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De Pierre et al.

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[45] **July 1, 1975**

[54] **METHOD OF FABRICATING A BILLET FROM METAL PREFORMS AND METAL POWDER**

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[73] Assignee: **United States of America as represented by the Secretary of the Air Force**, Washington, D.C.

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[52] **U.S. Cl.** **29/420**; 29/DIG. 31; 29/187.5

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

[58] **Field of Search** ..... 29/420, 420.5, DIG. 31, 29/187.5

[56] **References Cited**

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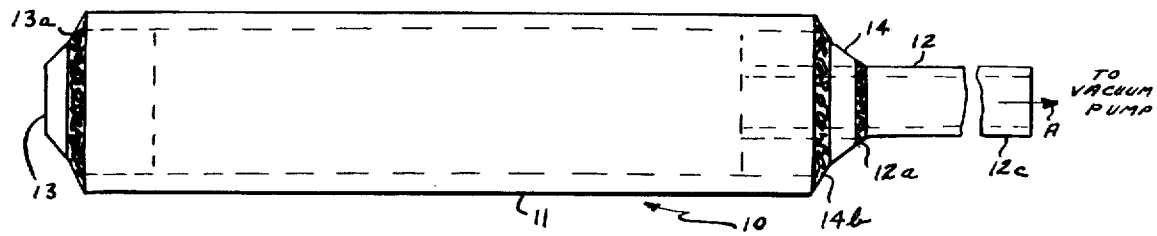
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[57] **ABSTRACT**

A billet-forming process and apparatus including selecting a hollow tube of thin-walled construction and having a relatively enlarged, interior chamber-passage or hole, partially filling the interior chamber-hole with loose metal powders, evacuating and heating the tube to eliminate substantially all air, moisture and gas particles from the interior hole thereof, sealing off the tube into an air-tight condition, and deforming the tube to squeeze together the metal powders into a solid mass of a predetermined approximate porosity in direct proportion to the amount of the simultaneous reduction occurring in both the outside and inside, hole diameters of the tube as a result of the controlled deformation thereof.

1 Claim, 7 Drawing Figures



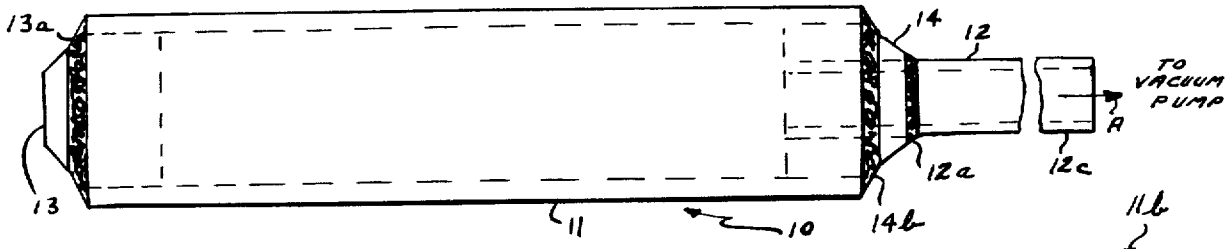


Fig-1

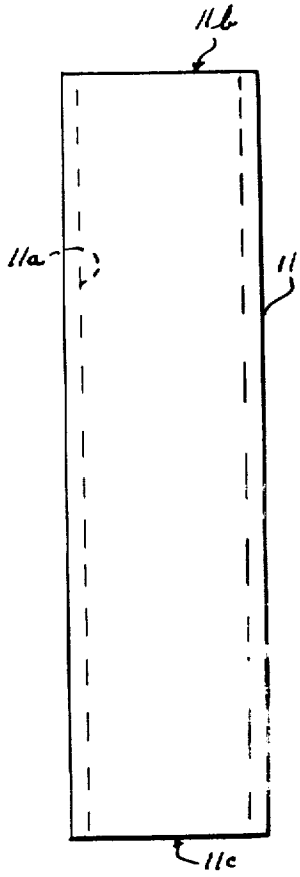


Fig-2

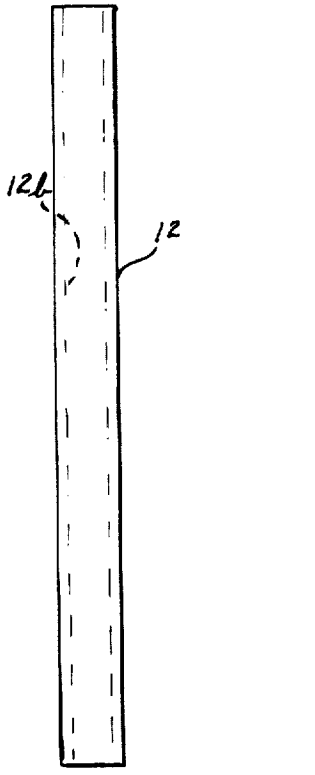


Fig-3



Fig-4

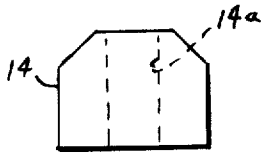


Fig-5

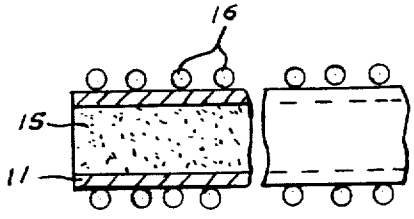


Fig-6

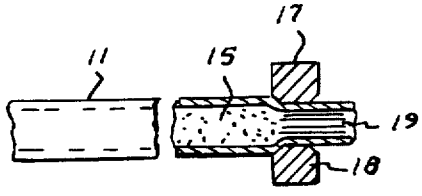


Fig-7

METHOD OF FABRICATING A BILLET FROM METAL PREFORMS AND METAL POWDER

RIGHTS OF THE GOVERNMENT

The invention described herein may be manufactured and used by or for the Government of the United States for all governmental purposes without the payment of any royalty.

BACKGROUND OF THE INVENTION

This invention relates generally to the field of powder metallurgy in which billets or ingots, for example, may be formed from the compacting of loose metal powders into a solid mass.

The various parts or components required for many metal products are frequently produced from the fabrication of a billet or ingot resulting from the pouring of molten metal into a casting mold, for example. Thereafter, the final or substantially final configuration to be applied to the billet or ingot may be accomplished, in many instances, by the application thereto of one or the other of many standard metal forming techniques, such as swaging, forging, rolling or extrusion.

Along with the formation of metal parts or components through use of the above-referred to methods where melting and casting are most often utilized, is another principal technique falling within the field known as powder metallurgy. In the latter field, it is the general practice to, first, produce metal powders or particles of a particular metal or alloy and then to unite or compact them into a common, solid mass through the use of some type of compacting pressure, with or without the application of heat. Many kinds of pressure is used to pack the individual metal powders or particles into a solid mass, to include static pressing where the metal powders are pressed together, in a press mold, either by means of a single movable punch acting downwardly against the powders or by the use of a pair of oppositely-disposed, movable punches.

The new and improved metal powder consolidation process of the present invention offers significant improvement over the aforementioned static press technique by placing the loose metal powders in a tube apparatus before being compacted together into a solid mass. In this connection, although in the prior art, the field of powder metallurgy does include the previous teaching of the general concept of the placement of the loose metal powders into a variety of containers, such as the flexible bag used in the well-known hydrostatic-/isostatic pressing, and the can of the technique referred to as powder forging, it will appear obvious hereinafter from the following disclosure of the present invention that the specific tube apparatus thereof, particularly when considered in the light of the overall combination in which utilized, offers unique advantages and benefits over other previously-developed containers both for the purpose of greatly facilitating the temporary storage of the metal powders in the forging position and to further improve the consolidation thereof into a solid mass. Finally, and more importantly, with the use of the present arrangement, a relatively easy control of the desired porosity of the billet or ingot being formed within certain well-defined limits is assured.

SUMMARY OF THE INVENTION

The present invention consists in forming a metal billet, for example, by the controlled deformation of a hollow tube apparatus or assembly containing loose metal powders to thereby squeeze together and compact the said powders into a solid mass. The tube apparatus is specially prepared by welding or otherwise affixing in a sealed relation a first, solid metal piece to one open end of a first, relatively enlarged, hollow and open-ended, main or primary tube to thereby constitute the closed bottom end thereof, and, further, by welding a second, central passage-containing metal piece to the opposite open end of the first, primary tube constituting the top end thereof.

The aforementioned second metal piece is uniquely utilized to rigidly affix in its central passage, as by welding, a second, leading and smaller, hollow and open-ended tube within the open top end of the primary tube in open communication with the hollow interior thereof, which hollow interior shall be hereinafter referred to as the hole of the primary tube. With this novel arrangement, the introduction of a supply of loose metal powders into the primary tube-hole is greatly facilitated through use of the said second, leading hollow tube. Thereafter, by use of a conventional vacuum-pump means attached to the outer, free end of the second, leading tube, and, moreover, by heating the tube assembly in any one of many standard ways, such as by means of a conventional resistance furnace, all or substantially all of the air, as well as any moisture and-/or gas particles, may be eliminated both from the hollow interior or hole of the first, primary tube, as well as from any moisture or gas entrapped in the loose metal powders.

After eliminating all or substantially all of the air, moisture and gas particles, as noted hereinabove, and with the vacuum pump still attached and operating, the open free-end of the second, leading tube may then be crimped or welded shut into a closed, air-tight condition, at which time, the inventive tube assembly is then ready for either cold or hot processing, as appropriate for the particular metal being used both for the loose metal powders and for the tube assembly itself, either by the conventional swaging thereof or by means of tube sinking through appropriate dies to thereby squeeze the said powders into a solid mass.

Inherent objects and advantages of this invention will appear self-evident hereinbelow in connection with the following disclosure, taken with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an overall assembly view, partly broken-away and schematic in form, of the improved tube apparatus or assembly used with, and as an integral part of the present invention;

FIGS. 2 and 3 respectively represent individual views of the principal components or parts of the tube assembly of FIG. 1; namely, the primary and secondary, leading tubes thereof;

FIGS. 4 and 5 separately and respectively depict the closed bottom and open top end pieces to be affixed in the opposite open ends of the primary tube of the invention;

FIG. 6 is a longitudinal sectional view, partly schematic and broken-away, and showing the condition of a fragmentary portion of the inventive tube assembly after the primary tube thereof has been partially filled with loose metal powders; and

FIG. 7 is a second longitudinal sectional view, partly schematic and broken-away, and showing the formation of a limited section of the loose metal powders of FIG. 6 into a solid mass after a portion of the primary tube has been fed between and deformed, as by swaging through the action of conventional and opposed die members.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring generally to the drawings and, in particular, to FIG. 1 thereof, the tube assembly used with and as an integral part of the present invention is indicated generally at 10 as consisting basically of a first, relatively enlarged primary tube 11 and a second, relatively small leading or secondary tube 12 (Also note FIG. 3). As is seen in both FIGS. 1 and 2, the primary tube 11 is made hollow in form so that a central, metal powder-containing enlarged passage or chamber or what is to be simply referred to hereinafter as the primary tube-hole, as at 11*a* (FIG. 2) may be formed therewithin, which primary tube-hole 11*a*, in the unassembled condition of the primary tube 11, terminates in opposite open end portions, indicated respectively at 11*b* and 11*c*.

The aforementioned tube assembly 10 is, in accordance with the novel teachings of the present invention, specially prepared, before use, to facilitate what is, in effect, a suitable and readily removable enclosure or enclosing means within which the loose metal powders to be compacted into a solid mass may be temporarily stored or positioned and, in addition, to provide a simplified and yet novel means further to facilitate the rather easy and quick introduction of the loose metal powders into the said hole 11*a*, preparatory to the formation or fabrication thereof into a billet, for example, and immediately thereafter quickly provide for the substantial decontamination of the said metal powders prior to the final steps required for the transformation thereof into a solid mass. More importantly, and in accordance with the further unique teachings of the invention, the tube assembly 10 provides and ensures a ready means for determining the inherent porosity of the particular metal powders, after, of course, the latter have been consolidated into a solid mass.

To complete the assembly of the tube apparatus 10 and thereby provide the unique device noted above, a solid metal bottom end piece of the configuration indicated generally at 13 in FIG. 4 may be welded, as by means of the weldment at 13*a* in FIG. 1, or otherwise sealed within one end portion, seen at 11*c* in FIG. 2, of the first, primary tube 11 to thereby effect a closed and air-tight relation to one end of the said primary tube 11, which may be considered the bottom end thereof. A second metal piece 14 (FIG. 5) which, however, incorporates a central and open-ended passage 14*a*, may be similarly welded, as by the weldment at 14*b* (FIG. 1), or otherwise rigidly affixed within the other, top open end, at 11*b*, of the said primary tube 11, with its central open passage 14*a*, of course, being in open communication with the interior passage, chamber or hole 11*a* of the said primary tube 11.

The above-noted central passage-containing top metal end piece 14 is utilized for the express purpose of rigidly attaching one end portion of the previously-described second, relatively small leading or secondary tube 12, as by means of the weldment at 12*a* (FIG. 1), which thereby places one end; namely, the inner end of the said second, leading or secondary tube 12 and an elongated and open-ended central passage thereof, as seen particularly at 12*b* in FIG. 3, in open communication with the primary tube-hole 11*a*. A supply of loose metal powders may then be poured with ease through the open free end of the second, leading or secondary tube 12 into the primary tube-hole 11*a*. Preferably, approximately 65% of the hole 11*a* is filled with the loose metal powders, which metal powders have been depicted in schematic form and generally at the reference numeral 15 in both FIGS. 6 and 7. In this connection, it is noted that a significant advantage of the instant invention resides in the use of the specially-prepared tube assembly 10. As described above, it consists of rather easily assembled components that permit and facilitate the relatively inexpensive test, as compared to other previously-developed apparatus, of a plurality of loose metal powders of different compositions, as well as providing a container that may be easily varied in size and the material used therefor to determine the best combination for a particular application. It also ensures another unique feature of the invention; namely, the initial production of solid billets or bars of relatively small size to be tested for initially determining the suitability of the particular metal powder composition for use in full-size applications. This is done by determining the mechanical properties of each test sample. Thereafter, for those samples found suitable for a particular use, a final solid bar or rod of a desired full-sized application may then be produced, again, by use of the inventive process and apparatus.

For applications where contamination of the metal powder particle surface is an important consideration, the entire tube assembly 10 may be placed in a controlled atmosphere region, such as a glove box (not shown), and sealed off, after the loose metal powder filling thereof, by clamping shut an appropriate segment of a vacuum hose used with a suitable vacuum pump to evacuate the primary tube-hole 11*a*. If the above-noted controlled atmospheric environment is not required in a particular application, after the chamber 11*a* is partially filled to about 65% of its capacity, for example, with loose metal powders, the vacuum hose of any suitable and already-available vacuum pump may be attached to the free end 12*c* (FIG. 1) of the second, relatively small tube 12, as is denoted at the arrow "A". At the same time, the entire tube assembly 10 may then be heated in any appropriate and conventional means, such as a resistance furnace, schematically depicted by the heating coils at 16 in the aforementioned FIG. 6, to thereby remove moisture and air, as well as absorbed gases generally from within the primary tube-hole 11*a* and, in particular, any moisture or gas that may have been entrapped in the metal powders. A temperature of about 700°F. may be used for this purpose. While still operating the vacuum pump system, the free end of the second, relatively small, leading or secondary tube 12 may be appropriately crimped or welded shut into an air-tight, closed condition. As noted hereinbefore, the outside diameter of the metal powder-containing, primary tube 11 may now be reduced in any suitable manner, as for example, by means of having successive sections of the length thereof swaged by being appropriately fed between a pair of swaging dies, as is schematically indicated at 17 and 18 in FIG. 7. In the latter FIG. 7, the loose metal

powders are indicated generally at **15**, as noted before, whereas, the solid mass resulting from the deforming of the primary tube **11** to thereby squeeze and compact together the powders in a particular section of the tube being compressed between the dies **17** and **18** is shown schematically at **19**.

The squeezing together of the loose metal powders **15** in successive sections of the tube **11** is, of course, accomplished by the operation of the die members **17** and **18**, in a conventional manner, to deform the primary tube **11** and thereby reduce its outside diameter. Naturally, by allowing the die members **17**, **18** to operate on and swage limited portions or successive sections of the length of the tube **11**, a more uniform density is assured for the solid mass being formed. Of course, a reduction in the outside diameter of the primary tube **11** automatically carries with it a reduction in the inside or hole diameter or, in other words, the diameter of the passage, chamber or hole **11***a* of the primary tube **11**. This reduction in the inside or hole diameter **11***a* continues until the loose metal powders **15** have been consolidated into a solid mass, representing, for example, the billet desired to be fabricated. The amount of deformation required for the metal consolidation is determined from the original outside diameter of the primary tube **11**, the degree or volume and the specific material of the loose metal powders, as at **15**, introduced into the primary tube-hole **11***a*, and the inherent friction existing between the outside tube diameter and the deforming dies, as at **17** and **18**, or other tools that may be used for the compacting step. If desired, a lubricant, such as mineral oil, may be used on the primary tube **11** which then would have the effect of inhibiting or lessening the amount that the diameter of the hole **11***a* would be reduced for a given swaging pressure and, in this manner, a relatively greater porosity in the solid mass would be produced.

By testing samples of the specially prepared tube assembly **10** of the present invention in which the above-outlined parameters have been selected, a metal powder consolidation of a desired degree and with the approximate porosity needed or desired for a particular application, such as a self-lubricating bearing, may be produced rather easily. Thus, in one such test sample, a tube assembly, as at **10**, was made of commercial pure titanium and filled with a titanium alloy powder. Thereafter, it was heated to **1650°F.** and the outside diameter reduced from **1.0** inch to **0.605** inches. The metal powder therein was consolidated into a solid mass with a porosity found to be at about **5%**. Three other titanium alloy metal powder samples were placed in separate titanium tube assemblies, again heated to **1650°F.** and the outside diameter, in these instances, of **1.050** inches reduced to **0.430** inches by swaging. The solid mass produced from each of these samples were found to approach a porosity of nearly **0%**.

Thus, it appears obvious that a new and novel billet-forming process and apparatus has been produced by the present invention in which the consolidation of loose metal powders into a solid mass is greatly simplified and facilitated by use of the specially-prepared tube assembly **10**. Moreover, by testing a number of samples, varying the dimensions of the enclosing tube assembly **10** and recording the change in outside diameter required to consolidate the loose metal powders of a given metal or alloy into a solid mass of varying porosities, which can easily be determined by known means, an overall graph may actually be plotted, if desired, recording the aforementioned data for tube assemblies of different dimensions and material, as well as loose metal powders of various compositions.

In the above improved manner, the technique of the present invention is easily adapted to control within reasonable limits the porosity of a particular billet being fabricated simply by controlling the amount of deformation and the actually measured reduction of the inside diameter required of the selected tube and particular metal powders contained therein for this purpose. The actual percent of porosity may be determined either from a previously-constructed graph, as noted hereinbefore, or by the use of known mathematics. Thus, the inventive technique may be used as a speedy and economical means of producing test samples, in the first instance, to determine the potential of the particular metal powders under consideration to achieve certain mechanical properties desired for a particular application and thus eliminate the rather expensive and time-consuming operation inherently present in relatively large scale production processes to be used in the making of certain parts from such metal powders, and, in addition, to rather easily fabricate these large scale products for full-sized applications after once having determined that metal powder samples of the same composition, in fact, have such desirable mechanical properties. More importantly, the invention, as noted hereinbefore, provides a novel and yet simple means of providing and controlling the desired porosity of the product being produced merely by specifically and positively controlling the swaging operation so that the outside diameter and hence the inside, hole diameter of the inventive tube assembly **10** is reduced only to the amount previously determined and selected from an already prepared graph or mathematically computed for a particular degree of porosity. Of course, since two of the parameters involved in the present process that will govern the degree of consolidation and density being applied to a particular composition of the loose metal powders are the original dimensions and material of the tube assembly **10**, the inventive process also embodies the initial selection of a tube having particular outside and inside diameters and a specific thickness.

We claim:

1. In a method for fabricating billets, raw stock and the like in preparation for the production of various parts, components and products to be assembled therefrom, the steps comprising; initially preparing a metal powder-receiving tube device by, first, selecting a rather easily deformable, first, relatively thin-walled and open-ended, hollow primary metal tube of a desired length, predetermined diameter and particular wall thickness, and forming a metal powder-receiving chamber therewithin, thereafter forming a closed bottom at one end of said primary tube, as by welding a first, solid metal end piece thereto, then affixing a second, readily removable, relatively elongated and reduced diameter-hollow, open-ended and centrally-disposed, temporary metal powder-storage, passage containing and feeding auxiliary metal tube in the opposite open end of said first, primary tube, as by sealing thereinto a second, relatively enlarged metal end piece having a central passage, an inner end extending substantially into said primary tube-chamber and rigidly mounting said second, auxiliary tube in the said central

passage with a first, inner passage end extending inwardly into the primary tube passage a significant degree to a position of exact alignment with the inner end of said second, metal end piece, and a second, outer passage end projecting outwardly a substantial distance of the outer end of said second, metal end piece and adapted to be releasably attached to a vacuum line and vacuum pump; subsequently introducing a predetermined supply of loose metal powders into the chamber of said primary tube, by way of and as may be measured by the amount thereof being respectively and initially admitted into, and temporarily stored by one or more fillings of, and further being selectively controlled by the selected size of said second, auxiliary tube; evacuating and heating the loose metal powders having been previously admitted into the primary tube-chamber to eliminate substantially all air, moisture and other gas particles from within the chamber per se and from the surfaces of the metal powders; sealing off the open outer end of the second, auxiliary tube at a position thereof adjacent or substantially adjacent its entry into its mounting-second, metal end piece, while simultaneously maintaining the evacuation being applied to the primary tube-chamber, by way of the vacuum pump and vacuum line adapted to be interconnected with the opposite outer, projecting end of said second, auxiliary tube, until the sealing off operation has been completed; and finally deforming said first, primary tube, as by swaging, a predetermined amount to thereby reduce both the outside and inside diameters a proportional amount relative to each other to thereby squeeze and thus compact together the loose metal powders within the primary tube-chamber into a solid mass exhibiting a given degree of porosity previously determined and specifically controlled by initially pre-selecting the material, diameter and wall thickness of the particular primary tube being deformed, as well as the particular material and size of the loose metal powders being compacted, and thereafter controlling the degree of deformation being applied respectively to both the outside and inside diameters and already found to give a particular porosity to the compacted metal powders in a test sample thereof.

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