United States Patent [19]

Saito et al.

[11] 3,786,552

[45] Jan. 22, 1974

[54] **METHOD OF MANUFACTURING A COMPOSITE BIMETALLIC SLEEVE FOR A DIE-CASTING MACHINE**

[75] Inventors: **Yuichi Saito**, Urawa; **Tokuzo Shikano**, Oomiya; **Masanori Kimura**, Saitama-ken, all of Japan

[73] Assignee: **Mitsubishi Kinzoku Kogyo Kabushiki Kaisha**, Chiyoda-ku, Tokyo-to, Japan

[22] Filed: **June 27, 1972**

[21] Appl. No.: **266,749**

[30] **Foreign Application Priority Data**

June 30, 1971 Japan 46/47289

[52] **U.S. Cl.** .... **29/420.5,** 29/182.3, 29/447, 75/208 R

[51] **Int. Cl.** **B22f 3/24**

[58] **Field of Search** .... 29/420.5, 182.3, 420, 447, 29/DIG. 31; 75/208 R

[56] **References Cited**

UNITED STATES PATENTS

464,165	12/1891	Raymond	29/420.5
1,989,186	1/1935	DeBats	29/182.3 X
3,014,266	12/1961	Samuels et al.	29/447 X
3,109,224	11/1963	Fearnside	29/420.5 X
3,672,881	6/1972	Sowko	75/208 R
3,678,567	7/1972	Manilla et al.	29/420.5

Primary Examiner—Charles W. Lanham
Assistant Examiner—D. C. Reiley, III
Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

[57] **ABSTRACT**

A sleeve is composed of a relatively thin inner layer made of such highly infusible material as molybdenum, tungsten or their alloys, and an outer layer made of an iron-base alloy. For manufacture, a mixture of powders compounded to form an iron-base alloy when heated is compacted to cylindrical shape around a hollow cylinder suitably molded of one of the listed metals and alloys. The compact is then sintered to provide an outer layer of the iron-base alloy solidly united with the hollow cylinder.

3 Claims, 6 Drawing Figures

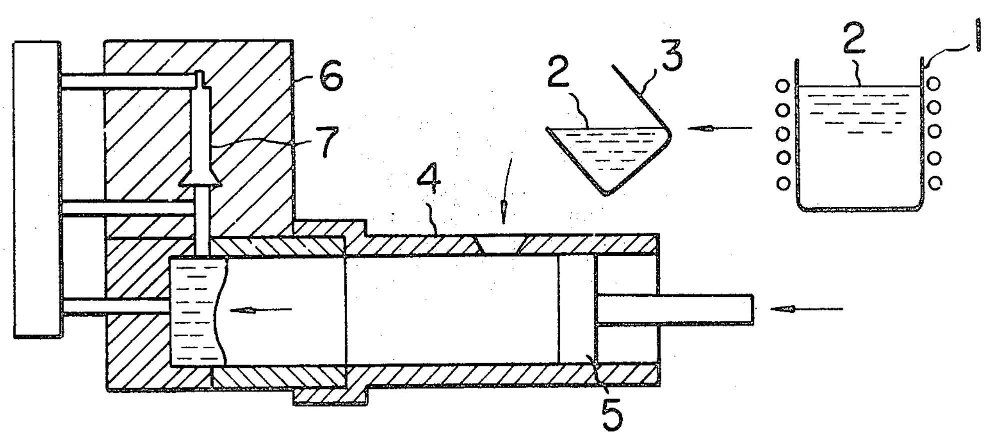


FIG. 1

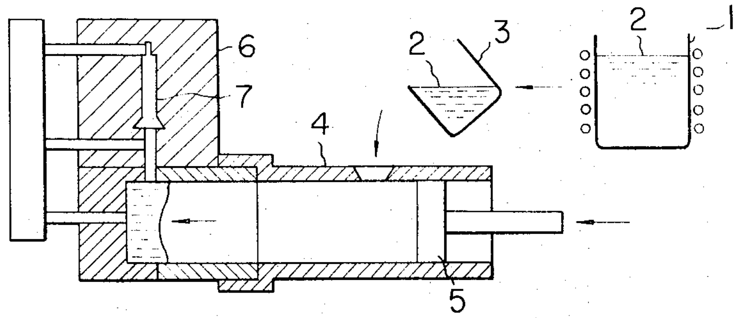


FIG. 2

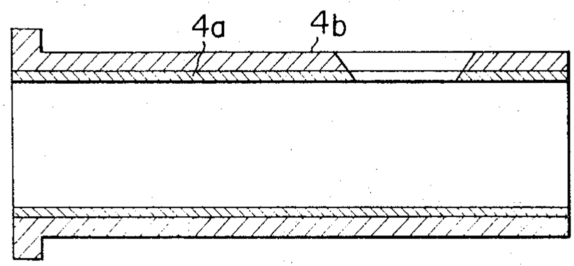


FIG. 3

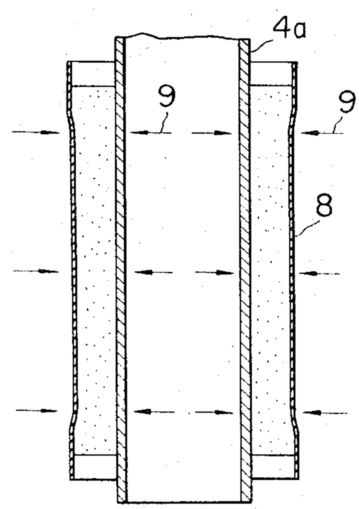


FIG. 4

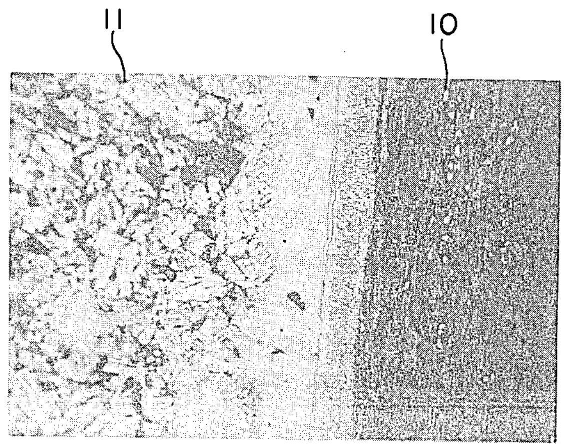


FIG. 5

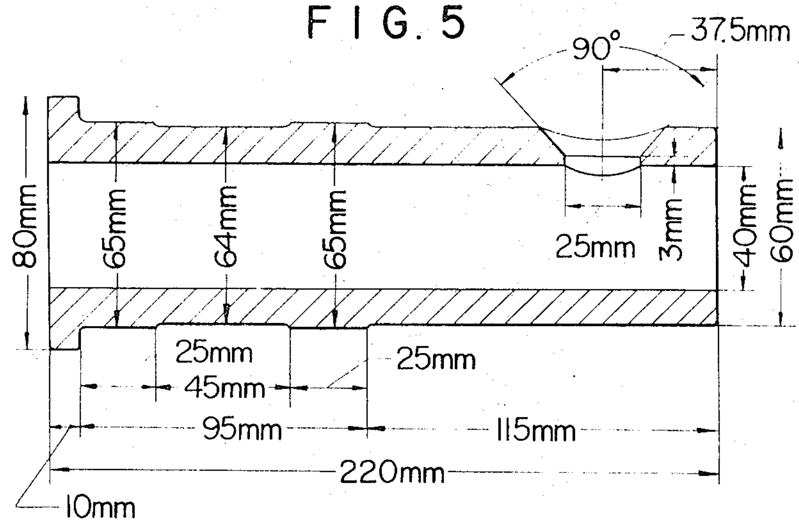
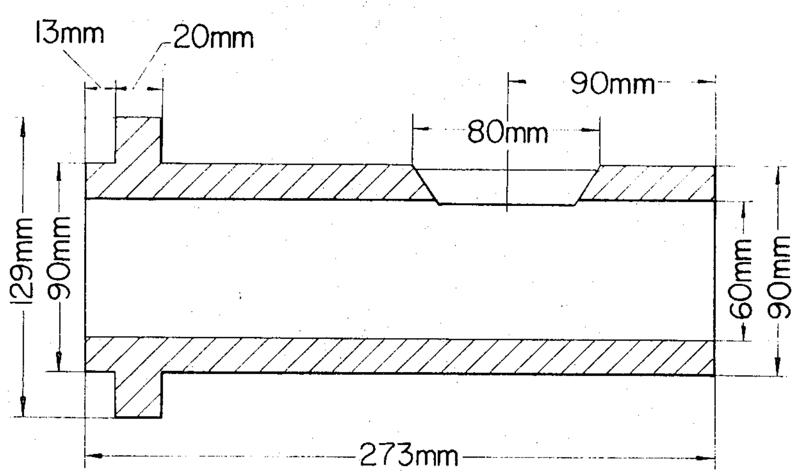

90°
37.5mm
80mm
65mm
64mm
65mm
25mm
3mm
40mm
60mm
25mm
45mm
25mm
95mm
115mm
220mm
10mm

FIG. 6


13mm
20mm
90mm
80mm
129mm
90mm
60mm
90mm
273mm

METHOD OF MANUFACTURING A COMPOSITE BIMETALLIC SLEEVE FOR A DIE-CASTING MACHINE

BACKGROUND OF THE INVENTION

This invention relates generally to die-casting machines, and in particular to an improved sleeve for use in injecting molten metal into the mold cavity of a die-casting machine. The invention is also directed to a novel process for the manufacture of the improved sleeve.

The art of die-casting has been widely utilized to produce precision-made castings of metals or alloys with a melting point of about 1,000°C or less, such alloys including those of aluminum, zinc, magnesium, copper, tin, and lead. There are two known types of die-casting machines, the "cold chamber" type and the "hot chamber" type. The cold-chamber machine, to which molten metal is supplied from a separately installed melting furnace, is employed for the die-casting of comparatively high melting-point metals or alloys such as aluminum-, magnesium- and copper-base alloys. The hot-chamber machine, having a built-in furnace, is used to produce castings of lower melting-point metals or alloys such as zinc-, tin- and lead-base alloys. In both types, molten metal or alloy is forced into the die cavity through a cylindrical sleeve built into the machines.

It is accordingly the sleeve, especially that of the cold-chamber machine, which contacts the molten metal at its highest temperature, so that it is required to be particularly heat-, wear- and corrosion-resisting. This is all the more so because in recent years the application of the die-casting machines to iron-base alloys have been seriously attempted. Heretofore, the sleeve of the cold-chamber machine has been made of a hot-die steel. This material is so unsatisfactory in regard to the aforementioned properties that the sleeve has a service life of from about 1 to 3 months or so when used for die-casting of aluminum-base alloy having a relatively low melting point. In the case of iron-base alloy casting, the sleeve can hardly undergo from several to several tens of shots without showing some signs of abnormality. Moreover, the alloy steel is a comparatively expensive material as compared with ordinary steel, and the surfaces of the sleeve made of this material require a costly heat treatment to prolong their life to some extent.

It is well known that such highly infusible metals as molybdenum and tungsten, as well as alloys having these metals as the principal constituents, can well withstand the high temperatures produced during die-casting of copper- and even iron-base alloys. These metals and alloys will certainly be satisfactory as sleeve materials. However, a sleeve made solely of the metals or alloys is so expensive that it will hardly be manufacturable on a commercial basis. It is an added disadvantage that since these materials are all highly heat-conductive, too much heat will be released from the molten metal passing through the sleeve.

During a die-casting operation, only a limited portion of the sleeve adjacent its inner surface is known to have a markedly high temperature rise due to the heat of the molten metal passing therethrough. Therefore, by using any of the above-mentioned infusible metals or alloys in this limited portion alone, the durability of the sleeve as a whole will be greatly increased. However, it will serve no practical purposes if molten molybdenum, tungsten or their alloys is sprayed onto the inner surface of a conventionally available sleeve, because the coating thus formed cannot possibly be sufficiently united with the surrounding sleeve material. It may also be contemplated to tightly fix, as by the process of shrinking-on, a hollow cylinder of a ferrous alloy or the like around a thin pipe of the highly infusible metals or alloys. As the sleeve manufactured in this manner is heated in actual die-casting operation, however, its inner and outer layers are certain to be displaced relative to each other.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved sleeve for use in a die-casting machine, which includes a relatively thin inner layer made of highly infusible material and an outer layer made of less expensive material, so that the service life of the sleeve is greatly extended without substantially increasing its manufacturing costs.

Another object of the invention is to provide a sleeve of the class referred to, in which the outer layer is made of a ferrous alloy such that heat to be released from molten metal passing therethrough can be properly controlled.

A further object of the invention is to provide a sleeve of the class referred to, in which the outer layer serves to protect the inner layer, which may be less resistant to oxidation, from deterioration due to the oxidative influence from its periphery.

It is also an object of the invention to provide a novel process for the manufacture of the above described sleeve, in which the outer layer is formed by first compacting around the previously molded inner layer a mixture of powders compounded to form a ferrous alloy when heated, and thereafter sintering the compact, so that no relative displacement or separation of the outer and inner layers will take place when the sleeve is heated by molten metal. This also prevents the overheating of the inner layer only.

According to this invention, briefly stated, there is provided a sleeve for use in a die-casting machine, comprising an inner layer made of material selected from the group consisting of molybdenum, tungsten and alloys containing at least one of the metals as the principal constituent, and an outer layer made of a ferrous alloy, the inner layer and outer layer being solidly united with each other.

The invention further provides a process for the manufacture of a sleeve for use in a die-casting machine, which comprises providing a hollow cylinder made of material selected from the group consisting of molybdenum, tungsten and alloys containing at least one of said metals as the principal constituent, compacting a mixture of powders to cylindrical shape around the hollow cylinder, the mixture of powders being compounded to form a ferrous alloy when heated, sintering the compact to form an outer layer solidly united with the hollow cylinder, and machining the thus-produced composite structure to specified dimensions.

The novel features which are considered as being characteristic of this invention are set forth in the appended claims. The invention itself, however, together with additional objects and advantages thereof, will be best understood from the following detailed description taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

In the drawings:

FIG. 1 is a schematic vertical sectional view showing one form of die-casting operation in a cold-chamber type machine by way of explanation of this invention;

FIG. 2 is a schematic longitudinal sectional view of a two-layered sleeve according to the invention;

FIG. 3 is a schematic longitudinal sectional view explanatory of the way pressures are applied for compaction of an outer layer around a previously formed inner layer;

FIG. 4 is a microscopic representation showing an example of "diffusive junction" between the inner and outer layers of a sleeve according to the invention;

FIG. 5 shows the dimensional specifications of an example of a sleeve constructed according to the invention for use in an 80-ton die-casting machine; and

FIG. 6 also shows the dimensional specifications of another sleeve constructed according to the invention for use in a 250-ton die-casting machine.

DETAILED DESCRIPTION

In order to fully appreciate this invention it is necessary first to describe the configuration of a cold-chamber type die-casting machine to which the improved sleeve of the invention is adaptable. Referring to FIG. **1**, therefore, molten metal **2** being kept at a suitable temperature in a furnace **1** is either ladled or automatically poured out of a vessel **3** into a sleeve **4.** The molten metal within the sleeve is then forced by a plunger **5** into a cavity **7** of a die **6,** where the metal is cooled, assuming the shape delineated by the mold cavity upon solidification. In a hot-chamber type machine, on the other hand, which is not shown in the drawings, the molten metal is supplied from a furnace built into the machine to the die cavity via a sleeve coupled directly to the furnace.

As may be apparent from the above description, the sleeve contacts the molten metal at its highest temperature, so that it must be made of material which is sufficiently heat-, wear- and corrosion-resistant. Generally, this sleeve has been made of a hot-die steel casehardened by the so-called "nitriding" process. It must be noted, however, that the temperature of the molten metal or alloy being cast in the cold-chamber machine is higher than the temperature of that being cast in the hot-chamber machine. The sleeve of the cold-chamber die-casting machine is thus placed under particularly hard working conditions. It is an admitted fact in the art that sleeves made of a casehardened hot-die steel cannot last for any extended period of use when incorporated in the cold-chamber machines.

As is well known, molybdenum, tungsten, or alloys containing one or both of these metals as base can well withstand as high a temperature as that of molten ferrous alloys. The present invention provides a highly durable sleeve made, in part, of any of these metals or alloys. FIG. **2** schematically illustrates this improved sleeve, comprising an inner layer **4*a*** made of one of the aforesaid metals or alloys and an outer layer **4*b*** made of a sintered ferrous alloy. These layers **4*a*** and **4*b*** are solidly united with each other by "diffusive junction" hereinafter described in greater detail. This composite structure is further suitably machined for use as a sleeve in a die-casting machine.

It will now be understood that, basically, the invention provides an improved sleeve, and a process for the manufacture thereof, which is composed of substantially completely integral inner and outer layers, the inner layer being capable of withstanding the high temperatures of the molten metal in a die-casting machine, and the outer layer being made of inexpensive material to reduce the overall cost of the sleeve. The thus-structured sleeve is confirmed to be extremely durable, as hereinafter set forth in more concrete terms. However, molybdenum, tungsten, and their alloys are very expensive, so that these metals or alloys may preferably be used in as small amounts as possible to further decrease the sleeve cost.

To this end there may be used as the inner layer of the sleeve a thin pipe of molybdenum or molybdenum-base alloy which has been available conventionally. This pipe can considerably reduce the thickness of the sleeve inner layer, does not cause any technical problem in the manufacture of the two-layered sleeve, and improves its corrosion-resistivity. The trouble, however, is the high manufacturing cost of the pipe itself, which must undergo highly involved steps of production, so that the sleeve cost is not reduced as much as it is desired to be.

A thin, as-sintered pipe of molybdenum, tungsten, or alloys containing one or both of these metals as the principal constituent is, of course, employable as the sleeve inner layer when machined into specific dimensions. This pipe is less expensive than the above-described pipe of molybdenum or molybdenum-base alloy and thus serves to reduce the sleeve cost.

It has long been considered impossible to produce, only through the compacting and sintering processes, a long, thin pipe of exactly specified dimensions. This difficulty is now overcome by a newly developed method known to the art, in which powdered material is compacted to desired shape around a sufficiently rigid, straight core by means of a hydrostatic press. A compact in the shape of a thin cylinder is obtained upon removal of the core. Proper moldability of the powdered material is accordingly a prerequisite of this method. Further, it requires considerable skill and utmost care to attain a high degree of exactitude of the compact dimensions.

The compact is then roasted, if necessary, and thereafter is sintered at a temperature suitably determined according to its composition, usually in the range of from about 1,250° to 1,800°C. In the case of liquid-phase sintering, however, the dimensions of the sintered product tend to deviate from the specifications. This is avoidable only through careful control of such factors as the composition of the material, the placement of the compact in the sintering furnace, and its sintering temperature. Further, if any of the aforementioned alloys thus used as the sleeve inner layer contains too much diffusion phase, it will be less resistant to corrosion. For example, in case the alloy contains too great quantities of nickel, iron, cobalt and other constituents, with the result that about 10 percent or more by volume of diffusion phase having a melting point considerably lower than that of the base is produced, then it will be highly reactive with the molten metal to be supplied for the die-casting operation.

The cylindrical sinter obtained as above may be further subjected to some postsintering operation to provide a product of the prescribed dimensions. It must be noted, however, that if the sintered metal or alloy has about 10 percent or more by volume of fine particles of refractory oxides, nitrides, carbides or the like dispersed therein, its strength will be considerably descreased. The cutting and grinding operations that may be necessary for finishing the cylindrical sinter will then be greatly hampered.

For formation of a surrounding outer layer on the thin pipe which has been produced by the above process for use as the inner layer of the sleeve according to this invention, a mixture of powders capable of forming an iron-base alloy when heated is compacted, as illustrated in FIG. **3**, and thereafter is sintered in a temperature range of from about 900° to 1,300°C. As indicated by the arrows **9** in the drawing, equal pressures are simultaneously applied from both sides of the powders, through the inner layer *4a* and through a rubber covering **8**, so that the thin inner layer *4a* is not subjected to any substantial deformation.

During the sintering of the powders thus compacted to shape, the mentioned "diffusive junction" is formed between the inner and outer layers. The junction is further strengthened by contraction which accompanies the sintering operation. FIG. 4 is a microscopic representation of such a junction obtained at about 1,250°C between molybdenum-base alloy [Mo (balance) - 0.48 wt.% Ti – 0.08 wt.% Zr] and sintered iron-base alloy [Fe (balance) – 2 wt.% Ni – 0.5 wt.% Mo – 0.5 wt.% C]. It will be clearly observed that the porosity of the sintered iron-base alloy **11** decreases toward the interface between the same and the molybdenum-base alloy **10**, and that these two layers are strongly united.

In general, the interface between such inner and outer layers is known to offer a resistive pressure of from about 5 to 20 kilograms per square millimeter against shearing. In order to obtain a proper state of diffusive junction between these layers, it is essential that: (1) the composition of the ferrous alloy and its sintering temperature be well regulated so that the outer layer molded of that ferrous alloy will contract linearly within the range of from about 0.2 to 10 percent upon sintering; and (2) this outer layer be compacted with as few irregularities as possible in density. While the outer layer must contact linearly about 0.2 percent or more upon sintering to be sufficiently united with the inner layer, the outer layer tends to be cracked if the contraction exceeds about 10 percent. Cracks are likewise developed on the outer layer if it suffers nonuniform length-wise contraction due to density irregularities suggested in (2) above. Provision of a thin nickel layer at the interface between the two layers will serve to further strengthen their junction.

The density control of the outer layer may be effected by carefully regulating the composition of the mixture of iron and other powders as well as its sintering conditions, or by employing the technique of copper impregnation. It is one of the advantages of this invention that by the same density control of the outer layer, its heat conductivity is regulatable so that heat to be released from molten metal within the sleeve can be appropriately predetermined. If desired, the inner surface of the sleeve inner layer may be carburized to form an additional carbide layer, while the outer layer may be further reinforced with a shrunk-on steel cylinder or covering.

The two-layered sleeve of this invention, manufactured as hereinabove described, was built into a die-casting machine to test its durability when placed in contact with molten aluminum-, copper- and iron-base alloys. No signs of abnormality were observed in this sleeve when up to 10,000, 5,000 and 1,000 shots respectively of these alloys were die-cast, although these figures are subject to some variation depending upon the material of the sleeve inner layer.

The present invention is hereinafter described more specifically in terms of several Examples thereof, which are meant purely to illustrate and explain and not to impose limitations upon the invention.

EXAMPLE I

Molybdenum powder (with a particle size of 3.5μ) and nickel powder (3 μ) were ball-milled for 24 hours. The thus-mixed powders (1.5 wt.% Ni and Bal Mo, with 1 percent paraffin added separately) were compacted to cylindrical shape with a hydrostatic press at pressures up to 1.5 tons per square centimeter around a straight, well-ground bar made of stainless steel ("SUS27" corresponding to AISI 304). The hollow cylindrical compact thus formed was then roasted at about 750°C for 2 hours in the presence of hydrogen and thereafter was sintered at about 1,350°C for 5 hours to provide a highly dense product with an outer diameter of 50 millimeters, an inner diameter of 36 millimeters, and a length of 260 millimeters. The outer surface of this sintered product was machined to an outer diameter of 46 millimeters.

A mixture of powders compounded to form an iron-base alloy when heated (2 wt.% Ni, 0.5 wt.% Mo, 0.5 wt.% C, and Bal.Fe), prepared by use of a kneading machine, was then compacted to cylindrical shape around the above obtained product with a hydrostatic press at pressures up to 1.5 tons per square centimeter, and was further sintered at about 1,250°C for 1 hour to provide an outer layer with an outer diameter of 100 millimeters. The two-layered hollow cylinder thus obtained was machined to the dimensions set forth in FIG. **5**, for use as a sleeve in an 80-ton type die-casting machine.

The sleeve was built into the die-casting machine, which had been in actual operation in a plant, to test its durability. No abnormality was exhibited at the moment when the sleeve had undergone up to 10,000 shots during die-casting operations.

EXAMPLE II

A sleeve was manufactured in substantial accordance with Example I, except that its inner layer was composed of molybdenum-base alloy (further containing 1.5 wt.% nickel and 1.5 wt.% iron), and that the sintering temperature of the inner layer was set to about 1,400°C. This sleeve was built into a die-casting machine for aluminum- and copper-base alloys. No abnormality was observed when up to 10,000 and 1,000 shots respectively of the said alloys were cast.

EXAMPLE III

A sleeve was manufactured in substantial accordance with Example I, except that its inner layer (with a thickness of 3 millimeters) was composed of tungsten-base alloy [W (balance) - 4 wt.% Ni – 4 wt.% Mo – 2wt.% Fe], and that the sintering temperature of this inner layer was set to about 1,450°C. This sleeve was then adapted for die-casting of aluminum- and copper-base alloys to test its durability, with results substantially identical with those set forth in Example II.

EXAMPLE IV

Molybdenum powder with a BET particle size of 0.2 μ, TiH_2 with a BET particle size of 0.1 μ, and τ-alumina with a specific surface area of about 100 square meters per gram were wet-mixed for 48 hours in a ball mill. Nickel was then added to this mixture. The thus-compounded mixture [(Mo(balance)-0.1 wt.% Ni-0.5 wt.% Ti)-3 vol.%Al_2O_3] was compacted to cylindrical shape with a hydrostatic press at pressures up to 2 tons per square centimeter. The compact was then roasted at about 1,000°C for 1 hour in the presence of hydrogen and was further sintered at about 1,650°C for 3 hours in a vacuum. The outer surface only of this sinter was machined to provide a cylindrical product of molybdenum-base alloy with an outer diameter of 70 millimeters, an inner diameter of 54 millimeters, and a length of 330 millimeters.

A mixture of 97.2 wt.% of iron powder, 2 wt.% of nickel powder, 0.5 wt.% of molybdenum powder, and 0.3 wt.% of graphite powder was compacted to cylindrical shape around the above obtained product with a hydrostatic press at pressures up to 2 tons per square centimeter. This compact was then sintered at about 1,300°C for 1 hour in the presence of hydrogen. The outer layer thus formed had an outer diameter of 140 millimeters.

The inner surface of the two-layered hollow cylinder produced in this manner was cut and ground to increase the inner diameter to 60 millimeters. The product was further machined to the dimensions specified in FIG. **6**, for use as a sleeve in a 250-ton die-casting machine. Used for die-casting of stainless steel ("18–8"), the sleeve showed no signs of abnormality up to 1,000 shots.

EXAMPLE V

Nickel was plated to a thickness of about 1 μ on the outer surface of a hollow cylinder molded of molybdenum-base alloy [Mo (balance) – 0.48 wt.% Ti – 0.08 wt.% Zr], the hollow cylinder having an outer diameter of 63.6 millimeters, an inner diameter of 59.6 millimeters, and a length of 330 millimeters. A mixture of 97.8 wt.% of iron powder, 2 wt.% of nickel powder, and 0.2 wt.% of graphite powder was compacted to cylindrical shape around the above plated cylinder with a hydrostatic press at pressures up to 2 tons per square centimeter. The compact was then sintered at 1,050°C for 2 hours in the presence of hydrogen. The outer layer thus formed by the sintered iron-base alloy had an outer diameter of about 90 millimeters.

After machining the surface of the outer layer to decrease its outer diameter to 80 millimeters, a pipe of carbon steel ("S45C" corresponding to "SAE1042") with an outer diameter of about 135 millimeters was tightly fitted on the outer layer by a shrink fitting process. This product was further machined to the dimensions set forth in FIG. **6**, for use as a sleeve in a 250-ton die-casting machine. No signs of abnormality were exhibited by the sleeve when up to 1,000 and 10,000 shots respectively of cast iron and aluminum-base alloy were die-cast by the 250-ton type machine.

Although the present invention has been shown and described hereinabove in terms of several specific examples thereof, it is understood that the invention itself is not to be restricted by the exact showing of the drawings and the description thereof, but is considered to include a latitude of modification, substitution, and change. It is therefore appropriate that the appended claims be construed broadly and in a manner consistent with the fair meaning and proper scope of the invention disclosed herein.

We claim:

1. In a process of manufacturing a composite bimetallic sleeve for a die-casting machine, wherein said sleeve consists of an inner layer made of refractory metal materials such as molybdenum, tungsten, and alloys containing therein at least one of these metals as the principal constituent, and an outer layer made of a ferrous alloy, said layers being diffusion bonded at their boundary region, the improvement which comprises compacting a mixture of powders in a cylindrical shape around the outer periphery of a hollow cylinder of refractory metal which constitutes the inner layer to a thickness greater than the thickness of said hollow cylinder, said mixture of powders being a mixture which will form the ferrous alloy by heat-treatment, thereafter sintering said compacted mixture of powders on said cylinder to form a composite structure consisting of an outer ferrous alloy layer solidly metallurgically bonded to said hollow cylinder, and finally machining the thus produced composite structure to desired dimensions.

2. The process according to claim **1**, further including a step of covering the outer surface of said hollow cylinder, prior to the compacting step, with a thin layer of nickel to increase the bonding strength between said hollow cylinder as the inner layer and the outer layer.

3. The process according to claim **1**, further comprising shrink fitting a hollow cylindrical steel covering on said outer layer.

* * * * *