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Comparison of dynamic tensile extrusion behaviour of WCu composites made by different processes

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Abstract. Composites with 60~90% of tungsten are used in liners of some specialty shaped charges. The penetration is enhanced by a factor against copper for homogeneous steel target. Tungsten powder based shaped charge liners are also especially suitable for oil well completion. In this study, WCu composites manufactured by different process are used for testing of dynamic tensile extrusion (DTE) behaviour. One samples were made by copper infiltrated method. The other samples were manufactured by metal injection molding methods with reduced tungsten copper composite powder. DTE tests were carried out by launching the sphere samples (Dia. 7.62mm) to the conical extrusion die at a speed of ~375m/s. The DTE fragmentation behaviour of tungsten copper composites after soft-recovered were examined and compared with each other.

1 Introduction

Tungsten–copper (WCu) is a mixture of tungsten and copper. As tungsten and copper are not mutually soluble, the material is composed of distinct particles of copper dispersed in a matrix of tungsten. So, we are called a tungsten copper composite instead of a tungsten copper alloy. The material combines the properties of both tungsten and copper, resulting in a material that is heat-resistant, ablation-resistant, highly thermally and electrically conductive, and easy to machine. Commonly used tungsten copper mixtures contains 90–60 wt.% of tungsten, the remaining portion being mostly copper [1].

WCu composites are used where the combination of high heat resistance, high electrical and thermal conductivity, and low thermal expansion are needed. Some of the applications are in electric resistance welding, as electrical contacts, and as heat sinks. As contact material, the composite is resistant to erosion by electric arc. WCu alloys are also used in electrodes for electrical discharge machining and electrochemical machining [2].

Tungsten copper shaped charge liner is part of armor-piercing projectile which plays an important role in action. Copper used as material for shaped charge liner with low melting point and good ductility, however the density of copper is low and easily deformation, so it commonly mixed with tungsten to improve the density, which increase the armor ability of tungsten copper shaped charge liner [3].

In this study, the metal jet formability of WCu composites obtained by different processes is compared to each other through DTE test.

2 Experimental

There are many methods making tungsten copper composite. The main three method are copper infiltration, liquid phase sintering and metal injection molding method [4]. The infiltration method is the most common way to manufacture WCu heat sinks. Infiltration method is that firstly prepare fixed density and strength of porous tungsten substrate skeleton, than infiltrate low melting point metal copper into the tungsten skeleton.

Tungsten has a much higher melting point than copper. This enables the use of high-temperature liquid-phase sintering to prepare WCu composite materials. However, it has some disadvantages which are its high sintering temperature, long sintering cycle, and relatively low sintered body density (typically at 90 to 95% theoretical density). In order to obtain qualified materials for heat sinks, it is necessary to further process high-temperature liquid-phase sintered WCu materials using forging, hot pressing, and other methods. The additional steps limit the use of high-temperature liquid-phase sintering method.

The nano tungsten coated copper composite powder was developed. Through this powder, the composite with homogeneous microstructure and neary full density in almost all range of composition, were manufactured successfully by the metal injection molding. Powder

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injection molding (PIM) is the optimum manufacturing technology to provide complex shaped components with low-cost and high-volume [5].

Table 1. The physical properties of tested materials.

Specimen		Density (g/cm3)	Hardness (HRB)	Electrical Conductivity (%IACS)
Infiltrated WCu	65W-35Cu	13.40(97.7%)	160	49
	80W-35Cu	15.30(95.8%)	222	36
MIM WCu	65W-35Cu	13.68(99.7%)	107	50
	80W-35Cu	15.49(98.9%)	111	38

The sphere samples of 7.62 mm diameter were machined from the central part of infiltrated WCu and MIM WCu composties for DTE tests. DTE tests were carried out by using an all-vacuumed gas gun system which consists of the gas gun, the sample flying barrel, the DTE die chamber, and the sample recovery station ; the details of the DTE equipment are described elsewhere [6]. The velocity of sample in this experiment was ~500 m/sec upon reaching the DTE die. After DTE tests, the sample fragments were soft recovered. The numbers and the order of fragments exiting the die were confirmed by the high speed photography. Besides, the complete fragment recovery was ensured by comparing the weight of all fragments with that of the initial sample.

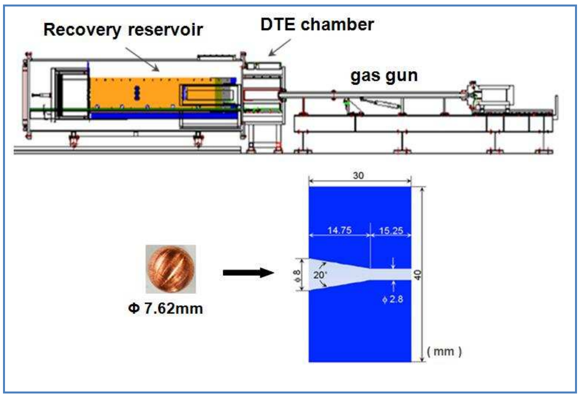

Fig. 1. (a) The schematic illustration of the DTE facility consists of gas gun system, (b) Configuration of the DTE die (dimension in mm).

3 Results and Discussion

3.1 Examine the microstructure of infiltrated WCu and MIM WCu materials

Infiltrated WCu materials are produced by sinter, and infiltrated process at ACHEMETAL. The density of these materials is 97.7% theoretical density (TD) of 65W-35Cu composite and 95.8%TD of 80W-20Cu composite. Tungsten coated copper composite powders with 20 and 35 wt-% of copper were used in this work. The mean particle sizes are 1.50 μm for 80W-20Cu and 1.57 μm for 65W-35Cu composite powders. Fig. 2 shows the microstructure of the W-Cu composite powders. The W-Cu composite powder consisted of lots of very fine tungsten particles that have been coated onto the copper powder. MIM tungsten copper powder and wax-polymer binder system was mixed to make MIM feedstock. The powder and binder were compounded in a twin shaft, co-rotating mixing. After compounding, the mixture was pelletized for feeding into the injection molding machine. MIM WCu composites are produced by CetaTech. The density of these materials is 99.7% TD of 65W-35Cu composite and 98.9%TD of 80W-20Cu composite.

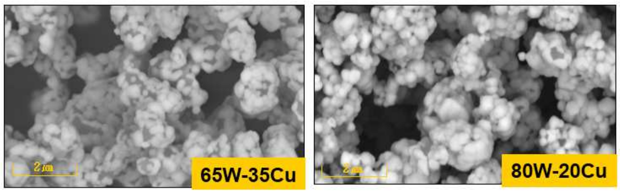

Fig. 2. Nano tungsten coated copper composite powder (by courtesy of CetaTech).

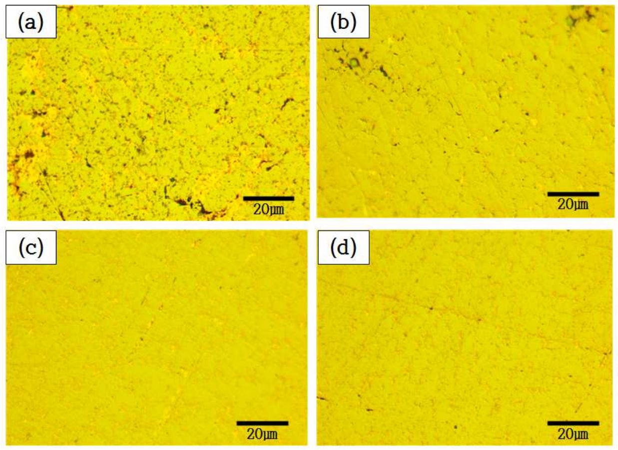

Fig. 3. Microstructure of Infiltraed WCu composites (a) 65W-35Cu, (b) 80W-20Cu and MIM WCu compostes , (c) 65W-35Cu, (d) 80W-20Cu.

The optical microstruture of tested materials were shown in Fig. 3. Infiltrated composites shows some pores and unevenly distributed copper microstruture Fig. 3. (a) and (b). MIM composites shows more evenly distributed copper microstruture than infilteated composites in Fig. 3. (c) and (d).

3.2 Mechanical properties of infiltrated WCu and MIM WCu materials

The stress-strain curves of infiltrated WCu and MIM WCu composites sample are shown in figure 4. The tungsten copper composites shows very low axial strain at all tested materials. The tensile strength of 65W-35Cu infiltrated samples were 600 MPa and 7.3% of elongation. The tensile strength of 80W-20Cu infiltrated samples were 647 MPa and 5.4% of elongation. The tensile strength of 65W-35Cu MIM samples were 289 MPa and 2.9% of elongation. The tensile strength of 80W-20Cu MIM samples were 588 MPa and 3.9% of elongation.

The elongation of these WCu composites was very low, so the application of these composites to military shaped charged liner seems to be not good. The metal jet formability of WCu composites which are made by different method were compared to each other through DTE test before the application.

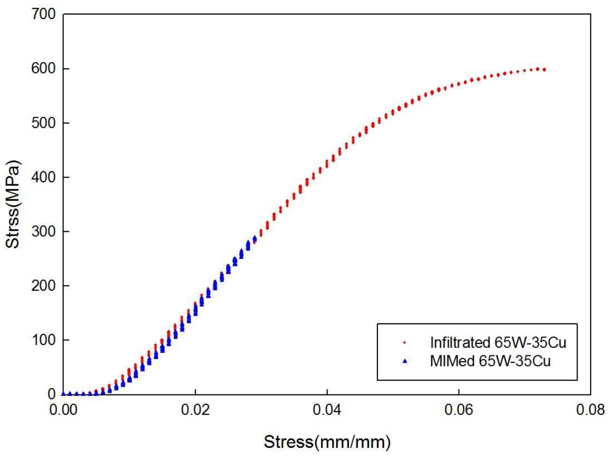

Fig. 4. True stress-strain curves of (a) Infiltrated and (b) MIMed 65W-35Cu.

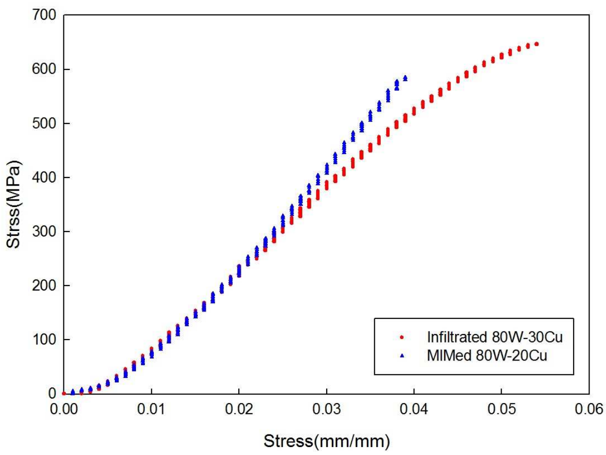

Fig. 5. True stress-strain curves of (a) Infiltrated and (b) MIMed 80W-20Cu.

3.3 DTE behaviour: fragmentation, ductility

The fragments of the WCu composite after DTE are soft-recovered: the conical fragment is the remnants remained in the DTE die. All the WCu composite were fragmented into so many pieces. All fragments were irregular shape indicating that fragmentation occurred by brittle fracture rather than plastic instability.

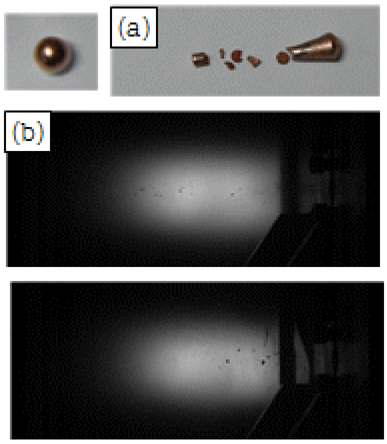

Fig. 6. (a) DTE fragments of infiltrated 65W-35Cu comopiste. and (b) high speed camera still frame exiting the DTE die.

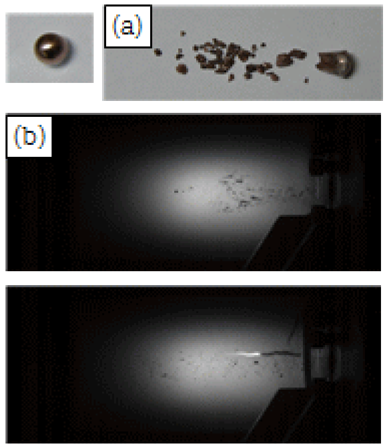

Fig. 7. (a) DTE fragments of MIM 65W-35Cu comopiste. and (b) high speed camera still frame exiting the DTE die.

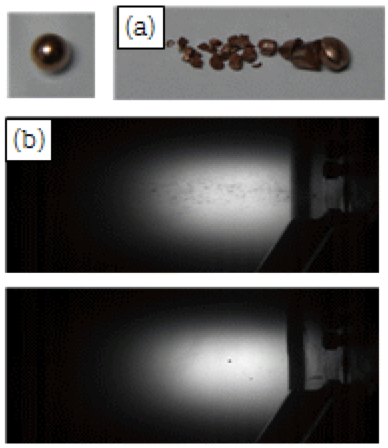

Fig. 8. (a) DTE fragments of infiltrated 80W-20Cu comopiste. and (b) high speed camera still frame exiting the DTE die.

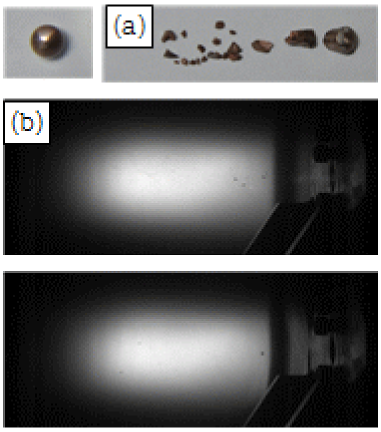

Fig. 9. (a)DTE fragments of MIM 80W-20 comopiste. and (b) high speed camera still frame exiting the DTE die.

The average DTE ductility of each sample were not determined because of so many fragmentation. The DTE ductility is the sum of the axial ductility of each fragment with respect to the initial sample diameter, i.e. DTE ductility = $(d_i - d_o)/d_o$ where d_i is the longitudinal length of the i^{th} fragment and d_o is the initial sample diameter.

4 Summary

1. A series of dynamic tensile extrusion (DTE) tests, the newly developed mechanical test at high strain rate, was conducted on WCu composites manufactured by diffferent process, but the average DTE ductility were not determined because of so many fragmentation.
2. The inferior metal jet stability of MIM WCu composite materials are caused by its improperly manufacturing process.
3. The metal jet formability of Wcu composite manufactured by different process are need more study with sound WCu composites.

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