

Application of compression lubricant as final porosity controller in the sintering of tungsten powders

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ARTICLE INFO

Article history:

Received 17 July 2016

Received in revised form 31 December 2016

Accepted 20 January 2017

Available online 04 February 2017

Keywords:

Lubricant

Infiltrable tungsten

Pore coarsening

ABSTRACT

Sintering behavior of two tungsten powders (1.2 μm and 6 μm) was studied for preparing infiltrable porous skeleton. Both powders were compressed by mechanical press (MP) and cold isostatic press (CIP) with and without stearic acid respectively as compaction lubricant. Results showed that presence of solid lubricant powder in addition of its essential effect on soundness of parts, depending on its size and distribution, could mainly affect sintered microstructure. Stearic acid as compaction lubricant in addition of decreasing friction between particles during the compaction, has acted as spacing particles between primary powder particles. In the cases that lubricant particles are much bigger than tungsten particles a big pore remained after evaporation of lubricant. During the sintering, big pores became bigger due to coarsening mechanism and formed an interconnected network of pores and on the other hand small pores shrank or even disappeared due to densification. By exact controlling of the size of tungsten powder and lubricant powder, infiltrable tungsten skeletons with 80% of theoretical density were produced successfully at low sintering temperatures such as 1500 $^{\circ}\text{C}$.

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1. Introduction

Powder metallurgy is the predominant production process for tungsten alloys and composites. Compression of tungsten powder can be carried out via cold isostatic press (CIP) or mechanical press (MP) [1]. Uniform pressure in CIP process results in a high uniformity for green density and consequently dimensional stability during sintering. In the case of mechanical pressing, tungsten powder is formed in a uniaxial solid die and severe die wall friction can yield to density inhomogeneity or cracks [2]. Lubricants in solid powder form are mixed with primary powders and reduce the friction between pressed compact and die wall. They provide more uniform density of compacts and prevent ejection defects. Lubricant particles evaporate or decompose at sintering early stages and leave equivalent voids [3]. Size distribution of pores plays a key role in evolution of consolidation. A homogeneous initial pore structure gives a higher sintered density [4]. Densification and coarsening are two apparently counter process during sintering. Although total energy reduction via surface decrease is the drive force for both phenomena, but during coarsening the pores grow while during densification the pores shrink [5]. Relatively large size initial pores enlarge during sintering and regions of initially high packing (small pores) shrink. Initial pores larger than half the primary particle often form big pores [6]. Agglomeration or poor consolidation may lead to this defects [7]. Consequently big pores are unavoidable after sintering of a compact with bimodal porosity [8]. Maximum densification is aim

of most sintering treatments but some sintered parts such as infiltrable tungsten skeletons must have controlled open porosity. Characteristics of final channels is controlled by primary powder, compaction and sintering parameters [9,10]. Growth of pores due to coarsening has been considered as a defect forming mechanism and never has been used as constructive mechanism for porosity control. In this research, the effect of lubricant induced porosity on sintering densification was studied.

2. Material and methods

Tungsten powders with two different particle size distributions were used. A tungsten powder with average particle size of 6 μm was one of them. This particle size is normally used for fabrication of tungsten skeletons. Besides that, a fine tungsten powder with average particle size of 1.2 μm was selected for studying behavior of a fine powder. SEM micrographs and particle size distributions of powders are shown in Figs. 1 and 2 respectively. The powder with average particle size of 1.2 μm and the powder with that of 6 μm will be referred as fine and medium powders respectively in whole text.

Without lubricants, soundless green tungsten parts was not producible by mechanical pressing. 1.5 wt% of stearic acid powder was added as compression lubricant. The mixture of tungsten and lubricant powders were ball milled for 90 min and passed through 100-mesh sieve twice. Therefore homogenous mixtures of tungsten and lubricant particles were obtained and all lubricant particles had broken down to small flakes. Lubricated powders were compressed in a steel matrix according to ASTM B331 standard test method for Compressibility of Metal

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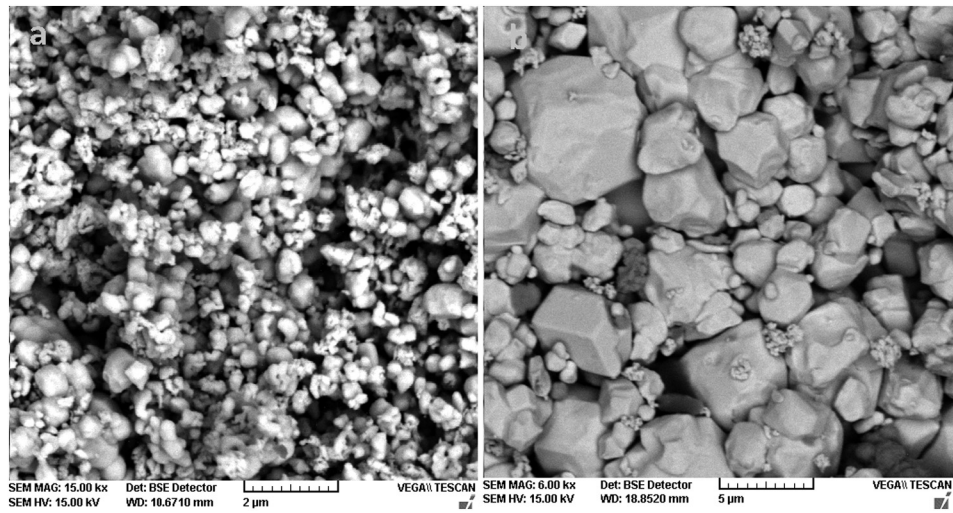


Fig. 1. SEM micrographs of the initial tungsten powders, a. Fine, b. Medium tungsten powder.

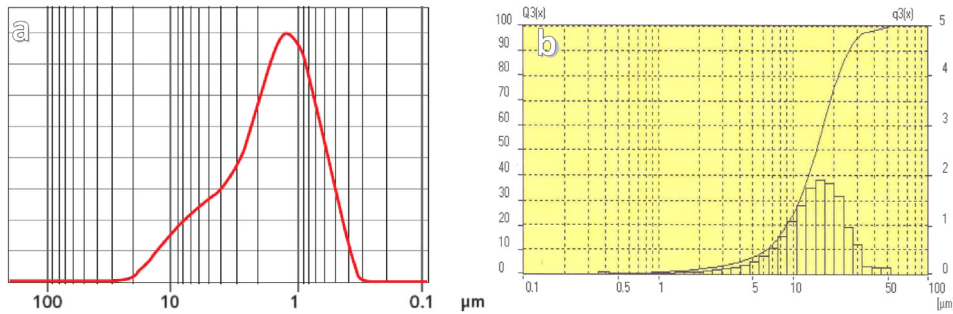


Fig. 2. Particle size analyzing of the initial tungsten powders, a. Fine, b. Medium tungsten powder.

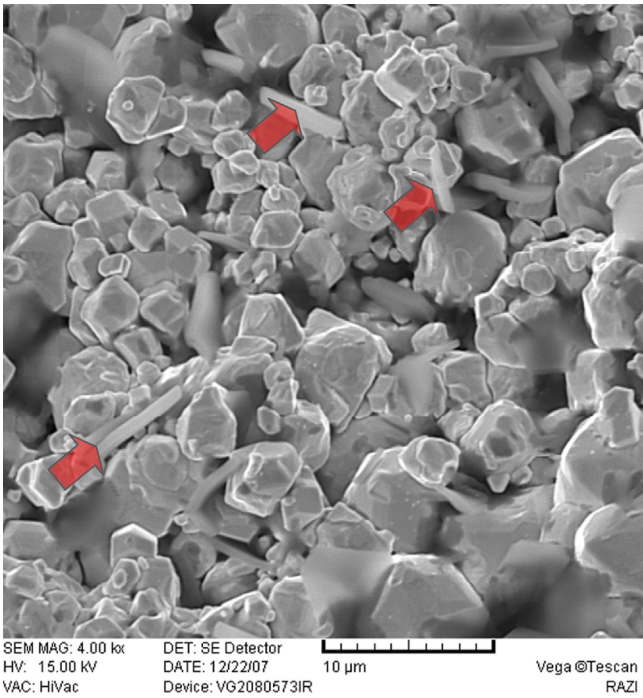


Fig. 3. SE-SEM micrograph of fractured section of mechanically compressed medium tungsten powder; some stearic acid flakes are marked.

Powder in uniaxial Compaction. Pressure of mechanical compression was about 500 MPa. On the other hand, Fine and medium tungsten powders were compressed via cold isostatic press (CIP) at pressures of 254, 495 and 663 MPa without any lubricant.

All specimens were sintered under a flow of dry hydrogen in a tube furnace. Sintering cycles also included delubrication and reduction components each for 1 h at 400 and 1000 °C respectively. Densities of green and sintered specimens were determined by water immersion method according to ASTM B328 standard. Eventually all porous tungsten specimens were infiltrated with molten copper at 1250 °C for 30 min under hydrogen atmosphere. Scanning Electron Microscope (SEM) was employed for in detail study of microstructure.

3. Results and discussion

3.1. Compression

Fracture surface of mechanically compressed green specimen of medium tungsten powder shown in Fig. 3. Primary powder is mixed with stearic acid flakes as lubricant. The milling and sieving of primary

Table 1
Green and sintered densities of compacted from two tungsten powders after mechanical pressing with lubricant.

	Green density		Sintered density	
Sintering temperature			1400 °C	1500 °C
Fine powder	54		58	76
Medium powder	72		72.3	72.8

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