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Development and Characterisation of Metal Matrix Composite Steel/Cu-Zn

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Abstract: The present investigation attempts to improve the mechanical and tribological performances of copper alloy by reinforcement of matrix. We have used chip and wire stainless steel with the several geometrical configuration of reinforcement (unidirectional, bidirectional and chechmate). The results of the mechanical and tribological test enabled us to conclude that the reinforcement of the copper alloy matrix (brass) by the chechmate stainless steel; offer a good mechanical properties, better wear resistance, a mass gain and a lowering of cost price for new composite material.

Key words: Composite, copper matrix, steel reinforcement, mechanical characteristic, Tribology

INTRODUCTION

Copper is very good conductive of electricity and has a very great resistance has corrosion (Levente *et al*., 2008) but it has a low mechanical and tribological resistance (Mandal, 2008, 2007; López *et al*., 2007). The composites with copper matrix can offer excellent properties of strength at high temperatures because the latter are thermodynamically stable at the high temperatures (Yongzhong and Zhang *et al*., 2006). The requests for such materials include welding electrodes, switches with high output and the interactive components of plasma in the feeding systems (Singh *et al*., 2004). The composites with copper matrix reinforced by ceramics are currently produced by sintering powder at high temperatures (Tillmann *et al*., 2007; Moustafa *et al*., 2001). The use of a treatment cyclic after realization of the composite type ceramic/cooper by sintering proves to be necessary for attenuates the formation of porosities and the weakening of bond between the reinforcements and the cooper matrix (Kuen and Tu, 2003). The objective in this research is to make a comparative study between the new composites reinforced by metal (Ho *et al*., 2007) and by ceramics (WC/Cu, SiC/Cu) (Moustafa *et al*., 2001). The composite with metal reinforcement that we propose has be develop by the process of molding, increases the productivity and to reduce the production cost (Zhou *et al*., 2005). The principal advantages and disadvantages of each process are discussed in the light of this study.

MATERIALS AND METHODS

The preparation of the samples and tensile specimens of the composites was carried out by direct moulding in a graphite mould. They were developed in Algeria USTHB-LSGM laboratory. The casting of the copper alloy matrix was made, after having centred the reinforcement in the middle of the print of the mould. The geometrical type of reinforcement that we used in the development of the composite are: unidirectional stainless steel, bidirectional stainless steel and chechmate stainless steel (Fig. 1).

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The chemical compositions of the matrix and reinforcement materials are presented in the Table 1.

The microstructure of composite materials was made before and after behaviour test of friction. The surfaces of composite materials were observed by optical microscopy and Scanning Electron Microscopy (SEM). Elements and phases analyzed using Energy Dispersive Spectroscopy (EDS) and X-ray element mapping method. Tensile testing was performed at room temperature using an Instron type testing machine. Hardness distribution of each material in the vicinity was measured with a load of 1.96 N for 10 sec. Finally, wear and friction properties were determined using a simple ball-on plat tribometer developed in LSIMP, INPG Grenoble France laboratory which was computer assisted for data acquirement and treatment. Curves representing friction coefficient evolution vs cycle's number were simultaneously plotted during tests (Fig. 2). The samples plates of dimension (10×15×5) are rubbed on hard ball steel (100 Cr6) of 10 mm diameter. Tests were achieved at room temperature in ambient air using a line sliding speed of 71 m min^{-1}. A normal load carried out with variable load increased in increments of 5 N every 2 min up to 30 N.

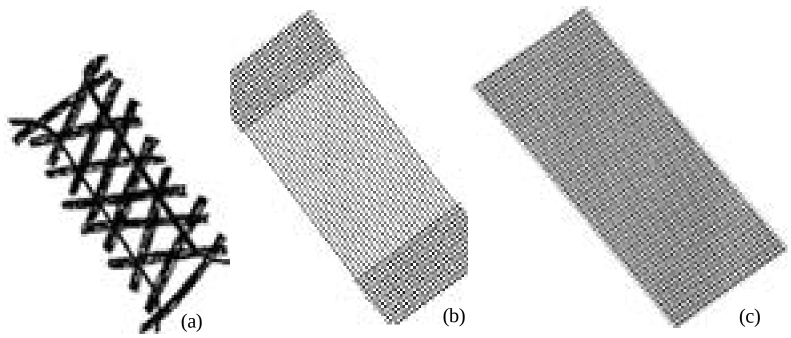

Fig. 1: Geometrical type of reinforcement, (a) stainless steel chips (reinforcement in chechmate), (b) stainless steel wire (unidirectional fabrics) and (c) stainless steel wire (bidirectional fabrics)

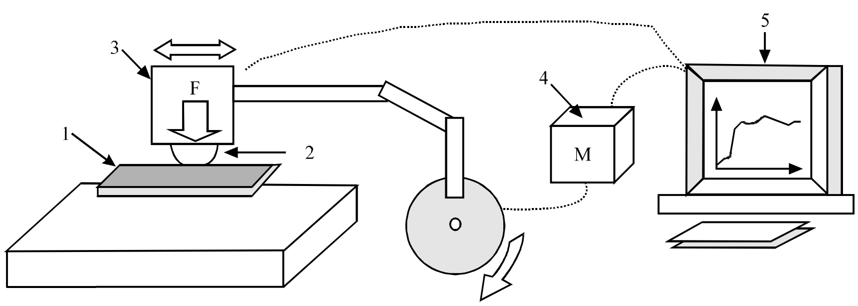

Fig. 2: Experimental sketch of a simple ball-on plate tribometer used, 1: sample; 2: 100Cr6 steel ball; 3: wear load; 4: sliding motor; 5: computer display

Table 1: Chemical composition of matrix and reinforcement materials (wt. %)

Materials (wt. %)	C	Mn	Si	Cr	Fe	Zn	Ni	Cu
Matrix copper alloy: CuZn	0	0	0	0	0	36.92	0	Bal
Reinforcement stainless steel: X5CrNi18-10	0.02	1.45	0.75	18	Bal	0	10	0

RESULTS AND DISCUSSION

Visual Examination and Micro Structural Evaluation of the Composite

The macro-view of the samples and traction specimens for brass matrix and the various composites is gives in Fig. 3. It's, reveals the test-tubes for copper alloy matrix (Fig. 3a) and various test-tubes according to the geometry of reinforcement by wire and chips stainless steel. Figure 3a shows a composite reinforcement by chips stainless steel and in Fig. 3b and c respectively and show the composite reinforcement with longitudinal and bidirectional stainless steel wire

Fine grains with two phases were observed in the metal matrix brass (Fig. 4d). It is about the solid solution α and the eutectic mixture. They are according with copper binary alloy (30% wt. Zn) described by (Bailon and Dorlot, 2000). The composite reinforcement with unidirectional and bidirectional stainless steel (Fig. 4a and b) shows an interdiffusion between reinforcement and matrix. They give a good adhesion of steel wire with the copper alloy matrix. In the matrix reinforced by the chechmate stainless steel (Fig. 4c), they show the uniformity distribution of short chip steel and a better adherence with the matrix; as well as a more important interdiffusion between the matrix and the reinforcement chechmate.

Mechanical Tests

Table 2 shows the result of mechanical properties investigated by tensile and hardness tests of all samples. The first result from tensile test confirms the increase in the values of resistance strength for reinforcement by long fibre and short fibre. These increases were noted respectively in the case; of unidirectional (420-480 MPa), bidirectional (400-420 MPa) and chechmate (380-392 MPa) steel/Cu-Zn composite. Moreover these values were increased after annealed (480-540 MPa).

On the other hand, the values of the hardness test measured on all samples shows an increase in the HV hardness of all composites (HV = 150-280). This increase is more important for the case of the chechmate stainless steel reinforcement (255-280 HV). The applied heat treatment for the various samples also made an increase the hardness values (200-350 HV), compared to the rough state (60-80 HV).

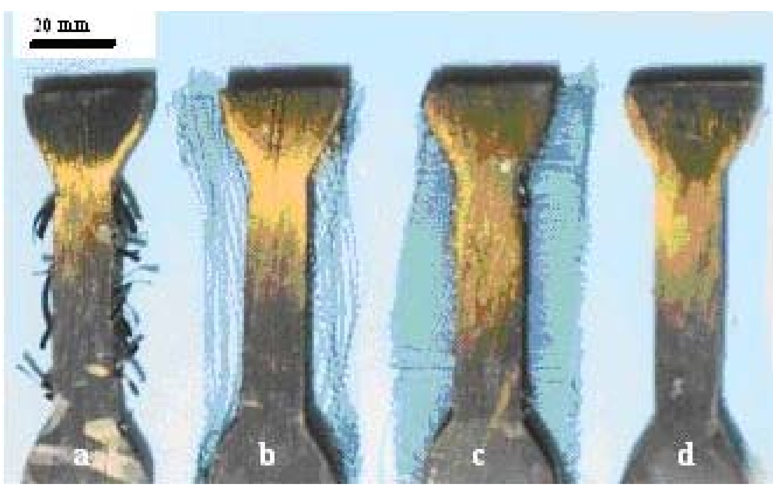

Fig. 3: Macro-view of samples test-tubes, (a) stainless steel chips (reinforcement in chechmate)/Cu-Zn, (b) stainless steel wire (unidirectional fabrics)/Cu-Zn, (c) stainless steel wire (bidirectional fabrics)/Cu-Zn and (d) copper alloy matrix

Table 2: Mechanics characteristics by tensile and hardness tests of all samples

		At rough state			After annealed		
Samples	Proprieties	HV_{10}	R_m (MPa)	A_{50} (%)	HV_{10}	R_m (MPa)	A_{50} (%)
Matrix: Cu-Zn	V* = 0% ρ = 8250.20	60-80	300-375	40	105-140	370-420	35
Steel/Cu-Zn unidirectional	V* = 18% ρ = 8169.06	150-180	420-480	21	200-210	480-540	18
Steel/Cu-Zn bidirectional	V* = 25% ρ = 8088.13	188-210	400-420	25	240-270	460-520	20
Steel/Cu-Zn, chechmat	V* = 20% ρ = 8065.62	255-280	380-392	28	320-350	387-410	25

* Fraction of reinforcement of steel in Cu-Zn matrix ρ (kg m^{-3})

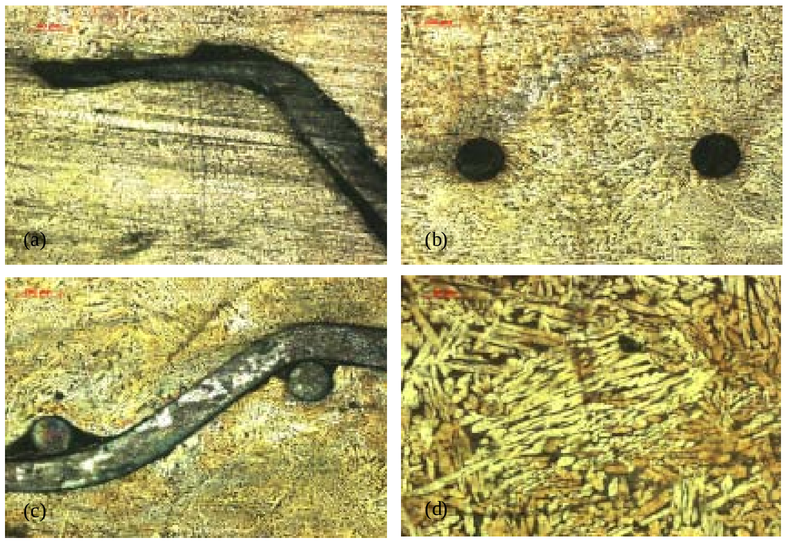

Fig. 4: Typical microstructure of metal matrix and composite steel/CuZn, (a) stainless steel chips (reinforcement in chechmate)/Cu-Zn, (b) stainless steel wire (unidirectional fabrics)/Cu-Zn, (c) stainless steel wire (bidirectional fabrics)/Cu-Zn and (d) copper alloy matrix

Tribological Tests

The result of wear test is enabled to find a correlation between the wear resistance of the composites and the adherence of reinforcement with the matrix. We noticed that a very good adherence of reinforcement with the matrix gives an excellent wear resistance in the chechmate reinforcement case. This result was already discussed to us in this research interior on the composites has metal matrix bases nickel reinforced by tungsten carbides, carbides silicon and alumina (Abdi *et al*., 2008). Also it was showed, for the composite reinforcement chechmate stainless steel an important relaxation of residual stresses after the post annealing at 850°C applications, compared of two composite's WC/Cu and SiC/Cu types (Moustafa *et al*., 2001). This new mechanical state can consequelly contribute to decreasing the wear rate. The heat treatments (Fig. 5b) make increase the attrition rate of the composites, in spite of the increase in their hardness after a heat treatment. That even is valid in the case of chechmate reinforcement. The scratches are more visible for the samples treated compared to the rough state (Fig. 5a). We can explain that by the reduction in the adherence of the reinforcement with the matrix after heat treatment.

Micrographic observations of some samples, which underwent a greater wear rate, are represented on Fig. 6. They show an important density of the scratches after heat treatment scratches smoothed after the passage of the sample and their depth depends on the size ofworn on surface and the load applied. Micrographics ofworn surface are taken after 900 cycles forsome reinforcement, that so show the quality of interfacenear reinforcement and matrix.

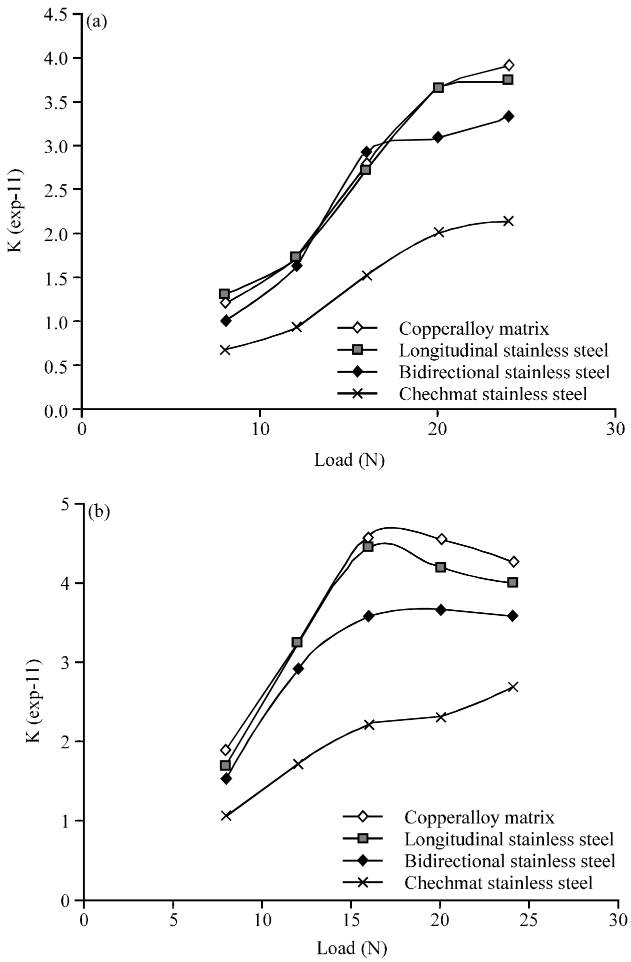

Fig. 5: Wear resistance (a) rough state and (b) after annealed, at V = 71 m min^{-1} in ambient air

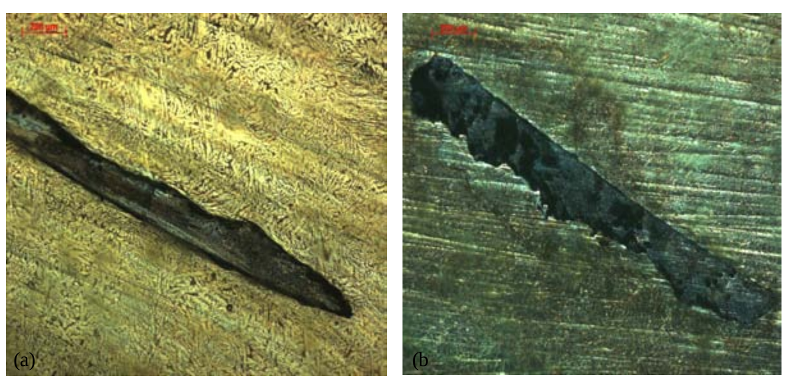

Fig. 6: Typical wear surface for composite: chechmat stainless steel/Cu-Zn, (a) rough state (b) after annealed

CONCLUSION

The study rests on the development by moulding of composite steel/brass and study the geometrical effect of reinforcement as well as the post of heat treatment on the mechanical and tribological behavior of the composite steel/brass. On the one hand, the mechanical results of the characterization of the composite steel/brass confirm the tensile strength respectively longitudinal and bidirectional reinforcement of the composite steel/brass. On the other hand the composites reinforced by chechmate stainless steel record a higher hardness report/ratio with the matrix and with the various composites studies. The heat treatments increased the values of the tensile strength as well as the hardness of all the composites compared to the rough state. The tribological results obtained on the matrix reinforced by chechmate stainless steel give a better wear resistance with a better weight saving. Too composites reinforced by fabric (longitudinal and bidirectional) gave results less important than those reinforced by chechmate stainless steel but the reinforcement by wire longitudinal did not cause any change on wear resistance compared to the brass matrix not reinforced. The heat treatment does not have any effect on the improvement of the wear resistance compared to the brass matrix. In all case the rough state is considered better for the wear resistance. That confirms the correlation which exists between the wear resistance of the composites and the adherence of reinforcement with the matrix. Moreover the rate of stripes is more visible in the reinforcement/matrix of samples which underwent a heat treatment than those of the rough state.

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