Ti and C powders are milled together, and then mixed with Cu powders. The microstructures of specimens were analyzed with XRD, SEM and TEM. The pin-disk wear test was carried. It was found that TiC reinforcement formed in sintering by direct reaction in the method. All the composites exhibit good wear resistance at 150 N normal load.

**Keywords:** Wear behaviors, Mechanical alloying

**INTRODUCTION**
Ductile copper is widely used in industrial products, however, the lower hardness, tensile strength and poor wear resistance limits its applications. Generally, there are two ways to improve the mechanical properties and wear resistance of copper or by an age hardening mechanism. Mechanical Alloying (MA) is one of the methods which can improve the wettability between the immiscible system. So these methods were employed to prepare TiC strengthened copper composites by different technological process.

**EXPERIMENTAL STUDIES**
Horizontal planetary ball mill was employed to the mechanical alloying with 5 mm diameter milling balls. The copper, titanium and graphite powders are selected as starting element powders. The titanium and graphite powders with 2:1 weight ratio and copper powders were added to the milled titanium-carbon powders to form copper-titanium-carbon powders. The titanium, graphite and copper powders were mixed with weight ratio of 19:4:50 and milled 78 h with 350 rpm speed and 30:1 ball to weight ratio as powders B. The dry sliding wear tests were conducted in air at room temperature with a pin-on-disc wear testing machine. Steel disc with a hardness of about 52 HRC was employed as counterpart.

**RESULTS AND DISCUSSION**
The specific diffraction peaks of titanium carbide are not observed, and titanium and carbon diffraction peaks become weaker and
broader significantly, which indicate sharp decrease grain size of titanium and carbon, and increase of dislocations due to the heavy deformation during mechanical alloying. The grain size of copper and titanium was estimated from the integral width of peak broadening. The peak move to higher angle which approach to diffraction peak of pure copper following rising of sintering temperature. For the composites A, it’s due to titanium atoms dissolved into copper matrix by electric field diffusion effect as a result of DC pulse current, and then the titanium as solid solute incopper matrix formed titanium carbide with residual carbon completely as the rising of sintering temperature, which lead to movement to higher angle of copper matrix peak.

However, for the composites B, it’s due to the titanium atoms dissolve into copper matrix in the milling process. The titanium as solid solute in copper matrix precipitated and formed titanium carbide with carbon atoms continuously as rising of sintering temperature. Moreover, the intensity of copper matrix peaks of the composites A decrease constantly during rising of sintering temperature, but the peak become broader. The calculation results of the grain size of the composites A show that copper grain size of the composites A decreases as rising of the sintering temperature, because that copper particulates melted as increasing sintering temperature and mixed with titanium carbide particles, and then molten copper rapidly solidified to from nanocrystalline. Instead, the intensity of the peak of the composites B increases following rising of sintering temperature, which due to the fine copper particles which were formed during milling growth up during sintering process.

Figures 1, 2 and 3 shows SEM images of the composites A sintered with different temperatures generated from milled titanium-carbon powders adsorbed to copper particles in the mixed process, and formed fine titanium carbide at the lower sintering temperature. Point A contains copper, titanium and carbon, but smooth areas, such as point B, is composed of almost pure copper. The copper particles melted continually with increasing sintering temperature and then molten copper mixed with titanium carbide and solidified to form coarse area. The average friction coefficients of the composites A increase gradually with rising of sintering temperature. As mentioned above, the decrease of content of the residual carbon which formed TiC. The average friction coefficients and specific wear rates of the composites B decrease linearly as rising of the normal load too without inflection point. The friction coefficients of the composites A and B sintered at 950 °C with wear distance were recorded which show that obvious vibration with maximal instantaneous friction coefficient 3.68 and minimum approximately to 1.2 which lead steeply increase of the average friction efficient when normal load was 10 N of the composites A. The local actual load of the samples increase steeply which is the result of rapid decrease of actual contact area which is reduced by accumulation of the mechanical mixed layer. In this study, when normal load was 10 N, the formation of fine mechanical mixed layer led to rapid increase of local actual load, which leaded to rising of shear stress
on the mechanical mixed layer. The higher shear stress induced falling of the mechanical mixed layer and sharp fluctuation in the wear test as mention above. As increase normal load, size of the mechanical mixed layer increase for resisting enhancement of local actual load. Ouyang et al. (2001) reported that the wear mechanism is not controlled by single mechanical wear in this test, and one of the dominant wear mechanisms in composites, were tribochemical wear as a result of higher loads and relatively higher temperatures. These tribochemical wear, which are stimulated by friction, can result in the formation of a mechanical mixed layer, which can reportedly lower the specific wear loss and gradually reduced friction coefficient as mention above. Akhtar et al. (2009) indicated that with loading conditions become higher, there is more and more fragmentation of the plate and hollows or valleys creation. The lower normal load leads to slight localized plastic deformation on the worn surface. As rising of normal load to 10 N, the consequent increased localized plastic deformation leads to the formation of subsurface cracks resulting in the delamination of surface layer. The wear mechanism of the composites A is the three-body abrasion, and the third body was formed by accumulation and compaction of the debris which come from the composites and corresponding disk, thus, the transfer of iron leded enhancement of iron content on the worn surface of the composites A. However, the worn surface occur a plastic deformation by shear stress along the direction of sliding during wear test, which caused the much less transfer of iron to the worn surface of composites B.
CONCLUSION

Titanium carbide reinforced copper matrix composites were fabricated by powder technology includes mechanical alloying and spark plasma sintering with different technological process. The composites show uniformly distributed titanium carbide, however, the composites with different technological process show different microstructure and phase composition. The specific wear rates and fraction coefficients of composites. A decrease during increase of normal load with obvious point of inflexion on the curves, however. The specific wear rates and fraction coefficients of composites B decreased gradually and linearly during increase of normal load.

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I would also like to dedicate this research work to my father late R S Mishra and mother K L Mishra.

REFERENCES