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Characterization of Copper Matrix Composite Reinforced with Aluminium Nitrate using Friction Stir Processing Techniques

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Abstract- *The main objective of this project is to be produce copper reinforced metal matrix composite (MMC) layers using micron sized AlN particles via friction stir processing (FSP) in order to enhance surface mechanical properties. Micro structural evaluation using Optical Microscopy (OM) and Scanning Electron Microscopy (SEM) indicated that an increase in traverse speed and a decrease in rotational speed cause a reduction in the grain size of different groove width (0,0.4,0.8,1.2 mm) of stir zone (SZ) for the specimens friction stir processed (FSPed) without AlN particles. It was found that upon addition of AlN particles, wear properties were improved. This behavior was further supported by SEM images of wear surfaces. Results demonstrated that the micro composite produced by FSP exhibited enhanced wear resistance and higher average friction coefficient in comparison with pure copper. Tensile properties and fracture characteristics of the specimens FSPed with and without AlN particles and pure copper were also evaluated. According to the results, the MMC layer produced by FSP showed higher strength and lower elongation than pure copper while a remarkable elongation was observed for FSPed specimen without AlN particles and been greatly developed by the use of AlN.*

I. INTRODUCTION

Copper is an excellent electrical conductor. Most of its uses are based on this property or the fact that it is also a good thermal conductor. However, many of its applications also really on one or more of its other properties. For example, it wouldn't make very good water and gas pipes if it were highly reactive. We look at these other properties as a good electrical conductor, a good thermal conductor, corrosion, resistant, easily joined, ductile, tough, non-magnetic, attractive, color, easy to alloy, recyclable, catalytic. Copper is low in the reactivity series. This means that it doesn't tend to corrode. Copper can be joined easily by soldering or brazing. This is useful for pipe work and for making sealed copper vessels. Copper exhibits high formability good resistance to oxidation and corrosion and a special position between all metals because of its electrical and thermal conductivity, so the most general application of copper is where high thermal and electrical conductivity are needed, low strength and poor wear resistance are the major limitation of copper and its alloy. The physical and mechanical properties of pure copper were shown in Table No. 1.1.

PROPERTIES	VALUES
Melting point	1083°C
Density	8.95 g/cm3
Thermal conductivity	391 W/mK

Table 1.1 Physical and Mechanical Properties of Pure Copper

The reinforcement of different ceramics i.e Boron Carbide (B_4C), Silican Carbide (SiC), Aluminium Oxide (Al_2O_3)), Titanium Carbide

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(TiC), Tungestan Carbide (WC) and Aluminium Nitrate (ALN) were selected and the various mechanical properties of those reinforcements were shown in Table No. 1.2. Thermal conductivity of the Aluminium Nitrate (ALN) was higher than the other ceramics. So Aluminium Nitrate (ALN) was selected as Reinforcement.

Property	B_4C	SiC	Al_2O_3	TiC	WC	ALN
Density (g/cc)	2.52	3.21	3.92	4.93	14.95	3.260
Melting Point (°C)	2763	2050	2700	3160	2870	2200
Coefficient of thermal expansion (10-6/°C)	5	4.8	7.5	8.3	5	-
Hardness (VHN)	2900	1937	1800	2850	2481	-
Thermal conductivity (W/mK)	29	132	33	20	42	285
Elastic modulus (GPa)	450	430	350	345	620	-
Compressive strength (MPa)	3000	2800	2500	2500	2700	-

Table 1.2 Comparisons of Various Mechanical Properties of Reinforcements

II. Surface Metal Matrix Composites

A composite material is a material consisting of two or more physically and/or chemically distinct phases. The composite generally has superior characteristics than those of each of the individual components. Usually the reinforcing component is distributed in the continuous or matrix component. When the matrix is a metal, the composite is termed a metal-matrix composite (SMMC). In SMMCs, the reinforcement usually takes the form of particles, whiskers, short fibers, or continuous. A metal matrix composite (SMMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. An MMC is complementary to a cermet.

III. Production and Optimization of FSP Parameters

In this study, the material used was a pure copper plate (99.91% purity) with 100 mm length, 0.4,0.8,1.2 mm width and 10 mm thickness. AlN particles size was less than 10 micron. The specimens were clamped onto thick H13 steel and the copper plate was fixed by the bolts. In order to produce surface composite layers, AlN particles were contrived in a groove with 0.4, 0.8, 1.2 mm width and 4 mm depth in the middle of the specimens. Then, the ALN particles were compressed into the groove and the upper surface of the groove was closed with a FSP-like tool without pin to prevent outpouring of the Cr particles. A cylindrical pin tool with a concave shoulder used as FSP tool that was made of hot-working steel with the shoulder diameter, square pin diameter and length of 20, 5 and 2.7 mm, respectively. The shoulder concavity was 6° between the edge of the shoulder and the pin. Square pin profiled tool produced good quality and defect free FSP region, irrespective of irrespective of shoulder diameter and rotational speeds .After preparing specimens, FSP tool was plunged into plate for stirring the SZ and producing the Composites. FSP tool was titled by an angle of 1.5°.Three traverse speeds of 40mm/min in constant rotational speed of 1000 mm/min were investigated. Sped surfaces were prepared by standard metallographic techniques and etched with a solution of 100 ml distillated water, 15 ml H2O2and 2.5g FeCl3. Micro structural changes from base metal to the stirred zone were examined by optical microscopy (OM) and field emission scanning electron microscopy (FESEM). Micro hardness properties of the specimens were measured on the cross-section of the specimens and perpendicular to the processing direction in depth of 1 mm from the Sped surface using an indenter with a 200 g load for 15 s. A pin-on-disc test machine was used to evaluate friction and wear performances of specimens. FSP Procedures to Fabricate Surface Composite: (a) Cutting a Groove, (b) Compacting the Groove With Ceramic Particles, (c) Processing Using a Painless Tool and (d) Processing Using a Tool With Pin, the below diagram shows the detailed diagram of the FSP process obtained from the optimized parameters taken from various concerns and from various process I with the comparisons to that the friction stir processing of copper with aluminum nitrate has been performed successfully at here is shown in figure 3.1.

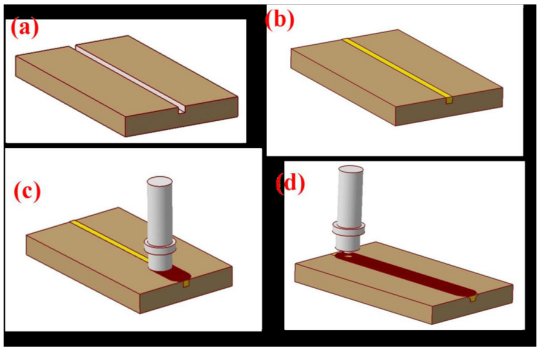

Fig. No.3.1 copper production using FSP process

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3.1 Identification of Process Parameters

For FSW, two parameters are very important: tool rotation rate (v, rpm) in clockwise or counterclockwise direction and tool traverse speed (n, mm/min) along the line of joint. The rotation of tool results in stirring and mixing of material around the rotating pin and the translation of tool moves the stirred material from the front to the back of the pin and finishes welding process. Higher tool rotation rates generate higher temperature because of higher friction heating and result in more intense stirring and mixing of material as will be discussed later. However, it should be noted that frictional coupling of tool surface with work piece is going to govern the heating. So, a monotonic increase in heating with increasing tool rotation rate is not expected as the coefficient of friction at interface will change with increasing tool rotation rate. In addition to the tool rotation rate and traverse speed, another important process parameter is the angle of spindle or tool tilt with respect to the work piece surface.

A suitable tilt of the spindle towards trailing direction ensures that the shoulder of the tool holds the stirred material by threaded pin and move material efficiently from the front to the back of the pin. Further, the insertion depth of pin into the work pieces (also called target depth) is important for producing sound welds with smooth tool shoulders. The insertion depth of pin is associated with the pin height. When the insertion depth is too shallow, the shoulder of tool does not contact the original work piece surface. Thus, rotating shoulder cannot move the stirred material efficiently from the front to the back of the pin, resulting in generation of welds with inner channel or surface groove. When the insertion depth is too deep, the shoulder of tool plunges into the work piece creating excessive flash. In this case, a significantly concave weld is produced, leading to local thinning of the welded plates. It should be noted that the recent development of ‘scrolled’ tool shoulder allows FSW with 08 tool tilt. Such tools are particularly preferred for curved joints. On the study of various parameters a typical process parameters have been made to concern of using and performed for our process, the parameters which we have been used are listed below in the following tables keeping values of all parameters as the same unless keep on changing the groove width for various experiments.

S.NO	PARAMETERS	NOTATION	UNIT	LEVELS			
1	Rotational Speed	N	Rpm	1000	1000	1000	1000
2	Transverse Speed	S	mm/min	40	40	40	40
3	Groove Width	W	Mm	0	0.4	0.8	1.2
4	Groove Depth	W	Mm	4	4	4	4
5	Ceramic particle	Aluminum Nitrate (AlN)					

Table No.3.1.Selected Process Parameters

Iv. Result and Discussion

4.1 Analysation of Copper and Aluminium After FSP

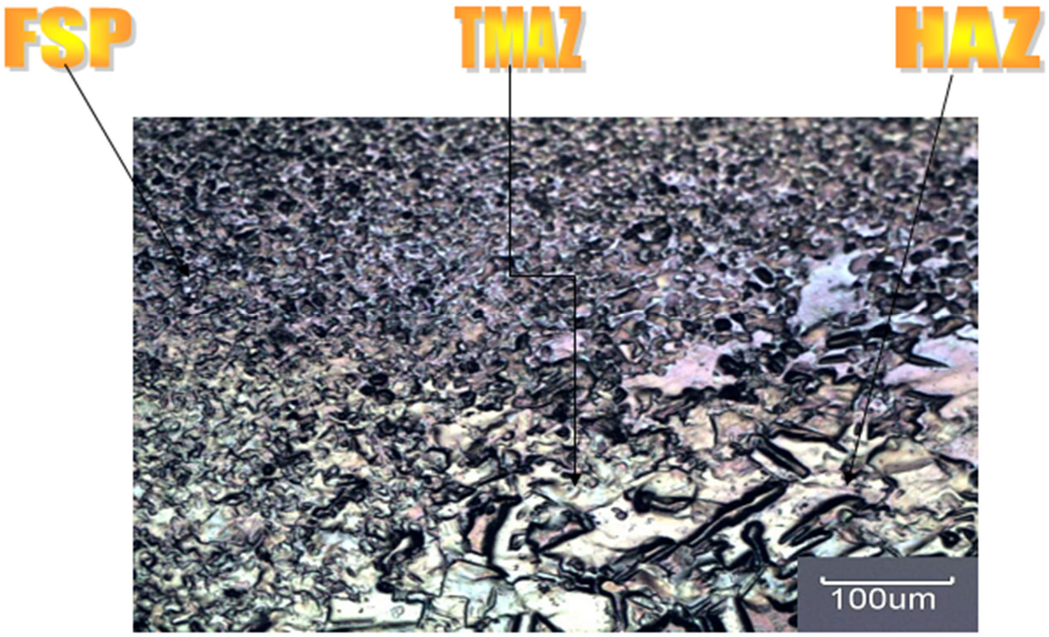

Fig 4.1 Optical Photomicrograph of Transient Zone between Cu and AIN

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The effect of volume fraction of AIN particles on the microstructure of the transition zone is shown in Figures The transition zone of friction stir processed monolithic alloys generally consists of heat affected zone (HAZ), thermo mechanically affected zone (TMAZ) and friction stir processed (FSPed) zone (Ma 2008). The boundary between HAZ and TMAZ is not seen clearly in Figure of FSPed copper (0 vol. %). The FSP zone spreads over TMAZ. The recrystallization during FSP occurs relatively easier in single phase copper which leads to such a wider FSP zone (Lee & Jung 2004). But the boundary between HAZ and TMAZ is clearly visible in Figures TMAZ reveals the alignment of AIN particles along the boundary. A parallel band-like distribution of particles is observed. The boundary becomes thicker when volume fraction is increased due to increased content of AIN particles. It is further evident from Figure 4.1 that there are no discontinuities or flaws along the boundary. The AIN surface composite is properly bonded to the copper substrate.

4.2 Evalution of Microstructure

The variation of microstructures when tool rotational speed increases from 200 to 1000 r/min. The traverse speed and axial force were kept constant. It is evident from the figure that the tool rotational speed significantly influences the area of friction stir processed zone that contains the surface composite. The area of the surface composite increases as the tool rotational speed increases. The area of the surface composite was measured using an image analyzing software and the values are listed. Frictional heat is generated as a result of rubbing of the tool shoulder on the copper plate. The quantity of frictional heat generated is dependent upon the tool rotational speed. The frictional heat causes copper to plasticize. The amount of plasticized copper is dependent upon the available frictional heat. As the tool rotational speed increases, the frictional heat generated increases. The amount of plasticized copper subsequently increases. The increase in the area of the surface composite leads to a reduction in the actual volume fraction of ALN particles in the surface composite as presented because the same amount of AlN particles packed in the groove is to be distributed to more amount of plasticized copper. It is evident from that the grains are coarsened as the tool rotational speed increases. The increase in tool rotational speed produces higher frictional heat that leads to coarsening of grains.

The effect of tool rotational speed on the microstructure of Cu/AlN surface composites. The optical micrograph clearly reveals the distribution of AlN particles in the copper matrix. The distribution is not uniform at 800 r/min due to the presence of AlN clusters at several places. Each cluster consists of closely located AlN particles. The SEM images as presented in the variation of microstructures at different tool rotational speeds with higher magnification. The average spacing between AlN particles increases when the tool rotational speed increases. The tool rotational speed does two more functions apart from frictional heat generation. Tool rotation stirs the plasticized materials as well as influences material flow behaviour across the friction stir processed zone. The formation of clusters at 800 r/min can be attributed to insufficient stirring and inadequate material flow from the advancing side to the retreating side. The worn surface is observed to be uniform due to the higher content of AIN particles and it is covered with wear debris. There are no apparent cracks or subsurface deformation. The debris does not adhere to the worn surface due to the hard

Conclusion

Pure copper matrix reinforced with different type of ceramic particles such as AIN were successfully fabricated by using a novel technique i.e. FSP. The mechanical properties like micro hardness, FSP area and dry sliding wear behavior of copper surface composite were studied. Mathematical models were developed to predict FSP area, micro hardness and dry sliding wear behavior of CMMCs and the FSP parameters were optimized using generalized reduced gradient method. Tool rotational speed, traverse speed and groove width were independently and significantly influenced the FSP area, micro hardness and dry sliding wear behavior of surface composites. Type of ceramic particles were not significantly influenced the responses.

The effect of tool rotational speed, traverse speed, groove width and type of ceramic particles on micro hardness, FSP area and wear rate was studied. The grain size was measured using a linear intercept method. Microstructural characterizations were carried out using OM and SEM. The AIN particles refined the grains of copper. The SEM microstructures revealed the presence of clear interface between particles and copper matrix without the presence of any voids or reaction products. The distribution of AIN particles in the surface composites was influenced by tool rotational speed and traverse speed. Lower tool rotational speed (N = 1000 rpm) and higher traverse speed (S = 40 mm/min) resulted in poor distribution of AIN particles and vice versa. The increase in groove width from 0.4 to 1.2 mm did not affect the distribution of AIN particles in a significant manner.

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