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EXPERIMENTAL ANALYSIS ON FRICTION STIR WELDING PROCESS PARAMETERS ON TEMPERATURE DISTRIBUTION

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Abstract

In most cases fusion welding of aluminium and its alloys is difficult because of their low melting point despite many useful properties like high thermal conductivity, less corrosive nature and light-weight. Although successful, but the implementation of FSW is difficult due to lack of literature, like parameters such as temperature distribution, torque etc., are not fully developed. In this project, the temperature distribution in Al alloy welding sample during Friction stir welding at different parameters has been analysed. The experiments were carried out in the universal milling machine where mild steel is used as a tool, which was prepared in the centre lathe machine available at Assam Down Town University workshop .The experiments were performed by varying the weld parameters such as feed rate, spindle speed and probe diameter. The temperature of welding specimen is measured at different zones of welding sample with the help of a laser temperature gun.

Keywords

FSW, Temperature Distribution, Feed Rate, Spindle Speed, Probe Diameter

1. INTRODUCTION

Welding is a process, where two metals are joined together and form one piece when heated to a temperature high enough to cause softening or melting of the metals. Friction Stir welding process is mainly suitable for low melting metals and researchers trying to develop its process. Rai et al [1] has found that the shape and size of the tool shoulder and pin affects the heat generation rate and plastic flow in the work piece. The tool is designed by trial and error method.. Mishra et al [2] found that friction stir welding exhibits a considerable improvement in strength, ductility, fatigue and fracture toughness, compared to fusion welding. Fatigue life of friction stir welds is lower than the base material but substantially than that of laser welds and MIG welds. After removing all the profile irregularities from the weld surfaces, fatigue strengths of friction stir welding specimens were improved to levels comparable to that of the base metal. The fracture toughness of friction stir welding weld is observed to be higher than or equivalent to that of the base material. For corrosion properties of friction stir welding, contradicting observation have been reported. D. Venkateswarlu et al [3] has found that pin diameter has the maximum influence compared to the shoulder of the tool, among control factors that determines the tensile strength of the weld. The weld cross-sectional area was also found to depend on the tool pin diameter and the affects was almost similar to the weld tensile strength.

Imer et al [4] has found that the tool has to bear significant loads and so for designing of the tool must considerations like material, surface quality and geometry of the tools should be taken into account. The tool has to undergo more evolution for better friction stir welding quality. Zang et al [5] has found that, low cost and long life welding and processing tools have been well developed for low strength materials such as aluminium and magnesium alloys. Yuh et al [6] has found that about 5% of the heat generated by the friction process flows to the tool and the rest flows to the work piece. The ‘‘heat efficiency’’ in Friction Stir Welding is thus 95%, which is very high relative to the traditional fusion welding where the heat efficiency is typically 60 to 80%. Liu et al [7] has found that the shoulder size and pin length are changed slightly, and the radial wear of the pin is most severe for the whole tool. The radial wear of the pin is very different at different locations of the pin, and the maximum wear is finally produced at a location of about one third pin length from the pin root. The welding speed has a decisive effect on radial wear rate of the pin. The lower the welding speed, the higher the wear rate, and the maximum wear rate are produced in the initial welding. Bruno de meester et al [8] has performed experiments on similar and dissimilar welds of Al alloys and has found that increase in tool rotation speed increases the maximum temperature during welding and the maximum temperature rise in both the welds doesn’t exceed 500° C.

2. THEORY

2.1Welding characteristics

Temperature profile and history of FSW process are resembled by the distinct regions at the weldment. These regions are characterized by discrete microstructure sizes, shapes and varying properties, produced by the significant thermal effect and mechanical deformation. Under the heat generation, lump effect and heat transfer of the process, thermal profiles are being distributed from the crown shaped heat source around the rotating tool to work material interface toward the peripheral work materials surfaces and edges. These regions are known as:

a) Weld nugget, the product of plastic deformation due to the stirring effect deposited behind the rotating tool pin at the trailing edge.

b) Thermo-Mechanically Affected Zone (TMAZ) of internally sheared plastic deformation within the work material away from rotating tool to work material interface.

c) Heat Affected Zone (HAZ) of structurally altered and thermally affected region due to intense temperature difference between TMAZ and base metal temperature region.

d) Base metal of work material which is not physically affected by the thermal effect.

2.2 Heat Transfer

One of the key elements in the friction stir welding (FSW) process is the heat generated at the interface between the tool and the work piece which is the driving force to make the FSW successful. The heat flux must keep the maximum temperature in the work piece high enough so that the material is sufficiently soft for the pin to stir but low enough so the material does not melt. The maximum temperature created by FSW process ranges from 50% to 60% of the melting temperature of the welding material, so the defects associated with fusion welding are minimized or avoided.

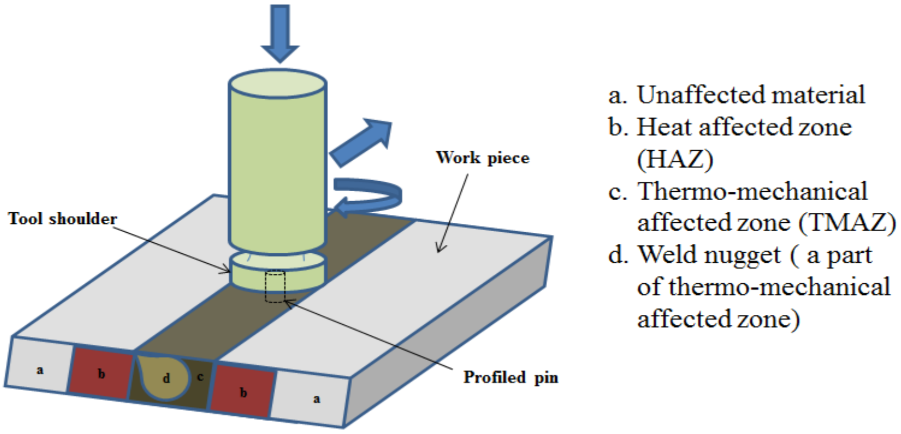

Fig.1 Weld zones

3. EXPERIMENTAL PROCEDURE

The experiments were carried out in a vertical milling machine where clamps of mild steel is fitted on the ramp head of the milling machine as shown in fig.3.The tools are made from mild steel rod of 50mm diameter and 100mm length in a Lathe machine at Assam down town University workshop. The tools are prepared at different probe diameter. The dimensions of the tool were taken so that it fits the smallest collet that fits the spindle of the milling machine. The diameter of the shank is taken 12mm and length 51mm and the probe diameters 5mm, 4mm and 3mm are varied according to the experiments and the shoulder diameter is 12mm as shown in fig 2.Then the tool is allowed to stir across the length of the aluminum sample as shown in fig 4 due to which the metal joins.

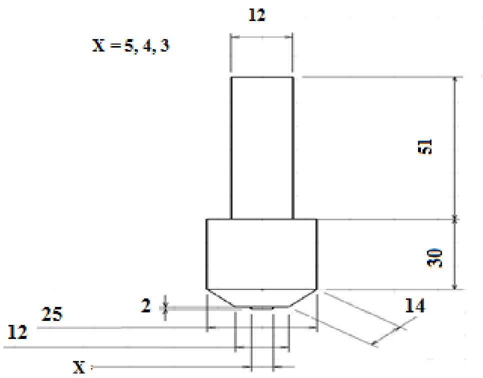

Fig.2 Tool with Dimensions

The welding process was carried out at different parameters such as feed rate, spindle speed and probe diameter as shown in table 1. Twenty seven experiments were conducted for investigating the variation of temperature with different parameters and the numbers of experiments was designed by using factorial method. The variation of temperature with respect to time, at the midpoint of the weld line is measured during welding using a laser temperature gun which when pointed at a particular point directly gives the reading of the temperature at that point.The temperature was measured by using a laser temperature gun and it was calibrated with a digital thermometer at boiling temperature of water.

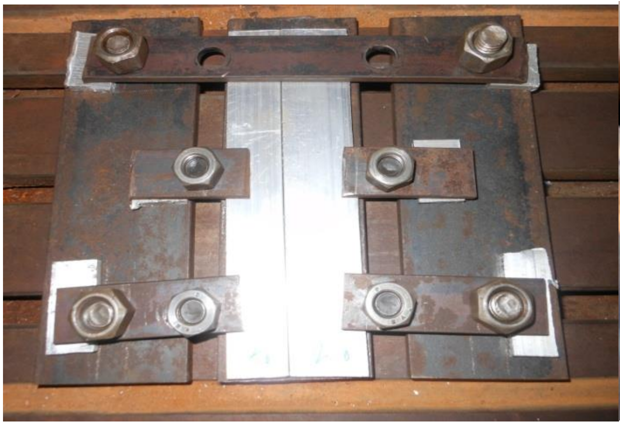

Fig.3clamping of specimen

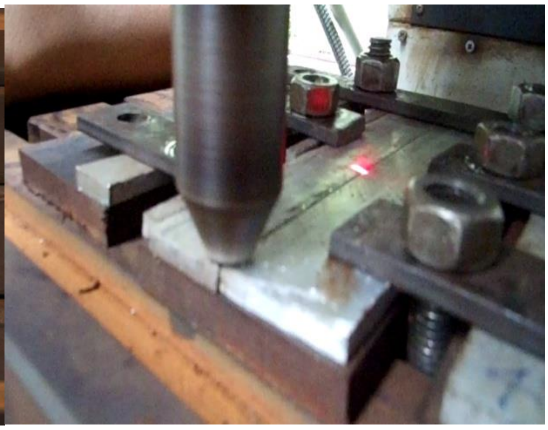

Fig.4 Welding process

Table: 1

Feed rate	Speed	Probe diameter
42 mm/min	495RPM	3 mm
74 mm/min	675 RPM	4 mm
98 mm/min	850 RPM	5 mm

Design of experiment:

No of experiments = (no of levels) $^{\text{no of factors}}$

= 27 experiments

4. RESULTS

The temperature at different weld zones of the work piece is measured at different time intervals to analyse the transient temperature distribution at the weld zone. It is found that temperature varyat different regions at different parameters .with respect to time. The temperature-time relations at feed rates (42mm/min , 74 mm/min , 98 mm/min) , spindle speeds (495 RPM , 675 RPM ,850 RPM) and probe diameters (3 mm,4 mm,5 mm) are shown in fig 5.

4.1. Temperature (k) vs. Time (sec)

The temperature-time graph for all the parameters is shown in fig 5. The temperature is measured at the mid-point of the welding line and it is seen temperature is highest during welding and it cools down very rapidly within 60 seconds. At probe diameter of 3 mm as shown in fig.5(a.1), temperature recorded was highest with the value of 417K, at feed rate of 42 mm/min and speed of 495 RPM and the least temperature recorded was 375.1K, at feed rate of 74 mm/min and speed of 495 RPM. At probe diameter of 4mm, highest temperature recorded was 408.6K, at feed rate of 42 mm/min and speed of 675 RPM and least temperature recorded was 349.5Kat feed rate or 98 mm/min and speed of 675 RPM and At probe diameter of 5mm, highest temperature recorded was 380.3K, at feed rate of 42 mm/min and speed of 850 RPM and lowest temperature recorded was 355.8K, at 98 mm/min and 850 RPM. So here we can say the maximum temperature achieved is about 50% to 60% of the melting temperature of the Al alloy.

4.2. Temperature (K) vs.feed rate (mm/min)

The temperature variation with respect to feed rate at constant probe diameter is shown in figure 6. Here we see the temperature decreases at the beginning and then it increases from 75 mm/min. At feed rate 42mm/min, temperature increases with increase in speed from 495 rpm to 675 rpm and decreases with further increase in temperature from 675 rpm to 850 rpm. At feed rate 74mm/min, temperature slightly increases with increase in speed of the rotating tool. At feed rate 98mm/min, temperature decreases with increase in speed from 495rpm to 675 rpm and slightly increases with increase in speed from 675rpm to 850 rpm. Highest temperature rise at constant probe diameter 4mm is about 386 K a feed rate of 42mm/min.

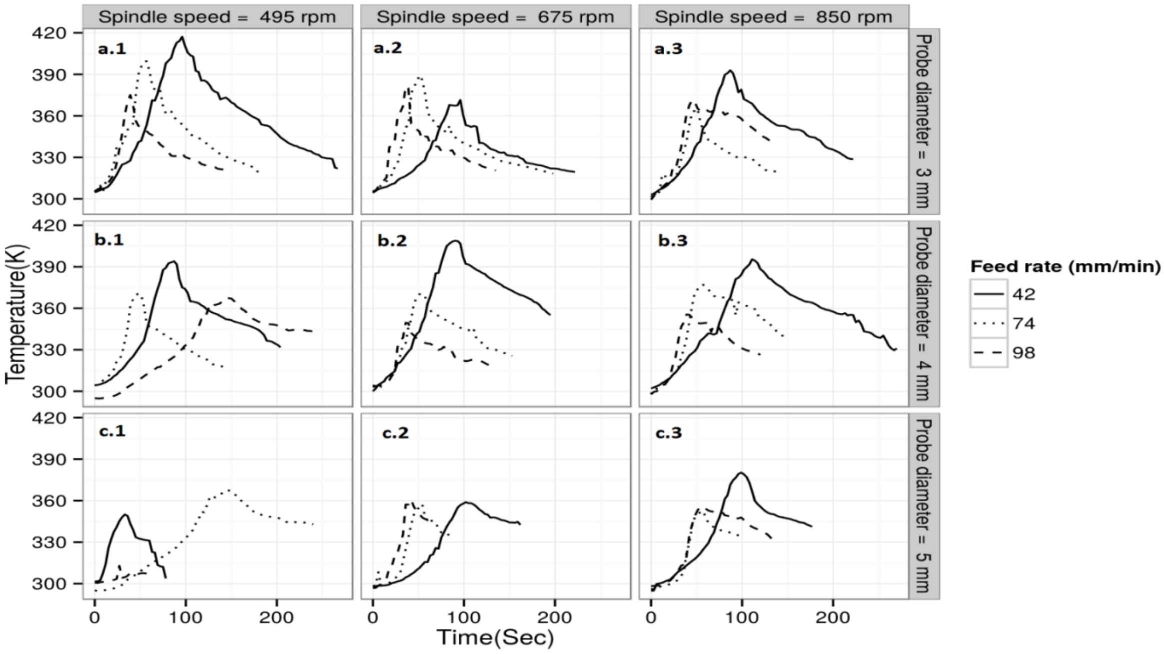

Fig.5Temperature (K) vs. time (sec) variation with varying spindle speed, probe diameter and feed rate

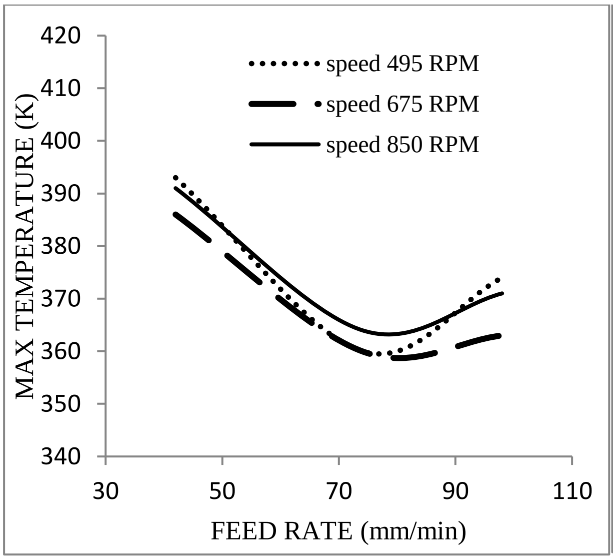

Fig 6: Temperature vs. Feed rate graph at different speed at constant probe diameter

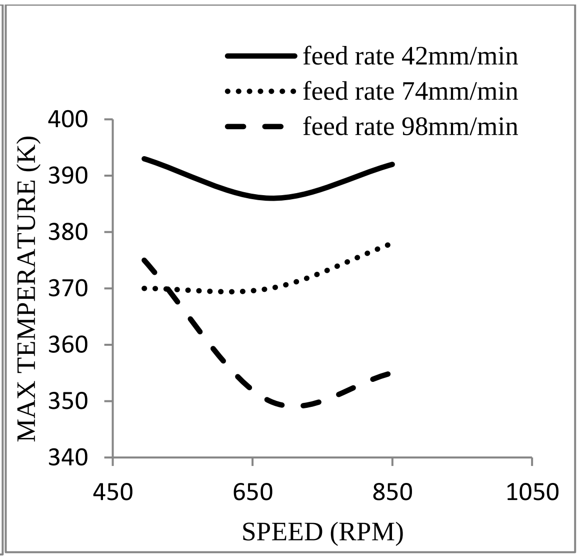

Fig.7 Temperature vs. speed graph with constant probe dia. at different feed rates

4.3. Temperature (K) vs. Speed (RPM)

The change in temperature with respect to spindle speed is shown in figure7. It can be concluded from the graph that temperature decreases with increase in feed rate from 42 mm/min to 98 mm/min. The highest temperature is achieved at feed rate 42 mm/min and lowest temperature is at feed rate 98 mm/min. The highest temperature is achieved at speed 675 RPM and lowest temperature is at speed 850 RPM.

5. CONCLUSION

The maximum temperature achieved by FSW process ranges from 50% to 60% of the melting temperature of the Al alloy, so the defects associated with fusion welding are to be minimized or avoided. The changes in temperature depend upon feed rate, probe diameter and spindle speed. The temperature is maximum when we increase or decrease the parameters up to certain level.

Brinile hardness testing was done for the weld specimen to compare the hardness between the welded and un welded zones of the specimen, where it is found that the hardness value at the welding zone is less than base metal.

6. ACKNOWLEGMENT

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