NOVEL BRONZE-BASED T-401 TROBALOY COMPOSITE FOR JOURNAL BEARING COMPONENTS

A. Tavakoli [a], R. Liu [a] and X.J. Wu [b]

[a] Department of Mechanical and Aerospace Engineering, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, Canada K1S 5B6

[b] Institute for Aerospace Research, National Research Council of Canada, 1200 Montreal Road, Ottawa, Ontario, Canada K1A 0R6

Introduction

Conventional bronze bearing composition is 90%Cu-10%Sn named tin-bronze. Lead, graphite and iron are additives to this type of bearing materials. The present research is aimed to develop novel bronze-based journal bearing materials with the T-401 Tribaloy alloy additive. Tribaloy alloys are cobalt-based or nickel-based alloys which are primarily strengthened by intermetallic Laves phases dispersed in a softer eutectic matrix, and are corrosion and wear resistant [1]. However, conventional Tribaloy alloys usually have low strength and fracture toughness in comparison with ductile materials, owing to the large volume fraction of Laves phase [2]. Different from conventional Tribaloy alloys, newly developed T-401 has a hypoeutectic microstructure (due to the lowered molybdenum and silicon contents) with the cobalt solid solution as the primary phase, and the eutectic phase being a mixture of cobalt solid solution and Laves phase. Previous research has demonstrated that T-401 maintains the excellent wear resistance of conventional Tribaloy alloys, while its ductility and corrosion resistance become much improved [3-5]. It is expected that this new Tribaloy alloy find new application in journal bearing industry owing to the combined superior mechanical and tribological properties as well as corrosion resistance.

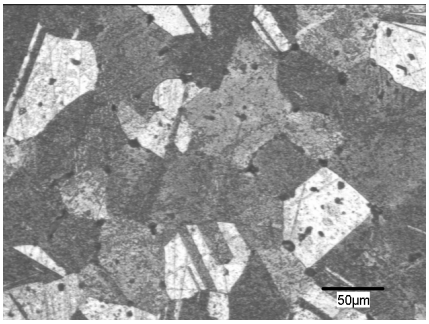
Specimen Fabrication

The specimens were fabricated using the powder consolidation technique. The compositions of the specimens consist of bronze base with variable T-401 contents; 0%, 10%, 15% and 20% (in weight). Two types of bronze powder were employed; one is premixed and the other is prealloyed. The powder sizes are all around -325 mesh.

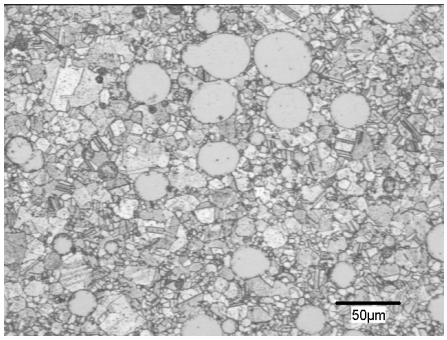
For designing the sintering/HIPping cycles, differential scanning calorimetry (DSC) test was conducted on the mixed powders to obtain the phase transformation temperature for each composition. The DSC results show that the melting temperature of the bronze is around 1000°C and that of T-401 Tribaloy is about 1250°C. Therefore, to obtain the solidus/liquidus sintering condition, the temperatures between 840°C and 870°C were selected in the sintering/HIPping processes, assuming that T-401 would not melt during the processes.

Microstructures and Performance Evaluation

The polished and ultrasonically cleaned specimens were examined under an optical microscope. The specimens were etched with the solution, 5g $FeCl_3$, 50 mL HCl, 100 mL H_2O. It is shown in Fig. 1 that the microstructures contain α phase bronze with T-401 particles well distributed in the matrices. The microstructures look very dense but contain a little quantity of pores. As known, pores are good sites for lubricants where the bearing is oil impregnated.



(a)



(b)

Fig. 1 Microstructures of pre-alloyed bronze (a) without T-401 and (b) with 20%T-401.

It is obvious that adding Tribaloy alloy particles to the compositions decreases the grain sizes of bronze and also with increasing the T-401 percentage in the compositions the grain sizes decreases more. In addition, the Tribaloy alloy additive could reduce pores. This is because the pores might be suitable sites for free solid Tribaloy alloy particles.

The hardness of the specimens was tested on a Wilson Series 2000 Rockwell Hardness Tester. Sliding wear test was conducted on a pin-on-disc tribometer. During the test the specimen (the disc) was spinning under a contact load (2 N) applied through a ball (pin). As a result, there would be a wear track or pit formed in the specimen surface. The wear loss of the material was evaluated by calculating the volume of the wear track. Each test last for 5400 s and the rotational speed of the disc was 500 rpm. The counterpart (pin) is WC-6%Co (1700 HV). The mechanical properties were determined on an MTS tensile testing machine in terms of the ASTM E 8-04 Standard. The test was performed in a strain-controlled mode with a loading rate of 0.05 min^{-1}.

The experimental results are presented in Table 1 and Table 2. Significant increase in hardness is observed by adding the Tribaloy alloy additive to the materials. Prealloyed bronze base materials show higher hardness compared with premixed ones. The hardness increases with the increase of the T-401 content. There is no significant difference in friction coefficient between the specimens with and without T-401, but the volume losses are significantly reduced when T-401 is added to the bronzes. Increasing T-401 additive from 10% to 20% has increased the wear resistance.

Table 1 Hardness and tribological properties

Specimen ID	Composition (wt%)		Bronze Type	Hardness and Wear Tests		
	T-401	Bronze		Hardness (HRB)	Volume Loss (mm^3)	Friction Coefficient
M	0	Bal.	Premixed	24.400	0.062	0.809
M-1	10	Bal.	Premixed	50.200	0.040	0.960
M-2	15	Bal.	Premixed	64.600	0.031	0.678
M-3	20	Bal.	Premixed	63.800	0.020	0.783
A	0	Bal.	Prealloyed	43.500	0.054	0.844
A-1	10	Bal.	Prealloyed	78.800	0.036	0.653
A-2	15	Bal.	Prealloyed	77.900	0.033	0.814
A-3	20	Bal.	Prealloyed	81.700	0.028	0.658

T-401 additive increases the yield stress and tensile strength of the bronzes significantly but decrease the elongation dramatically, as most reinforcements do in composite materials. Also, the yield stress and tensile strength are increased with the content of the Tribaloy alloy additive, but the elongations seem not influenced very much by the T-401 content. Between the premixed bronze based and the prealloyed bronze based materials the latter exhibits higher yield stress and tensile strength as well as large elongation.

Table 2 Mechanical properties

Specimen ID	Composition		Bronze Type	Tensile Test		
	T-401	Bronze		Yield Strength (MPa) 0.2%	Ultimate Tensile Strength (MPa)	Elongation (%)
M	0	Bal.	Premixed	170	206.77	2.02
M-1	10	Bal.	Premixed	230	243.71	0.60
M-2	15	Bal.	Premixed	280	331.56	0.94
A	0	Bal.	Prealloyed	215	297.77	7.07
A-1	10	Bal.	Prealloyed	300	356.15	1.67
A-2	15	Bal.	Prealloyed	315	365.58	1.44
A-3	20	Bal.	Prealloyed	300	394.13	1.97

Conclusions

T-401 exhibits beneficial effects in enhancing the hardness, wear resistance and mechanical properties of tin-bronze. These effects increase with the T-401 content in the composites, up to 20 wt.% in this research. The presence of the Tribaloy particles reduces the grain size and refines the microstructure of tin-bronze, thus improving the properties of the matrix. Prealloyed bronze matrix possesses better mechanical and tribological properties than premixed bronze matrix.

References

1. Halstead, A. and Rawlings, R. D. Structure and hardness of Co-Mo-Cr-Si wear resistant alloys (Tribaloys). *Met. Sci.*, **18(10)** (1984) 491-500.
2. Cameron, C. B. and Ferriss, D. P. Tribaloy intermetallic materials: New wear- and corrosion-resistant alloys. *Anti-Corr. Meth. Mater.*, **22(4)** (1975) 5-8.
3. Xu, W., Liu, R., Patnaik, P. C., Yao, M. X. and Wu, X. J. Mechanical and tribological properties of newly developed Tribaloy alloys. *Mater. Sci. Eng. A*, **452-453** (2007) 427-436.
4. Liu, R., Xu, W., Yao, M. X., Patnaik, P. C. and Wu, X. J. A newly developed Tribaloy alloy with increased ductility. *Scripta Materialia*, **53(12)** (2005) 1351-1355.
5. Yao, M. X., Wu, J. B. C., Xu, W. and Liu, R. Microstructural characteristics and corrosion resistance in molten Zn-Al bath of Co-Mo-Cr-Si alloys. *Mater. Sci. Eng. A*, **407(1-2)** (2005) 299-305.