May 19, 1970 F. C. HOLTZ, JR **3,512,962**

COBALT-TUNGSTEN CARBIDE ALLOY AND PROCESS

Filed Jan. 3, 1966 3 Sheets-Sheet 1

FIG. 1

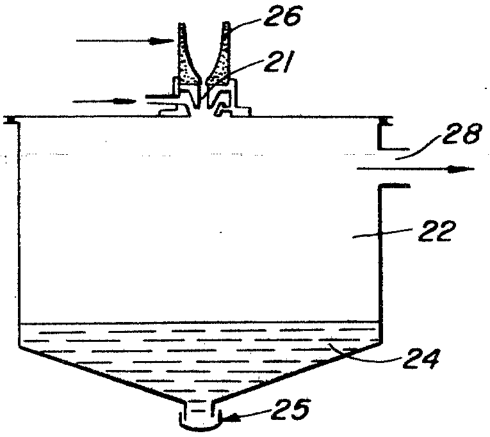
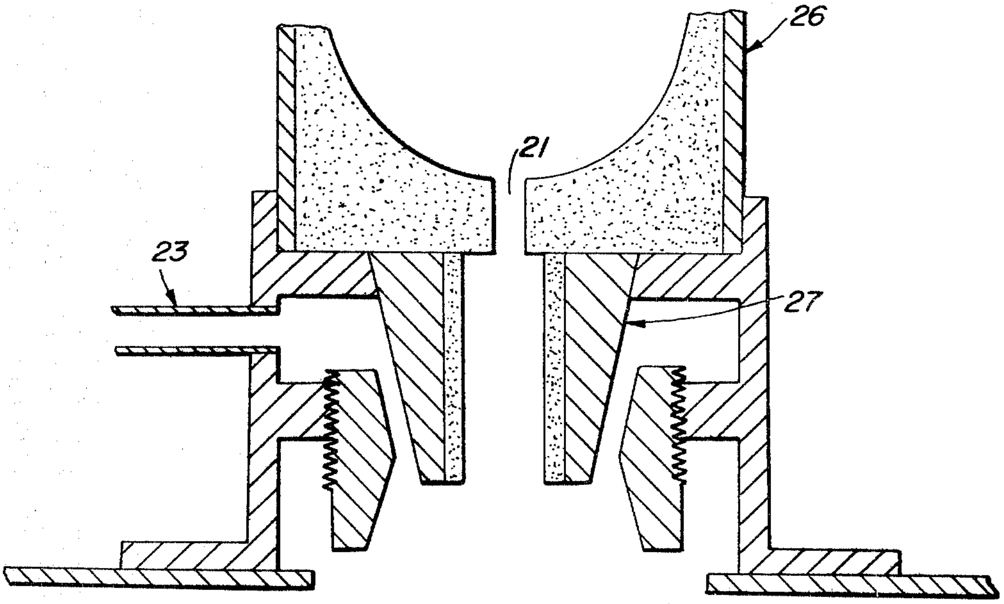


FIG. 2



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Atty

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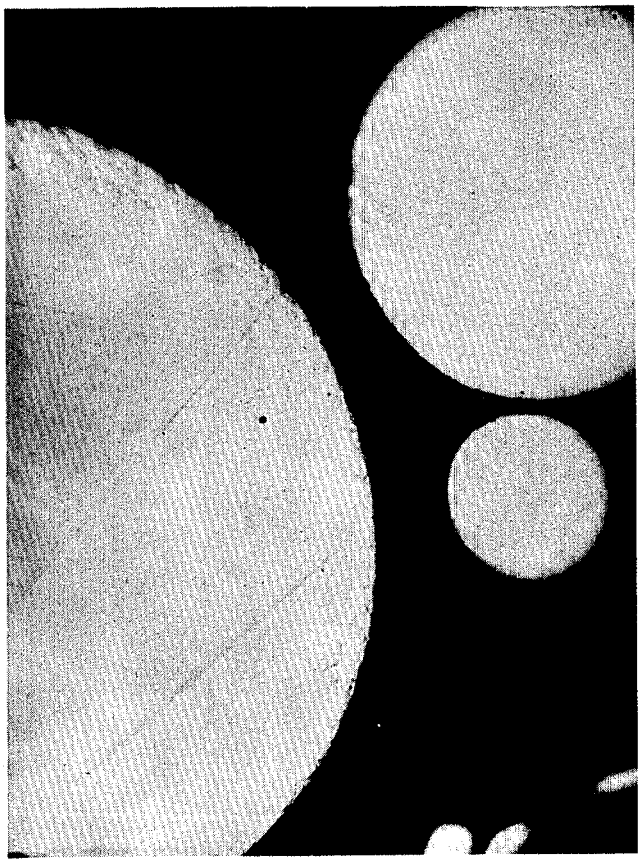

FIG. 3

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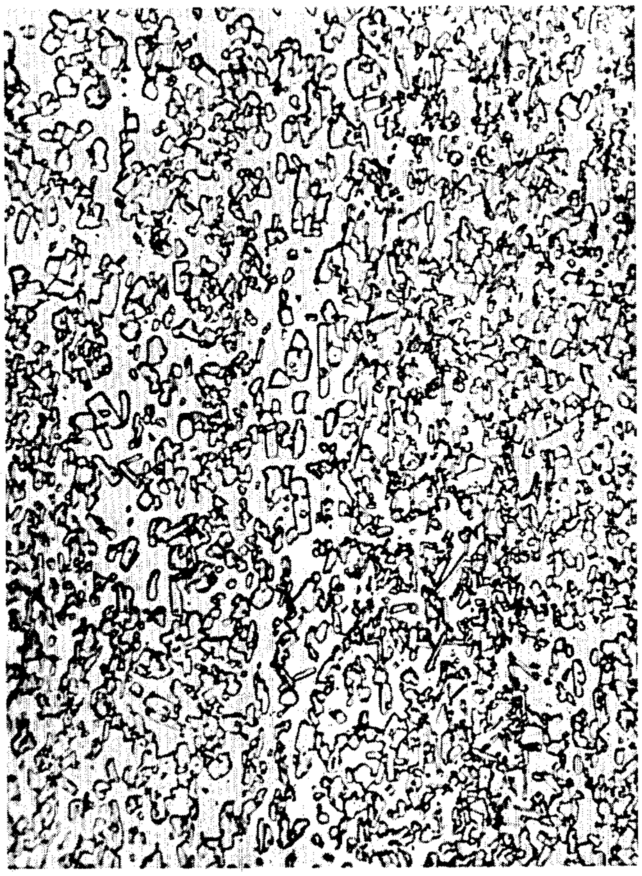

FIG.4

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COBALT-TUNGSTEN CARBIDE ALLOY AND PROCESS

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Continuation-in-part of application Ser. No. 435,733, Feb. 26, 1965. This application Jan. 3, 1966, Ser. No. 518,098
Int. Cl. C22c *19/00;* **B22f** *9/06;* **B22d** *23/08*
U.S. Cl. 75—170 **7 Claims**

ABSTRACT OF THE DISCLOSURE

Fully dense cobalt-tungsten carbide alloys characterized by a microstructure exhibiting a substantialy uniformly dispersed tungsten-carbide phase substantially all of which has a grain size less than 5 microns, are produced from prealloyed powders by rapidly quenching an atomized molten alloy charge consisting essentially of from 40 to 70 percent by weight of tungsten carbide, balance cobalt, and subjecting the solidified particles in a suitable container to the step of hot consolidation to produce a wrought alloy directly from prealloyed powder.

This patent application is a continuation-in-part of application Ser. No. 435,733, filed Feb. 26, 1965, by the same inventor.

The present invention relates to a group of cobalt-tungsten carbide alloys which are characterized by a uniformly dispersed, ultrafine tungsten carbide phase in a cobalt matrix and to the process whereby such exceptional metallurgical structures may be most readily achieved.

More especially my invention is directed to a wrought cobalt base alloy containing relatively large quantities of tungsten carbide, which alloys are composed of from 40 to 70% by weight tungsten carbide balance cobalt and wherein the tungsten carbide phase is in a grain size range of less than 5 micron. I achieve this very desirable feature by using an atomization and then subsequent powder consolidation technique which is hereinafter set forth in greater detail.

Some cobalt base alloys containing tungsten carbide have previously been made and used as is well known to those skilled in this art. Such alloys have been made predominanty by the process known as "liquid phase sintering." However to the best of my knowledge alloys have not been made wherein the cobalt content is greater than 40% by weight as is shown and claimed in the present specification and claims. The cobalt-tungsten carbide alloys of the prior art are made by blending cobalt powder with tungsten carbide powder, pressing the mixture in a die to the deired shape, then heating the pressed compacts at a temperature which causes the cobalt to melt while the tungsten carbide constituent remains solid but grows appreciably in size. If the liquid-phase sintered alloys contain more than about 35% by weight of cobalt, the volume of liquid cobalt present during sintering is so great that the tungsten carbide particles tend to settle out in the bottom of the alloy because of their high density. The large volume of liquid also causes the alloy bodies to "barrel" out or bulge during liquid-phase sintering. In addition such cobalt-tungsten carbide (Co-WC)) alloys of the prior art have never been characterized in the wrought state by an ultrafine uniformly dispersed tungsten carbide phase in the cobalt matrix.

The present alloys are made by first atomizing liquid compositions thereof followed by quenching as particulate powders after which such powders are consolidated into the solid stock as is described below.

Accordingly, a primary object of my invntion is to provide new and useful wrought alloys consisting essentially of cobalt and tungsten carbide wherein the tungsten carbide is present in amounts ranging from 40 to 70% by weight.

Another object of my invention is to provide such cobalt-tungsten carbide alloys wherein the carbide phase is of very fine grain size and substantially uniformly dispersed throughout the cobalt matrix.

Another more specific object of my invention is to provide cobalt base alloys having a high tungsten carbide content which are readily fabricated by hot working techniques.

Still another specific object of my invention is to provide an alloy atomization and consolidation process whereby such cobalt-high tungsten carbide alloys may be readily and conveniently made.

These and other objects, features and advantages of my invention will become apparent to those skilled in this particular art from the following detailed disclosure thereof and the accompanying drawings in which:

FIG. 1 schematically illustrates an atomizing chamber for use in the practice of the present invention;

FIG. 2 schematically illustrates atomizing apparatus for use herewith;

FIG. 3 is a photomicrograph, unetched, at 2000 magnification of the powders resulting from the practice of the present invention; and

FIG. 4 is a photomicrograph, unetched, at 2000 magnification of solid alloy stock resulting from the consolidation of the alloy powders shown in FIG. 3.

The alloys of the present invention consist of from 30 to 60% by weight cobalt, balance tungsten carbide and more specifically consist of a cobalt matrix containing some tungsten and carbon both in solid solution. The dispersed phase therefore is tungsten carbide and said dispersed phase when made as herein taught is of the size ranging from 0.5 to approximately 3 microns, although in some instances, less preferably, it may range up to 5 microns.

Tungsten carbide consists of 6.12% carbon and 93.88% tungsten. According, alloys designated as ranging from 30 to 60% cobalt and from 40 to 70% tungsten carbide have a tungsten content ranging from 37.6 approximately to 65.8 and a carbon content ranging from 2.4 to 4.2 balance cobalt. Within such ranges I note that the proper amounts of tungsten and carbon should be stoichiometrically controlled to yield tungsten carbide (WC) without too great an excess of either constituent. Minor variations in this can be tolerated in view of the relatively high cobalt content.

The present alloys can also be made by using tungsten carbide (WC) in the initial melting charge rather than the elemental constituents.

In order to prepare the present alloys reference should be had to the following table:

TABLE 1

Alloy	Chemical composition of charge		
	Co	W	C
30 Co-70 WC	30	65.8	4.2
40 Co-60 WC	40	56.4	3.6
50 Co-50 WC	50	47	3
60 Co-40 WC	60	37.6	2.4

Alloys consisting of 30 to 40% cobalt balance tungsten carbide illustrate good impact and wear resistance and thus are eminently suited for tool and die usage. On the other hand materials consisting of 50 to 60% cobalt, balance tungsten carbide find excellent utility as more ductile high strength structural materials. In either case the alloys made as herein taught comprise wrought alloys and have the finely, uniformly dispersed tungsten carbide phase referred to above.

In the practice of my invention I accomplish very rapid quenching of the molten, atomized alloy powders. By this means large quantities, relatively speaking, of hard, high-melting carbide phase is retained in solid solution in the atomized particles. Upon consolidation of such resulting powders followed by forging, hot rolling or extrusion, I find that while some carbide growth takes place during hot working the particle size remains quite small and the dispersion thereof in the cobalt matrix is remarkable uniform.

The present alloy compositions are made by an atomization process to form powders followed by the consolidation of such powders into appropriate structural masses and for the specifics involved in the atomization to form the powders reference should first be had to FIGS. 1 and 2 hereof. It should be understood of course that similar apparatus may be likewise employed. An appropriate alloy charge of the desired composition was first weighed up, melted in a suitable crucible and then the molten alloy was poured through the orifice **21** at the top of the atomizing chamber **22**. In such chamber the molten stream is first broken up into fine particles and then quickly quenched by a high pressure inert gas stream entering the chamber **22** through the gas inlet port **23**. In order to assure rapid quenching of the molten, atomized metal powders I provide at the bottom of the apparatus a water reservoir **24** which may operate in conjunction with the atomizing stream to quench the particles.

The atomizing chamber, which is fabricated of a steel shell, water-cooled, is approximately 3 feet in diameter by approximately 2 feet in height. Obviously, other dimensions and geometries may be employed without departing from the spirit or scope of my invention. At the bottom of the chamber is slightly conical and at the center thereof I provide a capped opening **25** for metal powder and water removal.

Approximately 5 pounds of the present alloy compositions, using the charges shown in Table 1, were heated and melted at about 300° F. under an argon atmosphere to protect the melt. Argon atomizing gas at 350 p.s.i. was fed into the chamber **22** through the inlet port **23** first to purge and then to atomize the molten metal. After purging the melt was poured into the tundish **26** (which was preheated to about 1500° F.) from whence it flowed to the chamber **22** through the opening **21**.

Beyond the opening **21**, I provide a refractory-lined cone **27** at the exit end of which the atomizing gas strikes the molten metal stream to break up such stream into fine particles. In addition this impact quenches the molten particles so that they are solidified even before they are finally cooled in the water reservoir. Quenching is therefore quite rapid.

The powders resulting from the atomization were consolidated by canning, forging and then rolling at 2150° F. to produce a plate stock containing a uniform dispersion of tungsten carbide grains of less than 3 microns in size or at the upper limit ranging from 3 to 5 microns in size in some cases. An alloy consisting of 50% cobalt-50% tungsten carbide had a transverse rupture strength of 390,000 p.s.i.

It will be understood that various modifications and variations may be effected without departing from the spirit or scope of the novel concepts of my invention.

I claim as my invention:

1. A wrought alloy consisting essentially of: from 40 to 70% by weight tungsten carbide balance cobalt, said alloy being characterized by the tungsten carbide phase being substantially uniformly distributed throughout the cobalt matrix thereof and by a tungsten carbide grain size of less than 5 microns.

2. The alloy as defined in claim **1** wherein there is about 40% by weight tungsten carbide.

3. The alloy as defined in claim **1** wherein there is about 50% by weight tungsten carbide.

4. An alloy consisting essentially of from 40 to 70% by weight tungsten carbide, balance cobalt.

5. The alloy as defined in claim **4** wherein there is about 40% by weight tungsten carbide.

6. The alloy as defined in claim **4** wherein there is about 50% by weight tungsten carbide.

7. The method of making a wrought alloy characterized by a substantially uniformly dispersed tungsten carbide in a cobalt matrix, said carbide having a grain size of less than 5 microns, which comprises the steps of: atomizing a molten alloy charge consisting essentially of from 37.6 to 65.8% by weight tungsten, from 2.4 to 4.2% by weight carbon, with substantial stoichiometric equivalency to form the compound tungsten carbide, balance cobalt, rapidly quenching said atomized material and consolidating said material into alloy stock.

References Cited

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W. W. STALLARD, Assistant Examiner

U.S. Cl. X.R.

75—05, 20; 29—182.7