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Measurement of hardness and properties of copper alloy processed by friction stir process

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Abstract. In this paper, friction stir processing (FSP) was used to refine the microstructure of the copper alloy using various parameters. The influence of the tool rotation and traverse speeds on the microstructural and mechanical properties of the processed copper alloy was measured and analyzed. Micro-hardness measurements were used to evaluate the mechanical properties of the material. The results show that copper alloy processed by FSP has an enhanced micro-hardness property than the unprocessed copper alloy, this makes the materials processed by FSP appropriate for use in industrial applications.

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 technique makes use of a non-consumable rotating tool to induce heat into the material being processed [2, 3]. The process has been used to applied to modify microstructural to improved mechanical properties through intense plastic deformation by grain refinement [4, 5] The advantage of FSP include densification, homogeneity of the processed material and microstructural refinement, homogenization of precipitates in various aluminium alloys and composites materials [6-8]. FSP method allow surface or bulk alloy modification by stir other elements into the alloys to become a metal matrix composite or an intermetallic alloy with wear resistance higher and hardness properties [9]. The microstructure and mechanical behaviour of light-weight materials subjected to the FSW/FSP are being studied extensively and the results shows that FSP is a suitable and effective method in producing an UFG material with good mechanical properties [1, 6, 8, 10].

In this research, study was done to investigate the way of improve the surface property, mechanical and wear resistance properties of copper alloy by using FSP technique and this will provide a better understanding of the material characteristics and wear behaviour after using FSP processing.

Experimental Material and Procedures

A copper alloy supplied as rectangular elements of dimension of $600 \times 160 \times 6mm^3$ was used for this experimental research (a chemical composition is presented in Table 1). The experimental setup and H13 tool steel and hardened to 52 HRC used as the tools is presented in Fig. 1.

The micro-hardness was measured using a micro hardness tester with a load of 300 g a dwell time of 15 s. Grain sizes were recorded (see table two) after FSP.

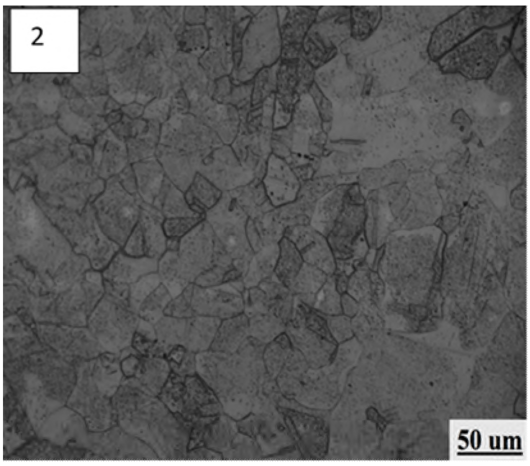
Table 1. Chemical composition of copper alloy used.

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

Fig. 1 The experimental setup showing the clamping fixture and the backing plate system and pinless tool used for the experiments.

Experimental Results and Discussions

Microstructure. Figs. 2-7 shows the optical electron Microstructures of the FSP process. Fig. 2 shows the microstructures of as received copper and Fig. 3 shows the microstructures of the FSP process at a rotational speed of 500 rpm and feed rate of 100 mm/min for one pass. The average grain size of as received and the FSP process at a rotational speed of 500 rpm and feed rate of 100 mm/min for one pass are 12 and 9.26 µm respectively. Fig. 4 shows the microstructures of the FSP process at a rotational speed of 500 rpm and feed rate of 100mm/min for three pass and Fig. 5 shows the microstructures of the FSP process at a rotational speed of 500 rpm and feed rate of 200mm/min for one pass. The average grain size of the FSP process at a rotational speed of 500 rpm and feed rate of 100mm/min for three pass and the FSP process at a rotational speed of 500 rpm and feed rate of 200mm/min for one pass are 7.12 and 6.81 µm respectively. Fig. 6 shows the microstructures of the FSP process at a rotational speed of 1000 rpm and feed rate of 100mm/min for one pass and Fig. 7 shows the microstructures of the FSP process at a rotational speed of 1000 rpm and feed rate of 200mm/min for one pass and the average grain size are 9.65 and 9.44 µm respectively. The average grain size is shown in Table 2. It shows that the FSP refined the grain structures of the materials. The results showed that the average grain sizes of as-received copper alloy were 12 µm and between 6 µm and 10 µm after processing by FSP.



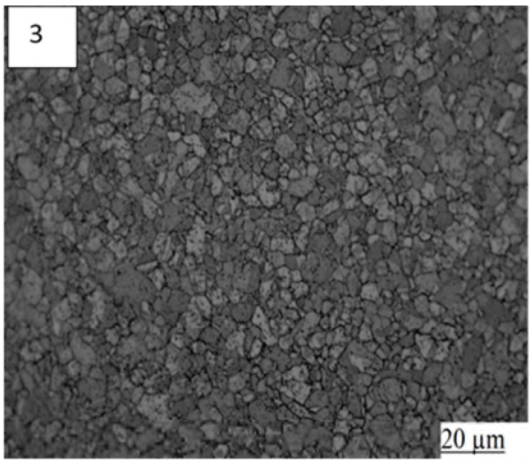
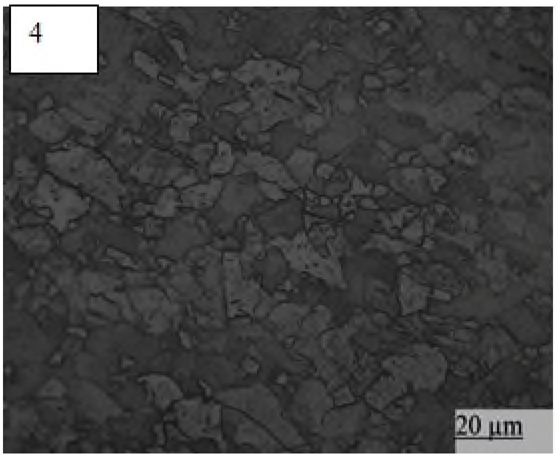


Fig. 2 Microstructures of as received material and Fig. 3 shows the Microstructures of the FSP process at a rotational speed of 500 rpm and feed rate of 100 mm/min for one pass.



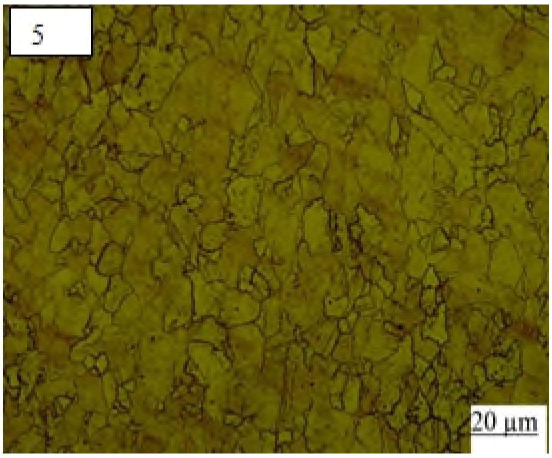
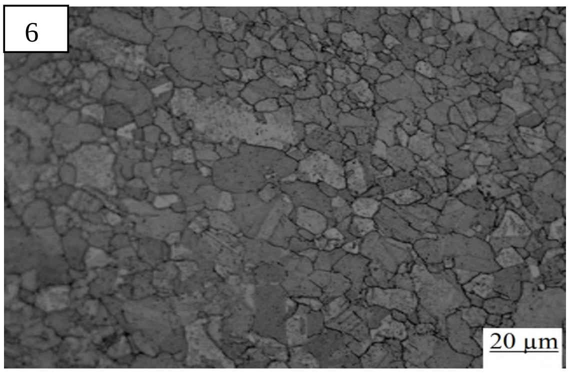


Fig. 4 Microstructures of the FSP process at a rotational speed of 500 rpm and feed rate of 100mm/min for three pass and Fig. 5 Microstructures of the FSP process at a rotational speed of 500 rpm and feed rate of 200mm/min for one pass



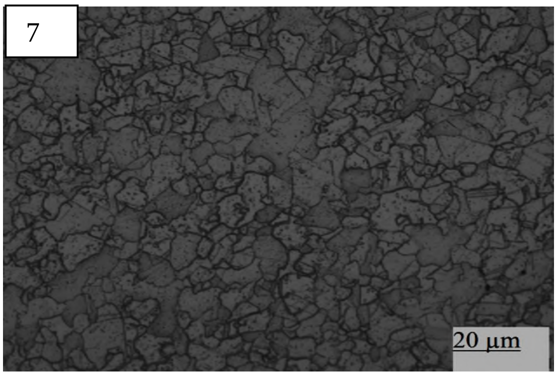


Fig. 6 shows the microstructures of the FSP process at a rotational speed of 1000 rpm and feed rate of 100mm/min for one pass and Fig. 7 shows the microstructures of the FSP process at a rotational speed of 1000 rpm and feed rate of 200mm/min for one pass.

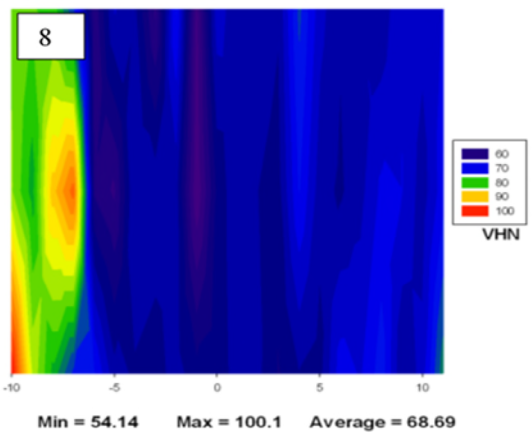
Table 2. Grain sizes recorded of as received and after FSP.

No	Parameters	Average grain size (µm)
1	As received copper	12
2	a rotational speed of 500 rpm and feed rate of 100 mm/min for one pass	9.26
3	a rotational speed of 500 rpm and feed rate of 100 mm/min for three passes	7.12
4	a rotational speed of 500 rpm and feed rate of 200mm/min for one pass	6.81
5	a rotational speed of 1000 rpm and feed rate of 100 mm/min for one pass	9.65
6	at a rotational speed of 1000 rpm and feed rate of 200 mm/min for one pass	9.44

Micro Hardness Results

Figs. 8–13 shows the Vickers micro-hardness measurements taken at incremental spacing of 1 mm were plotted as color-coded contour maps showing the distributions of the individual hardness values for each testing condition. The variation of micro hardness was taken across the disk surface. Fig. 8 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 100 mm/min for three passes using color-coded contour map, the minimum, maximum and average Vickers hardness value are 54.14, 100.1, and 68.9 Hv respectively and Fig. 9

shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 300mm/min for one pass using color-coded contour map, the minimum, maximum and average Vickers hardness value are 67.93 , 92.53 and 73.89 Hv respectively when Fig. 10 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 200 mm/min for one pass using color-coded contour map, the minimum, maximum and average Vickers hardness value are 65.2, 118, and 81.54 Hv respectively and Fig. 11 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 1000 rpm and feed rate of 200 mm/min for one pass using color-coded contour map. ,the minimum, maximum and average Vickers hardness value are 67,98.93, and 73.77 Hv respectively, Fig. 12 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 1000 rpm and feed rate of 300 mm/min for three passes using color-coded contour map, the minimum, maximum and average Vickers hardness value are 58.32, 94.93 and 68.30 Hv respectively and Fig. 13 shows the Vickers micro hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 100 mm/min for one pass using color-coded contour map, the minimum, maximum and average Vickers hardness value are 61.73 , 68.33 and 74.35 Hv respectively.



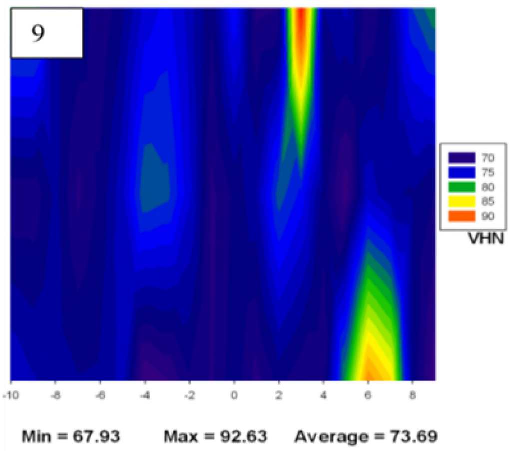
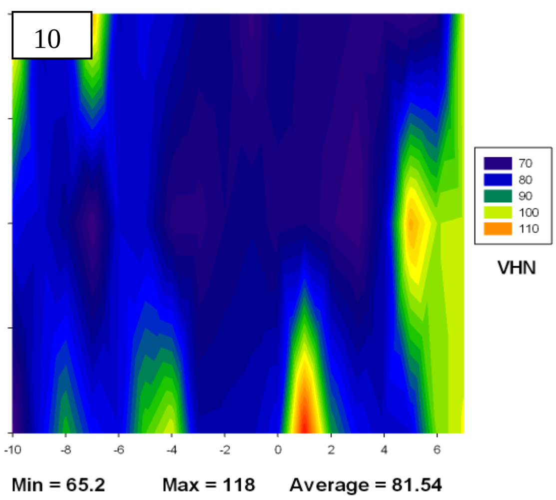


Fig. 8 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 100 mm/min for three passes using color-coded contour map and Fig. 9 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 300mm/min for one pass using color-coded contour map



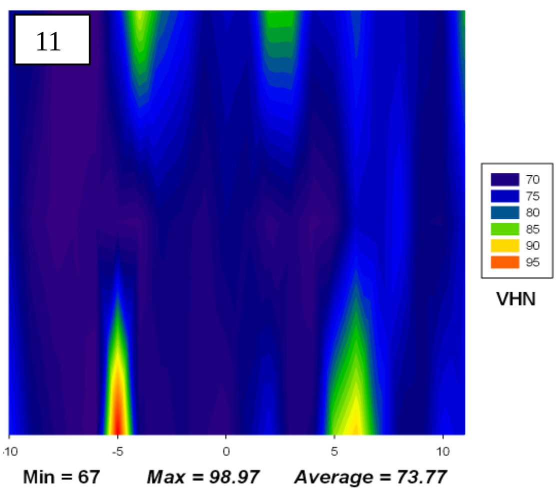
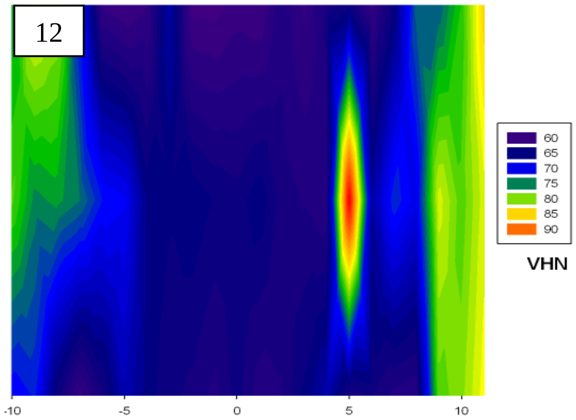
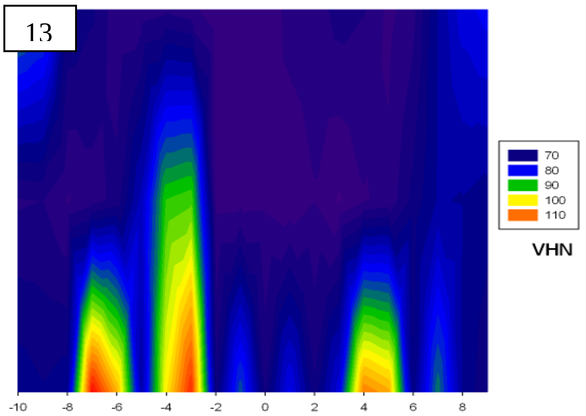


Fig. 10 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 200 mm/min for one pass using color-coded contour map and Fig .11 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 1000 rpm and feed rate of 200 mm/min for one pass using color-coded contour map.



Min = 58.32 Max = 94.93 Average = 68.30



Min = 61.73 Max = 68.33 *Average = 74.35*

Fig. 12 shows the Vickers micro-hardness of sample processed by FSP at a rotational speed of 1000 rpm and feed rate of 300 mm/min for three passes using color-coded contour map and Fig. 13 shows the Vickers micro hardness of sample processed by FSP at a rotational speed of 500 rpm and feed rate of 100 mm/min for one pass using color-coded contour map

Conclusion

The grain size of the copper alloy processed by FSP was refined microstructure by the intense plastic deformation. FSP process improved and enhanced microhardness property of copper alloy than unprocessed copper alloy. The higher hardness of materials processed by FSP causes a higher mass loss than in the as-received material and this appears to be inconsistent with the conventional Friction stir process is a good material process that can be use in industrial applications.

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