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Yamaguchi et al.

[45] March 13, 1973

[54] **CLOSED DIE FORGING METHOD OF MAKING HIGH DENSITY FERROUS SINTERED ALLOYS**

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[21] Appl. No.: **35,183**

[52] **U.S. Cl.**.......................................**75/221,** 75/226

[51] **Int. Cl.**..**B22f 3/12**

[58] **Field of Search**...............................75/221, 226

[56] **References Cited**

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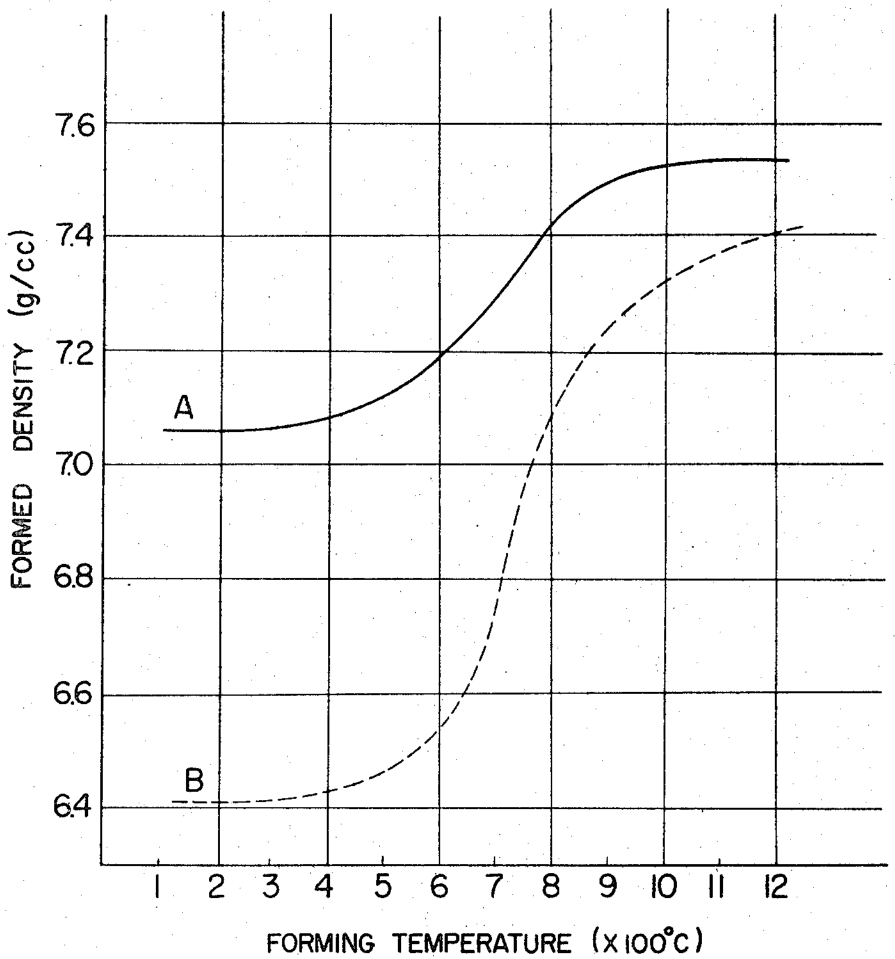
[57] **ABSTRACT**

Closed die forging method of high density ferrous sintered alloys, wherein an mixture iron based and added components is preformed, then the preform is presintered at a predetermined temperature, subsequently rapidly heated for a short period and finally hot-formed.

2 Claims, 5 Drawing Figures

FIG. 1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7.6
7.4
7.2
7.0
6.8
6.6
6.4
A
B
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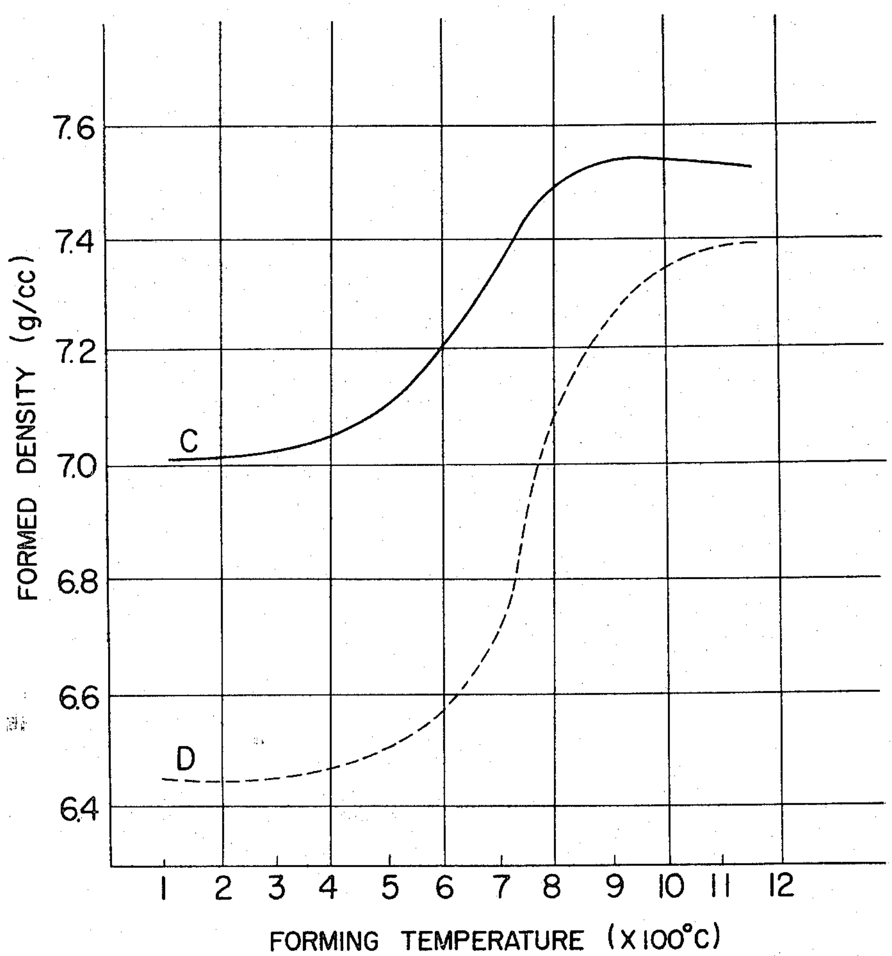
FORMING TEMPERATURE (X 100°C)

FIG. 2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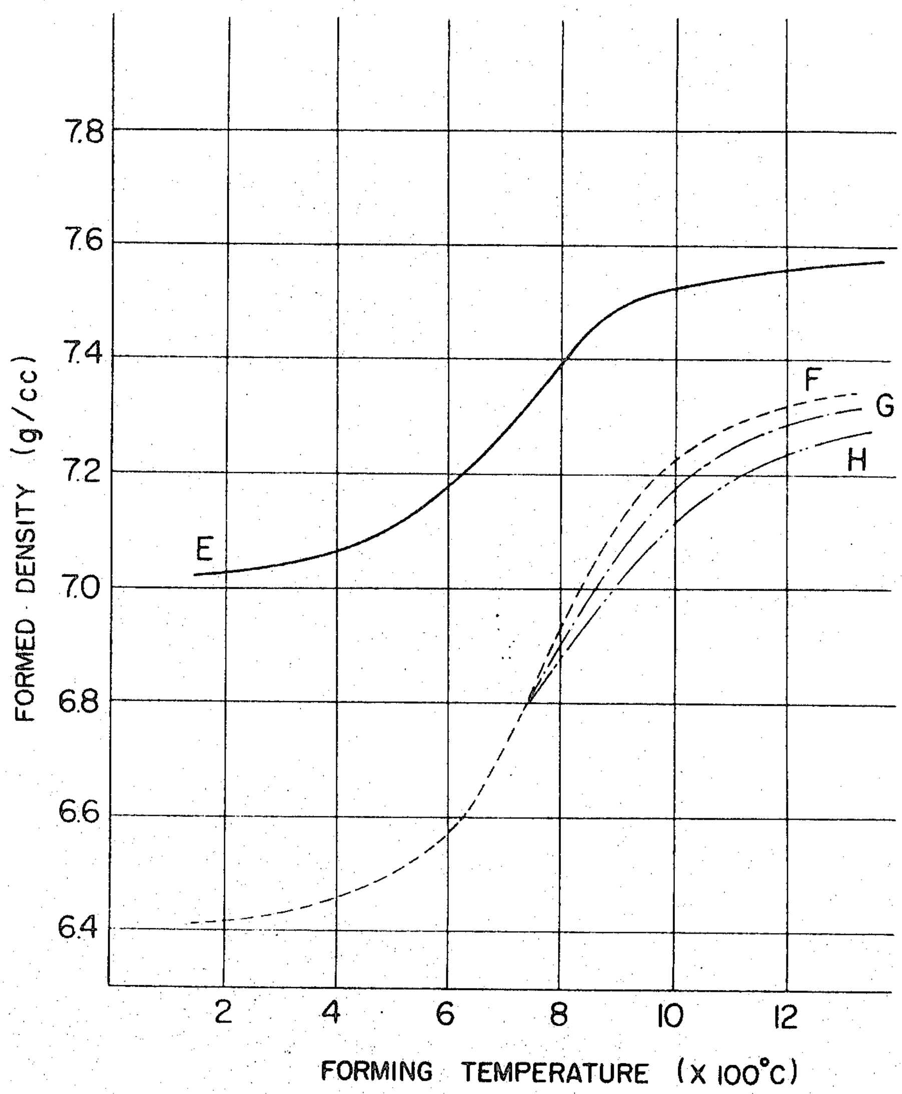
7.4
7.2
7.0
6.8
6.6
6.4
FORMED DENSITY (g/cc)
C
D
1 2 3 4 5 6 7 8 9 10 11 12
FORMING TEMPERATURE (X100°C)

FIG. 3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7.6
7.4
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6.8
6.6
6.4
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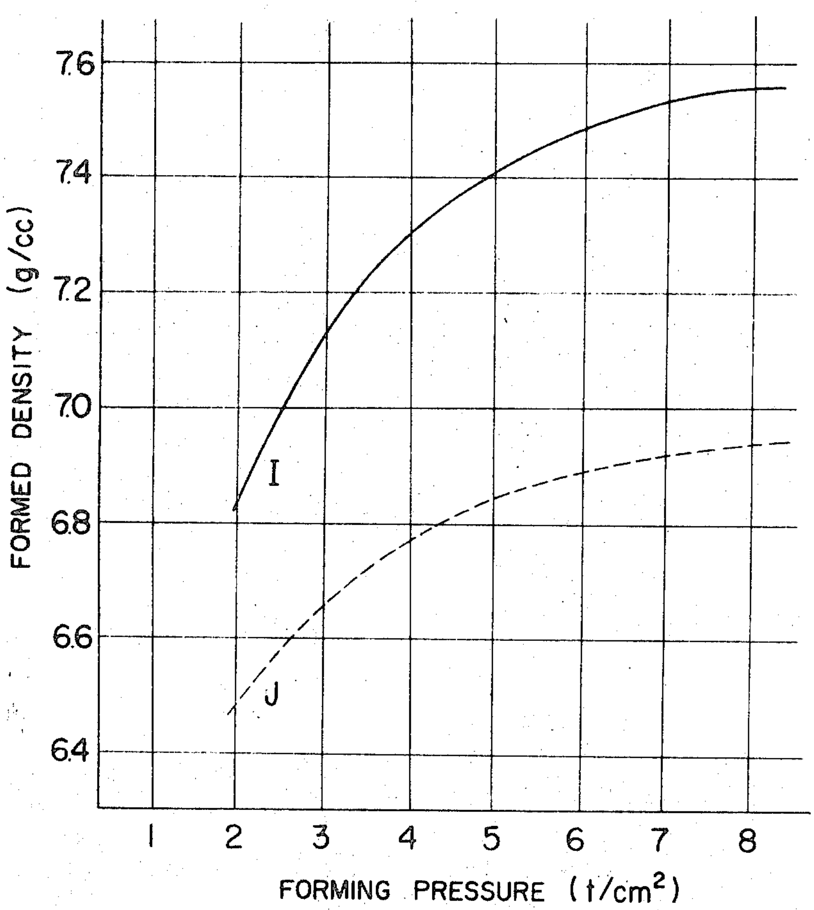
G
H
2
4
6
8
10
12
FORMING TEMPERATURE (X 100°C)

FIG. 4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7.2
7.0
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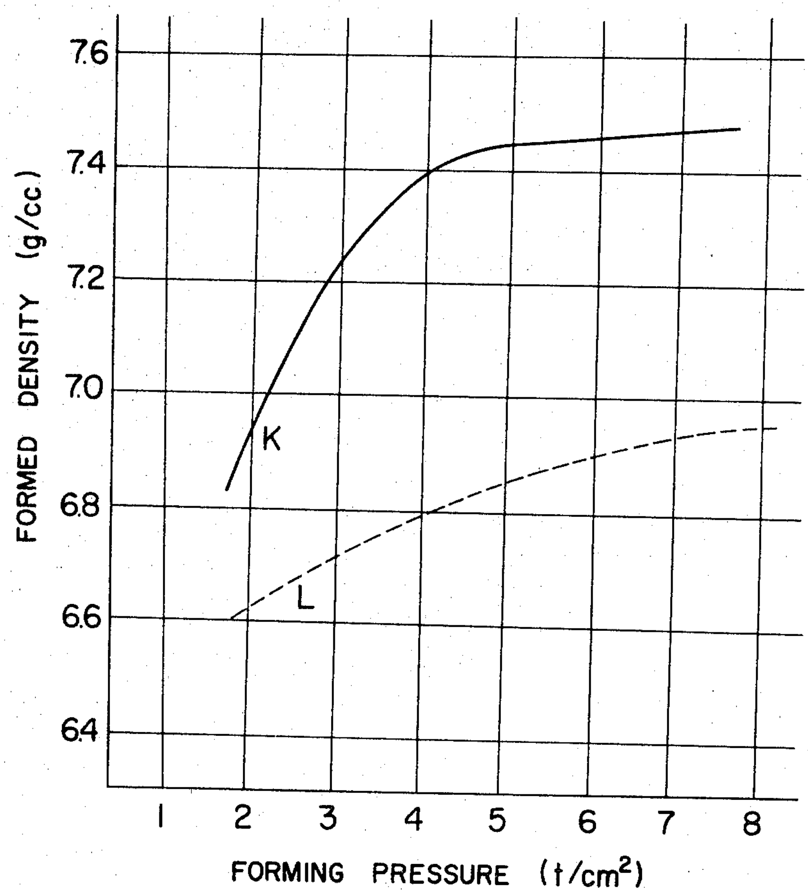
7
8
FORMING PRESSURE (t/cm²)

FIG. 5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7.2
7.0
6.8
6.6
6.4
FORMED DENSITY (g/cc)
K
L
1
2
3
4
5
6
7
8
FORMING PRESSURE (t/cm²)

CLOSED DIE FORGING METHOD OF MAKING HIGH DENSITY FERROUS SINTERED ALLOYS

FIELD OF INVENTION

This invention relates to closed die forging method of making high density ferrous sintered alloys, and, more particularly, it is concerned with a method of producing ferrous sintered alloys of improved physical strength by highly densifying the same. The alloys may contain one or more of fortifying components such as carbon, copper, nickel, chronium, managanese, molybdenum, tungsten, etc.

BACKGROUND OF THE INVENTION

In recent days, various machine parts made of sintered alloy material obtained from powder metallurgy have made a great stride in their production as a result of automated industrial production as well as due to characteristically high dimensional precision attributable to these sintered machine parts. However, with increase in production of machine parts, particularly, for the automobile industry, high the demand for stronger material has increased. Recent trend in research and development of such sintered alloys has been directed to the higher mechanical strength of the sintered material.

There are generally two methods of obtaining materials having high mechanical strength, i.e., the one is by the addition of fortifying components to the alloy composition, and the other is by considerably densifying the alloy material. The sintered alloy, in particular, can be improved its mechanical properties such as tensile strength, ductility, impact strength, and so forth by means of such high compacting. As an example, the following Table indicates comparison of the mechanical properties between the conventional ferrous sintered alloy and the highly densified sintered alloy of the same composition, from which it is recognized that the various physical properties of the high density sintered material are remarkably improved.

TABLE

	Conventional Ferrous Sintered Alloy	Highly Compacted Ferrous Sintered Alloy
Density (g/cm^3)	6.0 – 6.7	7.2 and above
Porosity (%)	15 – 25	10 and below
Hardness (Hv)	30 and above	100 and above
Transverse Rupture Strength (kg/mm^2)	20 – 120	60 – 150
Tensile Strength (kg/mm^2)	10 – 60	30 – 100
Ductility (%)	15 and below	30 and below
Impact strength (kg/cm^2)	1.0 and below	2.0 – 10.0

However, in view of the fact that, when metal powder is directly shaped, there exists a limitation in the increase in the formed density, if the forming pressure is raised as desired, and, moreover, then the metal mold is worn out more rapidly. The most economical pressure at the time of powder forming has been generally considered less than 5 to 6 tons/cm^2. There is also a limitation, for the very same reason, in the increase in the density of the sintered alloy obtained when the material is to be compacted by repetition of re-pressing and re-sintering. Furthermore, in the conventionally known methods, the sintered density of reduced iron material could only range between 6.3 to

6.7 g/cc and that of electrolytic iron powder was less than 7.2 g/cc at the best. Especially, a sintered body with additives which contribute to improvement in mechanical strength of the shaped body, such as carbon, copper, nickel, chromium, manganese, molybdenum, tungsten, etc. inevitably increases its plastic deformation resistance and is difficult to augment its density even a by re-pressing process.

It is therefore the primary object of the present invention to provide a method of obtaining ferrous sintered alloys containing therein fortifying components and having higher density than the conventional alloys by hot-forming the same at a pressure substantially equal to or less than the above-noted economical pressure values.

THE INVENTION

According to the present inventions, however, ferrous sintered alloy is first combined and/or mixed with the abovementioned additive components and then preformed into a required shape close to a desired final shape, after which the preform is pre-sintered under such temperature condition that does not cause diffusion or reaction between the iron powder, which is the principal constituent in the raw material, and the additive metal powders, and that is capable of relieving the preform from work-hardening, caused at the time of the preforming, as well as of improving the binding force among the particles of the iron powder. The plastic deformation resistance of the preformed sintered body thus treated is almost equal to that of an annealed pure iron powder sintered body, the value of which is much lower than that of the conventional sintered alloy. This sintered preform is subjected to rapid heating preferably by of high frequency heating so as to hot-form the same before the most part of the additive components diffuses into the base iron material or reacts with it, whereby the sintered body can be molded to high density and with the lowest plastic deformation resistance.

DETAILED DESCRIPTION

The invention will be more clearly understood and reduced into practice from the following explanations of the preferred embodiments of the invention taken in conjunction with the accompanying drawing, in which:

FIGS. 1, 2, and 3 are graphical representations respectively showing relationship between the forming temperature and the formed density of pre-sintered as well as sintered bodies of ferrous sintered alloy powder, when they are subjected to molding; and

FIGS. 4 and 5 are the graphical representations respectively showing relationship between forming pressure and formed density of the same sample alloy as in the above FIGS. 1 and 2.

Several kinds of specimens were prepared. The first specimen consists of 1 percent carbon and remainder of iron; the second consists of 1 percent carbon, 2 percent nickel, and remainder of iron; the third consists of 0.5 percent carbon, 2 percent manganese, 0.5 percent molybdenum, and remainder of iron; the fourth consists of 0.5 percent carbon, 2 percent nickel, 0.5 percent molybdenum, and remainder of iron; and fifth consists of 1 percent carbon, 2 percent chromium, and remainder of iron.

These components which are respectively in the form of graphite, carbonyl nickel powder, manganese powder, molybdenum powder, chromium powder, and reduced iron powder were mixed together and formed into rods of 20 mm dia, and 10 mm long at a forming pressure of about 4 ton/cm² to a density of 6.3g/cc and then respectively sintered at 600° to 700°C for 1 hour. Also, some of them were sintered at 1,150°C for 1 hour. Each of the specimens was rapidly heated by high frequency heating means within a period of 1 minute, thereafter they were re-pressed at respective pressure values as indicated in the graph.

In FIG. 1, the density versus temperature curve A (solid line) is for a specimen consisting of 1 percent carbon and remainder of iron which was sintered at 600°C, and the curve B (dotted line) is for a specimen of the same composition as that of A, but sintered at 1,150°C, both specimens having been shaped at a forming pressure of 4 tons/cm².

In FIG. 2, the density versus temperature curve C (solid line) is for a specimen consisting of 1 percent carbon, 2 percent nickel, and remainder of iron sintered at 600°C, and the curve D (dotted line) is for a specimen of the same composition as that of C but sintered at 1,150°C, both specimen having been shaped at a forming pressure of 4 tons/cm².

In FIG. 3, the density versus temperature curve E (solid line) is for three specimens having different compositions and sintered at 800°C, as follows: the first specimen consists of 0.5 percent carbon, 2 percent manganese, 0.5 percent molybdenum, and remainder of iron; the second consists of 0.5 percent carbon, 2 percent nickel, 0.5 percent molybdenum, and remainder of iron; and the third consists of 1 percent carbon, 2 percent chromium, and remainder of iron. These three specimens show substantially the same curve.

The curve F (dotted line) is for specimen consisting of 0.5 percent carbon, 2 percent manganese, 0.5 percent molybdenum, and remainder of iron sintered at 1,130°C.

The curve G (dot-and-dash line) is for specimen consisting of 0.5 percent carbon, 2 percent nickel, 0.5 percent molybdenum, and remainder of iron sintered at 1,150°C.

The curve H (dot-dot-dash line) is for specimen consisting of 1 percent carbon, 2 percent chromium and remainder of iron sintered at 1,180°C.

All of the abovementioned specimens were formed at a forming pressure of 4 ton/cm².

As shown in FIGS. 1, 2, and 3, the specimens sintered at 600° to 800°C indicate a resulting much higher increase in the density than the specimens sintered at from 1,130° to 1,180°C at every forming temperature level. In FIG. 2, the effect of the high compacting of the sintered body begins to slightly lower at 1,000°C because of partial diffusion of the additive components.

In FIG. 4, the density versus pressure curve I (solid line) is for a specimen consisting of 1 percent carbon and remainder of iron presintered at 600°C, and the curve J (dotted line) is for a specimen of the same composition as that of I, but sintered at 1,150°C, both specimens having been formed at the respective pressure values as indicated in the abscissa, when the formed density varied against the pressure changes.

Similarly, in FIG. 5, the density versus pressure curve K (solid line) is for a ferrous alloy specimen consisting of 1 percent carbon, 2 percent nickel, sintered at 600°C, and the curve L (dotted line) is for a specimen of the same composition as that of K, but sintered at 1,150°C, both specimens having been formed at the respective forming pressure values as indicated in the abscissa, when the formed density varied against the pressure changes.

As seen from FIGS. 4, the formed density of 7.2g/cc and above could be obtained with reduced iron powder by forming the material at a forming pressure of 3 to 4 tons/cm² or more at a forming temperature of 700°C, while in FIG. 5 such required density could be attained at a pressure of less than 3 tons/cm².

In order to enable persons having ordinary skill in the art to practice this invention, the following preferred examples are presented. However, it should be noted that the present invention is not limited to these examples alone.

Example 1

A mixture of iron powder with 0.8 percent graphite powder, 20 percent tungsten powder, 4 percent chromium powder and 0.6 percent manganese was press formed into a rod of 20 mm in dia., 10 mm in length, and a density of 6.3 g/cm³. The formed body was sintered at 1,200°C for 30 minutes, then it was heated very quickly to a temperature of 1,200°C and formed in a closed die at a pressure of 7 ton/cm².

After this treatment, the article attained a density of 8.4 g/cm³ which is 99.5 percent of the theoretical density. Then it was resintered.

Example 2

The specimen consisting of 3 percent copper, 3 percent nickel, 0.5 percent carbon and remainder of iron was press formed into a rod of 20 mm in dia., 10 mm in length, and a density of 6.3 g/cm³. The formed body was sintered at 800°C and forged at 600°C at a pressure of 6 ton/cm². The specimen attained the density of 7.4 g/cc, and then it was resintered.

Example 3

A mixture of iron powder with 0.3 percent graphite powder was preformed into a rod of 20 mm in dia., 10 mm in length, and a density of 6.3 g/cm³. The formed body was sintered at 600°C, then it was heated rapidly to a temperature of 900°C and formed in a closed die at a pressure of 4 ton/cm² to a density of 7.6 g/cm³ and then resintered.

After this treatment, the material had a tensile strength of 46 kg/mm², an elongation of 12 percent, a hardness of 120 Hv and an impact strength of 6.0 kg.m/cm².

Example 4

A mixture of iron powder with 3 percent nickel powder and 0.3 percent graphite powder was precompacted into a rod of 20 mm in dia., 10 mm in length, and a density of 6.3 g/cm³. The precompact body was sintered at 800°C for 30 minutes, then it was heated for 1 minute to a temperature of 800°C, and kept at this temperature during the forming at a pressure of 5 ton/cm². A density of 7.5 g/cm³ was attained.

This material had a tensile strength of 60 kg/mm², an elongation of 14 percent, a hardness of 170 Hv, and an impact strength of 6.9 kg.m/cm².

Example 5

From a mixture of iron powder with 2 percent nickel powder, 0.5 percent molybdenum powder and 0.5 percent graphite powder, a preform of a rod having dimension of 20 mm in dia. and 10 mm in length was obtained with a density of 6.4 g/cm³. The precompact body was sintered at 900°C for 30 minutes, then it was heated to a temperature of 1,000°C and rapidly formed at the same temperature with a pressure of 5 ton/cm² to a density of 7.5 to 7.6 g/cm³.

This material had a tensile strength of 80 kg/mm², an elongation of 6.0 percent, a hardness of 230 Hv, and an impact strength of 5.0 kg.m/cm².

Example 6

From a mixture of 97 percent iron powder 2 percent chromium powder and 1 percent graphite powder, a preform of a rod having dimension of 20 mm in dia. and 10 mm in length was obtained with a density of 6.4 g/cm³. The precompact was sintered at 1,000°C, then it was heated to a temperature of 1,100°C and formed in a closed die at a pressure of 6 ton/cm² to a density of 7.6 g/cm³, and then resintered.

After this treatment, the material had a tensile strength of 85 to 95 kg/mm², an elongation of 2.5 to 4.0 percent, a hardness of 220 to 250 Hv, and an impact strength of 3.0 to 5.0 kg.m/cm².

As stated in the foregoing, the closed die forging method according to the present invention is capable of producing shaped articles of density of more than 7.2 g/cc even with alloy composition containing fortifying components, which had been considered difficult to sinter-molding by the conventional methods. The sintered alloy obtained by sintering such shaped bodies according to this invention show remarkably high mechanical strength as indicated in Table 1, which could hardly be realized with the heretofore known sintered alloys.

What we claim is:

1. Closed die forging method of high density ferrous sintered alloys which comprises steps of:

a. press-forming a powder mixture consisting of metal iron powder and at least one powdered alloying component selected from group consisting of carbon, nickel, chromium, manganese, molybdenum, and tungsten;

b. subjecting the pressed preform to a pre-sintering at a temperature selected in the range 600°–1200 °C, at which said components do not diffuse into the iron powder, until any work-hardening resulting from said press-forming is relieved:

c. rapidly heating the preformed material to a hot-forming temperature within a period of time short enough to preclude diffusion of any substantial portion of said components; and

d. then hot-forming the heated preform at a pressure ranging from 4 to 7 tons/cm².

2. Method according to claim 1, in which the heating temperature at the step (c) is from 700° to 1,300°C.

* * * * *