WEAR AND HARDNESS PROPERTIES OF SURFACE MODIFICATION OF COPPER ALLOY PROCESSED BY FRICTION STIR PROCESS

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Abstract: In this work, FSP was used to refine the microstructure of copper alloy using various parameters. The influence of the tool rotation and traverse speeds on the microstructural and wear of the processed copper alloy was analyzed. Dry sliding tests were conducted to compare the wear behavior of the as-received copper alloy and the copper alloy processed using FSP.

Keywords : severe plastic deformation ; Friction stir processing; Copper ; Microstructure; Hardness ; dry sliding wear; copper alloy; tool rotation

Introduction: friction stir processing (FSP) was developed as a generic implement for microstructural modification based on the principles of FSW which can be used for changing the microstructure and the mechanical properties of conventional materials [1]. FSP makes use of a non-consumable rotating tool to induce heat and severe plastic deformation in the material being processed [2]. This process has been used to applied to microstructural modifications for enhanced mechanical properties through intense plastic deformation and results in grain refinement [1, 3] The benefits of FSP include significant microstructural refinement, densification, and homogeneity of the processed zone, homogenization of precipitates in various aluminium alloys and composites materials [4, 5, 6] . FSP method can be used to achieve surface or bulk alloy modification by mixing of other elements into the stirred alloys where the stirred material can become a metal matrix composite or an intermetallic alloy with much higher hardness and wear resistance properties [7] .The microstructure and mechanical behaviour of light-weight materials subjected to the FSW/FSP are being studied extensively which include the processing of the microstructure amenable to the high-strain-rate superplasticity which shows that FSP is very effective in producing an ultra-fine grained material with excellent mechanical properties [8, 5, 9, 10]. In this research work copper alloy was processed by SPD using FSP and their wear resistance and materials properties were studied. The research study is aimed to investigate the possibility of enhance the surface property, mechanical properties and wear resistance of copper alloy by using FSP technique.

Experimental material and procedures

The investigation used a copper alloy having a chemical composition presented in Table 1. The alloy was supplied as rectangular elements of dimension of 600 × 160 × 6mm^3. The FSP was conducted on an Intelligent Stir Welding for Industry and Research (I-STIR) Process Development System (PDS). The experimental setup showing the clamping fixture and the backing plate system is as presented in Figure 1. The tools used were machined from H13 tool steel and hardened to 52 HRC (see figure 2).

The Dry sliding wear tests were conducted on both the as received alloy and the copper alloy after processing by FSP using micro Tribometer module, CETR UTM-2 operating with linear reciprocating motion drive. The Vickers micro hardness was measured using a micro hardness tester with a load of 300 g and using a dwell time of 15 s. Energy dispersion spectroscopy (SEM–EDS) was analysed using scanning electron microscopy a JEOL JSM 6500 instrument and energy dispersive X-ray spectrometry was conducted with an INCA EDX analyser.

Table I: Chemical composition of commercial copper alloy used

Cu	Si	Fe	Al	Mg	Zn	Pb	Ni
Balance	0.007	0.009	0.027	0.05	0.025	0.017	0.009

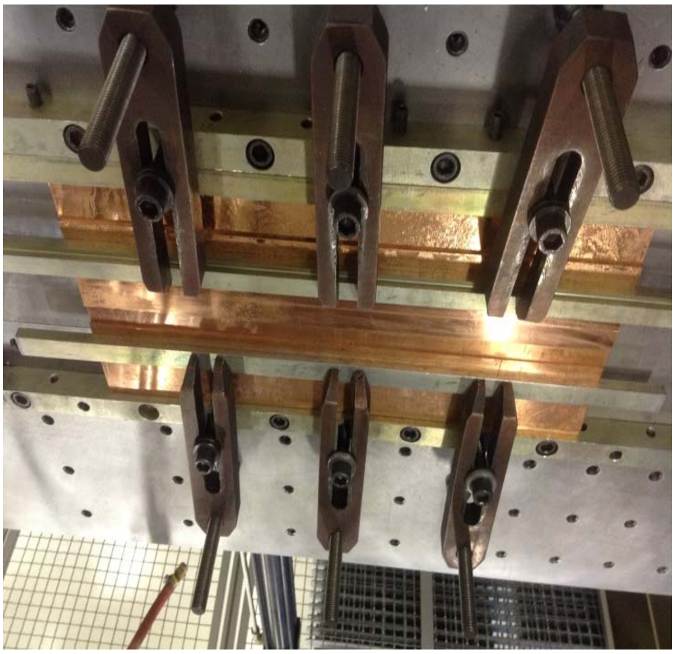

Figure 1: The experimental setup showing the clamping fixture and the backing plate system

Figure 2: a pinless tool across the surface of the material for all the experiments.

Experimental results

Figure 3 and 4 shows the microstructures of as received material and microstructures of the FSP process at a rotational speed of 1000 rpm and feed rate of 200mm/min for one pass respectively. From the results, the average grain size of as received copper alloy is measured to be 12 µm and microstructures of the FSP process at a rotational speed of 1000 rpm and feed rate of 200mm/min for one pass was measured to be 6.81 µm. this show that the grain size of the copper alloy processed by FSP was refined microstructure remarkably by the intense plastic deformation.

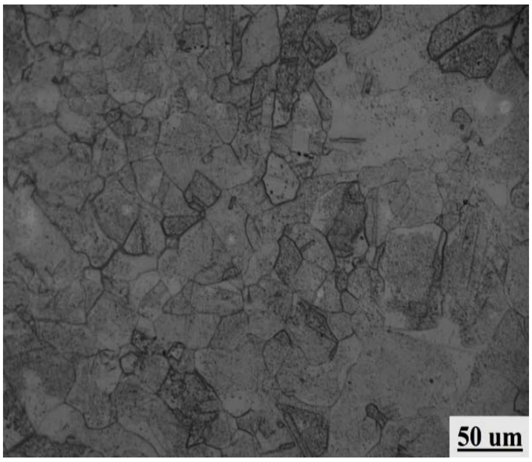

Figure 3: Microstructures of as received material

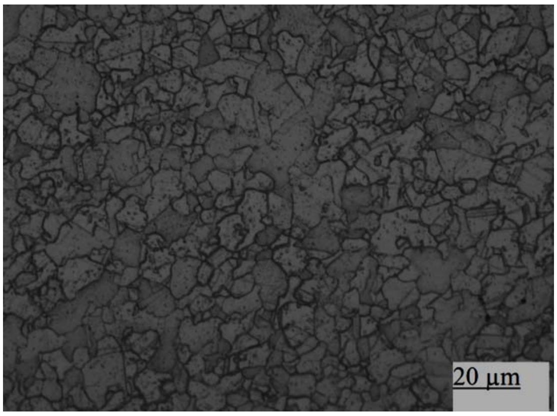

Figure 4: Microstructures of the FSP process at a rotational speed of 1000 rpm and feed rate of 200mm/min for one pass

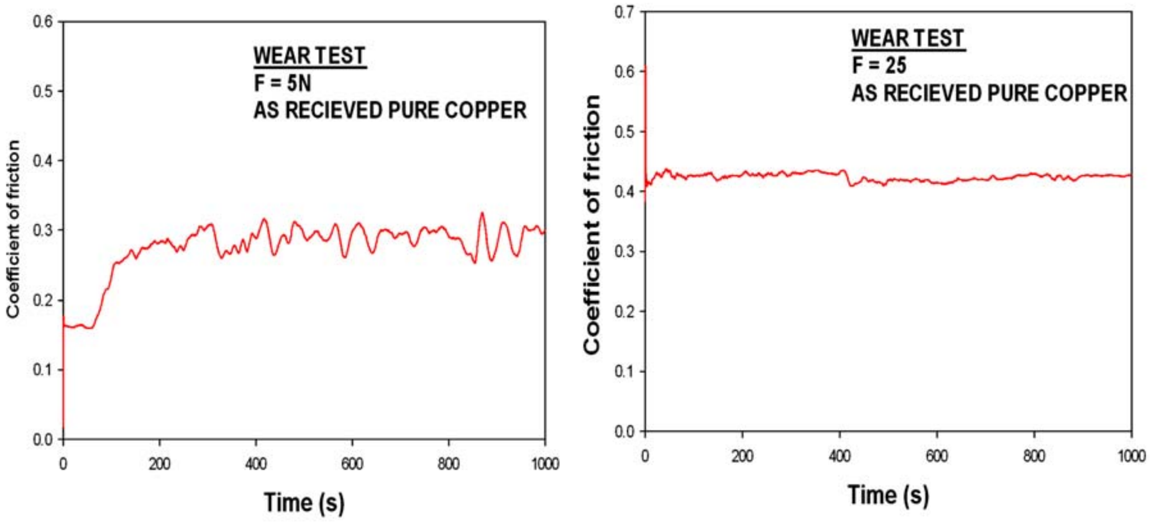

Figure 5: The coefficient of friction with time for wear tests under loads of 5 N and 25 N for the as-received copper

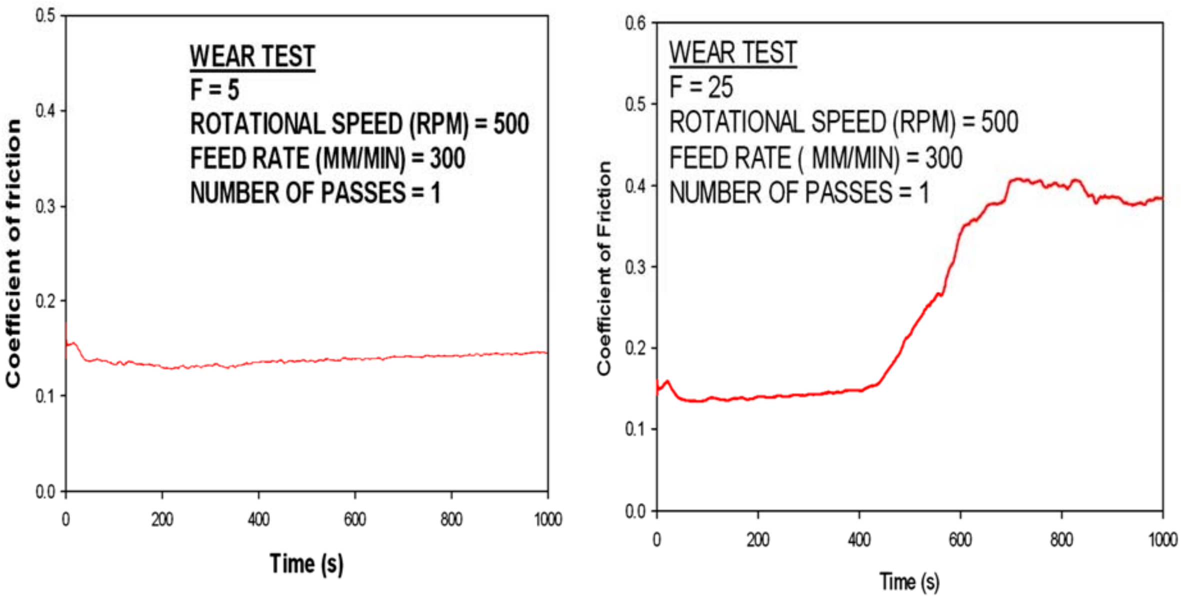

Figure 6: The coefficient of friction with time for wear tests under loads of 5 N and 25 N for the sample processed by FSP at a rotational speed of 500 rpm and feed rate of 300 mm/min for one pass

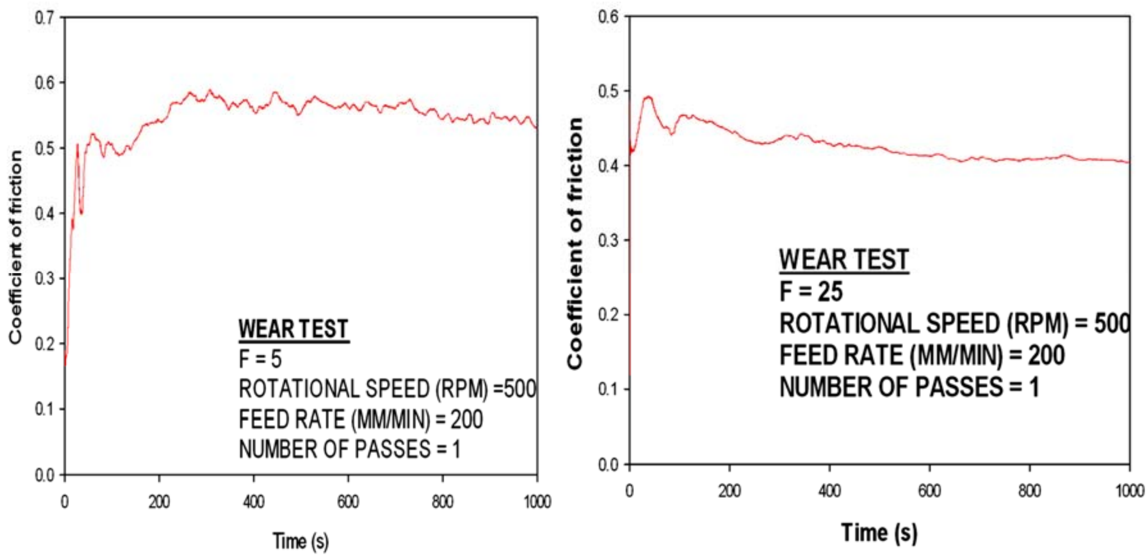

Figure 7: The coefficient of friction with time for wear tests under loads of 5 N and 25 N for the sample processed by FSP at a rotational speed of 500 rpm and feed rate of 200 mm/min for one pass

The results of this investigation provide useful information on the wear characteristics of a copper alloy processed by FSP to produce exceptional grain refinement. Processing by FSP leads to a small improvement in the average value of the COF for the processed copper alloy when wear testing under two different loading conditions of 5 and 25 N, there is a transfer of material to the counter surface during testing and there is also a very significant mass loss when using the higher load of 25 N. Studies of the debris, worn surfaces, and wear rates all indicate that these two loading conditions produce a severe wear mechanism. However, the higher hardness introduced by FSP leads to a higher mass loss than in the as-received material .

Summary and conclusions

- The grain size of the copper alloy processed by FSP was refined microstructure remarkably by the intense plastic deformation.
- FSP leads to a small improvement in the average value of the COF for the processed copper alloy.
- The copper alloy processed by were subjected to wear testing under loads of 5 and 25 N , it was observed that the processed copper alloy has a higher wear resistance than unprocessed copper alloy.
- Friction stir process is a suitable candidate material for use in industrial applications.

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