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SUPERPLASTIC FORMABILITY OF FRICTION STIR WELDED ALUMINIUM ALLOY

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Abstract: Superplastic forming has now become conventional for forming, complex parts from sheet metals. In many superplastically formed aerospace components, only a selective region undergoes superplastic forming. In those cases, instead of selecting a material exhibiting superplastic properties, a light weight and low cost material can be chosen and its microstructure can be modified locally by the Friction Stir Processing (FSP) technique. In this work, AA6061-T6 alloy is chosen, and friction stir processing is performed by varying the process parameters, such as tool traversing speed and tool rotational speed. The process parameter that produced equiaxed grains in the stirred zone with a grain size less than 10 µm is selected. Uniaxial hot tensile experiments were performed for the FSP specimens at a constant strain rate of $7.1 x 10^{-3} s^{-1}$ with constant temperature of $550^{o}C$. The strain rate sensitivity was found to be 0.4698 for the FSP processed specimens.

Keywords: Friction stir Welding, Super Plastic Forming

1 Introduction

Superplastic forming (SPF) process is a metal forming process that takes the advantage of the metallurgical phenomenon of superplasticity to form complex and highly complicated sheet metal parts[1]. Superplasticity refers to the formability of certain metal sheets and other materials to undergo very large plastic strain.

To begin with, the material must have an ultra-fine grain size. It is then heated up to promote superplasticity. For titanium alloys e.g. Ti 6Al 4V and some stainless steels this is around 900 °C (1,650 °F) and for aluminium alloys it is between 450–520 °C [3]. In this state the material is not very strong so processes that are usually used on plastics can be applied, such as: thermoforming, blow forming, and vacuum forming; it may also be deep drawn.

Hot tensile test is the method in which we use tensile testing machine with furnace and extensometer where the specimen is hold. By using this method we can find out the tensile strength, elongation, yield strength properties of different materials and its alloy, at high temperature. Also we can study the micro structural changes at high temperature by examine the fractured components under SEM and TEM.

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2. Experimental Setup

The schematic arrangements of the friction stir processing as shown in the Figure 2.1

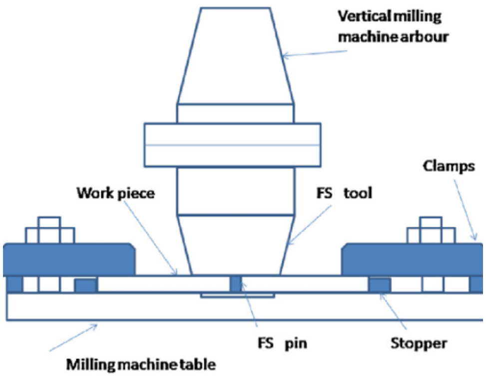


Figure 2.1 Schematic Arrangement of Friction Stir Processing

2.1 Tool design

As per the literature survey the shoulder should be 3 times of the thickness of the work piece and the pin diameter is equal to the work piece thickness[5]. The work piece is chosen is aluminium alloy with 2 mm thickness. HSS material was chosen and manufactured as per the given below diagram. The length of the tool is 60 mm, diameter of shoulder is 12 mm and the pin diameter is 3 mm with height of 1.5 mm. Taper were formed in the pin rom 3 mm to 2 mm to improve the flow of material during stirring. The nomenclature of the friction stir processing tool as shown in Figure 2.2.

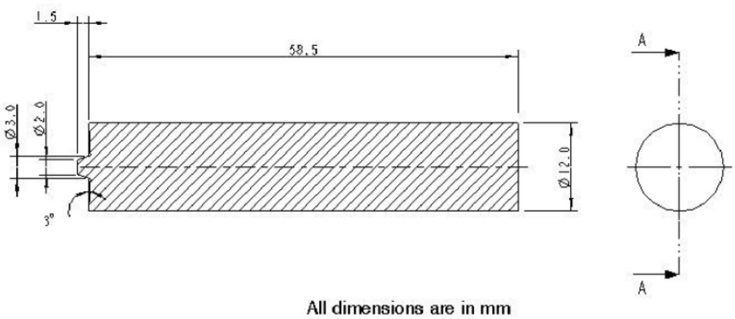
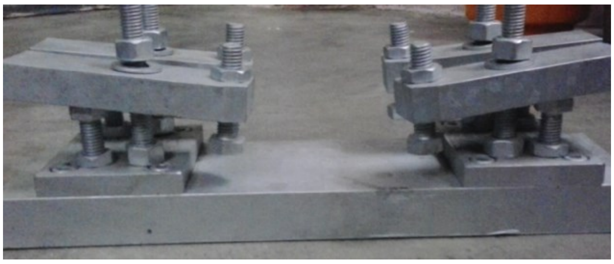


Figure 2.2 Tool Specifications

2.2 Fixture Design

After modeling the fixture, the parts of the fixture is detailed. Proper material is choosed for the fixture parts. Then the parts are machined and plated to prevent it from rusting. The fabricated fixture was shown in Figure below 2.3



3. Experimental Procedures

The following procedural steps are followed while doing friction stir processing
i. The aluminium alloys AA6061-T6 was chosen for this experiment.
ii. Required size of specimen was cut from the sheet and the edges are finished with the help of the vertical milling machine.
iii. The prepared specimen was fixed rigidly in the fixture.
iv. The total fixture was fixed with the clamping bolts the schematic arrangement.
v. FSP tool was fitted in the vertical milling machine arbor`
vi. The flatness of the work piece was checked by using dial gauge.
vii. Spindle rotation was set at 1100 revolutions per minute and feed rate of 30 mm/min.
viii. The tool is inserted into the workpiece and dwell period of 20 seconds were given to generate the heat.
ix. Then the longitudinal feed was given to complete the process.

4. Result and Discussion

The hot tensile test is carried out in FSP AA6061-T6 alloy at constant strain rate and particular temperature. Working condition of this specimen, Temperature T = 550°C

Strain rate $\acute{\varepsilon} = 7.1x10^{-3}\ s^{-1}$

4.1 Microstructure study

From the Figure 4.1 Shows the microstructure of parent metal-1 AA 6061 as per the sketch of the process. The micrograph shows parallel grains of cold worked sheet of 6061 with Mg_2Si eutectic constituents in the same direction in primary aluminium solid solution. The elongated primary aluminium is along the direction of rolling. The Mg_2Si precipitated particles are at the grain boundaries.

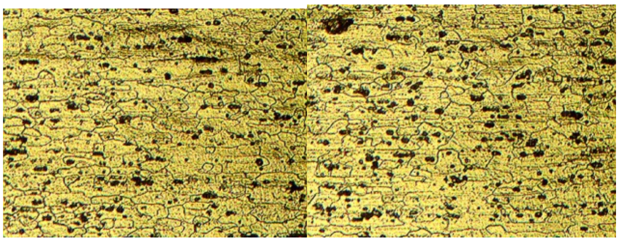


Figure 4.1 Microstructure of the Parent Material

From the Figure 4.2 the heat affected region of the fsw process close to the nugget zone. The metal matrix undergone dissolution of some Mg_2Si particles and the grains show partial re-crystallization.

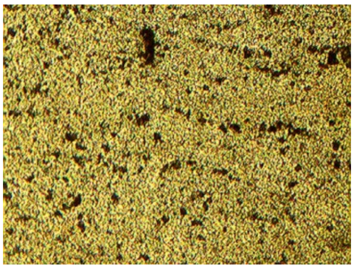


Figure 4.2 Heat Affected Zone

Figure 4.3 Shows the interface junction of parent metal-1 and the nugget zone with fusion line at the center. The fusion is complete without any discontinuities. The right side of the image shows nugget zone and the parent metal heat affected zone at the left side of the image. The nugget zone shows fine grained fragmented particles of Mg2Si in aluminium matrix. The left side shows heat affected zone and partial dissolution of some Mg_2Si particles.

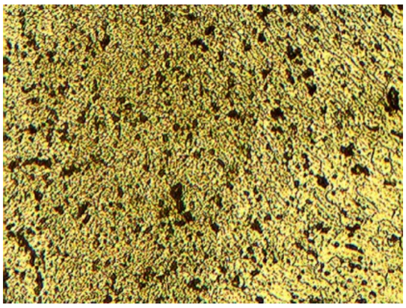


Figure 4.3 Heat Affected Zone 1

From the Figure 4.4 These micrographs were taken at the ngget zone at center and at the bottom of the nugget zone. The microstrcture shows fine fragmented particles of eutectic Mg2Si and the matrix undergone dynamic recrystallization due to the rapid process of fsw with heat and stress.

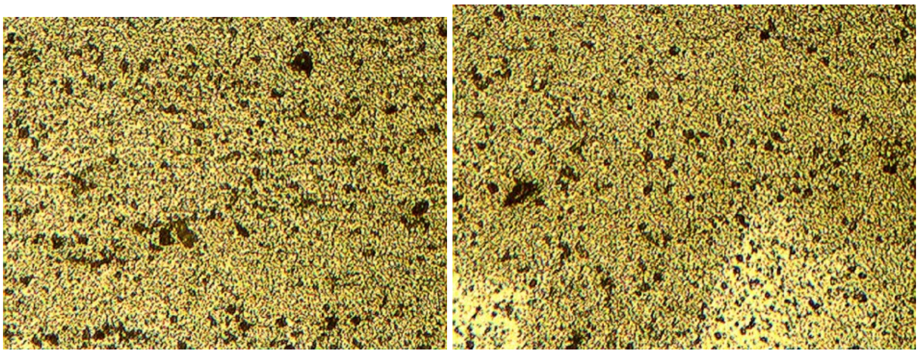


Figure 4.4 Nugget Zone

Photo-7: Shows the inter face junction of nugget zone and the parent metal-2 of the process. The left side parent metal shows some orientation due to spinning of the tool and the right side shows the nugget zone with fragmented particles. The particles of nugget zone is finer to 5 microns.

Photo-8: Shows the heat affected region of the fsw process close to the nugget zone of parent metal-2. The metal matrix undergone dissolution of some Mg_2Si particles and the grains show partial re-crystallization. Photo-9: Shows the microstructure of parent metal-2 AA 6061 as per the sketch of the process. The micrograph shows parallel grains of cold worked sheet of 6061 with Mg_2Si eutectic constituents in the same direction in primary aluminium solid solution.

5. CONCLUSION

The following conclusion has been drawn from superplastic forming

of friction stir processed aluminium alloy 6061-T6.

i. From the literature survey, the principle and process variables of FSP and superplasticity are well understood.

ii. Aluminium alloy AA6061-T6 has been selected for FSP.

iii. FSP process variable such as tool rotational speed of 1100rpm and feed rate of 30mm/min has been performed.

iv. Uniaxial hot tensile experiments had been performed for FSP specimens for strain rate of $7.1 x 10^{-3}$ s-^{1} and constant temperature of 550°C.

v. The strain rate sensitivity was found to be 0.4698 for the FSP processed specimens.

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