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COMPARATIVE STUDY ON PARTICLES BONDING OF TUNGSTEN SAMPLES WHICH WERE PRODUCED BY POWDER METALLURGY METHOD AND UNDERWATER EXPLOSIVE COMPACTION TECHNIQUE

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ABSTRACT

Powder metallurgy and underwater explosive compaction are two alternative methods for production of engineering parts from the powder of materials. In this research work powder metallurgy technique and underwater explosive compaction method applied for production of several samples. Tungsten powder with a mean grain size about 5 microns used as a raw material. The density and hardness of produced samples were measured and fragment surface of these samples analyzed using of scanning electron microscope (SEM) and the results were compared. Comparison of the results indicated that the strong bonding between the particles can be obtained using of underwater explosive compaction method and by using of this method the tungsten parts with high mechanical and physical properties can be produced.

Key words: powder metallurgy, explosive compaction, underwater, shock wave, tungsten, bonding

INTRODUCTION

Refractory materials such as tungsten have wide applications in various industries. Due to the special characteristics of these materials like high melting point temperature and high hardness, the production of the engineering parts made by these materials is very difficult. Powder metallurgy technique is one of the important technologies applied for production of tungsten parts, but achievement of high density and hardness is not possible by this method [1]. To achieve the maximum density and hardness by using of Powder metallurgy technique using of some additive such as nickel and ferrous powder were proposed in previous study [2].

To prepare high quality parts, explosive compaction method especially underwater explosive compaction method is an alternative way to consolidation of tungsten powder with a density near to theoretical maximum density (TMD) of tungsten.

Previous studies [3-8] have reported that by utilizing the shock waves which are generated by detonation of an explosive material, the production of denser compact pieces with high quality is possible within microseconds. Passing the high pressure shock waves through the powder medium, would cause the localized heating to generate on powder surface and a layer of powder surface would melt. By compaction of these powder particles, it is possible to obtain a strong bond between the particles [9, 14].

In the present investigation, several specimens of tungsten parts produced using of powder metallurgy and a setup of underwater explosive compaction processes.

After production of the specimens, the properties of two type's specimens such as the density and hardness were measured and the fragment surfaces of cross sectional area of the specimens were analyzed using the scanning electron microscope (SEM).

EXPERIMENTAL PROCEDURE

In order to compare the underwater explosive compaction process and conventional powder metallurgy some specimens produced by two these methods. Tungsten powder with a mean grain size about 5 microns used as a raw material. In conventional powder metallurgy the pure tungsten parts cannot be obtained and we have to add some additives. In order to obtain high quality parts one percent of nickel powder and one percent of ferrous powder added to tungsten powder and compacted at 440 Mpa pressure and sintered at 1350 degree of centigrade at 2 hours.

Other specimens produced using of a setup of underwater explosive compaction method. Fig. 1 shows the used setup of underwater explosive compaction.

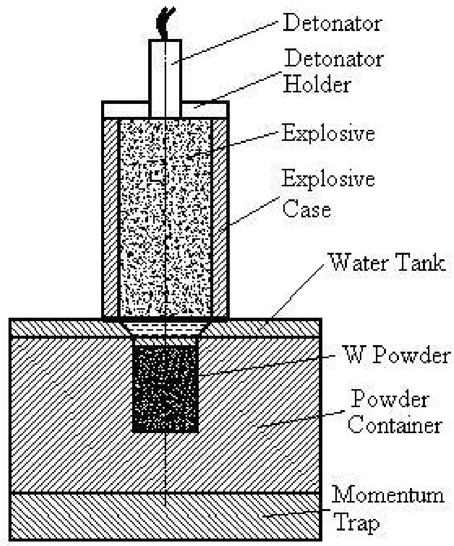

Fig. 1: Underwater explosive compaction setup

The underwater explosive compaction setup consists of several components, i.e. an electrical detonator, explosive material, an explosive container, a water tank and water, a powder container, pure tungsten powder and a momentum trap. The explosive material used in the present study was C4 with a detonation velocity of 8193 m/s. The tungsten powder was prepared and placed in the powder container. By ignition of the electrical detonator, the compaction process was successfully performed and several specimens were produced. In order to eject the product from the container, the powder container was precisely machined using turning operation.

RESULTS AND DISCUSSION

Fig. 2 shows typical specimens produced by powder metallurgy technique. These specimens were 20 mm in diameter and 3 mm in thicknesses.

Fig. 2: Tungsten specimens obtained through Powder metallurgy technique

Fig. 3 shows a typical specimen produced by underwater explosive compaction method. This specimen has a same dimension with powder metallurgy specimens.

Fig. 3: Tungsten specimen obtained through underwater explosive compaction method

The density of specimens measured using of a densitometer and hardness of these measured using a micro hardness testing instrument. Table 1 shows the density and hardness of six typical produced specimens.

Table 1: Measured density and hardness of the specimens

Specimen	Compaction Method	Density (g/cm^3)	Hardness (Hv)
PM # 1	Powder Metallurgy	17.01	219
PM # 2	Powder Metallurgy	17.10	216
PM # 3	Powder Metallurgy	17.06	221
EC # 1	Underwater Explosive Compaction	18.31	525
EC # 2	Underwater Explosive Compaction	18.57	576
EC # 3	Underwater Explosive Compaction	18.61	581

As shown in Table 1 the maximum density that was achieved by powder metallurgy technique is 89% (17.1/19.27) of the theoretical maximum density of tungsten, which is too low compare to the maximum density obtained by underwater explosive compaction method (96.5% of the theoretical maximum density of tungsten). This results illustrate that the total porosity of the powder metallurgy specimens are three time higher than the underwater explosive compaction specimens. Thus due to the higher porosity the hardness of the powder metallurgy specimens must be lower than the underwater explosive compaction specimens. This result observes in Table 1. The other reason of this low hardness of powder metallurgy specimens is referred to bonding between particles. To study of the particles bonding in two categories specimens, the fragment surface of the specimens analyzed using of scanning electron microscope. Fig. 4 shows the fragment surface of a powder metallurgy specimen (PM # 3) and Fig. 5 shows the fragment surface of an underwater explosive compaction specimen (EC # 3).

As shown in fig. 4, incomplete bonding observed in the selected fragment surface of powder metallurgy specimen and any particles in this surface bonded with other particles only in two directions. In addition the particles of the around of the porosity have a weak bonding with other particles.

In other hand as shown in Fig. 5, duo to compaction mechanism in underwater explosive compaction process (passing of shock wave through powder medium, melting a layer of particle surface, compaction and welding of particles) the complete bonding between particles observed in the selected fragment surface of underwater explosive compaction specimen. In addition any porosity isn't observed in this figure. Thus refer to above discussions and the results illustrated in Table 1, the hardness of the underwater explosive compaction specimens can be 2.5 times higher than the powder metallurgy specimens.

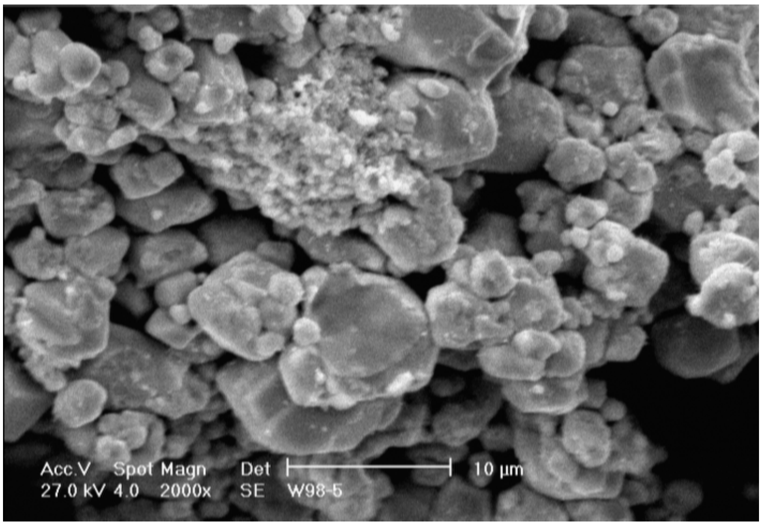

Fig. 4: Micrograph of the fragment surface of a powder metallurgy specimen (PM # 3)

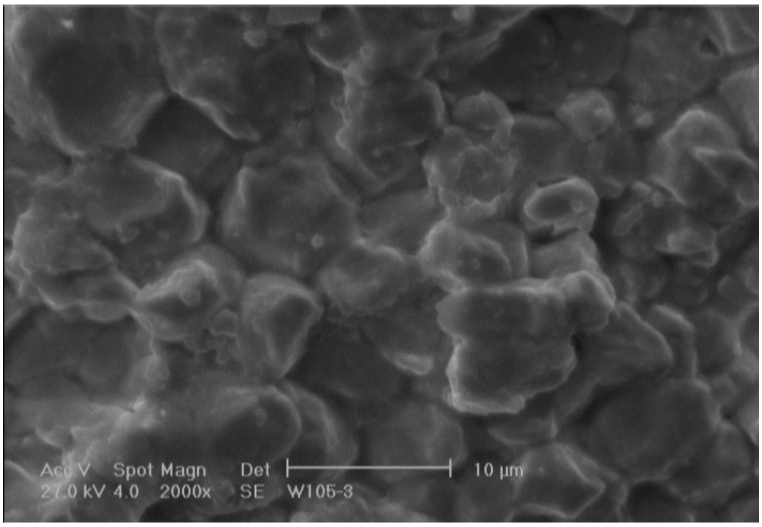

Fig. 5: Micrograph of the fragment surface of an underwater explosive compaction specimen (EC # 3)

Using of above results, we can predict that the mechanical properties of the engineering parts which were produced by underwater explosive compaction process is better than the parts produced by powder metallurgy technique.

CONCLUSION

Powder metallurgy technique and underwater explosive compaction method applied to production of several tungsten specimens. The results indicated that the complete bonding between particles can be obtained using of underwater explosive compaction method and the total porosity of underwater explosive compaction specimens is too lower than powder metallurgy specimens. In addition high density (near to theoretical maximum density of tungsten) and hardness can be obtained using of underwater explosive compaction method.

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