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STUDY OF CU-CEO2 COMPOSITE FABRICATED USING THE FRICTION-STIR PROCESSING METHOD

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ABSTRACT :

Composites are high-performance structural materials that have been used in a wide range of applications over the past ten years. Globally, researchers have become more interested in using composite materials based on copper in recent years. In this study, a metal matrix composite is fabricated by mixing the copper metal with cerium oxide nanoparticles via friction stir processing (FSP). The main goal of this study is to examine how the FSP process parameters affect the mechanical properties of the resulting composite. The 142.50 VH and 442.854 MPa were the maximum achieved values of hardness and tensile strength respectively recorded at 1200 rpm and 25 mm/min after 3 passes of tool in stirred zone.

Keywords: Composites, metal, hardness, tensile strength, Copper, cerium

Introduction :

Advanced material is the need of every industry. The composites can be the alternatives for the advanced material. Composite material is a double or multi-phase material, which is obtained through the combination of various materials [1]. The different phases are matrix and reinforcements. The multi-phases materials are not formed naturally but are externally introduced into other materials. This transformation of the material developed a new material called composite material.

Copper (Cu) has been used in various industries of electronic packing, welding electrodes, and thermal contacts manufacturing industries because of their enhanced thermal conductivity and electrical conductivity [2]. But we all know that pure copper does not have good tensile strength, yield strength, creep, and hardness. However, the incorporation of ceramics, carbide, and oxides materials as reinforcements in the copper matrix can enhanced these mentioned properties of the produced MMCs. A few researches have been reported on the metal matrix nanocomposites, which results in the improvement in the properties of the formed MMCs. In the current studies, cerium oxide is used as nano oxide reinforcement forming nano-oxide metal matrix composites. Brushes for motors, pantograph, railway collector shoes, sliding connectors, and bearing materials are some applications of above-mentioned copper-cerium oxide MMCs [3].The surface composite of copper-based composites was prepared with cerium oxide as reinforcement. The matrix and reinforcement are not limited to selected materials and can be explored with other matrices (aluminum, titanium, magnesium, etc.) and reinforcements (SiC, TiO_2, Y_2O_3, Al_2O_3, etc.)

Preparation of Specimen Size

For FSP the plates of copper, the raw material (500 x 40 mm) was cut into new sizes which have 5 mm thicknesses. The Power hacksaw and hand cutter can be utilized for this. The new dimension is 150 x 40 x 5 mm. A groove of 1.8 mm was created on the plate along the 150 mm side and cerium oxide was filled in the groove with 5 volumes percent of the reinforcement. The surface grinder can also be used for this. Table 1 refers to the dimension of the prepared workpieces.

Table 1: Dimensions of Raw Material (copper)

Length (mm)	150
Width (mm)	40
Thickness (mm)	5

CNC Milling Procedure for FSP Technique

The CNC milling machine was used to perform the process. In this research, pure copper plates of aspects 150 x 40 x 5 mm3 were ready and considered as base material and a square section of 1 x 1.8 mm was machined along the focal point of the work plate. The cerium oxide powder is firmly compacted into the notch for additional handling. The tube-shaped FSP device made of H13 steel with shoulder width - 19 mm, pin dia.- 4.7 mm and pin length of 4.7 mm were retrofitted into the native make CNC processing machine in SIEMENS place having a stacking limit of 1.5 ton. At first, the furrow was shut utilizing pin-less apparatus to forestall the sprinkling of reinforcement particulates. The examples were handled at various interaction boundaries like instrument rotational speed of (1000-1200) rpm, translational speed of (25-45) mm/min, number of passes (1-3). These boundaries were fixed in light of a progression of preliminary trials through deformity-free examples.

Pilot-Run Experimentation

Before producing and conducting the main experiments for the FSP-ed samples, a pilot-run experiment was also conducted. The process parameters were taken in the range of 750-1450 rpm as rotational speed, 20-60 mm/min as transverse speed, and 1-4 number of passes.

Table 2: FSP input variables range for Pilot Experiment

Parameters	Units	Values
Rotational speed	rpm	750-1450
Translational speed	mm/min	20 - 60
No. of passes	--	1-4

The defects and combination of process parameters were expressed in table 3 mentioned below.

Table 3: Composite quality at different parametric settings

S. No	Rotational Speed (rpm)	Transverse Speed (mm/min)	Number of Passes	Defects / Problems	Remarks
1	750	35	2	Material Flashing	Not Feasible
2	1000	35	2	Successfully processed	Feasible
3	1200	35	2	Successfully processed	Feasible
4	1450	35	2	Machine Overloading	Not Feasible
5	750	60	4	Tool breakage	Not Feasible
6	1450	60	4	Machine Overloading	Not Feasible
7	1000	45	3	Successfully processed	Feasible
8	1200	45	3	Successfully processed	Feasible
9	750	20	4	Potholes formation	Not Feasible
10	1450	20	4	Tool breakage	Not Feasible
11	1000	20	1	Successfully processed	Feasible
12	1200	20	1	Successfully processed	Feasible
13	750	20	1	Groove formation	Not Feasible

In order to avoid such defects and problems during FSP-ed process the amendment in the process parameters were necessary to enhance the tribological and mechanical properties for the production of Cu-CeO_2 composite samples. The design of experiment was designed according to the modified range of process parameters as 1000-1200 rpm, 25-45 mm/min, and 1-3 number of passes respectively as mentioned in table 4.

The selection of the parameter range was based on the literature survey and the pilot experiments conducted.

Table 4: FSP input variables range

Parameters	Units	Values
Rotational speed	rpm	1000-1200
Translational speed	mm/min	25 - 45
No. of passes	--	1-3

Testing Machines or Equipment

Nine examples were taken for thought and sequential passes will generally produce tremendous imperfections. Base metal copper and the handled example without any reinforcements (FSP-ed) were additionally considered for examination. The experimental setup along with surface composite specimens is presented in Fig 3.

Fig. 3 (a) and (b): Specimens before and after friction-stir processing

Effect of Process Parameters on Mechanical Properties

Table 5: Experimental Values for Hardness & Tensile Strength

S. No	Rotational Speed (rpm)	Transverse Speed (mm/min)	No. of Passes	Experimental Values	
				Hardness (VHN)	Tensile Strength (MPa)
1	1000	25	1	75.24	226.239
2	1000	35	2	74.88	225.678
3	1000	45	3	62.94	196.289
4	1100	25	2	97.47	301.053
5	1100	35	3	105.68	324.283
6	1100	45	1	81.59	246.668
7	1200	25	3	142.50	442.854
8	1200	35	1	138.28	438.79
9	1200	45	2	85.33	261.969

Conclusion

Following conclusions can be inferred from current work

- The surface composites of Cu-CeO_2were successfully fabricated using the friction-stir processing method.
- Transverse speed has 25.41% and 26.68% relative contribution over tensile strength and micro hardness respectively.
- Hardness showed maximum dependency on rotational speed as RPM had 61.69% relative contribution on hardness. It increased with increase in RPM and showed reverse trendsi.e. decreased with increase in transverse speed.

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