2006 POWDER METALLURGY
World Congress

The Effects of Molybdenum Content on the Dynamic Properties of Tungsten-based Heavy Alloys

Woei-Shyan Lee[a] and Tien-Yin Chan[b]

Department of Mechanical Engineering, National Cheng Kung University, Tainan 701, Taiwan
[a]wslee@mail.ncku.edu.tw, [b]tyc59@ms41.hinet.net

Abstract

Hopkinson bar dynamic test under strain rates ranging from 2000 s^{-1} to 8000 s^{-1} at room temperature revealed that the flow stress of tungsten heavy alloys depended strongly on the strain, strain rate, and the content of molybdenum. The variation of flow stress was caused by the competition between work hardening and heat softening in the materials at different strain rates. The high temperature strength of the matrix phase was increased by the addition of molybdenum, which enhanced the strength of the tungsten heavy alloys in high strain rate test.

Keywords : molybdenum, dynamic properties, tungsten heavy alloy, Hopkinson bar

1. Introduction

Mo element has significant influences on the micro-structures of W heavy alloys such as contiguity, grain shape, interfacial phase, etc.[1-2]. Current studies on the effects of Mo on the mechanical properties of W-Mo-Ni-Fe alloys are based on quasi-static tests and analyses. In this study, the split-Hopkinson bar apparatus is employed and dynamics properties tests are conducted to study the effects of varying the Mo content on the characters of tungsten heavy alloys subjected to high strain rates.

2. Experimental and Results

The compositions of five samples were designed to have an equivalent volume ratio of W and Mo to Ni and Fe, but with different ratios of W to Mo, in the powder state, and fixed weight ratio of Ni to Fe (7/3). Table 1 lists the designed composition in this study. Dynamic compression test is performed using split-Hopkinson bar at strain rates ranging from about 2000 to 8000 s^{-1}. Quantitative elemental analysis was carried out by electron probe microanalysis (EPMA).

Table 1. Designed composition in this study

Composition[wt%]	W	Mo	Ni	Fe
alloy 1	90	0	7	3
alloy 2	86.64	3.08	7.2	3.08
alloy 3	83.09	6.34	7.4	3.17
alloy 4	79.33	9.79	7.62	3.26
alloy 5	75.36	13.44	7.84	3.36

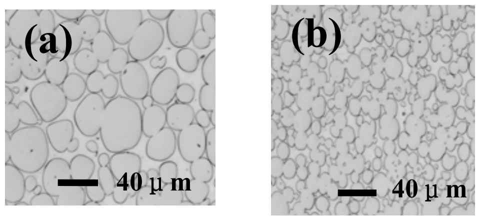

Fig. 1. Microstructure of the alloys sintered for (a)W-7Ni-3Fe (b)W-13.44Mo-7.8Ni-3.36Fe.

Fig. 1 shows the evolution of microstructures of alloy 1 and alloy 5 sintered at 1520°C and isothermally held for 60 minutes. It can be seen that the grain size differs evidently as the Mo additive is added in the tungsten alloy, the averaged grain size is 32.5μm before Mo is added and 17μm after a 13.44wt% of Mo is added.

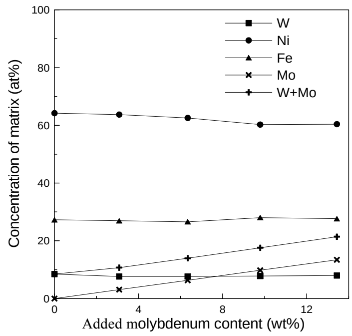

Fig. 2. Variations of the concentrations in the matrix phase.

An EPMA measurement is performed next for the variation of the compositions of the matrix. The results are shown in Fig.2. The increase of Mo content in the matrix results in an increase of the combined solubility of W and Mo but a decrease of Ni content, while the content of Fe has no significant change.

Fig. 3 show the flow stress-strain curves for the alloy deformed at different strain rates. The alloy strength increases as strain rate increases regardless the amount of added Mo element. The alloy 4 especially presents significant increase in strength even in much higher strain rates. Fig. 3 also discloses that the higher the strain rate, the more effective of the Mo content becomes on the strength of the alloy.

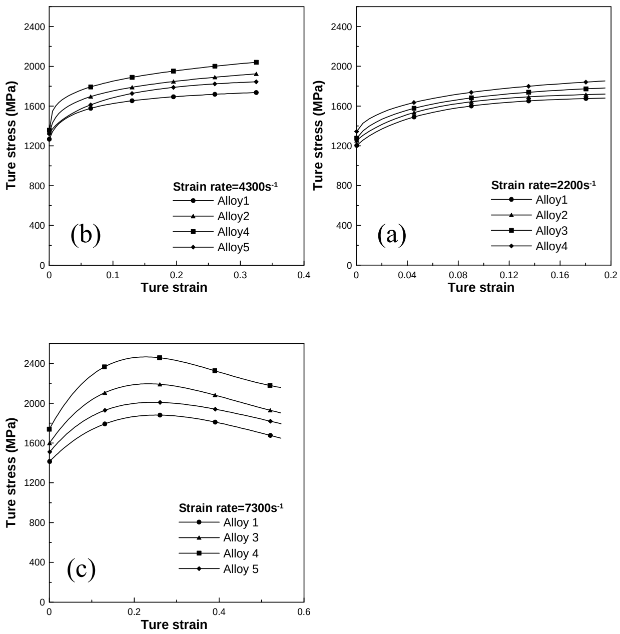

Fig. 3. Molybdenum content dependence of true Stress-strain curves of (a) 2200 s^{-1} (b) 4300 s^{-1} (c) 7300 s^{-1}.

Fig. 4 presents the influence of strain rate on flow stress. It can be seen that the strength increases as the strain rate increases. It is also noticed that the rate change of the slope of the curve for Alloy 4 is the rapidest indicating that Alloy 4 has the most strain rate sensitivity and that optimal strength is achieved under high strain rate. Previous study [4] on 92.5W-5.25Ni-2.25Fe tungsten alloy under impact test has shown that the alloy has an ultimate strength of 1600 MPa subjected to 4000 s^{-1} strain rate at constant temperature. The alloy considered in this study under relatively close condition shows an ultimate strength of 1800 MPa, about 12% in gain. The improvement on mechanical properties can be attributed to the effect of grain refinement and more solute atoms (about 3.2 at.%) are increased with respect to the W-Ni-Fe alloy having the same solid/liquid volume ratio, which strengthens the matrix.

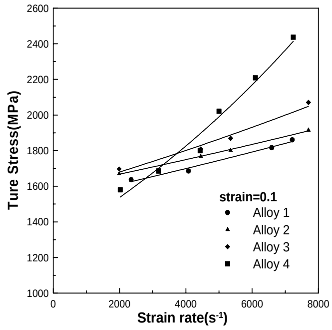

Fig. 4. Influence of strain rate on flow stress at a constant plastic strain of 0.1.

3. Summary

The tungsten-based alloy is of potential as an alternative to depleted uranium alloys in defense application provided that the Mo addition is moderately controlled and precipitation of intermetallic phase is prevented.

4. Reference

1. T. Y. Chan, and S. T. Lin, J. of Mater. Sci., 35, p. 3759-3765, (2000)
2. Chen-Sheng Hsu, and Shun-Tian Lin, Scripta Materialia, Vol.46, pp. 869-873 (2002).
3. W. S. Lee, G. L. Xiea, C. F. Lin, Mater. Sci. and Eng., A 257, p. 256-267, (1998).