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EXPERIMENTAL INVESTIGATIONS ON FRICTION STIR WELDING OF AL2219

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ABSTRACT

Friction stir Welding Process (FSW) is a solid state welding method developed by The Welding Institute (TWI), and now it is increasingly used in Aluminium and Steel Welding. FSW is now extended to variety of materials including steel and polymers. This paper highlights the optimum process parameters are obtained in this process. Tensile strength is decreased with increasing rotational speed. Tensile strength is decreased with increasing welding speed. Hardness is increased with increasing rotational speed. Experiments are conducted on CNC vertical milling machine. Micro structure examination has been done before and after welding. In addition Effect of heat treatment (annealing) process has been examined after welding.

Key words: *Friction, welding, Tool, Geometry, FSW, TWI and Heat treatment*

1. Introduction

Friction stir welding (FSW) process is an innovative technique to join metals in the plasticity field, thus not reaching the melting temperature and consequently the liquid state as it happens in traditional welding processes. Friction stir welding process has a wide application potential in ship building, aerospace, automobile and other manufacturing industries. Friction stir welding is a relatively simple process as shown in Fig.1. A specially shaped tool, made from material that is harder and wear resistant relative to the material being welded is rotated and plunged into the abutting edges of the material parts to be joined. After entry of the tool pin to almost the thickness of the material the rotating tool is transitioned along the joint line to enable the tool shoulder to just penetrate into the base metals. As a consequence of the contact between the rotating tool and the base metals, frictional heating of the material occurs. This causes the base metals to plasticize and flow from the front of the tool to the back where it cools and consolidates to produce a high integrity weld in the solid phase.

2. Experimental work

Aluminium alloy Al2219 plates of 6mm in thickness are cut in to the required size (200*100mm) by power hack saw cutting and milling. The Initial joint configuration is obtained by securing the plates in position using mechanical clamps. The direction of welding is normal to the rolling direction. Single pass welding procedure is followed to fabricate the joints. Non-consumable tools made of high carbon steel are used to fabricate the joints. To carry out the FSW experiments a vertical milling machine shown in fig.1.with a capacity of 7.5 H.P. motor is used, maximum tool speed 2000rpm and axial force 25KN. Al2219 chemical composition is shown in table.1.

The quality of joints prepared by FSW process depends on a number of variables including pin tool geometry, axial force, rotational speed and traverse speed of the pin tool. This necessitates a proper methodology for carrying out experiments for identifying the appropriate values of these variables, and for achieving the desired results in a shorter span as well as with a minimum cost. Fig. 2 illustrates a flowchart showing the methodology [4] for carrying out experimental investigations in FSW process.

Fig. 1Friction Stir Welding Machine (Vertical Milling Machine)

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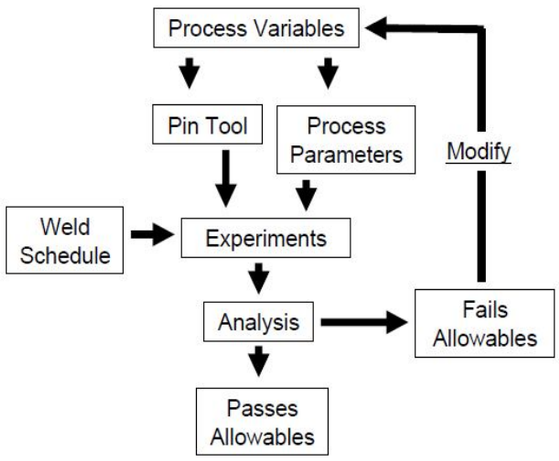

Fig.2 Flowchart showing the Experimentation Methodology for FSW

Table 1: Chemical Composition of the Al 2219 Investigated (wt. %)

Al	Cu	Mn	Ti	V	Zr	Si
93	6.16	0.3	0.06	0.10	0.18	0.2

3. Results and Discussion

Extensive FSW experiments are carried out to optimum the process parameters which give the good quality of welded joint by using the designed geometry. From the experimental observation the optimum process parameters are decided which is shown in Table 2. The results of tensile strength versus rotational speed and welding speed are shown in figs 3 and 4. At constant welding speed the tensile strength tends to decrease with the increase in the rotational speed. Similarly, at constant rotational speed, the tensile strength tends to decrease with the increase in the welding speed. It is also observed that hardness is increased with tool rotational speed shown in fig.5. The maximum of 410MPa is obtained at a rotational speed of 1000rpm and welding speed 2.5mm/sec.

The effect of tool rotational speed on strength properties of FSW joints of Al2219.The joint fabricated at a tool rotational speed of 700 rpm have shown lower tensile strength, the maximum strength attained at 1000rpm.Olga[12] reported that in FSW, as the rotational speed increases ,the heat input also increases. However, the calculated maximum temperatures are nearly the same in all the rotational speeds. This phenomenon can be explained by the two following reasons: first the co-efficient of friction decreases when a local melt occurs, and subsequently decreases when a local input: secondly, the latent heat absorbs some latent heat absorbs some heat input. When the rotational speed increases the heat input within the stirred zone also increases due to the higher friction heat which in turn result in more intense stirring and mixing of materials. As spindle speed increased from lower to higher, strength improved. Higher tool rotational speed resulted in higher heat generation and this led to the excessive release of stirred material to the upper surface. which resultantly produced micro voids in the stir zone. Moreover, the higher heat generation caused slow cooling rate and this lead to the formation of coarse grains. The joint fabricated at a rotational speed of high depends on material produced finer grains with uniformly distributed dimples, this is one of the reasons for higher strength of the joints. The effect of welding speed on strength properties of FSW joints of Al2219.Higher welding speeds were associated with low heat inputs, which result in faster cooling rates of friction stir welded joint. At high welding speed, low heat input may cause lack of weak bonding inside the material .This is one of the reasons for decreases the strength [13].

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Micro structure of the work piece Fig.6. shows a)coarse grain structure b) shows the micro structure of the deformed position. It contains ultra fine grain structure and also it contains dendritic structure due to presence of silicon in the matrix the material become hard.By close observation in fig(b) the orientation of grains are in particular direction.This may be due to the heat flow in that direction.

Heat treatment: 1)Normally heat treatment is done at 350^0 c to 400^0c (annealing)for 3 to 4 hours and then cooled in natural air in this condition tensile strength of the work piece reaches to 415 Mpa,

2) Another work piece same thickness is water quenched 1 hour, tensile strength reaches to 412 Mpa

Tools used for FSW process are fabricated from high carbon steels. Tool which is shown in the first place of fig.7, is enlarged because increase in thickness of work piece from 6mm to 12mm. Second tool is not enlarged because carbon percentage is high. In this process, Material selection plays a major role to obtain proper parameters in tool geometry.

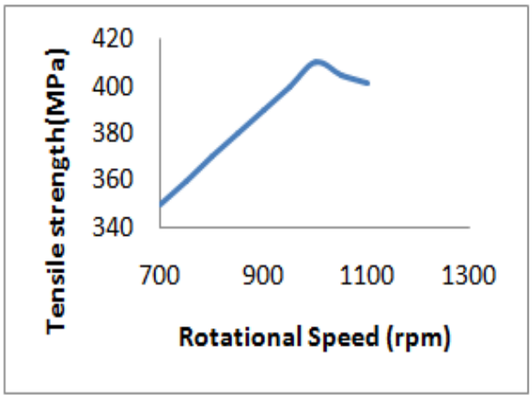

Fig. 3 Tensile Strength Vs Rotational Speed

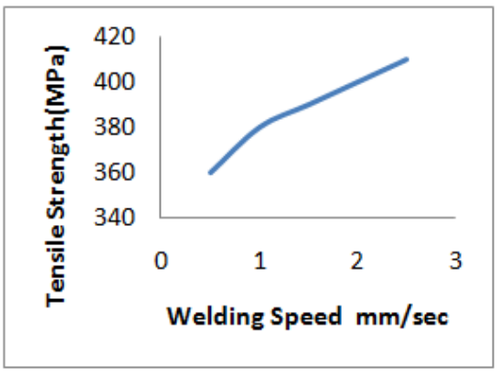

Fig. 4 Tensile Strength Vs Welding Speed

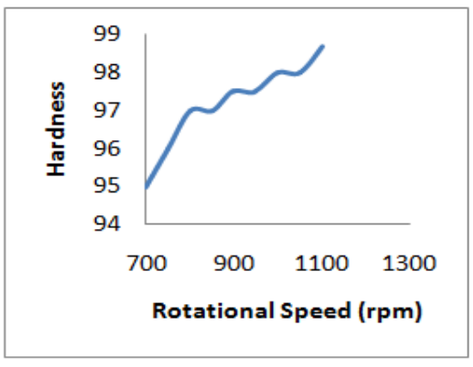

Fig. 5 Rotational Speed Vs Hardness

Fig. 7 High Carbon Tools

Table 2: Welding Process Parameters

FSW Process parameters	Values
Tool Rotational Speed, rpm	1000 rpm
Welding speed, mm/min	2.5mm/sec
Axial force, ton	7.5KN

a)

b)

Fig. 6 Shows Microstructure of Al2219 a) before b) after welding

4. Conclusions

i. A Flow chart of suggested design methodology for conducting experimental investigations on FSW process has been presented.
ii. The optimum process parameters are obtained.
iii. Tensile strength is decreased with the increase in the rotational speed. The effect of tool rotational speed on strength properties of FSW joints of Al2219.The joint fabricated at a tool rotational speed of 700 rpm have shown lower tensile strength, the maximum strength attained at 1000rpm. Tensile strength is decreased with increasing welding speed. Slow welding speeds generates high heat zones than higher welding speeds[12].
iv. Hardness is increased with the increase in the rotational speed. Friction between the tool and work piece increases hardness can be increased[13]
v. Examined the effect of heat treatment process on tensile strength
vi. It is hoped that the material presented is helpful for researchers in Friction Stir Welding.

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