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Research Paper

HEAT INPUT & JOINT EFFICIENCY OF THREE WELDING PROCESSES TIG, MIG AND FSW USING AA6061

Ashwani Kumar[1]*, Shakti Singh Gautam[1] and Alok Kumar[1]

Friction Stir Welding (FSW) is a process in which the welds are prepared with the help of a tool having a profiled pin. In this welding process the material does not reach to its melting point and the welds are made in the plastic stage condition by applying an axial force on the stirred work material keep halt with the help of the fixtures. Here, a short of comparison is made between conventional welding processes TIG and MIG to FSW on the basis of heat input and joint efficiency. For doing this AA6061 is used in the study. It was found that, for less heat input best weld joint with higher efficiency up to 80% can be obtained with the help of FSW process as comparison to TIG & MIG welding processes

Keywords: FSW, TIG, MIG, AA6061

INTRODUCTION

This new technique of welding was invented in 1991 by Wayne Thomas of The Welding Institute (TWI) of United Kingdom. For the Friction Stir Welding (FSW) the jobs (metal sheets/metal plates) to be joined are aligned and clamped to each other and placed on a backing material. A non-consumable cylindrical tool having a profile probe or pin rotates and plunged in to the joint line. The tool also does a transverse motion along the joining line, this produces the rubbing action and heat is generatedwhich softens the job and the heated soft job material stirred by the probe and plastic flow of material takes place.

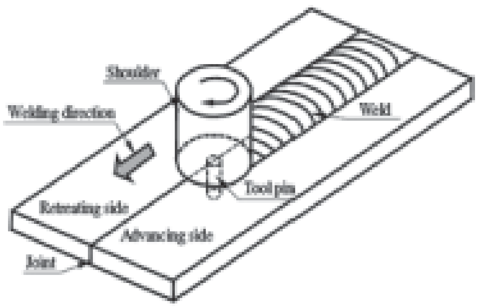
This is the solid state welding process in which the material does not reach at its melting point which reduces so many problems like segregation, severer residual stresses, distortion and evaporation of volatile elements. Figure 1 shows the main processes.

Originally, the FSW has been develop for joining high strength aluminum alloys and advanced aluminum alloys produced by power metallurgy.

Friction Stir Welding in comparison to the automated gas metal arc welding improves the dimensional accuracy of the assembly and produces a 30% increase in joint strength (Soundararanjan *et al.,* 2006).

[1] Mechanical Engineering Department, Quantum School of Technology, Roorkee.

Figure 1: FSW Process



FSW relies on localized forging of the weld region to produce the joint. In FSW heat is caused by rubbing of the tool faces against the work piece, and by viscoplastic dissipation of mechanical energy at high strain rates developed through interactions with the tool. During welding, the material along the joint is heated to a softened condition transferred around the periphery of the tool and subsequently recoalesced along the back surface of the pin to produce weld. Minimization of distortion and residual stress is extremely important in welding of thick section material, such as in the ship building and heavy manufacturing industries (Lienert *et al.,* 2003). It is evident that, aluminum and its alloys are the best suitable materials used in various industries like aerospace, shipbuilding, automotive, architectures etc, as these are the lightweight materials and provide the better strength. The main advantage of using aluminum and its alloys, in the industries is that, the high strength to weight ratios may be obtained. As we know that welding of aluminum and its alloys is not an easy task, but the invention of FSW makes easy to weld aluminum and its alloys. Hence the use of FSW instead of conventional fusion welding processes (TIG and MIG) to weld aluminum and its alloys create a possibility to get the best joint with higher strength within the economic constraints. Here, a short of comparison is made between conventional welding processes TIG & MIG to FSW on the basis of heat input and weld efficiency using AA6061.

Working Material: Aluminium alloys widely used in aerospace, automobile industries, railway vehicles, bridges and high speed ships, because it has light weight and higher strength to weight ratio, corrosion resistance and ductility. In all the discussed areas welding is the most used manufacturing process with a great challenge for designers and technologists.

Aluminium alloy AA6061 (Al-Mg-Si) is the most widely used medium strength aluminium alloy, and has gathered wide acceptance in the fabrication of light weight structures (Balasubramania *et al.,* 2007).

The Extruded form of aluminium alloy AA6061 is used in the present investigation. It is heat treated up to 3000C. It was in the sheet form having thickness 6 mm and width 50 mm. Chemical compositions, physical properties and mechanical properties of the material are given in Tables 1, 2 and 3 respectively.

Table 1: Chemical Composition of Aluminium Alloy AA6061

Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
0.63	0.42	0.42	0.12	0.19	0.05	0.08	0.02	Bal.

Table 2: Physical Properties of Aluminium Alloy AA6061

Density (g/cm^3)	Melting Point (^0C)	Modulus of Elasticity(GPa)	Poison Ratio
2.7	600	70-80	0.33

Table 3: Mechanical Properties of Aluminium Alloy AA6061

Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation (%)	Reduction in cross sectional area (%)	Hard-ness (HRB)
280	310	16	11	65

METHODS

Three welding methods TIG, MIG and FSW is used in the study. The different welding parameters are shown in the following Table 4.

Table 4: Process Parameters Used in TIG, MIG and FSW

Process	MIG	TIG	FSW
Welding machine	Pana auto Panasonic	Pana auto Panasonic	Vertical Milling Machine
Tungsten electrode diameter (mm)	-	3	-
Filler rod/wire diameter (mm)	1.6	3.15	-
Voltage (volts)	20	20	-
Current (amps)	180	170	-
Welding speed (mm/min)	100	120	60
Heat input (kJ/mm)	1.62	1.275	0.79
Shielding gas	Argon	Argon	-
Gas flow rate (lit/min)	15	15	-
Tool rotational speed (rpm)	-	-	635
Axial force (kN)	-	-	7
Tool shoulder diameter (mm)	-	-	16
Pin diameter (mm)	-	-	7
Pin length (mm)	-	-	4.7
Tool tilt angle	-	-	20
Pitch (mm)	-	-	1
Tool pin profile	-	-	Threaded (anti-clockwise)

RESULTS AND DISCUSSION

Heat Input: Heat input is a relative measure of the energy transferred during welding. It is a useful tool in evaluating welding procedures within a given process. The cooling rate, weld size and material properties may all be influenced by the heat input.

Some welding codes place specific controls on the heat input. To ensure high quality in welded construction, it is important to understand and apply these principles (Funderburk, 1999).

In TIG and MIG welding the main welding process parameters are voltage and current while in case of FSW there are three main process parameters and these are rotational speed of tool, welding speed or feed of tool and axial pressure applied through the tool on the working material.

In case of TIG and MIG welding process the heat input is given by the following relation,

$$\text{Heat Input, } q = \frac{V \times I \times \eta \times 60}{s \times 1000} \quad \ldots (1)$$

where V = Voltage in volts;

I = Current in Amperes;

η = Arc efficiency is assumed as 0.75 for TIG and MIG welding processes;

s = Welding speed (mm/min) (AWS, 1996)

In case of FSW process the heat input is given by the relation as follows,

Heat Input,

$$q = \frac{2\pi}{3s} \times \mu \times p \times \omega \times R_s \times \eta \qquad ...(2)$$

where, μ = Co-efficient of friction;

p = Normal force in kN;

ω = Rotational speed in rev/s;

R_S = Shoulder radius in m;

s = Welding speed in mm/s (Heurtier *et al.,* 2006)

Peel *et al.* (2003) determined that as the weld speed increase, there was less overall heat applied because the tool moves more quickly, thereby reduces the amount of frictional heat (Peel *et al.,* 2003)

After calculation, we get heat input 1.275 kJ/mm in TIG welding process and 1.62 kJ/mm in MIG welding process which means, the energy consumption or heat input was 27.06% more in case of MIG welding process then in TIG.

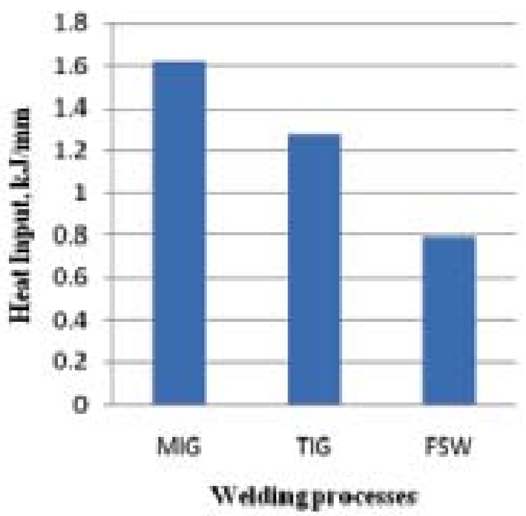
On the other hand in case of FSW, the heat input was 0.79 kJ/mm (for 635 rpm and 60 mm/min, 7 kN). Means on less heat input we can get fine weld joint in comparison of TIG and MIG welding process.

If we consider TIG and FSW process, it is seen that the heat input is less in case of FSW by 38%. In the same way in case of MIG and FSW processes the heat input also less in FSW by 51.2%.

Here it is cited that in case of FSW the heat input is less or decreased relative to arc welds TIG and MIG. Because of lower heat input the mechanical properties of the weld increases and distortion and residual stresses reduces. This becomes an advantage of the FSW process.

Situation may be easily understood with the help of Figure 2. In this figure, it can be clearly seen that heat input is less in case of FSW than that of the other two conventional welding processes TIG and MIG.

Figure 2: Heat Input in Welding Processes TIG, MIG and FSW



As we know that higher heat input lower will be the cooling rate and lower heat input cooling rate will be higher. This thing affects the mechanical properties of the weld material. In case of welding, aluminium alloys, it should be keep in mind that the heat input should not reach at the value where temperature becomes too high and the mechanical properties of the welding material degraded too much to get the weld with good strength. In case of FSW the heat input is such that the welding material does not reach at its melting point, because of that, it is possible in FSW that the material can be weld with fine mechanical properties having nice orientation of grains.

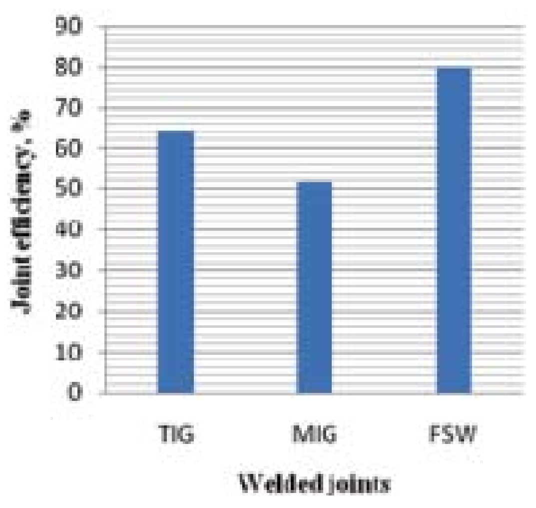
Table 5: UTS and Joint Efficiency of Welded Joints

Type of Joint	Ultimate Tensile Strength (MPa)	Joint Efficiency (%)
TIG	200	64.5
MIG	160	51.6
FSW	248	80

Joint Efficiency: The joint efficiency is the ratio of ultimate tensile strength of welded joint to the ultimate tensile strength of BM. The UTS of different welds is shown in the table given below:

The joint efficiency of TIG welded joint is 64.5% and the joint efficiency of MIG welded joint is 51.6%. The joints fabricated with the help of FSW shown the higher joint efficiency. The joint efficiency is 80% in FSW. This value is 19.4% higher as compared to TIG welded joint efficiency and 35.5% higher as compared to MIG welded joint efficiency. These results show that the joint fabricated with the help of FSW possess having higher joint efficiency. These efficiencies can be shown graphically as follows:

Figure 3: Tensile Properties of BM and Different Welded Joints



CONCLUSION

In the present work TIG, MIG and FSW welding processes were used to weld aluminium alloy AA6061. As we know that the welding of aluminium and aluminium alloys is not an easy task and it requires a lot of considerations for the proper joining of the BM. Following conclusions may be drawn from the study:

1. The heat input in case of FSW is less than that of TIG and MIG welding processes. Among these three welding processes, in FSW heat input are 38% less as compared to TIG welding and 51.2% less as compared to MIG welding process.
2. In welded joints obtained by three welding processes, the joint fabricated by FSW process exhibited higher joint efficiency than that of TIG and MIG welding processes.
3. FSW joint efficiency is 19.4% higher as compared to TIG welded joints and 35.5% higher as compared to MIG welded joints.
4. With the help of FSW as comparison to TIG and MIG, nice welds having higher joint efficiency with less heat input can be get.

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