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Evaluate the Effects of Friction Stir Welding Parameters on the Impact Strength of Butt Welded Joint

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Abstract

Friction Stir Welding is basically a combination of extruding and forging process. It can be also stated as a process of Solid State and Thermal - Mechanical Joining. Joining of two metals is widely used in the industrial areas these days which motivates the work in this area. The overall objective of this dissertation work is to evaluate the optimum parameters for the materials under considerations, to obtain the maximum impact strength of the welded joint, the welding process was done by using conventional milling machine. An Izod Charpy test is used to evaluate the impact strength, Suitable parameters were used for the process such as toll rotational speed, tool traveling speed and tool shoulder diameter. It is observed that the impact strength highly influenced by diameter than feed than speed. The experiments were designed by Taguchi methodology. L9 Orthogonal Array was used and Results of the experimentation were analyzed by MINITAB software analytically as well as graphically.

Keywords: *FSS; Charpy test; Impact Strength; Taguchi Analysis; Welding; Welding Joint*

1. Introduction

Welding is a process of joining the metal with or without pressure and with help of heat. It is a fabrication process that joins the materials by causing fusion. The process is distinct from a lower temperature metal-joining process such as soldering and brazing, which do not melt the base metal.

Friction-stir welding is a process of solid-state joining that uses a separate tool to join the two facing surfaces. Generated heat between the tool and material leads to softs the region near the FSW tool. It mechanically intermixes two pieces of metal at the joint and then softened the metal can be joined using mechanical pressure applied by the tool much like a joining clay. It is primarily used on aluminium and extruded aluminium and on structures which need superior weld strength without a past weld heat treatment.

It was invented at The Welding Institute UK in December 1991. TWI holds patents on the process, the first being the mast descriptive.

A non-consumable cylindrical-shouldered tool rotated at constant speed with a profiled probe transversely fed into the butt joint between two clamped pieces of material used. Probe is slightly shorter than weld depth, with tool shoulder riding at the top of the work surface. Heat is generated between the two welding components and the work pieces due to friction. Heat generated cause the stirred materials to soften the material without melting. As pin is moved forward its leading face forces plasticized material to rear where clamping forces assists in a forged manner consolidation of the weld.

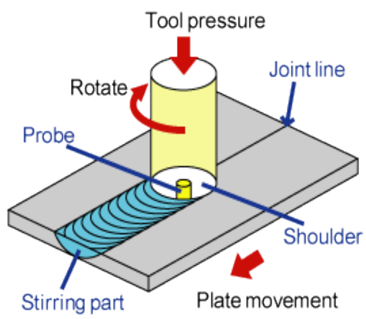

Figure: 1 FSW Welding

2 Literature Review

Extensive review of literature pertaining to the research work has been carried out and is reported in this chapter. The various aspects included in the review are effect of welding parameters, and their effect on the strength, review of friction welding process. Major papers covering these aspects are reported below.

K. Kimapong *et al*. (2004) [1] performed friction stir welding on an aluminum alloy with magnesium to steel. The effects of rotation speed, pin offset and the structure

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of a joint were investigated. It is concluded from the experiment that lowering the rotation speed give rise to an insufficient increase in temperature at weld thus the pin wore out in a small time. At a high rotation speed, the temperature increase was so much that the magnesium in the Aluminium alloy oxidized and gives an unsound joint.

G. H. Payganeh *et al*. (2011) [2] pp composite plates with 30% GF were welded with this process. The effects of tool geometry were first investigated on tensile strength and weld appearance experimentally. It is found that the tensile strength of specimens was 9 MPa which is found almost 25% of the base plate.

Vukcevic Milan *et al*. (2009) [3] The research successfully performed the joining of aluminum alloy 6082-T6 using FSW. experiment has established the shoulder diameter; pin diameter and tilt angle of the pin have large effect on welding speed and rotation speed. The paper presents a measurement of force which is defined by the components in x, y and z direction and mechanical tests were performed - determination of the tensile strength of welded joints and the tensile strength of welding zone.

Pasquale Cavaliere *et al*. (2013) [7] experimentally studied the various effect of processing parameters on the tensile strength, fatigue and the crack behavior of aluminum alloys. It is concluded that parameters affect defects, heat input, microstructure and residual stresses. Also, the welding force decrease with increase in the revolutionary pitch and the welding force increases with decreasing in tool tilt angle.

3. Experimental Methodologies

A well-known technique i.e. Taguchi method provides an efficient and systematic methodology for optimization of process parameters and this proves to be a powerful tool for the design of experiment. The gained wide popularity in the field of engineering and the scientific community. This is methodology for obtaining the parameters which are minimally sensitive for the various causes of variation and those produce high-quality products with low development. Orthogonal array and Signal to noise ratio are two major tools used in robust design. The S/N ratio characteristics can be divided into three categories when the characteristic is continuous.

- Nominal is the best
- Smaller the better
- Larger is better characteristics.

For the maximum material removal rate, the solution is "Larger is better" and S/N ratio is determined according to the following equation:

S/N = -10 *log(Σ(1/Y2)/n)

Where, S/N = Signal to Noise Ratio,

n = No. of taken Measurements, y = Value Measured

The effects of each factor can be easily and more clearly presented with the help of response graphs. Using S/N response graphs optimal cutting conditions of control factors can be very easily evaluated. Parameters selection and design is the essential step in the Taguchi method to get the reliable results without experimental costs increased.

In comparison to above method the Taguchi orthogonal array make list of nine experiments in a order which cover all factors. Those nine experiments will give 99.96% accurate result. By using this method number of experiments reduced to 9 instead of 27 with almost same accuracy.

Figure 2 Vertical Milling Machine with some special Attachments and modifications

The manually designed toll made of HS 13 is used to for stirring purpose. A butt joint is made using working material using three parameters as rotating speed of tool, feed rate and the shoulder diameter of the tool. The various levels of rotating speed are 600, 1200, 1800 rpm. Similarly, the various levels of feed rate are 25, 35, 45 mm/min also the levels of shoulder diameter are 12, 15, 18 mm

Impact Strength

To determine the life of a structure or machine impact is a very important factor. The impact strength must be calculated for the safety point and to design the component of high factor of safety. In studying the toughness of material impact tests are used. Toughness is ability to absorb energy during deformation. The impact value of a material also changes with temperature. Almost at lower temperatures, the impact energy of a material is decreased. The size of the specimen also affects the value of the Izod impact test because different number of imperfections in the material, which act as stress risers and lowers the impact energy.

Charpy Impact Test

Charpy impact testing has striking a notched standard specimen with a weight pendulum that swung from a preset height. A Charpy-V notch standard specimen has

55mm length, has 10mm square and a 2mm deep notch having tip radius of 0.25mm machined on the one face. Specimen is supported at two ends on an anvil and struck on the notch by the pendulum. The energy absorbed in fracturing the test-piece sample is measured and that gives an indication of toughness of the test material. The pendulum swings through the test, the height of the swing is a measure of the energy absorbed in the fracturing of specimen. Earlier, three specimens are teste The appearance of a fracture surface also gives information about the type of fracture that has occurred; a brittle fracture is bright and crystalline, a ductile fracture is dull and fibrous. When a ductile metal is broken, the test-piece deforms before breaking, and material is squeezed out on the sides of the compression face. The amount by which the specimen deforms in this way is measured and expressed as millimeters of lateral expansion.

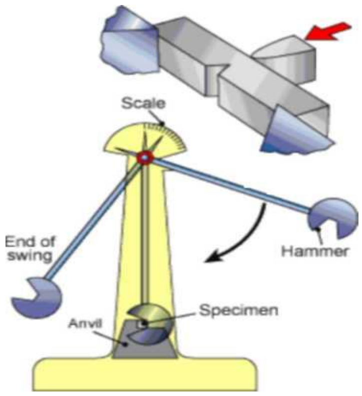

Figure 3 Charpy Test Appratus

Work Piece Material

In the present work material Aluminium 6063 is used for the experimentation. Aluminium 6063 have good impact strength, tensile strength and low fusion temperature. Lower fusion temperature making it suitable for friction stir welding process. In this work H13 tool is used for welding steel plate of 55 mm x 10 mm x 3 mm is used for Experimentation.

Figure 4 Workpiece

Experimental Procedure

The experiments carried out on a Vertical Milling Machine (Packmill Manufactured) having advanced attachments and modifications. The tool of vertical milling machine is replaced with the special designed tool for friction welding. Various experiments were made at different levels of parameters.

4. Result and Analysis

Table 1 Observation table Izod Charpy Test for Impact Strength

Expt. No.	Tool Rotation(RPM)	Feed Rate(mm/min)	Shoulder Diameter(mm)	Impact Strength
1	600	25	12	10
2	600	35	15	8.5
3	600	45	18	11
4	1200	25	15	10
5	1200	35	18	11.5
6	1200	45	12	10.5
7	1800	25	18	12
8	1800	35	12	14.05
9	1800	45	15	8

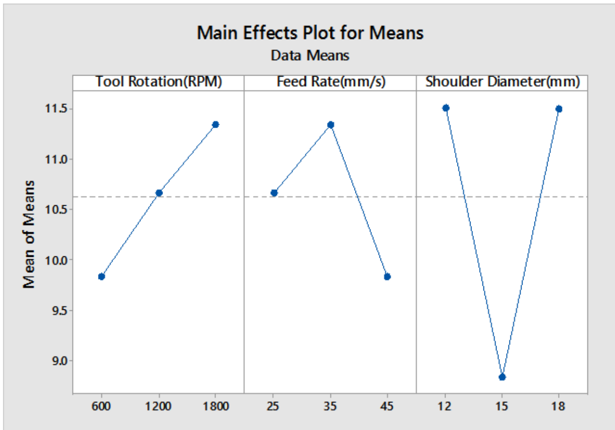

Figure 5: Effects of Process Parameters on Impact Strength (S/N Data)

Result and Discussion for Impact Strength (Izod Charpy Test)

The value of impact strength increases with increase in the rotating speed of the tool. The rate of increase of impact strength is high as the speed increases from 600 rpm to 1200 rpm. But the rate of increase of impact strength is increasing with less response as the speed increases from 1200 rpm to 1800 rpm. The impact strength follows approximately linear relationship with the speed of the rotating tool. The trend is observed same in both SN Ratio and Mean Plot.

The impact strength increases sharply as the feed rate increases from 25 mm/s to 35 mm/s and it decreases sharply as the feed rate increases from 35 mm/s to 45 mm/s. The trend is observed same in both SN Ratio and Mean Plot.

The impact strength is sharply decreases with increase of shoulder diameter from 12 mm to 15 mm and it sharply increases as the shoulder diameter increase from 15 mm to 18mm. The trend is observed same in both SN Ratio and Mean Plot.

After the observation from experimentation and from Izod Charpy test for impact strength, the data thus obtained is used in MINITAB software for the calculations of S/N ratio and mean.

Table 2 Response Table for Signal to Noise Ratios(Larger is better)

Level	Speed	Feed	Diameter
1	19.81	20.53	21.13
2	20.55	20.92	18.88
3	20.87	19.77	21.21
Delta	1.06	1.15	2.33
Rank	3	2	1

Conclusion

The following conclusions are drawn from the experimental study: (Izod Charpy Test)

- It is concluded that the impact strength highly influenced by diameter than feed than speed.
- Impact strength is increasing with increasing speed.
- Impact strength is maximum at maximum speed.
- Impact strength is decreasing with increasing feed rate.
- Impact strength is maximum at feed rate 35 mm/ min.
- Impact strength is minimum at diameter of shoulder 15 mm.

Table 5.1 Optimal combination for Impact Strength

Physical	Optimal Combination		
Requirements	Speed(RPM)	Feed Rate (mm/S)	Shoulder Diameter (mm)
Maximum Impact Strength	1800	35	12
	Level-3	Level-2	Level-1

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