Sept. 9, 1952 M. S. ROUSH ET AL 2,609,576

METHOD OF MAKING HOLLOW SHAPES

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Fig. 1

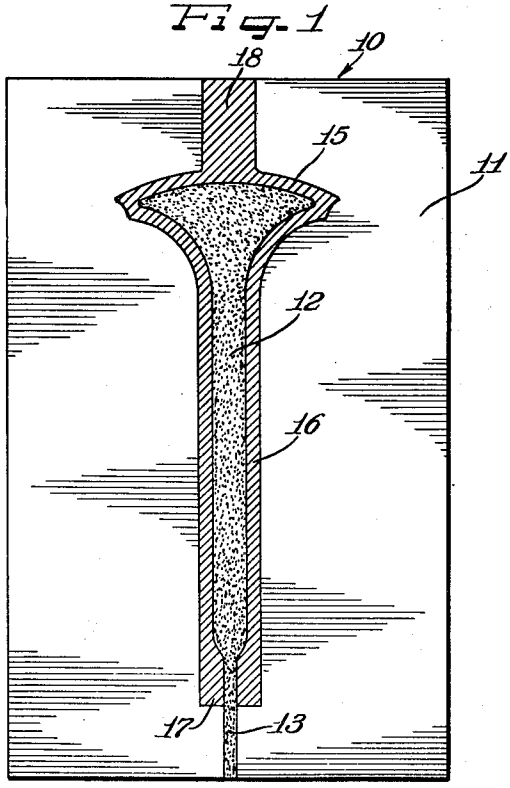


Fig. 2

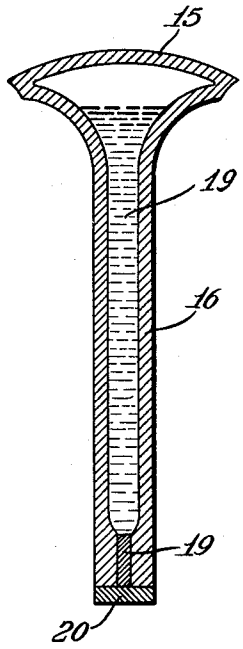


Fig. 3

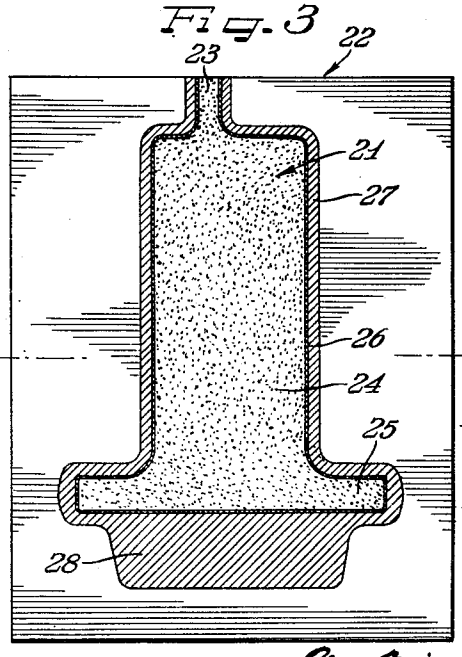


Fig. 4

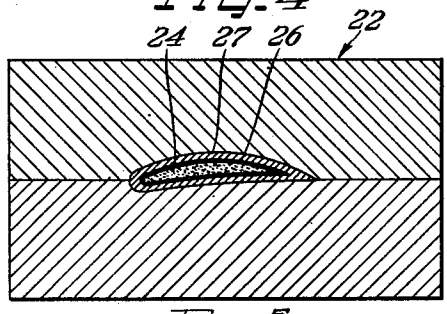
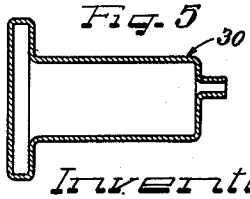


Fig. 5



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METHOD OF MAKING HOLLOW SHAPES

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9 Claims. (Cl. 22—200)

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The present invention relates to a method for making hollow shapes, particularly hollow castings of complex configuration.

In the fabrication of various elements for internal combustion or gas engines, it is often desirable to provide such elements with hollow interiors into which suitable coolant materials may be inserted for the purpose of enabling the element to withstand the effects of high temperature operating conditions. One such element is a poppet valve in the exhaust system of an internal combustion engine, wherein it is customary to provide the poppet valve head and stem with a hollow interior into which metallic sodium or other coolant material is incorporated. Other elements in which use is made of hollow body structure are the blades and turbine buckets used in jet propulsion engines.

An object of the present invention is to provide a method for making such hollow shapes, and in particular for making hollow castings having a uniform wall thickness.

Another object of the present invention is to provide a method for casting a corrosion resistant casing about a preformed core while providing means for quickly and efficiently removing the core structure after the casting has been completed.

Still another object of the present invention is to provide a method for making castings having hollow interiors, with the dimensions of the void space within the casting being controllable to precise limits.

Other objects and features of the present invention will be apparent to those skilled in the art from the following description taken in connection with the attached sheet of drawings.

As one feature of the present invention, we have provided a method for producing hollow shapes by forming a core by powder metallurgy technique having the configuration of the void space desired in the ultimate shape, forming the body or casing around such a preformed core structure, and dissolving the powder metal core out of the interior of the casing by means of a suitable reagent. The core material and the body metal are so selected that the core metal will not be melted by the body metal which is cast upon it, although it may have a lower melting point than the body metal. The core is preserved, irrespective of its melting point, if the molten body metal is not permitted to heat the core close to its melting point, so that no buckling of the core occurs during the casting operation. In addition, it is preferred that the

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body metal be such that it does not wet the core, thus preventing or minimizing the amount of infiltration of body metal within the core structure. In addition, the core is such that it is capable of dissolution by acid or alkali solutions, while the body metal is of such composition that it is extremely resistant to attack by such reagents, thus facilitating removal of the core from the finished casting.

While the powder metal core preferably has a high degree of porosity it may be infiltered with an easily dissolved metal, such as copper, to provide strength and increase its heat conductivity. The infiltered core, for purposes of this invention, may be considered "porous" in that the infiltrant filling the voids instead of air is easily attacked by the dissolving media to open up the channels or voids in the powder metal core.

By using a powder metal core in a casting procedure several advantages are to be realized. First of all, the porosity of the compact is such that it is easily penetrable by the acid or other reagent and is quickly dissolved from the interior of the cast article. Then, too, the core is rigid enough to permit twisting or coining of the cast article, with the core in place, to a final shape before the removal of the porous core. This latter feature is esential in the fabrication of complex shapes such as the air-foil sections of turbine buckets.

The core metal preferably used in connection with this invention is a powdered iron compact which has been compacted to the shape desired in the ultimate hollow section of the casting, and sintered at the appropriate transformation temperatures according to conventional powder metallurgy techniques. The density of such compact will normally be on the order of 50 to 60% of the density of solid iron. The iron particles initially have a size of from about 80 to 325 mesh, and are compacted at pressures from about 6 to 50 tons per square inch. The temperature of sintering is preferably at the alpha-gamma transformation point of iron (about 1600° F.) although temperatures up to 2000° F. may be used.

A sintered metal core of the type described has the further advantage that it is relatively compressible, so that no cracking of the casting occurs upon cooling.

In addition to ferrous metal compact, suitable core materials may be made from compacted copper powder, aluminum powder, or titanium powder. Where the outer casing of the casting is to consist of a relatively low melting plastic

material, a low melting metal such as tin may be compacted into a suitable core shape. All of the above core metals may be easily removed from the ultimate core structure by means of treatment with acids, such as nitric acid, while in the case of aluminum, caustic alkali may be used as the reagent.

The features of the invention therefore include the use of a body metal which will withstand attack by acid without substantial dissolution, the use of powder metallurgy technique to form an easily dissolved core, and the use of a casting technique which will not melt or buckle the powder metal core.

The casting of hollow articles may be facilitated by this invention, since the porous core permits evacuation of the mold cavity through the core by merely connecting the core to a source of vacuum. Further, the invention makes possible the use of powder metallurgy technique to form molds which can be dissolved off of the casting.

Where the finished article is to be used under conditions of high temperature corrosion, the preferred body metal which forms the exterior casing is preferably a corrosion resistant alloy of the type known commercially as the Vitallium alloys. A typical composition for such an alloy includes 30% chromium, 6 molybdenum, and the balance cobalt. Portions of the cobalt may be replaced by nickel, and portions of the molybdenum content replaced by tungsten. Other suitable alloys are those of the Stellite series, which contain about 45–55% cobalt, 28–32% chromium, 10–15% tungsten, and about 2.5% carbon. These alloys have melting points around 2450° F. These alloys are extremely resistant to lead oxide corrosion and are substantially unattacked by mineral acids such as hydrochloric acid and nitric acid. In addition, they do not wet the porous iron compacts to any substantial degree, so that infiltration of the latter is avoided during the casting operation.

Another method for forming the body of the article about the preshaped porous core consists in chromizing the powder metal compact in a conventional chromizing procedure.

This procedure consists in packing the material to be chromized in a closed container with chromium powder and then heating to a temperature between about 1800° and 2600° F. in an atmosphere of hydrogen.

The chromizing operation is carried out until such time that a self-sustaining outer shell or casing is provided about the porous metal core. The thickness of the casing may be conveniently controlled by controlling the time or temperature of the chromizing operation. The casing may be made more dense by coining the sintered porous compact to a high density, or by sintering the same in a carburizing atmosphere.

The case which is produced in such a chromizing operation is essentially a iron-chromium alloy having a diminishing chromium concentration throughout the body of the case. The outside layer of the case has been found to contain approximately 60% chromium, while the layer immediately adjacent to the porous compact has a chromium concentration of approximately 10%.

A more detailed description of the present invention will be made in conjunction with the description of the attached sheet of drawings, in which:

Figure 1 is a vertical cross-sectional view of a poppet valve casting around a porous compact core in a casting mold assembly shown in elevation;

Figure 2 is an axial cross-sectional view of a finished poppet valve prepared according to the process of the invention;

Figure 3 is a vertical cross-sectional view with parts in elevation of a mold assembly including one-half of the mold used in the formation of a turbine bucket having a hollow air-foil portion;

Figure 4 is a transverse cross-sectional view taken substantially along the line IV—IV of Figure 3 and including the other half of the mold; and

Figure 5 is a vertical sectional view of a hollow turbine blade composed of a metal built up on the core as a coating, by chromizing or the like.

As shown on the drawings:

In Figure 1, the reference numeral **10** denotes generally a permanent mold consisting of two symmetrical halves such as **11** mating at a parting line. While a permanent mold is used for purposes of illustration, it will be understood that sand and plaster molds may be used where appropriate. Disposed within the recess of the mold is a core comprising a powder metal compact **12** shaped to the configuration desired in the void space of the finished article, as described previously. In the illustration shown in Figure 1, the compact core **12** forms the neck and stem portions of a poppet valve assembly. The base of the compacted core **12** is provided with an appendage which forms a core print **13** held between appropriate recesses formed in the mating spaces of the mold **10**, thereby holding the compacted core **12** within the mold **10**.

As shown in Figure 1, a casting alloy which is to form the body of the poppet valve is cast around the compacted core **12** while the same is held within the mold **10**. The body thus formed consists of an arcuate valve head portion **15**, an elongated stem portion **16**, and a base portion **17**. It will be noted that the base portion **17** terminates short of the lower base of the mold **10** so that the core print **13** extends downwardly beyond the limit of the base **17**. A sprue portion **18** is also formed during the casting operation.

When the assembly shown in Figure 1 is removed from the mold **10**, the sprue portion **18** may be trimmed off, and the core **12** removed from the cast body. This removal may be most conveniently effected by immersing the cast valve into a solution of acid or other reagent capable of removing the porous core without substantially affecting the body metal. By virtue of the high degree of porosity of the core, the acid will be quickly soaked up into the interstices of the core, and dissolution will be effected very rapidly. The dissolved core may then be drained from the interior of the valve structure through the opening provided by the dissolution of the core print **13**. Coolant material, such as sodium **19** is then inserted through the opening provided by the core print portion **13** to partially fill the hollow interior of the valve. To close the sodium filled chamber, a tapered plug **19** is inserted into the valve base **17**, and a cap **20** applied to the valve base **17** as by means of welding.

Figures 3 and 4 illustrate a method similar to that described in connection with Figures 1 and 2 for the production of a hollow cast turbine bucket. As shown in Figure 3, a porous core **21** is provided within the mating faces of an appropriately recessed mold **22**, the core **21** having a core print **23** extending therefrom and serving to secure and to index the position of the core **21**

within the mold assembly. The porous core 21 is shaped into a central portion 24 which defines the hollow interior of the air foil section of the finished bucket, and terminates in a well portion 25 which ultimately forms a laterally extending recess in the root portion of the finished blade. For the purpose of preventing solution of the core metal into the body metal when the latter is cast around it, the core 21 is provided with a coating 26. The coating may be applied by casting, dipping, spraying, electroplating and similar techniques well known by those skilled in the art. This coating may consist of a metallic coating, such as chromium or nickel, or may suitably be composed of a vitrified ceramic composition.

The casting metal is poured into the mold structure, around the preformed porous core 21, to define an air foil section 27 and a root portion 28 of the finished bucket. A sprue 29 remains, partially enclosing the core print 23 of the core 21.

The cast assembly may then be removed from the mold and coined or otherwise shaped to its final configuration. To insure a proper degree of rigidity in the air-foil section during such finishing operation, it is preferable to leave the compacted core 21 within the cast body until the final shape is attained. The compacted core may then be removed by acid dissolution in a manner already described, leaving the body metal and as much of the coating 26 as has not been dissolved by the acid.

It will be noted that in the process described above the casting of the article may be accomplished while leaving only a small outlet aperture for the removal of the porous core. Thus, an element may be cast to close tolerances initially and the closure of such outlet is all that is necessary to provide a sealed hollow chamber extending throughout the cast body.

As shown in Figure 5, a hollow turbine blade 30 can be produced by this invention by forming the blade metal as a coating on a core such as the core 24 of Fig. 3 and by dissolving out the core. No casting operation is then involved. The blade 30, if formed by chromizing, will have the exact shape and dimensions of the core, since the chromized layer is actually created by replacement of the core surface and an external building up of an added layer is not involved. It will be of controlled porosity, depending upon the porosity of the core, but it will be less porous than the core on which it is formed. The porous blade in use in a turbo-jet engine can be sweat-cooled by oozing alcohol or some other vaporizable material through the blade.

From the foregoing it will be appreciated that we have herein provided a convenient method for producing articles having complex interior voids. The articles so produced have uniform wall thicknesses and may be precision cast to close tolerances.

It will be evident that various modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

We claim as our invention:

1. A method of producing hollow articles which comprises compacting powdered metal into a core having the configuration desired in the hollow portion of the finished article, casting metal to form the body of the article about said core without melting or buckling the core, and dissolving out said core with a reagent capable of dissolving the core without substantially affecting the body material.

2. The method of making hollow castings which comprises forming a core comprising a porous sintered powdered iron compact into the configuration desired in the hollow portion of a finished article, casting an acid resistant body metal about said core, and dissolving out said iron core with an acid.

3. The method of making hollow castings which comprises forming a core comprising a porous sintered powdered aluminum compact into the configuration desired in the hollow portion of the finished article, casting body metal about said core, and dissolving out said aluminum core with an alkali.

4. The method of making hollow castings which comprises forming a core comprising a porous metal compact into a shape having the configuration of the hollow portion of the finished casting and also having an appendage forming a core print, supporting said core in a mold by means of said core print, casting an acid resistant body metal about said core while supported in said mold, removing the cast article from the mold, and dissolving the core from said cast article through said core print.

5. The method of making hollow castings which comprises forming a core comprising a sintered powdered ferrous metal compact into a shape having the configuration of the hollow portion of the finished casting, coating the core with a metal coating, casting an acid-resistant body metal about said coating, and dissolving out said core with an acid capable of dissolving said ferrous core without substantially affecting the body metal.

6. The method of making hollow castings which comprises forming a core comprising a sintered powdered ferrous metal compact into a shape having the configuration of the hollow portion of the finished casting, coating the core with a refractory coating, casting an acid resistant body metal about said coated core, and dissolving out said core with an acid capable of dissolving said ferrous core without substantially affecting the body metal.

7. The method of making hollow castings which comprises forming a core comprising a sintered powdered ferrous metal compact into a shape having the configuration of the hollow portion of the finished casting, chromizing the core, casting an acid resistant body metal about the chromized core, and dissolving out said core in an acid capable of dissolving the core without substantially affecting the body metal.

8. The method of making a hollow metal article which comprises forming a core comprising a porous sintered powdered metal compact, casting the body metal of the article about said core, and dissolving out said core with a reagent capable of dissolving the core without substantially affecting the body metal.

9. The method of making a hollow metal article which comprises forming a core comprising a porous sintered powdered metal compact, casting the body metal of the article about said core, deforming the resulting article with the core in place to produce an irregularly shaped member, and thereafter dissolving out said core with a reagent capable of dissolving the core without substantially affecting the body metal.

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