Oct. 8, 1963

A. F. BAUER

3,106,002

DIE-CASTING METHOD

Filed Aug. 8, 1960

3 Sheets-Sheet 1

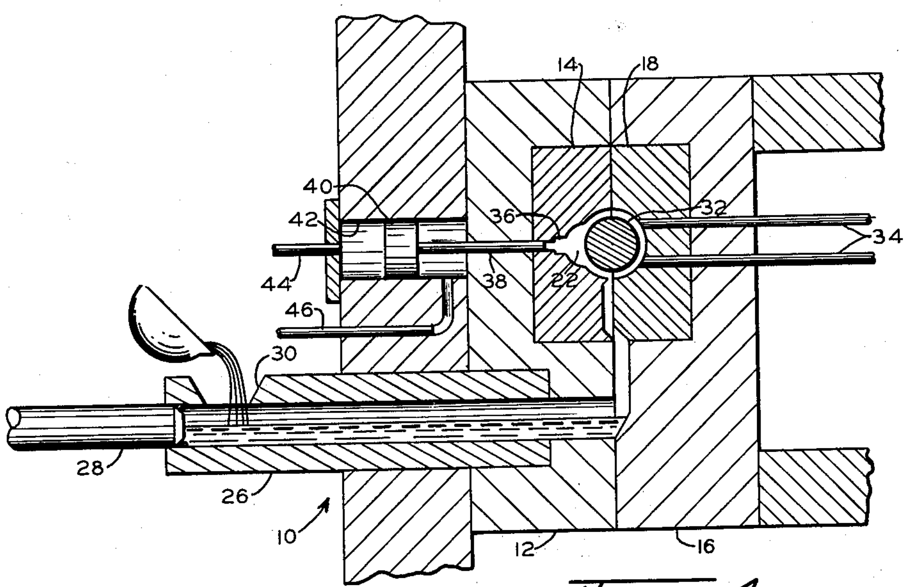

FIG. 1.

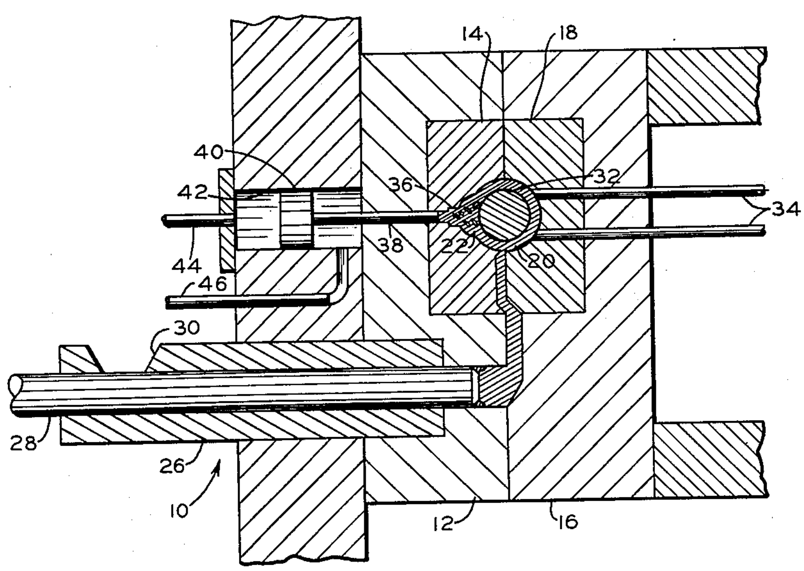

FIG. 2.

INVENTOR.
ALFRED F. BAUER
BY Owen & Owen

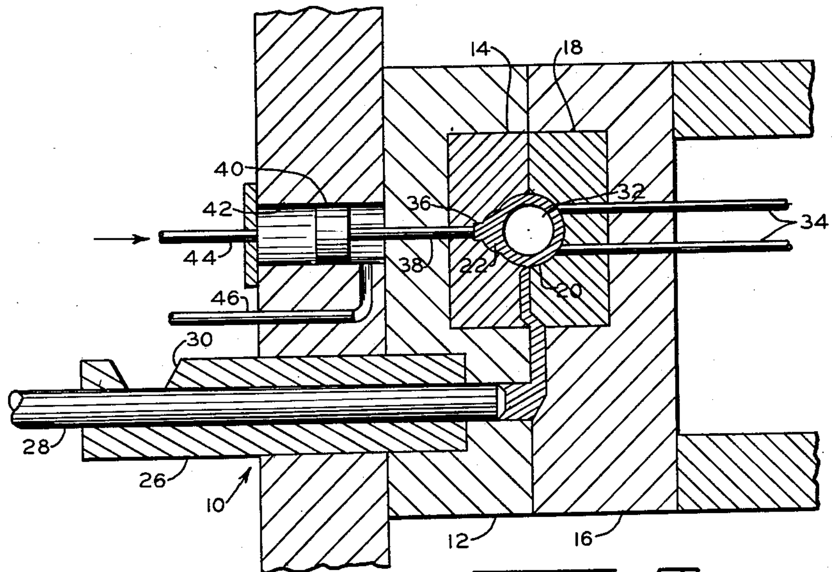

Fig. 3.

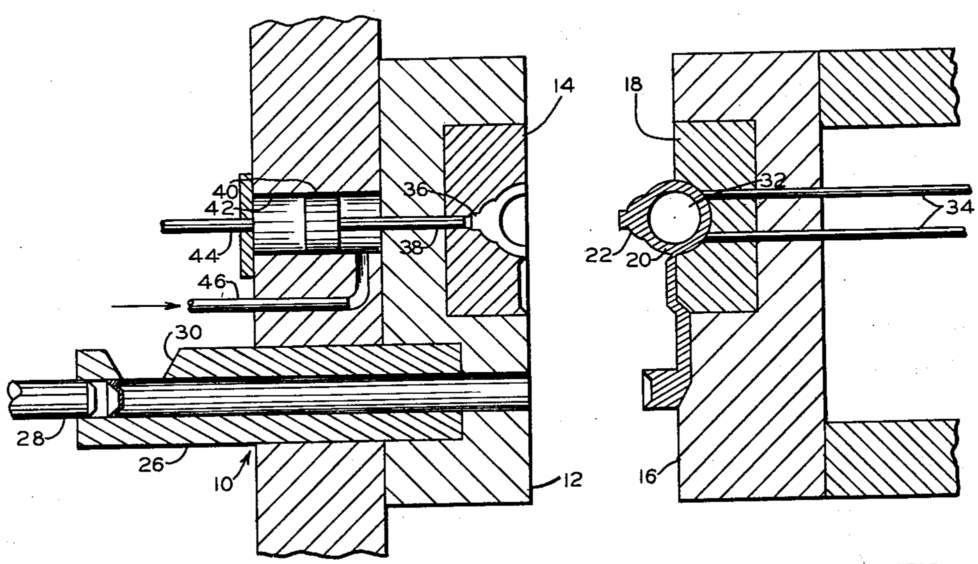

Fig. 4.

INVENTOR.
ALFRED F. BAUER
BY Owen & Owen

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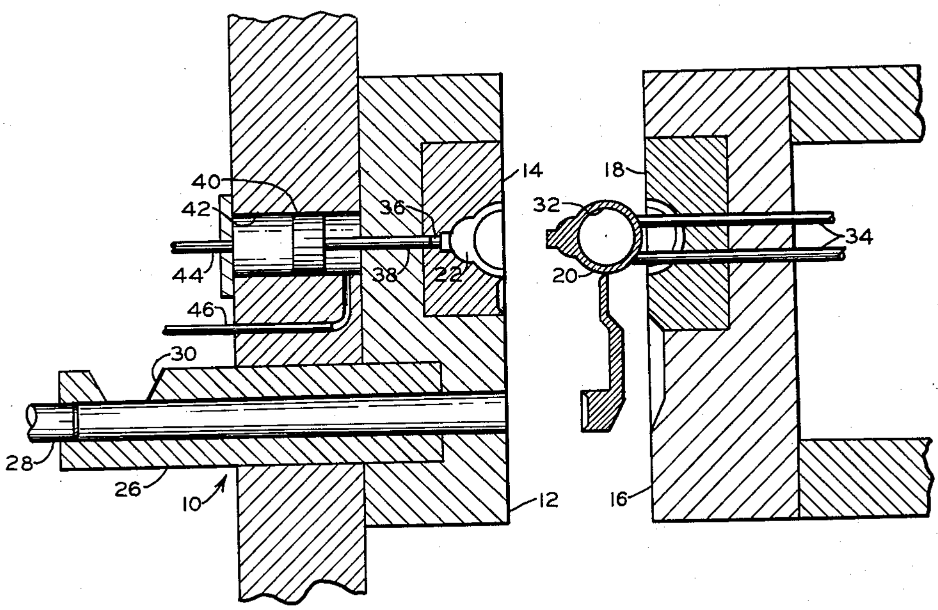

Fig. 5.

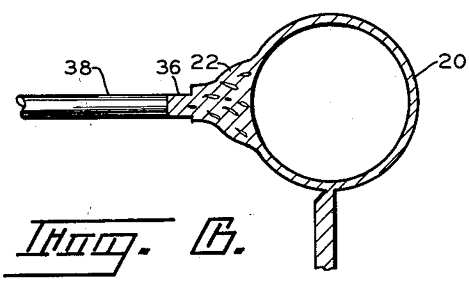

Fig. 6.

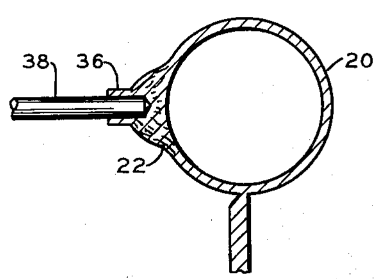

Fig. 8.

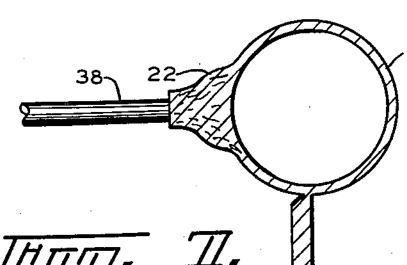

Fig. 7.

INVENTOR.
ALFRED F. BAUER
BY Owen & Owen

United States Patent Office

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DIE-CASTING METHOD

Alfred F. Bauer, Toledo, Ohio, assignor to National Lead Company, New York, N.Y., a corporation of New Jersey

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1 Claim. (Cl. 22—215)

This invention relates to a method and apparatus for forming metallic parts and is particularly directed to a method of improving the physical properties of parts produced by pressure die-casting. While the invention is useful broadly in the die-casting art it is particularly applicable to die-casting of light metals such as aluminum and magnesium and their alloys.

In the manufacture of metallic parts by pressure die-casting, it has long been recognized that extensive and sometimes prohibitive porosity will occur in thick or heavy sections, particularly when those sections are adjacent to a relatively thin section in the die. Because of the rapid chilling of the metal adjacent to the die walls and cores, and the temperature gradient extending from the outside of the casting toward the center of the section, heavy sections which cool more slowly are likely to develop relatively larger grain, greater porosity, and lower mechanical strength than thin sections. This porosity takes place because, during the solidification process the adjacent thin sections tend to shrink in volume first and to draw metal from the still molten heavy sections. The thick or heavy sections thus act in a manner somewhat analogous to the action of risers for the thin sections with the result that the thin sections are sounder and the porosity occurs almost entirely in the heavy sections. Because this result has been well recognized, the art has avoided the accumulation of metal in thick sections such as bosses and at intersections in the casting wherever possible and has gone to great lengths to relieve this accumulation by coring and by re-designing the parts.

The art has known that as the casting pressure increases the soundness of the parts also increases, but not proportionately. It has thus been proposed to carry out the pressure die-casting process with injection pressures as high as 80,000 to 100,000 p.s.i. However, such attempts have not been successful except for very simple castings because of the tremendous complications introduced into the design of the machine and of the dies by the increased pressure.

It has also been proposed to assure uniform filling of a die under high pressure by the use of a sub-divided shot sleeve comprising a multiplicity of small cylinders, each containing its own shot piston, and all intersecting at a sprue or gate opening leading into the die. By this expedient it has been hoped to force metal under very high pressure through the sprue or gate into the die, while keeping a relatively moderate total pressure on each of the individual pistons. However, the porosity problem has still not been solved by this method.

In the usual pressure die-casting art employing cold chamber machines and moderate pressures of from 6000 p.s.i. to 12,000 p.s.i., the most practical solution to the porosity problem of heavy sections has been to avoid them and to re-design the part to exclude them as far as possible. Where grain structure and mechanical strength are important, the art has substituted judiciously placed strengthening and stiffening ribs which can be of approximately the same cross section as the adjacent sections of the part being cast. In some pieces, however, heavy sections cannot be avoided, and the art has uniformly recognized the desirability of being able to cast such heavy sections without porosity and with good mechanical strength.

The primary object of the present invention is to provide a method and apparatus for producing die-castings in which heavy sections of non-porous metal having excellent grain structure and high mechanical strength can be made.

Another object of the invention is to provide a method and apparatus for producing die-castings in which a heavy section, fed through or adjacent to a thin section, may have the same grain structure and mechanical strength as the adjacent thin section of the part.

Another object of the invention is to provide a method of producing a part by a combined pressure die-casting and forging operation, the forging being relied upon to improve the grain structure, and reduce the porosity of a heavy section, and to improve greatly its mechanical strength.

Broadly defined, the present invention provides a method of forming a sound, non-porous body of die-cast metal, under the usual die-casting pressures by casting the metal into a die cavity having a portion that will form a thick or heavy section in the final part, permitting the cast part to solidify in the die to a temperature at least 50° F. below the liquidus point, but not more than 200° F. below such point so that the part, while solid, will retain a fair degree of plasticity, and finally applying a localized forging pressure of, for example, 80,000 p.s.i. to the heavy section while the part is still in its original position in the die. Thereafter the part is ejected in the usual manner. I have found that, in parts made in accordance with this practice, the heavy section is without porosity and of fine grain structure.

The accompanying drawings illustrate an apparatus embodying the present invention and capable of carrying out my new method. In the drawings:

FIG. 1 is a central vertical sectional view through a die and shot end of a die-casting machine, with the die closed and indicating metal being ladled into the shot sleeve;

FIG. 2 is a view similar to FIG. 1 with the parts shown in the position occupied at the end of the injection stroke of the shot plunger, the die being filled;

FIG. 3 is a view similar to FIG. 1 with the parts shown in the position occupied after the forging step;

FIGS. 4 and 5 are views similar to FIG. 1 with the parts shown in the positions occupied after the dies are opened and the casting ejected, respectively;

FIGS. 6 and 7 are somewhat enlarged diagrammatic sectional views of the casting alone, before and after forging; and

FIG. 8 is a view similar to FIG. 7 showing a casting after completion of a modified forging step.

Referring to the drawings, a die-casting machine of the cold chamber type is designated generally **10** and includes a stationary platen **12** carrying a cover die **14**, and a movable platen **16** carrying a complemental ejector die half **18**. For purposes of illustrating the present invention the dies are shown as being arranged for the casting of a cylindrical article having a relatively thin wall **20** with a heavy boss or projection **22** extending from one side thereof. Thus the boss represents a mass of metal which will require a much longer time to solidify in the die than the adjacent thin wall sections.

The die cavity formed by the mating die halves **14** and **18** is fed through a gate **24** from a conventional shot sleeve **26** having a shot plunger **28** reciprocable therein. A pour opening **30** is provided in the shot sleeve for the reception of a charge of molten metal. The die is provided with a laterally movable core **32** and with appropriate ejector pins **34**. The parts so far described are conventional and are shown apart from their conventional operating devices such as are commonly used for the reciprocation of the ejector die **18**, the shot plunger **28**, the core **32** and the ejector pins **34**.

The die cavity of the cover die 14 is formed with an extension 36 connecting directly with that portion of the cavity which forms the boss 22. This extension is preferably cylindrical, although it may be rectangular in cross section and unequal in its several dimensions, depending on the shape of the boss as will be hereinafter described.

A forging plunger 38 normally held in a retracted position forms the outer wall of the cavity of the die extension 36 and may be circular and of the same diameter as the die extension or of a lesser diameter. The plunnger 38 is connected to a forging piston 40 which is reciprocated by fluid pressure in a cylinder 42 mounted in or on the stationary platen 12. The cylinder 42 and its piston 40 may be carried in the ejector die 18 or, if desired, may be mounted in such a manner that the piston 40 reciprocates between the die halves in a manner similar to the reciprocation of the movable core 32. The direction of movement relative to the casting and the location of the forging plunger will vary depending on the shape and location of the heavy section of the part being cast.

The forging cylinder 42 is provided with fluid connections 44 and 46 on each side of the piston 40 so that the piston may be moved with a positive force in either direction in its cylinder, which is thus a double-acting cylinder. A single-acting cylinder may be used as a means to apply a forging pressure to the piston 40 and thus to the normally retracted forging plunger 38, if desired.

The casting chosen to illustrate the operation of the present invention has a relatively thin wall portion 20 and an adjacent heavy section in the boss or extension 22. Such a part is difficult to die-cast with known methods for the reason that the boss 22 will exhibit a high degree of porosity in the finished casting. This porosity is caused by passage of the metal from the heavy section back into the adjacent thin sections to compensate for the volume shrinkage of the thin sections upon cooling. This shrinkage is substantial, particularly in aluminum and magnesium alloy castings and is, of course, unavoidable. In sand casting these metals, risers can be used to supply the molten metal needed to make up for shrinkage both in the thin sections and in the thick sections, but in die-casting this is not possible. For this reason it has been the practice to replace bosses and other heavy sections with reinforcing ribs or to recognize that the heavy section will be porous and to so design the part that its physical properties are considered to be well below the physical properties of the sound adjacent thin sections. The present invention provides a means and a method to correct the deficiencies of the heavy sections and results in a casting which is free from voids and in which the grain structure and physical properties of the castings are uniform throughout the thin and thick sections alike.

The method of the present invention comprises introducing molten metal into the die under normal pressures usually used in cold chamber machines, for example 6000 p.s.i. to 12,000 p.s.i. At this pressure it is not difficult to fill a die completely if the die is properly vented and properly designed and gated. Thus, the molten metal of the charge enters equally well into the thin and heavy sections and into the die extension 36 in front of the forging plunger 38. The metal solidifies rapidly in the die and, during solidification, shrinks in volume. After a few seconds the metal even in the heavy section freezes. When the metal has solidified but while it is at a temperature of between 50° F. and 200° F. below the liquidus point, a forging pressure is applied by admitting fluid (either air or oil) to the forging cylinder 42. The area ratio of the forging piston 40 and the forging plunger 38 and the pressure behind the piston are so chosen that the localized forging pressure applied to the casting is in the neighborhood of 80,000 p.s.i. if an aluminum alloy is being cast. The forging pressure forces the metal from the die extension 36 into the boss or heavy section 22 and all of the pores or voids left by shrinkage are completely closed.

Ideally the forging pressure exerted on the metal contained in the die extension 36 is sufficient to force out of the die extension and into the boss or heavy section 22 a volume of metal approximately equal to the total volume of the pores or voids. The pores or voids are thus completely filled with metal. During this filling operation, the grain structure of the boss or heavy section is refined by hot working. Forcing a lesser quantity of metal out of the die extension 22 may result in some residual porosity, of the heavy section, but the advantage of grain refinement and some increase in strength of the part will still obtain, but to a somewhat lesser extent.

The time of application of the forging pressure is related primarily to the temperature of the casting. If the casting is allowed to cool to too low a temperature it is possible that the localized high pressure will cause cracks and distortion of the casting unless the alloy being cast is very dutile and capable of being cold worked. If the pressure is applied while the interior of the boss or heavy section is still molten, the metal will not undergo the desired grain refinement by reason of the forging step.

If the time and temperature relationships are properly chosen it is not possible to discern, in a sectioned part, any line of demarcation between the metal introduced by forging from the die extension 36 and the surrounding metal of the heavy section. If the forging takes place after the metal of the boss has been allowed to cool to too low a temperature a sectioned part will show a distinct line between the introduced metal and the remainder. While the porosity has been overcome in this instance, the condition is not optimum and is not desired.

Forging the metal while solid but at an elevated temperature refines the grain structure to a very desirable extent. It has been found that the grain structure of a very heavy boss can be made equal to that existing in an adjacent thin wall by the practice of the present invention.

Also it has been found that forging while the metal is cooling from its original molten state results in a complete union of the walls of voids previously existing therein, because these walls have not had an opportunity to become coated with oxide, as would happen if the casting were cooled and reheated. It is thought that the voids are filled with a reducing gas at low pressure (probably methane) which is replaced by air after the part is removed from the die and allowed to stand at room temperature. The oxide coating which forms upon complete cooling of a die-cast part effectively prevents the part from being properly improved by subsequent working.

Since a very thin oxide coat forms rather quickly on the walls of the metal in the die extension 36, it is sometimes desirable to make the diameter of the forging plunger 38 slightly less than the diameter of this die extension. By this expedient, only the unoxidized inner metal from the die extension will be forged into the heavy section 22 of the casting.

While it is usually necessary to make only a single stroke of the forging plunger to accomplish the desired result, repeated and rapid forging blows may be imparted by the plunger by reciprocating the forging piston 40 in its cylinder. This, of course, requires only that the fluid pressure be applied alternately and cyclically in the fluid connections 44 and 46.

When the forging step has been completed the core 32 is withdrawn, the dies opened, and the part ejected in the usual manner.

In the form of the invention shown in the drawings, the die extension 36 in which metal is accumulated for the forging step has been described as circular in cross section. If the heavy section of the casting is greatly elongated, it will be preferable to use a forging plunger which has an elongated or rectangular face in order that the metal forced into the heavy section by forging may be more evenly distributed throughout the mass of the heavy section.

Further, as shown in FIG. 8, grain refinement and porosity reduction of a heavy section that will ultimately include a tapped hole or similar opening may be accomplished by displacing, by forging, the metal of the section itself prior to its removal from the die. This is most readily accomplished by driving a forging plunger 38 into the newly solidified metal. The plunger 38 may be pointed, if desired, so that a tap may enter the hole left thereby without difficulty. In this form of the invention the displacement of the metal from one area of the heavy section to the surrounding areas fills all of the voids and the force of the forging tool works the metal to assure a dense, fine grain structure in the completed casting.

The present invention is especially useful in die-casting blades for turbines or centrifugal compressors. In such blades the hub portion is massive and of relatively large cross section while the blade portion itself is usually thin in cross section. By utilizing the process and apparatus of the present invention a dense, non-porous hub can be produced having grain properties similar to those of the blade portion.

Other uses and structures will suggest themselves to

those skilled in the art, and various modifications and changes may be made without departing from the scope of the appended claim.

What I claim is:

The method of forming a sound, non-porous body of die-cast metal which comprises casting metal under pressure into a die cavity having a portion forming a heavy section of a die-cast body, lowering the temperature of the interior of the casting to between 50° F. and 200° F. below the liquidus point, displacing metal within said heavy section by forcing a displacing member into said heavy section under forging pressure, withdrawing said displacing member, and ejecting the cast and forged body from the die.

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