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3,254,995

HEAVY METAL ALLOYS

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This invention relates to heavy metal alloys and particularly to alloys having relatively high tungsten content. It is particularly useful in applications involving metal powders and metal powder techniques.

The alloys of the present invention are characterized by high tensile strength, high density, and high elongation, even when made into relatively thick bodies. In the past, some of these properties have been obtainable in relatively thin bodies of heavy metal alloys, but, when bodies of greater than minimal thickness were attempted to be made with those prior known alloys, the cores of such thicker bodies were normally relatively weak and brittle as compared with the surface.

Heavy alloys, based upon a high tungsten content, are used for applications requiring high mass in a small volume. Typical applications are counterweights for aircraft frames and instruments, gyro rotors, and for shielding of X-rays and other types of radiation. These alloys should be machinable and must, particularly for stressed applications, be of high strength and good ductility. These properties should prevail throughout the thickness of the piece.

For many years the most popular heavy metal alloy has consisted of approximately 90% tungsten, the balance being a copper-nickel binder with nickel predominating. The most popular compositions contain between 6% and 7½% nickel and 2½ to 4% copper, with the 90% tungsten. All parts and proportions mentioned herein are by weight.

Iron and nickel have also been tried in the past as a binder or matrix metal for heavy alloy, but with the nickel significantly predominating. The literature mentions, for example, a binder of 7% nickel and 3% iron, with 90% tungsten. In the literature, particular emphasis was placed on the fact that the nickel in the binder should always be well in excess of the other element whether it be copper or iron. For stressed parts, up until this time, there has been a practical density limitation of about 17 (grams per cc.) because the use of more than 90% tungsten to increase density resulted in a severe reduction in mechanical properties, so that structures of higher density were limited to non-stressed applications. As the size of parts produced from these alloys has increased, it has become more and more apparent that the prior alloys (stressed and unstressed) show a severe diminution of desirable properties in the core of relatively thick sections. For example, it has been demonstrated that a standard alloy of 90 parts tungsten, 6 nickel, and 4 copper may show a tensile strength as high as 120,000 p.s.i. with 5% or 6% elongation in the form of a thin molded test bar. However, a test bar made of the same alloy and machined from the center of a large section shows a drop in properties to about 80,000 p.s.i. tensile strength and 1% elongation. Compositions of 90% tungsten, 7% nickel and 3% iron on which the literature contains much information on

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small test bars show even more severe diminution in properties on test bars made from the center of thick sections.

An object of the present invention is to produce a heavy alloy in which the core of the alloy has substantially as good properties as the outside surfaces. A further object is to produce a high tungsten content alloy which will permit the use of higher proportions of tungsten without severe diminution of desirable properties, thus increasing the practical range of density for stressed parts to well above 18 grams per cc. Contrary to the prior literature, we have found in the case of iron-nickel binders for high tungsten alloys that the properties of the alloy are enhanced by the use of such proportions that the iron is substantially equal to or greater than the nickel in the range herein disclosed, and that such range substantially and unexpectedly improves the character of the alloy, particularly insofar as core properties are concerned. We have also found that, quite unexpectedly alloys containing considerably more tungsten can be produced with the new binder proportions of iron-nickel and still maintain high core strength and ductility. For some purposes it has been found advantageous to add small amounts of cobalt to the tungsten-iron-nickel alloy to increase the sintering temperature range and to stabilize the part during sintering, which tends to eliminate warpage during the shrinkage which takes place. The cobalt additions do not impair the properties and in fact, may even slightly enhance them.

The alloys of the present invention contain between about 80% and about 99.9% tungsten, and preferably from about 90% to 99.5% tungsten. Each alloy of the invention also contains nickel and iron in proportions wherein the iron content is approximately equal to the nickel content or, within critical limits, significantly greater than the nickel content. The term "approximately equal" as used herein with reference to the nickel-iron content includes the range of weight ratios between about 17:23 and about 23:17. As may be seen from the examples below, the ratio of nickel to iron ranges generally from about 23:17 to about 3:7 when the tungsten content is 90 parts. The nickel-to-iron proportion may vary between 575 parts nickel to 425 parts iron all the way progressively to 3 parts nickel to 7 parts iron. It will be noted that when significantly larger proportions of nickel to iron are utilized, e.g. 7:3, the product is very brittle, the ultimate tensile strength (U.T.S.) drops off to 88,000 p.s.i. and the percent elongation drops off to 1.3. When even lower proportions of nickel-to-iron than 3:7 are utilized, the product becomes so brittle that no significant tests can be made as to tensile strength, or elongation.

Cobalt may also be used effectively in the alloy in amounts up to about 1% of the total weight of the alloy. Higher amounts of cobalt may be added if desired, but for most applications about 1% or less has been found adequate. When 1% cobalt is used in a 90% tungsten alloy, as shown below, the "approximately equal" nickel-to-iron ratio may be 5:4, and the proportion of nickel to iron may vary with increasing parts of iron to 17:19. When the nickel-iron ratio, in the presence of 1% cobalt, is raised to 13:32, the alloy becomes very brittle and is outside the range of usefulness contemplated by this invention.

Similarly, in the presence of 0.5% cobalt in 90% tungsten alloys, the nickel-iron ratio may appropriately

be approximately equal in the range of 9:10 and may extend at the other end to 31:64. When the range is

The following examples illustrate the present invention in comparison with prior art alloys:

Ex. No.	Machined	Nickel	Fe	Co	Density	RC Hardness	U.T.S.	Percent Elong.
1-----	No-----	6	(none) 4 Cu	-----	16.85	27	112,000	5
2-----	Yes-----	6	(none) 4 Cu	-----	16.80	25	88,000	3
3-----	No-----	7	3	-----	17.0	28	137,000	27
4-----	Yes-----	7	3	-----	17.0	28	88,000	1.3
5-----	Yes-----	5.75	4.25	-----	17.0	27	133,200	12.15
6-----	Yes-----	5.5	4.5	-----	17.04	27.5	132,200	14.2
7-----	Yes-----	5.0	5.0	-----	17.0	29	130,100	16.65
8-----	Yes-----	4.0	6.0	-----	17.0	29.5	130,000	11.8
9-----	Yes-----	3.7	6.3	-----	17.0	29.5	129,000	11.0
10-----	Yes-----	3.0	7.0	-----	17.0	30	127,000	7.8
11-----	Yes-----	2.8	7.2	-----	16.95	34	very brittle—no check	
12-----	Yes-----	2.6	7.4	-----	16.93	36	very brittle—no check	
13-----	Yes-----	5.0	4.0	1.0	17.09	28	129,700	12.5
14-----	Yes-----	4.75	4.25	1.0	17.1	29	133,400	14.2
15-----	Yes-----	4.25	4.75	1.0	17.02	29	134,100	12.49
16-----	Yes-----	2.6	6.4	1.0	17.0	32	very brittle—no check	
17-----	Yes-----	4.5	4.0	0.5	17.0	29	133,000	16.0
18-----	Yes-----	3.5	6.0	0.5	17.0	30.5	124,000	12.5
19-----	Yes-----	3.1	6.4	0.5	17.0	32	134,000	10.6
20-----	Yes-----	2.8	6.8	0.4	16.95	33.5	very brittle—no check	

further extended, however, to 14:34 nickel to iron, the product becomes very brittle and useless for the purposes of this invention in the presence of 0.4 parts cobalt.

It will be noted that the relatively small amounts of cobalt (up to about 1%) may be substituted in lieu of

Examples 21 and 22

In Example 21, 95.2 parts tungsten were used. In Example 22, 97.0 parts tungsten were used. The other characteristics and results are as follows:

Ex. No.	Machined	Nickel	Fe	Co	Density	RC Hardness	U.T.S.	Percent Elong.
21-----	Yes-----	2.16	2.4	0.24	18.1	32	135,000	7
22-----	Yes-----	1.35	1.5	0.15	18.5	34	117,000	4

part of the iron or the nickel, so long as the basic nickel-iron ratios are maintained as disclosed herein.

Molybdenum may be substituted for the tungsten, as is well known in this art, for example, in substantial amounts, but normally below 10%, although for some purposes higher than 10% molybdenum may be substituted for tungsten based upon the total weight of the alloy.

The following examples compare the properties of both unmachined test bars, and machined tensile bars taken from cores made of various alloys including prior art alloys, of the present invention, and alloys outside the range of the present invention.

In each of the examples, powders for the compositions tested utilized the same grade, particle size, and percentage by weight (90%) of tungsten powder which had approximately 2.5 micron average particle size, and 99.99% minimal tungsten content. Each powder was mixed and blended in a ball mill for approximately three hours. Flat bars were produced in accordance with the drawing of U.S. "Military Specification—Tungsten Powder Compacts (Sintered and Hot-Pressed)" designated "MIL-T-21014 (Aer)," by molding at about 10 t.s.i. pressure. For the machined bars, cylinders were molded at the same unit pressure, and sintered to 1½ inch diameter by two inches long and test bars were machined from the center of the core, according to the drawing of the ¼ inch specimen illustrated on page 88 of "Metals Handbook," 1958, published by The American Society for Metals, in which the gage length is ½ inch.

In each case the specimens with the copper-nickel binder were sintered at approximately 2600° F. and those with the iron-nickel binder at approximately 2700° F. All sintering was performed in a hydrogen atmosphere for approximately one hour at the designated temperature. The results shown in the following examples are with standard cooling rate of approximately one hour to room temperature. Some specimens were subjected to rapid cooling (water quench) and some to slower cooling (furnace-cooled for 8 hours) without significant effect on the results.

It is apparent from the foregoing examples that the prior art Examples 2 and 4 which do not contain an iron-nickel ratio between substantial equality and 7:3 are deficient in tensile strength, elongation or both when machined from cores, as contrasted with the results obtained with Examples 1 and 3 where the thin bars were originally molded and therefore were not representative of the prior art problems encountered with cores of relatively thick bodies. It is also apparent from Examples 11, 12, 16, and 20 that when the iron-nickel ratio exceeds 7:3, a very brittle test core was obtained upon which effective tensile and elongation checking tests could not be successfully performed.

It is to be understood that the invention may be otherwise embodied within the range and scope of this disclosure without departing from the spirit of the invention.

What is claimed is:

1. A machined body of a high density alloy at least one-eighth inch thick, consisting essentially of tungsten, nickel and iron, wherein the tungsten is present between about 80 and 99.9%, and the iron is at least substantially equal to the nickel, and the iron-nickel ratio is less than about 7:3, said percentages and ratios being by weight.

2. A body according to claim 1, in which the tungsten is present between about 80 and about 95%.

3. A body according to claim 1, in which the iron is substantially equal to the nickel.

4. A body according to claim 1, in which the iron exceeds the nickel by less than about 35% of the weight of the nickel present.

5. A body according to claim 1, in which the iron is partially replaced by cobalt.

6. A body according to claim 5, in which the cobalt is present in an amount less than about 1% of the weight of the alloy.

7. A body according to claim 1, in which the nickel is partially replaced by cobalt.

8. A body according to claim 7, in which the cobalt is present in an amount less than about 1% of the weight of the alloy.

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9. A body according to claim 1, in which molybdenum at least partially replaces the tungsten.

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