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Experimental and Numerical Analysis of Thermal Bonding Process in Friction Stir Welded- Different Brass Plates

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Abstracts

In this paper we have investigated application of FSW technology in aircraft structures mainly as substitution on stringer reinforced plates. Manufacturing process steps were determined and further optimization procedures were suggested. Knowledge base for setting basic welding parameters has been created and comparison of a sample of plates and FSW technologies on a simple final element method model plates examined in order to identify differences in stress distribution character in the finalized using COMSOL 4.3b Multiphysics software.

Keywords: Friction stir welding, Thermal Bonding Stress, Experimental, FEA, COMSOL.

Introduction

Friction stir welding is a relatively new joining technique, invented at The Welding Institute (Cambridge, UK) in 1991 and developed initially for copper alloys. It involves the joining of metals without fusion or filler materials. It is used already in routine, as well as critical applications, for the joining of structural components made of aluminium and its alloys. Since FSW is essentially solid-state, i.e., without melting, high quality weld can generally be fabricated with absence of solidification cracking, porosity, oxidation, and other defects typical to traditional fusion welding.

FSW can be used to join many types of similar and dissimilar material combinations provided that tool head can be developed to operate compatibly in the hot working temperature range of the work pieces. Friction stir welding was used to control properties in structural metals including aluminium and the other nonferrous alloys. The pin may have a diameter one-third of the cylindrical tool shoulder.

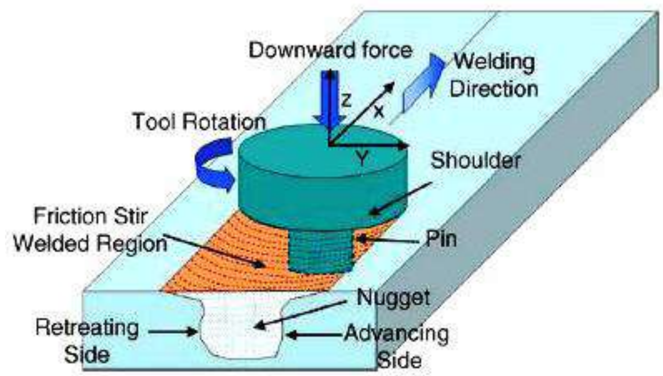
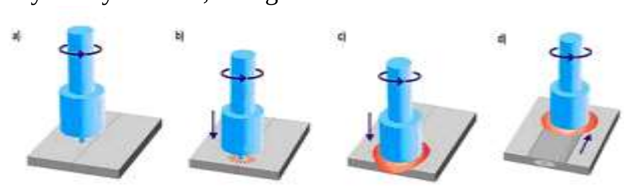


Fig.1 Arrangement of Friction Stir Welding

Friction stir welding process(Fig.1.2) : (a) rotating tool prior to contact with the plate; (b) tool pin contacts plate creating Shear; (c) shoulder of the tool contacts the plate, restricting further penetration while expanding the hot zone; (d) plate moves relative to rotating tool creating a fully re-crystallized, fine grain microstructure.



(a) (b) (c) (d)

The maximum om 70% to 80% of the melting temperature of the work piece, so that welding defects and large distortion commonly associated with fusion welding are minimized or avoided.FSW joints usually

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consist of four different regions as shown in figure 1.3They are:

(A) Unaffected base metal
(B) Heat Affected Zone (HAZ)
(C) Thermo-Mechanically Affected Zone (TMAZ) and
(D) Friction Stir Processed (FSP)

zone.

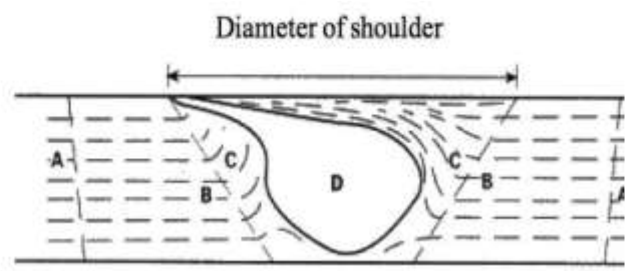

Fig.2 Different regions of FSW joints

Moreira et al have been produced the stir butt weld of AA6082-T6 with AA6061-T6. In this report, we see that the friction stir welded AA6082-T6 material revealed lower yield and ultimate stresses, and the dissimilar joints displayed intermediate properties. In the tensile tests, failures occurred near the weld edge line where a minimum value of hardness was observed. This corresponds to the location of rupture when tensile testing the dissimilar joints. Nevertheless, in the nugget zone all three joints present similar values. In the analysis of the dissimilar joint the mixture of the two alloys is easily identified by the different etching response of both alloys.

Cavaliere et.al have been studied the mechanical and micro structural behavior of dissimilar FSW AA6082-AA2024. The joints were realized with a rotation speed of 1600rpm and by changing the advancing speed from 80 to 115 mm/min. The vertical force was observed to increase as the travel speed for all the produced joints increases. The best tensile and fatigue properties were obtained for the joints with the AA6082 on the advancing side and welded with an advancing speed of 115 mm/min.

Shanmugasunndaram et. al, has found the effects of FSW process parameters viz. tool rotational speed, welding speed and tool axial force on ultimate tensile strength and tensile elongation of dissimilar FS welded joints are evaluated for various tool pin profiles. He stated that the ultimate tensile strength of FSW joints is lower than both the base metals irrespective of the operating parameters used to fabricate the joints. It is observed that when the combinations of parameters create very low or very high frictional heat and material flow, then lower tensile strength is observed.

S.T.Amancio-Filho et.al had produced the defect-free FSW of dissimilar alloys AA2024-T351/AA6056-T4.The maximum temperatures close to the weld centre measured during process within 300-400˚C. Tensile test have shown reasonable joint efficiencies in terms of ultimate tensile strength (around 56. 0% of the 2024-T351 and 90% of the 6056-T4 alloys) but poor efficiency in terms of elongation at the rupture (9.0%). The TMAZ of AA6056-T4 was the location where a crack could initiate and propagate.

Methodology

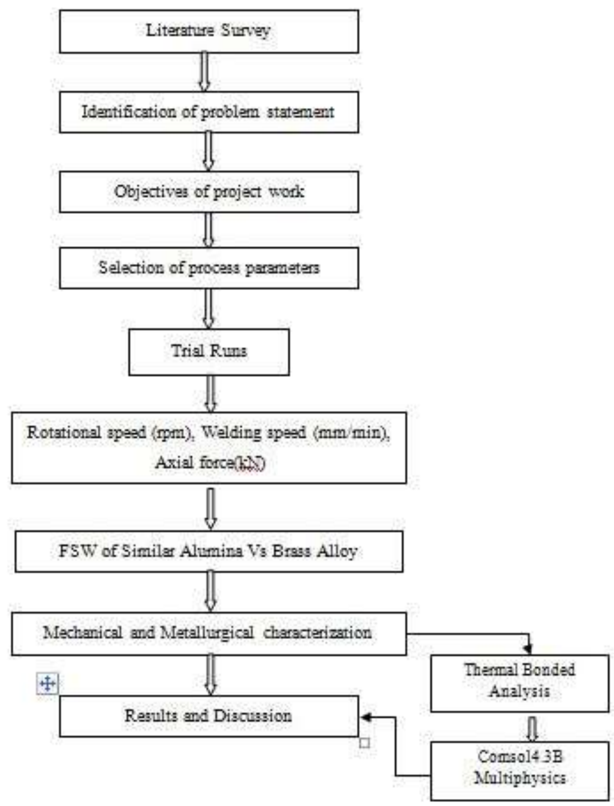

Fig.3 Methodology

FSW process parameters

There is a volumetric contribution to heat generation from the adiabatic heating due to deformation near the pin. The welding parameters have to be adjusted so that the ratio of frictional to volumetric deformation-induced heating decreases as the work piece becomes thicker. This is in order to ensure a sufficient heat input per unit length. The microstructure of a friction stir weld depends on the tool design, the rotation and traverse speeds, the applied pressure and the characteristics of the

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material being joined. There are a number of zones. Weld quality depends on

1. Tool rotation (spindle speed)
2. Traverse speed or welding speed (feed rate)
3. Applied pressure
4. The material characteristics
5. Tool depth
6. Tool profile

Tool design

Tool design influences heat generation, plastic flow, the power required, and the uniformity of the welded joint. The shoulder generates most of the heat and prevents the plasticized material from escaping from the work–piece, while both the shoulder and the tool–pin affect the material flow. In recent years several new features have been introduced in the design of tools. The Whorl and MX-Triflute have smaller pin volumes than the tools with cylindrical pins.

Fig.4 Round Type Pin Tool

Consequently, more intense stirring reduces both the traversing force for the forward tool motion and the welding torque. Although cylindrical, Whorl and Triflute designs are suitable for butt welding, they are not useful for lap welding, where excessive thinning of the upper plate can occur together with the trapping of adherent oxide between the overlapping surfaces.

Fig.5 Round Type Pin Tool (Isometric Model)

The Flared-Triflute tool is similar to MX-Triflute with an expanded flute, while A-skew TM tool is a threaded tapered tool with its axis inclined to that of the machine spindle. Both of these tools increase the swept volume relative to that of the pin, thus expanding the stir region and resulting in a wider weld and successful lap joint.

Tool rotation and traverse speed

There are two tool speeds to be considered in friction-stir welding, how fast the tool rotates and how quickly it traverses the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient welding cycle. The relationship between the welding speeds and the heat input during welding is complex but, in general, it can be said that increasing the rotation speed or decreasing the traverse speed will result in a hotter weld. In order to produce a successful weld it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimize the forces acting on the tool. If the material is too cool then voids or other flaws may be present in the stir zone and in extreme cases the tool may break.

Development of FSW tool

Tool design (materials and configuration) is one of the most important factors that influence joint profile, microstructure and properties. Tool materials, apart from having to satisfactorily endure the welding process, affect friction coefficients, hence heat generation. The same is true for any coatings that might be applied to tool surfaces. Tool configuration influences joint size and profile. In general, pin length needs to be optimized around stock thickness

The various stages involved in fabrication of FSW tool are,

- Material Selection for the tool
- Design of tool geometry

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- Specifications of FSW Tool
- Shoulder
- Pin
- Material Selection
  (High Carbon High Chromium Steel)
- Manufacturing Technique
  (Oil Hardening-63HRC)

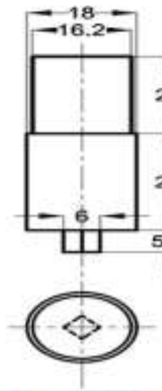

Fig.6 Straight type pin tool attached with FSW machine

Work holding device

Work holding device consists of base plate and fixture which is used to hold the specimen rigidly. The size of the fixture can be varied according to the dimensions of the specimen. The primary objectives of using a work hold device in a FSW machine are,

- To position the work piece in a definite location relative to the worktable
- To withstand holding and tool forces
- Maintaining the precise location of joint
- High degree of safety

The work holding device of the FSW machine is shown in Fig 2.4

Fig.7 work holding device

Numerical analysis

In friction stir welding, a rotating tool moves along the weld joint and melts the aluminum through the generation of friction heat. The tool's rotation stirs the melted aluminum such that the two plates are joined. Figure 1 shows the rotating tool and the aluminum and copper plates being are thermally joined.

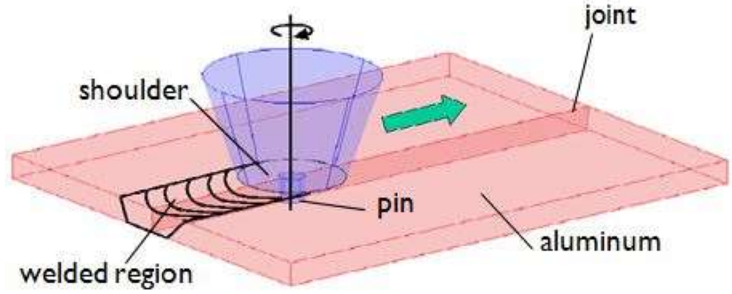

Fig.8 Two aluminum plates being joined by friction stir welding.

The rotating tool is in contact with the aluminum plates along two surfaces: the tool's shoulder, and the tool's pin. The tool adds heat to the aluminum plates through both interfaces. During the welding process, the tool moves along the weld joint. This movement would require a fairly complex model if you want to model the tool as a moving heat source. This example takes a different approach that uses a moving coordinate system that is fixed at the tool axis (Ref. 1 also takes this approach). After making the coordinate transformation, the heat transfer problem becomes a stationary convection-conduction problem that is straightforward to model.

Model definition

The model geometry is symmetric around the weld. It is therefore sufficient to model only one aluminum plate. The plate dimensions are.120 mm-by-102 mm-by-12.7 mm, surrounded by two infinite domains in the *x* direction. Fig.9 shows the resulting model geometry:

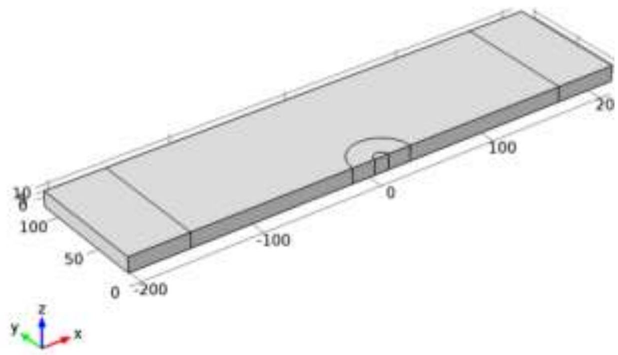

Fig.9 Model geometry

Meshing

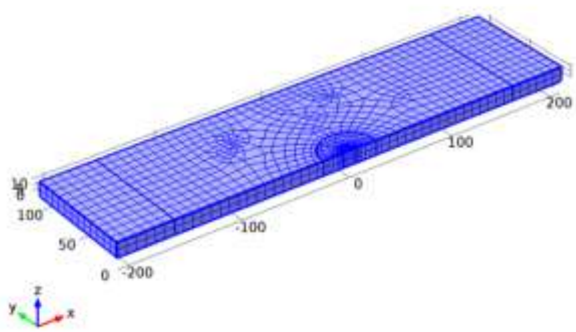

Fig.10 Mesh model

Boundary Conditions

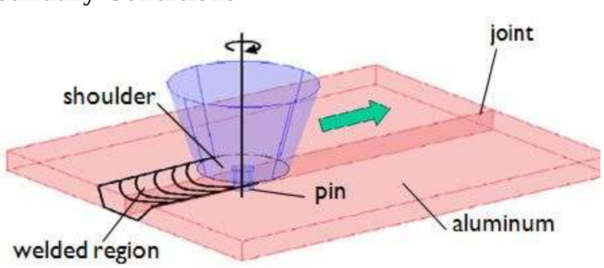

Fig.11 Boundary conditions

Numerical results

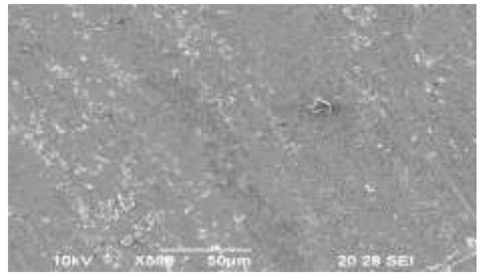

Fig.12 The SEM images of Brass alloy 50µm x 500

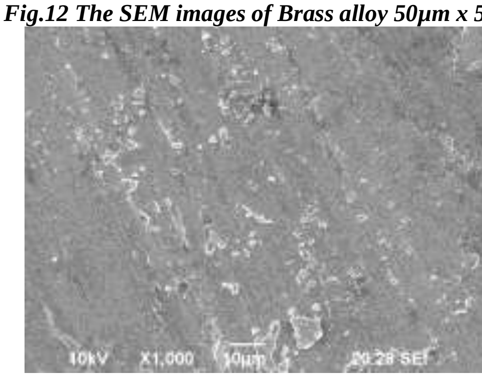

Fig.13The SEM images of Brass alloy 10µm x 1000

From the fig.12-15 it was observed that there will be a fine film is visible which reduce the friction of the material, that means it increase the lubricating property of the material. The black portions represent the MoS2. Moreover the SEM image shows the uniformity in the distribution.

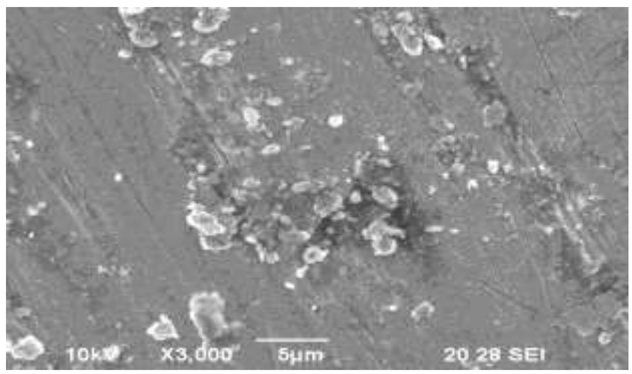

Fig.14 The SEM images of Brass material 5µm x 3000

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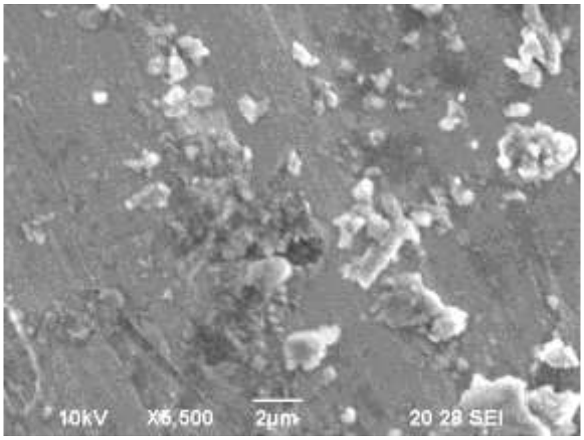

Fig.15 The SEM images of Brass Material 2μm x 5500

The image shows the unevenness of the specimen and hence the white patches here and there are seen. During welding the hard particles creates voids which are seen in the image.

Numerical discussion:

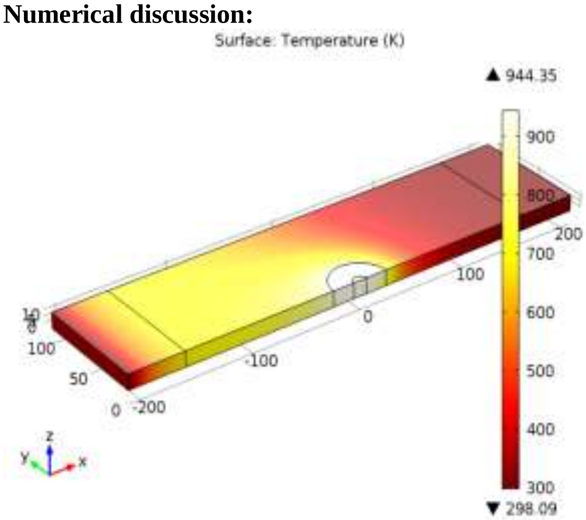

Fig.16 Surface: Temperature (K)

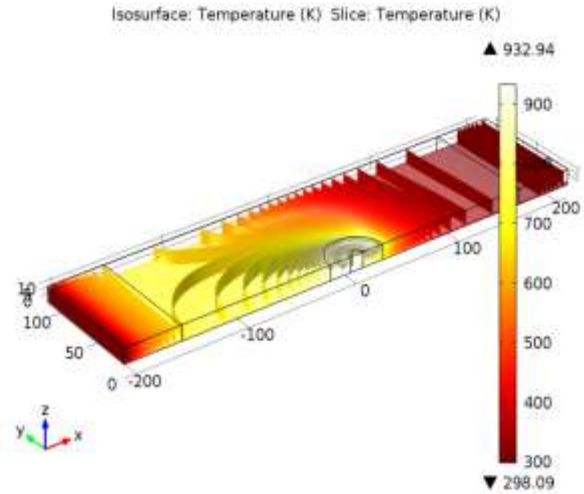

Fig.17 Isosurface: Temperature (K) Slice: Temperature (K)

In this Operating temperature its consisting to simulate the results are validated and numerically analyzed results are simulated as shown this graph.

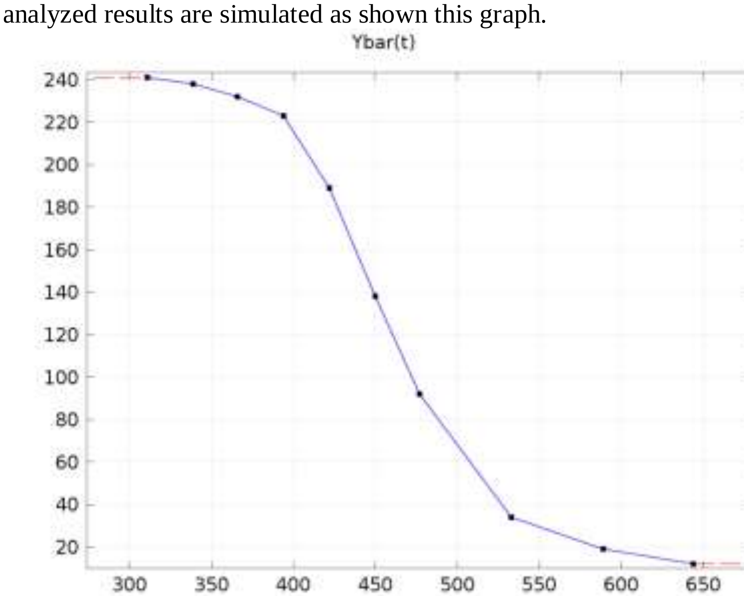

Fig.18 Temperature graph and Pressure

Conclusion

The Brass a l l o y was Internal reinforced with Aluminum alloy material. The presence of Sic will strengthen the Al matrix. The developed Brass composite were tested for mechanical properties like hardness, tensile. They are also tested for adhesive wear using pin on plate to apply different stir welding apparatus. The developed Brass material with welded in friction stir welding was characterized using SEM and numerical analysis.

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1. Reinforcement improves the Brass material hardness to an extent of 15% when compared with base alloy aluminium alloy thermal bonding.

2. The Tensile strength improves to an extent of 21% due to the addition of Aluminum alloy.

3. Results from SEM and NDT convey the presence of reinforcement and uniform distribution.

4. Finally comparing numerical results are to consumed old cause material in Aluminum alloy Vs brass material alloy to comparing thermal bonding material should be very quickly and effectively and without failure to be consist to apply bonded material causes in Better performance analysis in Brass causes material in 326 rpm of this speed range it's perfectly bonded in natural thermal conduction.

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