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Friction Stir Processed Copper Studies with Carbon Nanotubes

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Abstarct : *FSP has been successfully applied to various cast aluminium and magnesium and copper alloys to eliminate casting defects and thereby improve their mechanical properties. Processing parameters such as tool geometry, tool rotational speed, tool tilt angle, processing speed, axial load and groove width &depth have been studied along with their effect. The hardness number comes out to be highest for third pass in comparing with single and double passes. Microstructure obtained gets more compact and defect free as number of passes increases.*

Keywords: *Friction stir processing, copper, carbon nanotubes, microstructure, wear, mechanical properties.*

INTRODUCTION

Friction stir processing (FSP) is used to enhance ductility, induces super plasticity and improve corrosion resistance properties. Friction stir processing (FSP) was developed for microstructural modification of metallic materials where the tool consists of a shoulder and a pin. One of the main function of the tool is to 'stir' and 'move' the material. Tool rotational speed and feed depends upon the hardness of the material. An increase in traverse speed and decrease in rotation of the FSP tool may cause reduction in the grain size of the stir zone for the specimen friction stir processed without any metal particles. Higher traverse speed affect microhardness. Addition of metal powder non-metallic powder and nano materials found increasing the wear resistance of the material. Axial load is the force acting upon the FSP tool which helps the tool pin plunge into the material. Groove width and depth depends upon the amount of metal powder non-metallic powder and nano materials to be used to make the metal matrix also it depends upon the depth of composite material.

The main objective of this paper is to discuss the study of FSP of copper with use of carbon nanotubes. The effect of FSP parameters such as tool rotational speed, processing speed, axial load, groove width and depth on microstructure and micro hardness investigated. Carbon nanotube particle were used in the processing and its effect on process parameters of FSP is determined. Microstructure of processed copper with and without CNT in multiple passes are discussed.

II. EXPERIMENTAL RESULTS

The experiments have been performed on friction stir processing machine shown in figure1. The experimental work is conducted as per the following steps:

1. Preparation of the work piece and tool
2. Filling carbon nanotube material in the groove
3. Friction stir Processing
4. Preparation of specimens for tests
5. Tensile, Hardness and microstructure tests conducted

Fig. 1. Friction stir welding / processing machine

Dimension of the work piece produced are as follows:

Length (mm) 200 mm
Breadth (mm) 75 mm
Thickness (mm) 8 mm

Dimension of groove are as follows:

Depth of cut (mm) 2.5 mm
Width (mm) 1.0 mm

For making the groove of 1mm width, cutter of 1mm thickness is used. Material of cutter is High Speed Steel (HSS). The Tool used for friction stir processing is a Cylindrical Threaded Tool made up of High Speed Steel (HSS). Tool is "Vacuum Hardened" to 60 BHN.

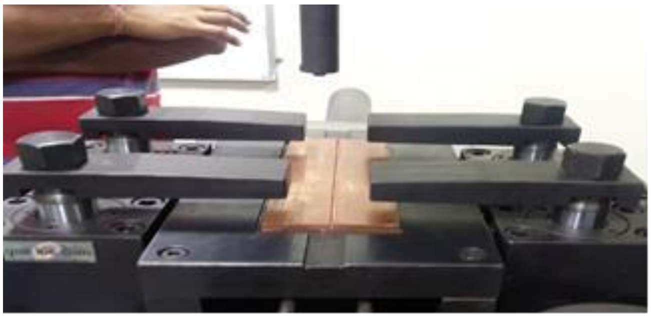


Fig. 2. Work piece fitted on the FSP Machine

Fig. 3. Tools used during Friction stir processing

Fig. 4. Cylindrical Threaded Tool Probe

Dimension of the tool are as follows:

Length of tool	120mm
Diameter of the tool	19.95mm
Length of the probe	3mm
Diameter of the probe	7mm

Cylindrical threaded tool have certain advantages over the cylindrical tool are as:

1) Better processing results
2) Reduce weld force
3) Enable easies flow of plasticized material
4) Increase interface between the pin and the plasticized material, thereby increasing heat generation.

Properties of Carbon Nano tube powder are as follows:

Diameter	50-85nm
Length	10-15 micrometer
Nitrogen surface area	10-90 m2/gm
Volume resistivity	2i<< 5*10-4ohm-cm
Carbon content	>94%

Advantages of using Carbon Nano tube powder in the Processing:

- Develop High Tensile strength in the material upto 63 GPascals.
- Leads to strong interfacial adhesion
- Increases stiffness and strength of the material.

The parameters used during processing are as follows:

Load (Kg)	1000 kg
Feed (mm/min)	20 mm/min
Rotational speed of tool (rpm)	1100rpm

These parameters are kept constant during the processing. For Analysis of the micro structure and mechanical properties, the processing is done in “Multiple Passes” on the work pieces.

Fig. 5. Tensile test specimens cut from processed Area

Tensile test determines the strength of the material subjected to a simple stretching operation. The primary use the testing machine is to create the stress-strain graph. The aim of the test is to asses some mechanical characteristics of the testing material. The results of the tensile tests are used in selecting materials for engineering applications. Tensile properties frequently are included in material specifications to ensure quality.

In this project we are determining the tensile strength of specimens of multi passed friction stir processed copper.

A universal testing machine (UTM) is used to test the tensile strength and compressive strength of the materials. The result of tensile test is shown in table1.

Table 1: Specimen Details and output Results during Tensile Tests

Output(Generic metals tensile from position)	**Without processing**	**Single pass without CNT**	**Single pass with CNT**	**Two pass with CNT**	**Three pass with CNT**
Width(mm)	5.98	6.01	6.01	6.01	6.0
Thickness(mm)	5.87	5.81	5.81	5.66	5.79
Gauge Length (initial)(mm)	25	25	25	25	25
Gauge Length(final) (mm)	32.9	46.4	31.5	28.7	29.1
Area (mm^2)	35.1	34.9	34.9	34	34.7
Ultimate Force(N)	8560	6840	2520	2570	4340
Ultimate Stress(MPa)	244	196	72.1	75.5	125
Offset @ 0.2%(N)	7600	4120	1610	2340	3760
Offset @ 0.2% (MPa)	217	118	46.2	68.7	108
TE(Auto)(%)	30.5	91	24.6	13.3	16.0

The stress-strain curves for respective specimens are shown as:-

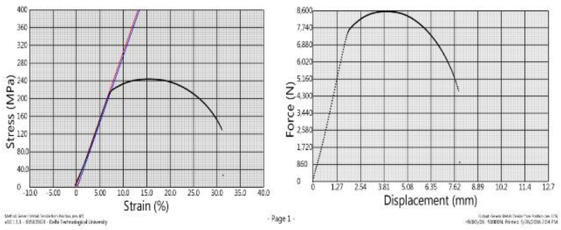


Fig 6: Stress-Strain and Displacement curve for Specimen without processing

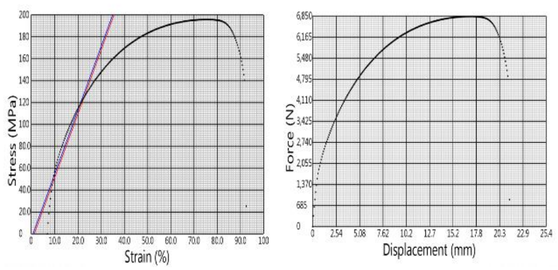


Fig 7: Stress-Strain and Displacement curve for Specimen without CNT processing

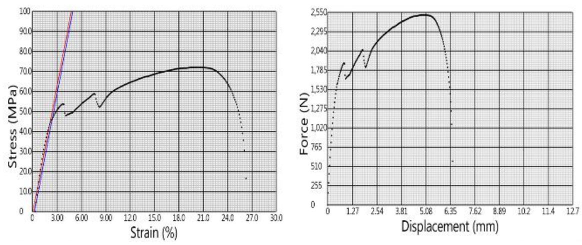


Fig 8: Stress-Strain and Displacement curve for Specimen without CNT processing

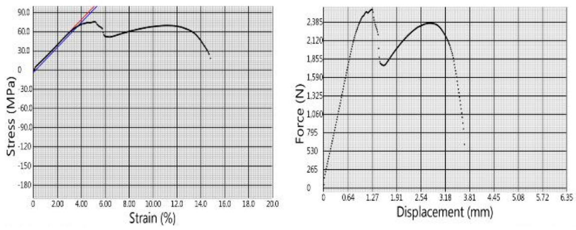


Fig 9: Stress-Strain and Displacement curve for Specimen with CNT double pass processing

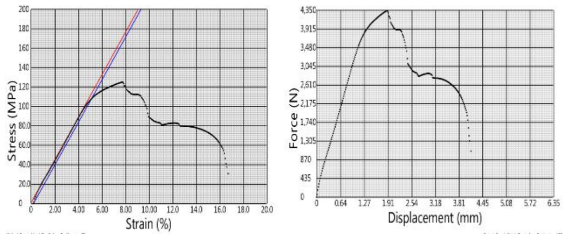
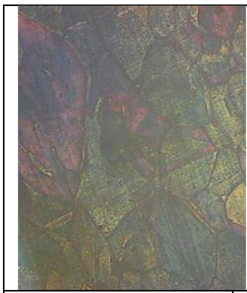
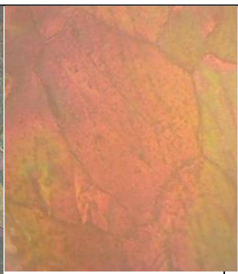
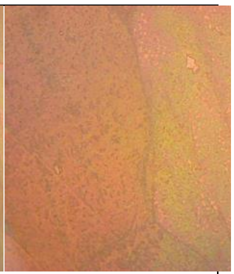
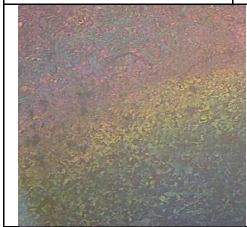
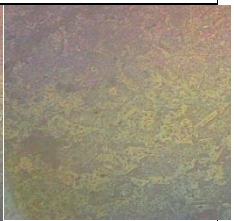


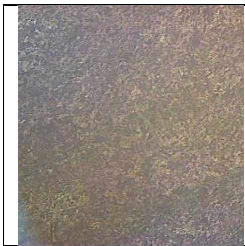
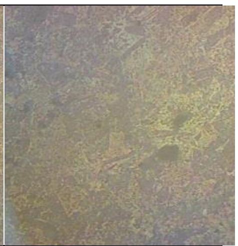
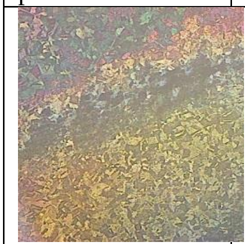
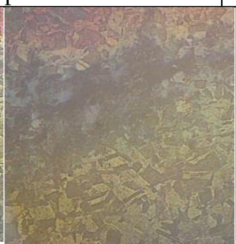
Fig 10: Stress-Strain and Displacement curve for Specimen with CNT triple pass processing

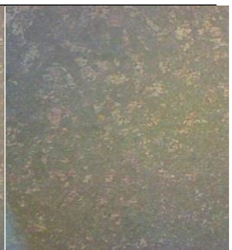
Table 2: Rockwell hardness test results

Sr. No.	Specimen	Rockwell hardness test (HRB)	Brinell hardness number(BHN)
1.	Base metal	32-36	147
2.	Specimen Processed without CNT	95	210
3.	Processed with CNT single pass	102	253
4.	Processed with CNT double pass	112	371
5.	Processed with CNT triple pass	118	487

Output result from the hardness test is shown table 2. Test was performed on Rockwell hardness machine, corresponding result is converted to Brinell hardness number. In the above result as the processes increases with multiple passes hardness also increases.

		
11(a) Specimen at 10x	11(b) Specimen at 20x	11(c) Specimen at 50x
		
12(a) Specimen without CNT with singlepass- Specimen at 10x	12(b) Specimen without CNT with singlepass- Specimen at 20x	12(c) Specimen without CNT with singlepass- Specimen at 50x

		
13(a) Specimen with CNT single pass- 10x	13(b) Specimen with CNT single pass- 20x	13(c) Specimen with CNT single pass- 50x
		
14(a) Specimen with CNT double pass- 10x	14(b) Specimen with CNT double pass- 20x	14(c) Specimen with CNT double pass- 50x

		
15(a) Specimen with CNT triple pass- 10x	15(b) Specimen with CNT triple pass- 20x	15(c) Specimen with CNT triple pass- 50x

CONCLUSION

In this study the following conclusions are made on the basis of tests performed:

The ultimate tensile strength of the processed material comes out to be lesser than the parent material.

Hardness of the processed specimens increases as the number of passes are increased due to more compact microstructure. The hardness number comes out to be highest for third pass in comparing with single and double passes.

Microstructure obtained gets more compact and defect free as number of passes increases.

In tensile testing, the ultimate force decreases from 8560 to 6840 N from base material to single pass specimen without CNT. But in case Specimens with CNT with single, double and triple passes the ultimate force increases.

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