Microstructure and Tensile Properties of Tungsten Heavy Alloys

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Abstract

The main object of this research was to examine the effect of sintering conditions on the microstructure of tungsten heavy alloys and how the resulting modification of the microstructure can be used to optimize their mechanical properties. Alloys composed of 88%, 93% and 95% wt. of tungsten and the balance is Ni: Fe in the ratio of 7:3 were sintered at different temperatures for different sintering holding times in hydrogen atmosphere. It was shown that the mechanical properties of the alloys, and especially their ductility, are harmed when tungsten grains are contiguous.

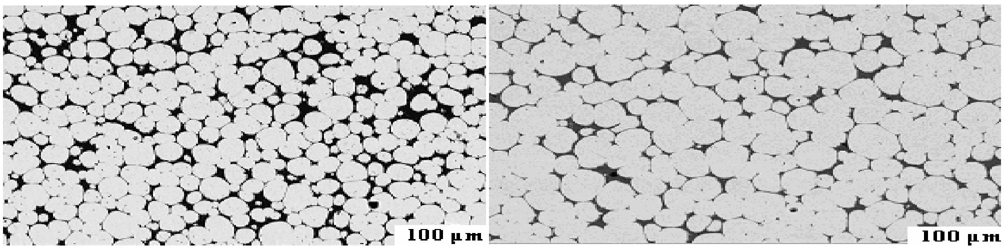
Keywords: tungsten heavy alloys, liquid phase sintering, microstructure analysis

1. Introduction

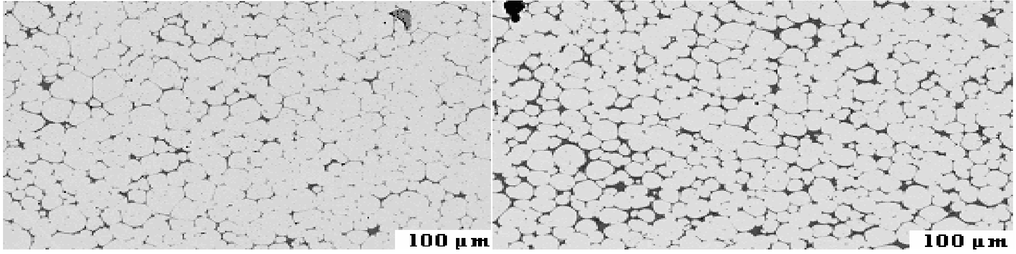
Tungsten is a refractory metal with a fusion point of 3420^{0}C. A typical tungsten heavy alloy contains 80-98 % tungsten. The balance is generally a mixture of relatively low melting transition elements, such as nickel, iron, copper and cobalt [1]. Tungsten heavy alloys differ from many other sintered alloys due to the unique combination of high density, high strength and plasticity deformation and their capability to improve their mechanical properties by strain hardening [2]. Microstructural factors, such as tungsten particles size, matrix volume fraction and tungsten-tungsten contiguity, affect the mechanical properties of tungsten heavy alloys [3].The purpose of the investigation was to examine the effect of sintering conditions on the microstructure of tungsten heavy alloys and how the resulting modification of the microstructure could be used to optimize their mechanical properties.

2. Experimental and results

Elemental powders of tungsten, nickel and iron were mixed to produce tungsten heavy alloys with compositions of 8%, 93% and 95% wt. of tungsten and the balance is Ni: Fe in the ratio of 7:3. The green compacts were solid-state sintered at a temperature of 1350 0C for 1 hour in hydrogen atmosphere. Solid-state sintered tungsten heavy alloys were subsequently sintered at 1450 0C for 1 hour and 15000C for 3 min and 30 minutes in hydrogen atmosphere. Quasi-static tensile testing was carried out using a CMT 4105 testing system with a constant cross head displacement rate of 0.5



88W-8.4Ni-3.6Fe (3 minutes) 93W-4.9Ni-2.1Fe (3 minutes)



95W-3.5Ni-1.5Fe (3 minutes) 95W-3.5Ni-1.5Fe (30 minutes)

Fig. 1. Microstructure of WHAs sintered at 1500 ^{0}C

Table 1. Microstructural parameters of WHAs at 1500 ^{o}C

Microstructural parameters	88W-8.4Ni-3.6Fe		93W-4.9Ni-2.1Fe		95W-3.5Ni-1.5Fe	
	3 min	**30 min**	**3 min**	**30 min**	**3 min**	**30 min**
Avg. Grain Size	18.2	23.6	22.5	28.5	27.9	33.4
Contiguity	30.2	25.6	53.9	47.5	60.6	60.4
Connectivity	1.8	1.4	2.7	2.5	3.4	3.2
Volume Fraction	73.4	72.3	85.4	80.5	90.5	90.1

mm/min. in ambient air at room temperature. The size of the tungsten particles, the volume fraction of the matrix phase, the connectivityand tungsten- tungsten contiguity of the sintered tungsten heavy alloys were characterized using scanning electron microscope.

As can be seen from the Fig.1, the matrix volume fraction decreases as the W content increases from 88% to 95% and the W particles are more spherodized and less contiguous when the sintering holding time increases. The low contiguity alloys have a matrix phase homogeneously distributed throughout the microstructure, but those of higher contiguity exhibit matrix phase pools, indicating that the microstructure is less homogeneous.

According to the grain size data in table 2, the mean grain size slightly increases with the effective sintering time because of the Ostwald-ripening. Interestingly, for sintering holding time changes from 3 minutes to 30 minutes, the mean contiguity decreases. Increase in tungsten content increases the solid phase fraction, and leads to an increase in contiguity. Like contiguity, it is found that the connectivity slightly decreases with the effective sintering time due to the increase in tungsten solubility in the matrix phase which also increases the matrix volume phase, as can be seen in Fig. 1.

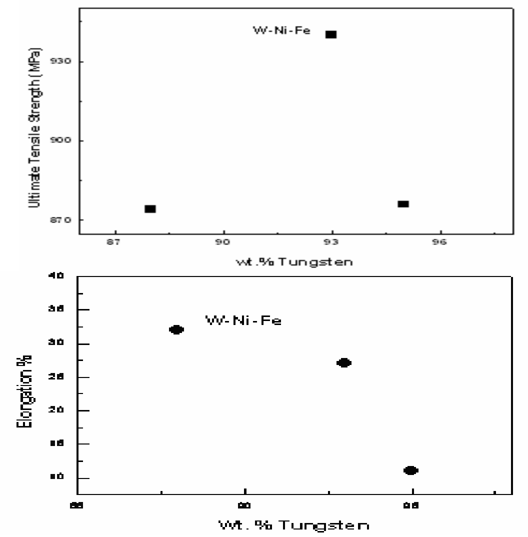


Fig. 2. Ultimate tensile strength and elongation as function of wt.% tungsten.

From the figure 2, it is readily apparent that tensile strength increases far more significantly in the 93% wt. tungsten composition than in the 88% and 95% wt. ones. With respect to ductility, because of higher tungsten-tungsten contiguity, the lowest values of elongation were recorded with the composition of 95% W sinter at 1500 0C. The tensile properties of 93% wt. tungsten were superior to 88% and 95% wt. tungsten and these superior properties were result of grain refinement, comparatively less contiguity and passable matrix volume fraction.

3. Summary

The tensile properties of tungsten heavy alloys largely depend on the composition and uniform distribution of the matrix phase and amount of solid tungsten particles. Low ductility may appear in case of non uniform distribution of matrix phase. The tensile properties of 93% wt. tungsten are superior compared to 88% and 95% wt. ones because of comparatively less contiguity, grain refinement and passable matrix volume fraction. Mean values of contiguity and connectivity slightly decrease with effective sintering time during initial liquid phase sintering. The matrix volume fraction and contiguity are the most important microstructural parameter that affects the mechanical properties of liquid phase sintered tungsten heavy alloys.

4. References

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