Investigation On The Change Effected By The Tool Type On The Hardness Of Friction Stir Processed By Copper

GOLLU NAIDU
M.Tech (AMS) Student, Dept.of Mechanical Engineering, Sai Ganapathi Engg. College, visakpatnam, Andhra Pradesh, India

Dr .M.MURALI KRISHNA
Professor, Principal, Dept.of Mechanical Engineering, Sai Ganapathi Engg. College, visakpatnam, Andhra Pradesh, India

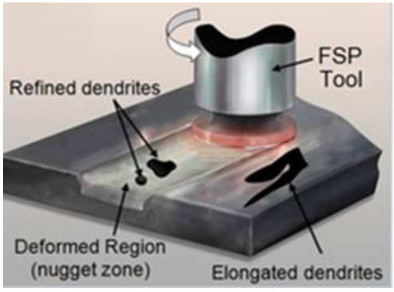
***Abstract*: Friction Stir Processing (FSP) is a new solid-state processing technique for micro structural modification which was developed based on the principle of Friction Stir Welding (FSW). The basic concept of FSP is remarkably simple. A non-consumable rotating tool with a pin and shoulder is inserted into a single piece of material and traversed along the desired path for localized micro structural modification for specific property enhancement in the processed zone due to intense plastic deformation, mixing and thermal exposure of material.**

Friction Stir Processing (FSP) is a solid–state surface modification technique to alter the properties of metals and alloys. This work studies the effect of FSP on pure copper with three different tool pin profiles (plain cylindrical, square and taper) at low-heat input condition. The tool rotational speed and tool traverse speed were kept constant to maintain the low heat input., micro hardness and tensile strength were analyzed to evaluate the modifications occurred in the mechanical properties.

Key words: **Friction Stir Process; Hardness; Tensile Strength; Copper Material;**

INTRODUCTION

Friction Stir Processing (FSP) is a new solid-state technique, which uses the principles of friction stir welding to process materials leading to new improved metallurgical conditions. In FSP a tool containing a shoulder and a pin provides mechanical mixing and heating resulting from interfacial friction and visco-plastic deformation, in the area processed by the tool. The FSP has four distinct regions; the nugget which is the region that is thermo mechanically processed zone where the grain size is refined and homogenized, the thermo mechanically affected zone (TMAZ) where the grain is elongated like it was mechanically deformed, the heat affected zone (HAZ) that as the same grain structure of the base material and the base material (BM) is the region that was unaffected by the process. The improvement of properties is related to the refinement of grain size in the nugget due to the large processing strain. FSP has been very successful in modification of various properties such as formability, hardness, yield strength, fatigue and corrosion resistance. It is becoming very effective in the production of metal matrix composites. FSP has also been very successful in the production of materials with super plastic behavior.



Friction Stir Processing (FSP)

• Friction Stir Processing (FSP) is a novel surface modifying technique that provides microstructural modification and control in the near-surface layer of metal components.

• FSP provides the ability to thermomechanically process selective locations on the structure's surface and to some considerable depth to enhance specific properties

• FSP was developed based on the basic concepts of Friction Stir Welding (solid state welding process), but FSP is used to modify the local microstructure and doesn't join metals together.

Working Principle of FSP

• A specially designed non-consumable cylindrical tool is rotated and plunged into the selected area, to friction process the required location within a plate or sheet

• Tool has a small diameter pin with a concentric larger diameter shoulder

• Tool shoulder and length of entry probe control the penetration depth

• When tool descended to the part, the rotating pin contacts the surface, rapidly friction produced between tool pin and metal surface heats and softens a small column of metal

• Rotating tool provides:

• Continuous heating of work piece

• Plasticizing metal

• Transporting metal from the leading face of the pin to its trailing edge

When the shoulder contacts the metal surface, its rotation creates additional frictional heat and plasticizes a larger cylindrical metal column around the inserted pin • The shoulder additionally provides a forging force that contains the upward metal flow caused by the tool pin.

• During FSP, work piece and the tool are moved relative to each other such that the tool traverses, with overlapping passes, until the required area is processed

• The processed zone cools, without solidification, as them is no liquid, forming a defect-free recrystallized, fine grain microstructure.

LITERATURE REVIEW

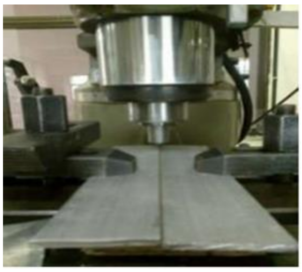
Surface composites by friction stir processing

Surface composites are suitable materials for engineering applications encountering surface interactions. Friction stir processing (FSP) is emerging as a promising technique for making surface composites. FSP can improve surface properties such as abrasion resistance, hardness, strength, ductility, corrosion resistance, fatigue life and formability without affecting the bulk properties of the material. Initially, FSP was used for making surface composites in aluminum and magnesium based alloys. Recently surface composites including steel and titanium based alloys have also been reported. While influence of process parameters and tool characteristics for FSP of different alloys has been considerably reviewed during the last decade, surface composites fabrication by FSP and the relation between microstructure and mechanical properties of FSPed surface composites as well as the underlying mechanisms have not been wholesomely reviewed. The present review offers a comprehensive understanding of friction stir processed surface composites. The available literature is classified to present details about effect of process parameters, reinforcement particles, active cooling and multiple passes on microstructure evolution during fabrication of surface composites. The microstructure and mechanical characteristics of friction stir processed surface micro-composites, nano-composites, in-situ composites and hybrid composites are discussed. Considering the importance of tool wear in FSP of high melting point and hard surface composites, a brief note on tool materials and the limitation in their usage is also provided. The underlying mechanisms in strengthening of friction stir processed surface composite are discussed with reported models. This review has revealed few gaps in research on surface composites via FSP route such as fabrication of defect-free composites, tailoring microstructures, development of durable and cost effective tools, and understanding on the strengthening mechanisms. Important suggestions for further research in effective fabrication of surface composited by FSP are provided.

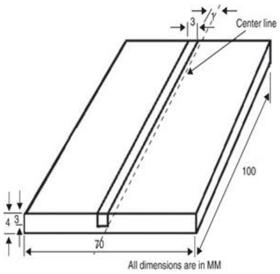
EXPERIMENTAL PROCEDURE

The experimental study includes the butt joining of 3 mm pure copper plates. The welding process is carried out on a vertical milling machine (Make HMT FM-2, 10hp, 3000rpm) as shown in Fig6.1. Tool is hold in tool arbor as shown in Fig 6.2. Special welding jigs and fixtures are designed to hold two plates of100mm X 70 mm X 4mm thickness as shown in fig 6.4.1. Table 6.1 shows the combinations of the tool rotational speed (RPM), welding speed (mm/min) and tool geometry and diameter of the tool shoulder to the diameter of the tool pin (Ds/Dp). These combinations are chosen based on the literature survey and the capability of the milling machine used for the experimental study.

Experimental setup was established using a conventional vertical milling machine Figure 1. No extra setup is required for friction stirwelding except tool and fixture, so as to place piece in proper position during welding. The specimen is fixed in the machine between the grips and machine the displacement between its cross heads on which the specimen is fixed. The objective of tensile testing was to determine the tensile yield strength and percentage of yield elongation of friction stir welds of copper.

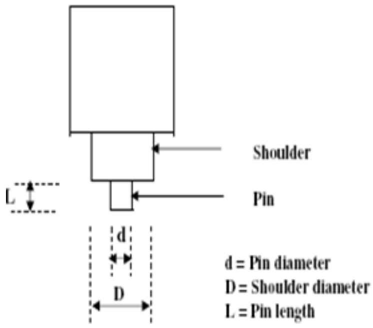


Schematic diagram of Vertical Milling Machine



Schematic sketch of composite

Element	Min.(% by Weight)	Max.(% by Weight)
Carbon	0.37	0.42
Manganese	0.2	0.5
Phosphorus	0	0.025
Sulphur	0	0.005
Silicon	0.8	1.2
Chromium	5	5.5
Vanadium	0.8	1.2
Molybdenum	1.2	1.75



Schematic diagram of tool

FSP process parameters and tool dimensions

Process Parameters	Values
Tool rotation speed (rpm)	1120, 900
Welding speed (mm/min)	31.5, 20
Pin length (mm)	2.5
Tool shoulder diameter, D (mm)	24
Pin diameter, d (mm)	8/6
Tool tilt angle	2.5
Tool pin geometry	Cylindrical taper threaded
Tool material	H13 tool steel

Non consumable tool made of H13 tool steel (Typical chemical composition is shown in the table 6.2) is used to fabricate joints, and diameter of shoulder and pin used were 24 and 8mm and the length of the pin 2.5mm (depend on the plate thickness). The tools used for the present study are square pin profile and triangle pin profile with shoulder as shown in Fig 6.5. A constant axial force is applied for the entire friction stir processing (FSP) experiments.

Tool pin profiles

Chemical Compositionof H13 Tool Steels

The direction of welding is normal to the rolling direction. Single pass welding procedure is used to fabricate the joints. After welding NDT (X- ray radiography) was performed to detect any defects in the composites. The welding parameters are presented in Table6.4. Joints were fabricated using different combinations of rotational speed and welding speed and different tool profile. The photographs of the fabricated joints are shown in Fig 6.6,. Mechanical properties of base metal as shown table 6.3 Experiments conducted at deferent combination tool rotating speed, welding speed and tool profile.

Round tool work piece

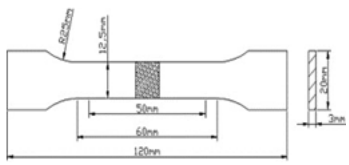
Square tool work piece

Tapered tool piece

Characterization of Composites

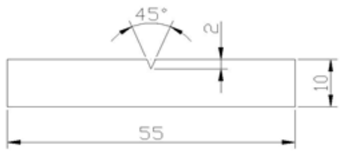
The composites were sliced using wire cut EDM and then machined to the required dimensions to prepare microstructure, tensile, impact specimens as shown in Fig 6.9. The specimens for metallographic examination were sectioned to the required sizes from the joint comprising weld zone (WZ), thermo mechanically affected zone (TMAZ), and heat affected zone (HAZ) and base metal (BM) regions. The specimens were polished using different grades of emery papers. Final polishing was done using the diamond compound (0.5μm particle size) in the disc-polishing machine. Specimens were etched with a solution of 100ml distillate water, 15ml hydrochloric acid and 2.5gram $FeCl_3$. Micro structural analysis was carried out after deep etching the specimens using optical microscope (Make: Leitz) with image analyzing software (Biovismat).

Tensile specimens were machined as per ASTM E8M in the traverse direction from the welded joints and are shown in Fig 6.10.Tensile test was carried out in 60 tons, servo controlled Universal Testing Machine (Make: FIE-Blue star, India; Model: TUE-600©) the specimens were loaded at the rate of 1.5 kN/min as per ASTM specifications. Impact tests was performed by using Charpy impact test equipment.



schematic sketch of Tensile Specimen

Impact specimens were machined as per ASTM E8M in the traverse direction from the welded joints and are shown in Fig 6.11. Impact test was carried out by using Charpy impact machine as shown in Fig.6.12. To study microstructure, the specimens were mounted by using mounting machine as shown in Fig 6.13.



Tensile Testing

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined young’s modulus, poisons ratio, yield strength and strain-hardening characteristics.

TENSILE TEST RESULTS

TOOL TYPE	TENSILE STRENTH(N/mm^2)
Round	149.523
Square	145.543
Taper	152.312

HARDNESS TEST REULTS

MACHINE DETAILS

Name –HARDNESS

TEST DETAILS

Test Reference – IS 1586:2000

Type of Hardness – HRC

Machine Model – 2008/073, MRB 250

Sample ID – Hardness Test at Weld Zone

CONCLUSION

The effect of heat input on mechanical properties of the pure copper plates friction stir processed by different FSP tool pin profiles were investigated in this study. The observations of this investigation are summarized below.

1. Of the three tool pin profiles used to form FSP zones on copper plate, the three pin profiles (round, square and taper) show successful formation of FSP surface on copper

2. The microhardness of the processed copper plates was influenced by their grain sizes. The grain sizes were monitored by heat input during processing. High heat generation leads to grain growth in the stir zone which lowers the microhardness values.

3. Pin profiles are also responsible for heat generation during processing at stir zone. If the contact area of the pin is more with flowing material, then generation of frictional heat is also more.

4. Tensile properties of the processed copper plates depend on the heat input and subsequent mechanical mixing in stir zone. taper and round pin profiled tools show better mechanical mixing and better tensile strength values.

REFERENCES

[1]. R.S.Mishra, Murray W.Mahoney (2007), Friction stir welding and processing, E-publishing, ASM International.

[2]. Z.Y.Ma (2008), Friction stir processing technology: A review, Metallurgical and Materials Transactions A, Vol.39A ; 642-657.

[3]. K. Elangovan , V.Balasubramanian (2007), Influences of pin profile and rotational speed of the tool on the formation of friction stir processing zone in AA2219 aluminium alloy. Materials Science and Engineering A 459 ; 7-18.

[4]. M.Karthikeyan, A.K. Shaik Dawood (2012), Influence of tool design on the mechanical properties and microstructure in friction stir welding of AA6351 aluminium alloy. Engineering Science and Technology: An International Journal, Vol.2, No.2 ; 233-237.

[5]. B.M.Darras, M.A.Omar, M.K. Khraisheh (2007), Experimental thermal analysis of friction stir processing. Material Science Forum, Vols.539-543; 3801-3806.

[6]. L.Karthikeyan, V.S. Senthilkumar, V. Balasubramanian, S. Natarajan (2009), Mechanical property and microstructural changes during friction stir processing of cast aluminium 2285 alloy. Materials and Design 30 ; 2237-2242.

[7]. G.M.Xie, Z.Y. Ma, L. Geng (2007) , Development of a fine-grained microstructure and the properties of a nugget zone in friction stir welded pure copper. Scripta Materialia, 57,;73-76.

[8]. H. Khodaverdizadeh, A. Heidarzadeh, T. Saeid (2013), Effect of tool pin profile on microstructure and mechanical properties of friction stir welded pure copper joints. Materials and Design 45 ; 265-270.

[9]. K.Surekha, A. Els-Botes (2011), Development of high strength, high conductivity copper by friction stir processing. Materials and Design 32 ; 911-916.

[10]. S.Srinivasan, K. Oh-Ishi, Alexander P.Zhil Yaev, Christian B.Fuller, Blair London, Murray W. Mahoney, Terry R.Mcnelley (2010), Peak stir zone temperatures during friction stir processing. Metallurgical and Materials Transactions A, Vol.41, Issue 3 ; 631-640.

[11]. L. John Baruch, R. Raju, V. Balasubramanian (2012), Effect of tool pin profile on microstructure and hardness of friction stir processed aluminium die casting alloy. European Journal of Scientific Research, Vol.70, No.3 ; 373-385

