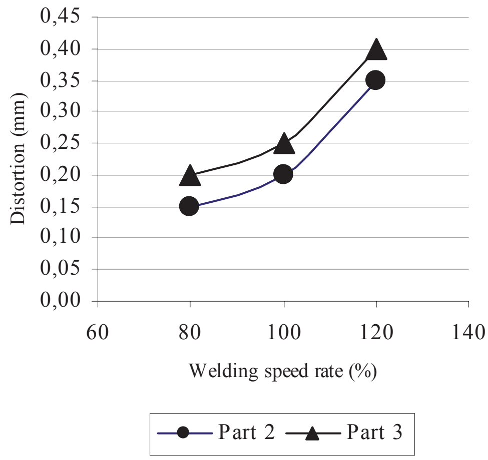

Fig. 8. Distortions measured at cooling outside of fixture

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