United States Patent

Haller

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[54] **FLUID-CONDUCTING HOT-FORGING DIE AND METHOD OF MAKING THE SAME**

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[52] **U.S. Cl.** .....**72/45,** 72/253, 72/463, 72/467, 76/107 R

[51] **Int. Cl.** **B21b 45/02,** B21c 43/00, B21k 5/20

[58] **Field of Search**.....76/107, 107 A; 72/476, 463, 72/467, 342, 38, 41, 43, 45; 25/DIG. 15

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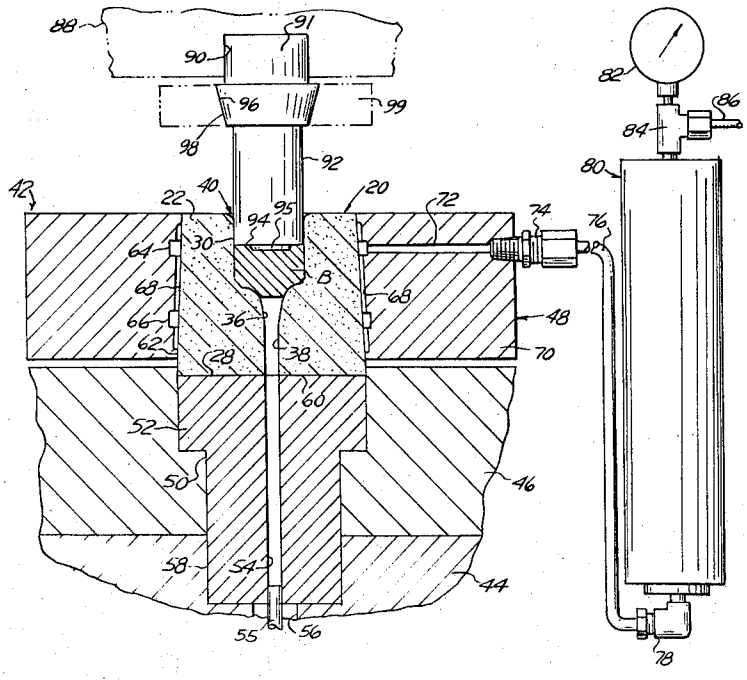
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Assistant Examiner—R. M. Rogers
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[57] **ABSTRACT**

A foraminous ordinary-duty hot-forging die is provided with minute fluid passageways therethrough for the conduction of a coolant, a lubricant or a protective atmosphere under high pressure. A porous hot-forging die is made by forming a briquette of coarse powdered tool metal or carbide, sintering the briquette, machining a die cavity or die bore therein, and heat-treating the thus-formed die for the required hardness and wear resistance.

1 Claim, 12 Drawing Figures



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SHEET 1 OF 3

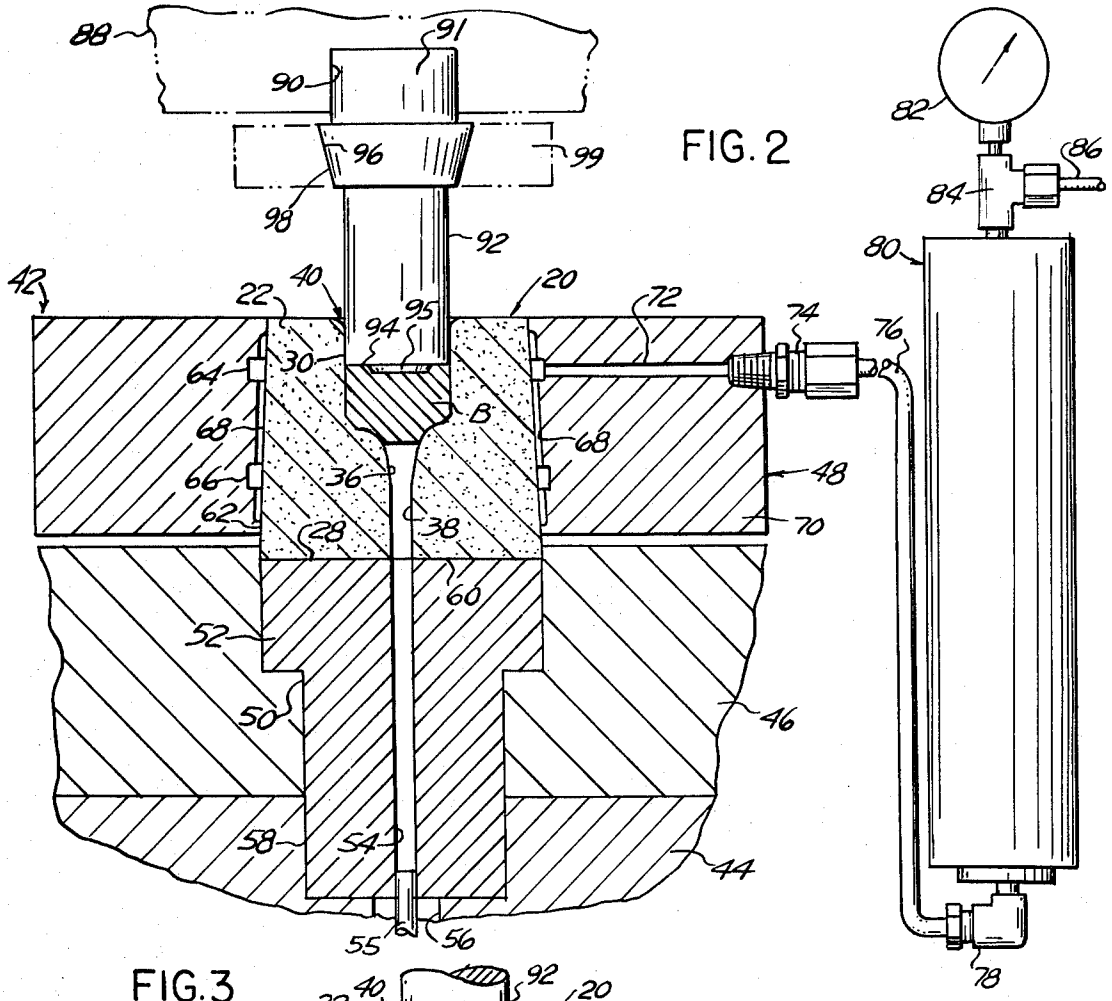


FIG. 2

FIG. 3

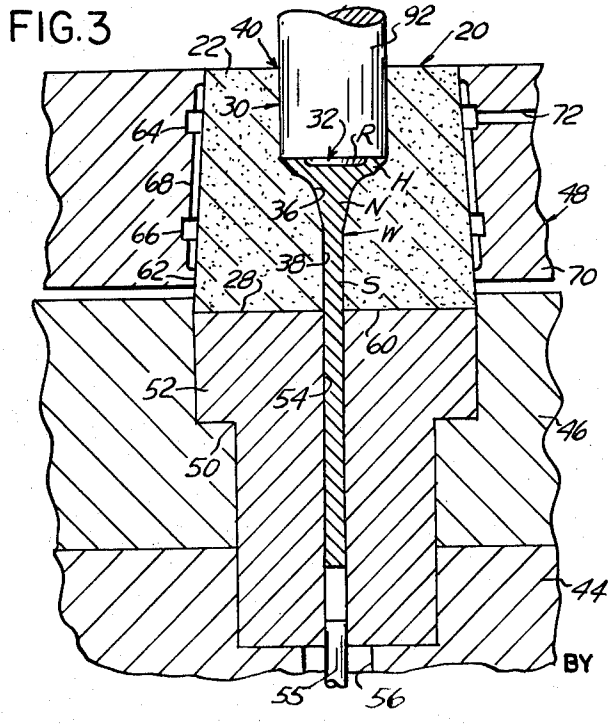
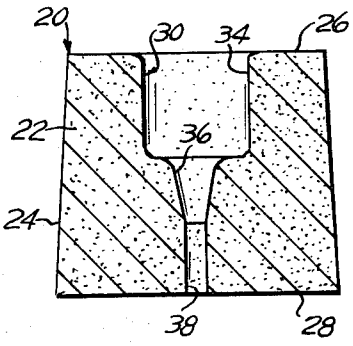


FIG. 1



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FIG. 9

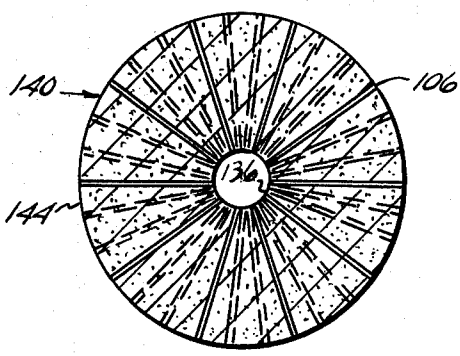


FIG. 5

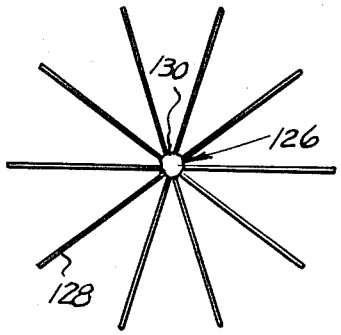


FIG. 8

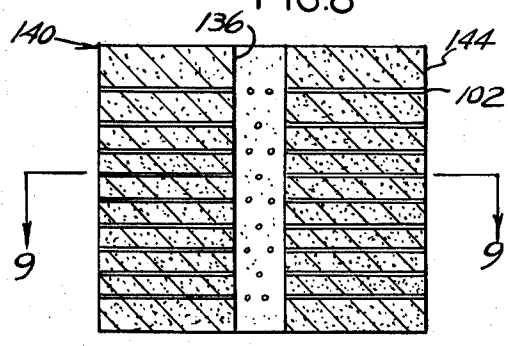
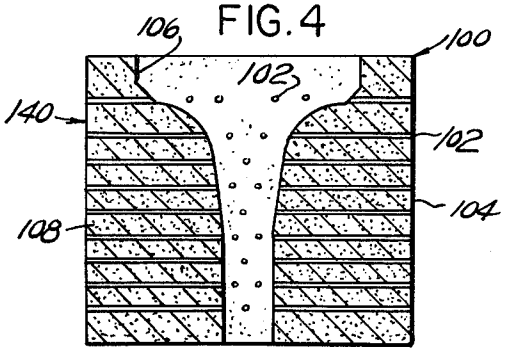


FIG. 4



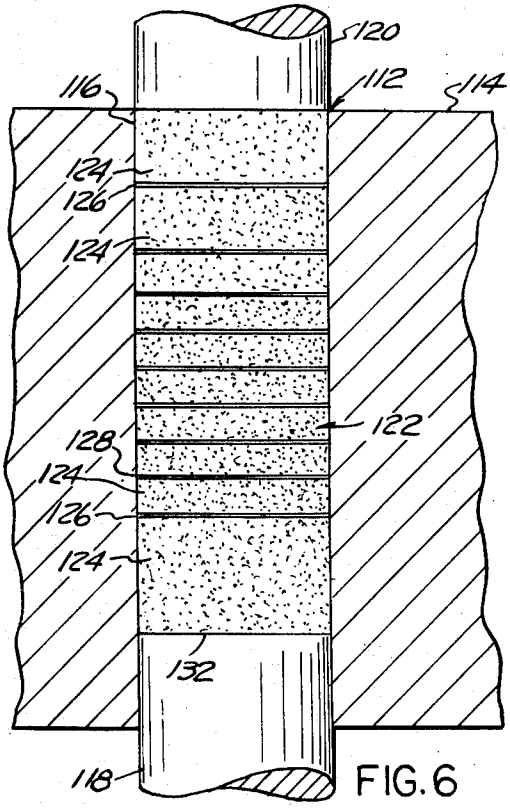


FIG. 6

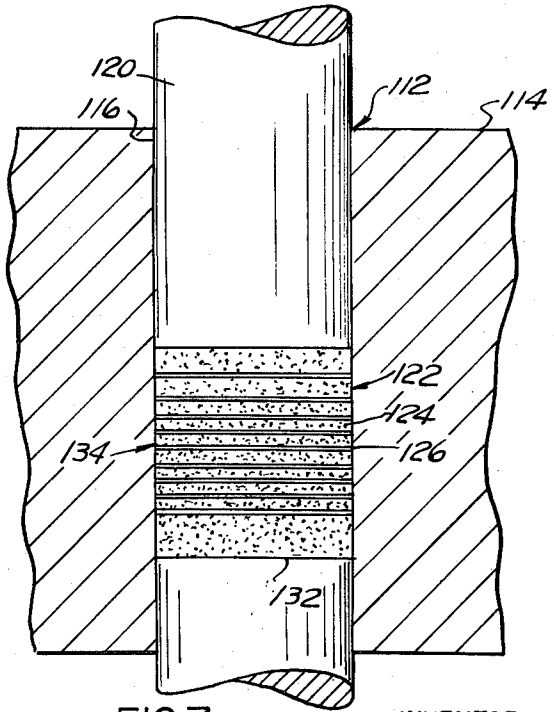


FIG. 7

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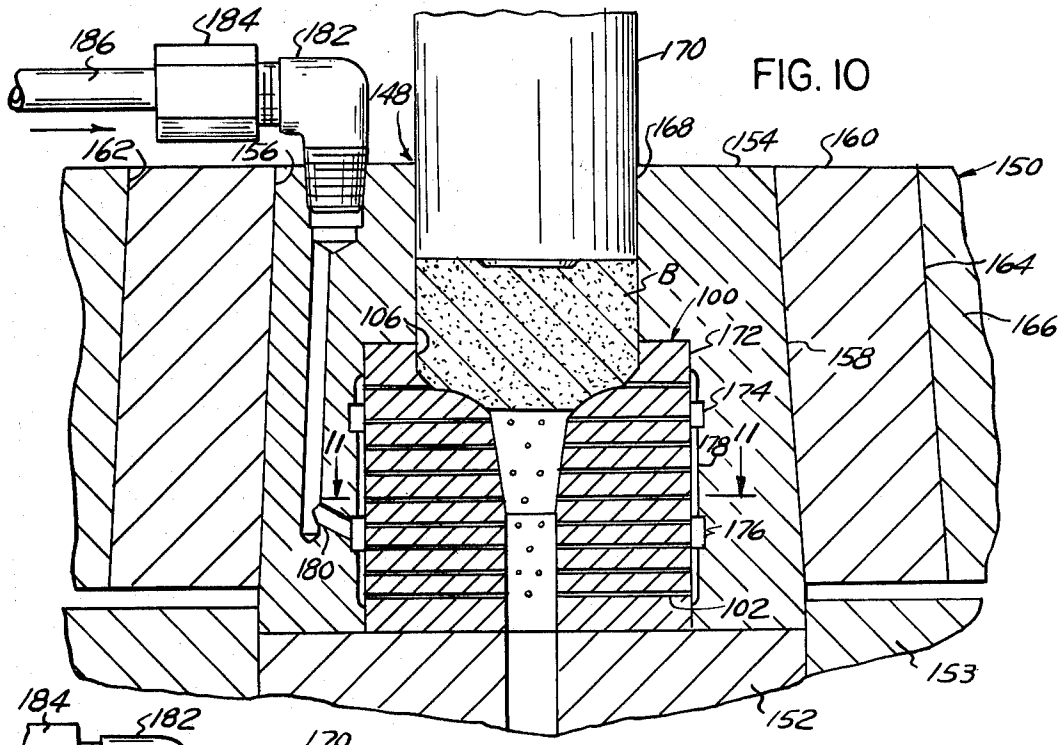


FIG. 10

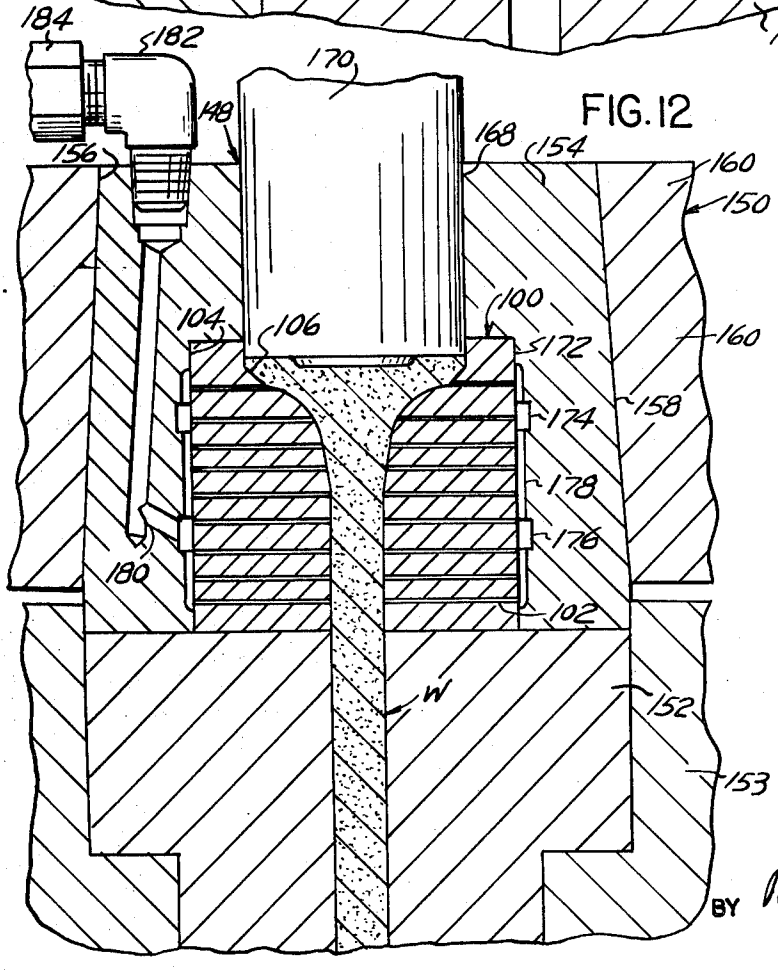


FIG. 12

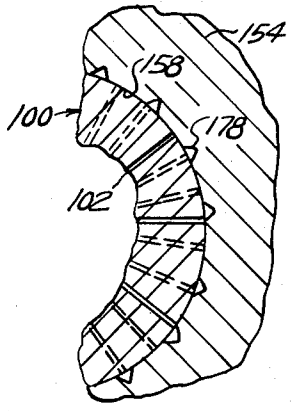


FIG. 11

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FLUID-CONDUCTING HOT-FORGING DIE AND METHOD OF MAKING THE SAME

A modified heavy-duty fluid-conducting hot-forging die is formed from powdered material by loading the die cavity of a briquetting press with a charge consisting of alternate layers of powdered tool metal or carbide and fusible wire inserts extending thereacross and compressing this charge into a briquette. This briquette is then sintered at a temperature below the melting point of the insert material, hot-forged to density it so as to produce a substantially solid die forging of approximately 100 percent density, annealed, and bored to form a central pilot hole therethrough. The die forging is then vacuum-sintered at a temperature higher than the melting point of the insert material with a sufficiently low vacuum to vaporize the insert material and withdraw it from the body, leaving perforations therethrough. The sintered perforated die forging is then machined to provide the desired shape of die cavity or die bore and finally heat-treated to obtain the necessary hardness and wear resistance. Either form of die is mounted in a bore in a die-holding block having a chamber therearound. During hot-forging operations, this chamber is supplied with a coolant, a lubricant or a protective atmosphere agent under a sufficiently high pressure to force it through the pores of the porous die or through the perforations in the solid die while the die is being used to hot-forge, extrude or otherwise form workpieces.

BACKGROUND OF THE INVENTION.

Hitherto, hot-forging dies of solid metal have possessed short working lives and have been subject to considerable oxidation as a result of the high pressures and high temperatures to which they have been subjected during use. The present invention enables an ordinary-duty die to be formed from powdered metal or carbide with pores sufficiently large for the passage of a coolant, a lubricant or a protective atmosphere agent, increasing the working life of the die. The substantially solidified sintered powdered metal perforated heavy-duty hot-forging die of the modification of the invention enables higher temperatures and higher forging pressures to be employed yet with increased working life than in previous hot-forging dies.

In the drawings:

FIG. 1 is a central vertical section through an ordinary-duty fluid-conducting hot-forging die of sintered powdered metal or carbide, according to one form of the invention;

FIG. 2 is a central vertical section through a hot-forging or extrusion press showing the hot-forging die of FIG. 1 at the start of a hot-forging or extrusion operation;

FIG. 3 is a view similar to FIG. 2, but showing the position and shape of the workpiece at the conclusion of the hot-forging or extrusion operation;

FIG. 4 is a central vertical section through a heavy-duty fluid-conducting hot-forging die of densified sintered powdered metal or carbide, according to a modification of the invention;

FIG. 5 is a top plan view of a fusible wire insert employed in making a heavy-duty solidified hot-forging die, according to the modification of the invention shown in FIG. 4;

FIG. 6 is a central vertical section through the die bore of a briquetting press showing the formation of the briquette for the heavy-duty die of FIG. 4 at the start of the briquetting operation;

FIG. 7 is a view similar to FIG. 6 but showing the briquette at the end of the briquetting operation;

FIG. 8 is an enlarged central vertical section through the presintered briquette of FIG. 7 after a pilot hole has been drilled therethrough;

FIG. 9 is a cross-section taken along the line 9—9 in FIG. 8;

FIG. 10 is a central vertical section through a hot-forging or extrusion press showing the hot-forging die of FIG. 4 at the start of a hot-forging or extrusion operation;

FIG. 11 is a fragmentary cross-section taken along the line 11—11 in FIG. 10; and

FIG. 12 is a view similar to FIG. 10 but showing the shape and position of the workpiece at the conclusion of the hot-forging or extrusion operation.

Referring to the drawings in detail, FIG. 1 shows a porous ordinary-duty hot-forging die, generally designated 20, according to one form of the invention, as consisting of a porous body 22 of sintered powdered metal or carbide preferably with a slightly tapered side surface 24 and with top and bottom surfaces 26 and 28 respectively interconnected by a die cavity 30. The die cavity 30 is shown by way of example to have a shape adapted for the production of a poppet valve workpiece 32 (FIG. 3), such as is used in the manufacture of internal combustion engines and in this instance consists of an approximately cylindrical upper cavity portion 34, tapered intermediate cavity portion 36 and a straight cylindrical lower cavity portion 38.

The body 22 is first formed as a briquette or compact by conventional briquetting or compacting methods and apparatus known to those skilled in the powder metallurgy art, using a preponderance of a coarse metal or carbide powder, such as 150 mesh tool steel, or tungsten carbide, titanium carbide or silicon carbide powder with or without the addition of a finer mesh powder thereof, depending upon the porosity desired for the die. This powder is mixed with other necessary ingredients, such as graphite, and a lubricant in order to obtain a homogeneous blend of the component materials possessing the proper chemical composition. The charge of this powder mixture is placed in a conventional briquetting or compacting press and compacted at a pressure higher than the pressure to which the die is expected to be subjected in service. For example, if the die 20 is expected to be used in hot-forging service at pressures not exceeding 50 tons per square inch, it would be compacted at a pressure of about 70 tons per square inch.

The compact or briquette is then removed from the briquetting press and sintered in the conventional manner for the particular die material employed, and in a protective atmosphere, such as a hydrogen or dissociated ammonia atmosphere if oxidizable ingredients, such as chromium, are present. After the briquette has been sintered, it is bored or otherwise machined to form the die cavity or die bore 30 with the shape required for the production of the particular workpiece 32 to be produced. The die 20 thus formed is heat-treated in a conventional manner to provide it

with the necessary hardness and wear resistance. If, during machining, the porosity of the die body **22** has been impaired, such as by wholly or partially closing up the pores, these may be re-opened by the use of a conventional chemical etching agent.

The porous hot-forging die **20**, thus produced, is mounted in a conventional hot-forging or extrusion press or machine, generally designated **40**, shown diagrammatically in FIG. **2**. This is shown, in its working parts adjacent the die **20**, to include a press bed assembly **42** consisting of a lower punch support **44** mounted on a lower bolster plate (not shown), a back-up plate **46** resting on the lower punch support **44**, and a die holder plate **48** disposed above the back-up plate **46**. The lower punch back-up plate **46** is provided with a stepped bore **50** in which is mounted a correspondingly-flanged lower punch **52** containing an elongated central bore **54**. The bore **54** slidably receives the upper end portion of an ejector or knockout rod or plunger **55** and opens into an enlarged bore **56** in the lower punch support **44**, which contains a counterbore **58** snugly receiving the lower portion and lower end of the lower punch **52**, which has an upper end surface **60** upon which the lower end surface **28** of the die **20** rests.

The die holder plate **48** contains a bore **62** which is tapered according to the taper of the side surface **24** of the die **20** so as to fit snugly therewith. Intermediate the opposite ends of the tapered bore **62** there are provided upper and lower annular passageways **64** and **66** respectively interconnected by circumferentially-spaced fluted fluid transmission grooves collectively constituting a flock chamber **68**, similar to those shown in FIG. **11**. Extending outward through the body **70** of the die holder plate **48** is a passageway **72**, the outer end of which is threaded to receive the correspondingly-threaded high pressure coupling **74** connecting the passageway to a high-pressure conduit **76** which at its opposite end is connected by a high pressure elbow coupling **78** to a high pressure fluid accumulator, generally designated **80**. The accumulator **80** is adapted to contain a lubricant, a coolant or a protective atmosphere agent subjected to a standing pressure indicated on a pressure gauge **82** communicating therewith by a Tee fitting **84** which in turn is connected to a conduit **86** leading to a pressure-regulated pressure source (not shown).

The hot-forging or extrusion press or machine **40** also includes an upper platen or ram **88** (FIG. **2**) which is provided with a socket **90** receiving the upper or butt end **91** of an upper punch **92** having a lower end surface **94** with a nose portion **95** thereon and also having an annular tapered portion **96** thereon urged toward the upper platen **88** by its engagement with the correspondingly-tapered bore **98** in retaining plate or ring **99** bolted or otherwise secured to the upper platen **88**.

In the operation of the hot-forging or extrusion press or machine **40** employing the ordinary-duty fluid-conducting hot-forging die **20**, let it be assumed that the upper platen **88** and upper punch **92** have been moved upward to their retracted positions so as to leave open for loading the die cavity **30** in the hot-forging die **20**. Let it also be assumed that the latter and its die holder **70** and back-up plate **46** have been heated to a suitable pre-heating temperature between 600° and 1,000° F. by conventional means (not shown). Let is also be assumed that the accumulator **80** has been placed in operation to cause a flow of coolant or lubricant, as the case may be, through the passageway **72** into the chamber **68** whence this fluid surrounds the body **22** of the hot-forging die **20** and penetrates the pores thereof to reach the die cavity **30**. This contemplates the use of a pressure within the range of **100** pounds per square inch up to 5,000 pounds per square inch, depending upon the size of the pores in the die body **22** and the viscosity of the fluid being transmitted therethrough.

A workpiece slug or bland B having been heated to a suitable forging temperature, is now dropped into the die cavity **30** of the now-heated porous hot-forging die **20** and the platen **88** then made to descend, causing the upper punch **92** to enter the upper portion **34** of the die cavity **30**. The lower end **94** and the nose portion **95** thereof engage the hot slug or blank B and push it downward, causing the material thereof to undergo flow and to be extruded through the tapered intermediate bore **36** into the straight cylindrical lower bores **38** and **54** (FIG. **3**). The foregoing action forms a workpiece W having a head H with a recess R and an elongated stem S interconnected by a tapered neck N. It will be understood, however, that the workpiece W is merely one form of workpiece which may be hot-forged by the porous die **20** of the present invention and that many other forms of workpiece may also be hot-forged thereby in a similar manner according to the configuration of the workpiece W/and the consequent shape of the die cavity **30** required to produce it.

The upper platen **88** and punch **92** are now retracted upward away from the die cavity **30**. The workpiece W, which for purposes of illustration has been illustrated and described as for a poppet valve for an internal combustion engine, is now caused to be ejected from the die cavity **30** by moving the ejector rod or plunger **55** upward in the bore **54** so as to engage the lower end of the workpiece W and first dislodge it and then push it upward out of the die cavity **30**. Meanwhile, the high pressure coolant or lubricant fluid reaching the die cavity **30** through the conduit **72**, chamber **68** and pores of the die body **22** cools or lubricates, or both cools and lubricates the wall of the die cavity **30** and also cools the hot-forging die **20**, inhibiting oxidation, deterioration and wear and greatly increasing the life of the die **20**. In the alternative, a gaseous protective agent reaching the die cavity **30** through the pores of the die body **88** from the passageway **72** and chamber **68** prevents oxidation of the heated workpiece slug or blank B and the workpiece W forged or extruded therefrom.

The modified heavy-duty fluid-conducting hot-forging die, generally designated **100**, shown in FIG. **4** is also adapted to be cooled, lubricated or supplied with a protective atmosphere but is employed for heavy-duty hot-forging where the pressures involved are beyond the capacity of the porous ordinary-duty hot-forging die **20** of FIGS. **1**, **2** and **3**. Unlike the porous hot-forging die **20** of porous sintered powdered material, the densified fluid-conducting hot-forging die **100** is composed of sintered powdered material which has been subjected to hot-forging itself in order to compress its particles, close up its pores and densify it so as to render it substantially solid with a density approaching

100 percent. Instead of fluid-conducting pores of the porous die **20** of FIG. **1**, the heavy-duty die **100** of FIG. **4** is provided with elongated minute fluid-conducting passageways or channels **102** extending from its external surface **104** to its die cavity **106** through/its body **108**.

To produce the densified substantially solid hot-forging die **100**, powdered material, such as powdered metal or powdered carbide, with conventional sizes of particles is briquetted or compacted in a conventional briquetting press **112** shown diagrammatically in FIGS. **6** and **7**. The briquetting press **112** is shown as including a briquetting die **114** containing a briquetting die cavity or bore **116** with a lower punch **118** entering the lower end thereof and an upper punch **120** movable into and out of the upper end thereof. The upper punch **120**, like the upper punch **92** of FIG. **2**, is connected to an upper platen (not shown) which, at the start of operation, is retracted upward away from the briquetting die **114**. The die cavity **116** is then filled with a charge **122** consisting of alternate layers **124** and **126** of metal or carbide powder and fusible inserts respectively.

Each fusible insert **126** (FIG. **5**) possesses the configuration of the pattern of holes or perforations desired in the finished die **104** and consists of multiple fusible wire arms **128** arranged in a wheel-spoke or star shaped pattern and secured at their midportions to one another in any suit-able manner as by solder **130**. The inserts **126** are conveniently formed from copper wire because of its ease of soldering and convenient melting point of 1,980° F., but it will be understood that other suitable fusible materials may also be employed for this purpose. The powder layers **124** of the charge **122** are conveniently composed of so-called high speed steel or tool steel powder or of carbide powder, such as tungsten carbide, titanium carbide or silicon carbide. The loading of the briquetting die cavity **116** with the charge **122** is performed by placing the lowermost layer **124** of powder on the top surface **132** of the lower punch **118**, whereupon an insert **126** is placed on top of the powder layer **124**. A second layer **124** of powder is then placed on top of the first insert **126**, followed by another insert **126** in a slightly rotated position (FIG. **9**) and so forth until the die cavity **116** is filled to the extent necessary to produce the desired size of die **100** with the arms **128** of the inserts **126** offset relatively to one another in different layers of the charge **122** (FIG. **9**).

The briquetting press **112** is then operated to cause the upper punch **120** to descend and enter the die cavity **116** (FIG. **6**), compressing the charge **122** therein (FIG. **7**). Meanwhile, the lower punch **118** is held stationary or, if the die **114** is mounted upon a conventional die cushion (not shown), the assembly of die **114** and lower punch **118** descends slightly, The result is the compressed insert-equipped briquette **134** shown in FIG. **7**. The upper punch **120** is then retracted upward, whereupon the briquette or compact **134** is ejected from the briquetting die cavity **116** by moving the lower punch **118** upward.

The briquette or compact **134** is then pre-sintered in a suitable atmosphere such as hydrogen or dissociated ammonia at a temperature sufficiently below the melting temperature of the inserts **126** to prevent melting thereof yet at the same time sufficient to pre-sinter the entire briquette **134**. The pre-sintered briquette is then normally re-heated to the presintering temperature to still avoid melting the inserts **126** and is then subjected to hot-forging to convert the pre-sintered compact into a substantially solid die forging **140** (FIG. **8**) approaching 100 percent density. In the alternative, the hot working of the forging **140** can also be accomplished without reheating if the pre-sintered compact is removed quickly from the pre-sintering furnace and hot-forged immediately before it has had time to cool. The forging operation upon the sintered compact distorts the cross-section shape of the inserts **126** very slightly from their original shape, thereby converting the wires **128** from circular cross-section to approximately oval cross-section.

The hot-forged sintered compact or die forging **140** is then annealed in a conventional manner to soften it sufficiently to permit the drilling of a central pilot hole **136** (FIG. **8**), whereupon the insert-equipped forging **140** is then fully sintered in a vacuum at 2,000° to 2,500° F. depending upon its material. This action melts and vaporizes the material of the inserts **126** and withdraws it by suction, leaving the perforated hot-forging die blank forging **140** (FIG. **8**) provided with the holes, passageways or channels **102** radiating outward from the pilot bore **136** to the external surface **144** of the die blank **140**. If the inserts **126** are made from copper wire which has a melting point of 1,980° F., the hot-forging is performed at approximately 1,900° F. and a 1-micron vacuum at a temperature of 2,100° F. The procedure just described melts, vaporizes and removes the copper material of the inserts **126**.

The die forging **140** thus equipped with multiple passageways **102** is now machined to form the heavy-duty substantially solid fluid-conducting hot-forging die **100** by boring or otherwise producing its die cavity **106**. This die cavity or die bore **106** can also be produced by so-called electrical discharge machining and can be of any suitable configuration. The particular die cavity **106** shown in FIG. **4** is presented solely by way of example for forming a poppet valve workpiece similar to the workpiece W shown in FIG. **3**. In the event that the mouths of the perforations or passageways **102** become partially or wholly clogged during the machining operation which produces the die cavity **106**, these openings can be cleared by the use of a conventional etching agent, such as an etching acid.

In the use of the perforated heavy-duty die **100**, the latter is mounted in a conventional hot-forging or extrusion press or machine, generally designated **148**, shown diagrammatically in FIGS. **10**, **11** and **12** and includes a press bed assembly **150** having a lower punch **152** mounted in a lower punch back-up plate **153** above a lower bolster plate (not shown) in a manner similar to the arrangement shown in FIGS. **2** and **3**. An outer die **154** is provided with a tapered outer surface **156** and is mounted in the correspondingly-tapered bore **158** of a pre-stressed annular die holder **160** which in turn is provided with a tapered outer surface **162** mounted in a tapered bore **164** in a die holder plate **166**.

The outer die **154** is provided with an upper die bore **168** snugly receiving an upper punch **170** and is also provided with a counterbore **172** snugly receiving the

outer surface **108** of the die **100** at its upper and lower ends. The counterbore **172** intermediate its upper and lower ends is provided with a pair of vertically-spaced annular upper and lower fluid passageways **174** and **176** interconnected by grooves **178** (FIG. **11**) extending therebetween and sufficiently therebeyond to reach all of the passageways **102** in the die **100**. From the lower annular fluid passageway **176** a fluid passageway **180** extends upward within the outer die **154** and at its upper end is threaded to receive a high pressure elbow fitting **182** connected to the coupling **184** of a high pressure fluid supply line **186**.

The operation of the hot-forging or extrusion press **148** employing the perforated solid hot-forging die **100** is sufficiently similar to that of the hot-forging or extrusion press or machine **40** described above as to require no repetition, hence is not repeated in order to avoid duplication. The high pressure fluid reaching the annular passageways **176** and **174** by way of the passageway **180** and elbow coupling **182**, **184** from the high pressure fluid line **186**, whether a coolant, a lubricant or a protective agent, passes through the minute perforations or passageways **102** in the hot-forging die **100** and cools, lubricates or protects both the die **100** and the workpiece therein (FIG. **12**) as the heated or blank B is forced downward through the die cavity or die bore **106** to become the elongated workpiece W. The upper punch **170** is then retracted upward and the knockout rod or ejection plunger (not shown, but similar to the member **55** in FIGS. **2** and **3**) is then moved upward to eject the workpiece W from the die cavity **106** and die bore **168**.

I claim:

1. A fluid-conducting porous hot-forging die device, comprising

a die holder having a bore therein,

a porous die body composed of particles of sintered powdered heat-treated tool steel and having a die cavity therein and an outer peripheral surface therearound spaced outward from said die cavity and spaced inward from said die holder bore and defining therewith a fluid chamber,

means for supplying a lubricant fluid under high pressure to said chamber,

fluid-conducting means in said porous die body consisting of a multiplicity of minute fluid-transmissible passageways formed by the pores between said particles and extending continuously from said fluid chamber outside said outer peripheral surface to said die cavity with their opposite ends open to said chamber outside said outer peripheral surface and to said die cavity respectively,

said die cavity having an elongated substantially cylindrical upper cavity portion, a substantially cylindrical lower cavity portion of smaller diameter than said upper cavity portion, and a tapered intermediate cavity portion connecting said upper and lower cavity portions and merging smoothly at its junctions with said upper and lower cavity portions,

and an elongated power-operated substantially cylindrical punch of substantially the same diameter as said upper cavity portion reciprocably movable into and out of closely-fitting but relatively-sliding telescoping relationship with said elongated cylindrical upper cavity portion.

* * * * *