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(54) **METHOD AND APPARATUS FOR CASTING OBJECTS MADE OF ALUMINUM, ALUMINUM ALLOYS, LIGHT ALLOYS, BRASS AND THE LIKE**

VERFAHREN UND VORRICHTUNG ZUM GIESSEN VON GEGENSTÄNDEN AUS ALUMINIUM, ALUMINIUMLEGIERUNGEN, LEICHTLEGIERUNGEN, MESSING UND DERGLEICHEN

PROCÉDÉ ET APPAREIL DE MOULAGE D'OBJETS EN ALUMINIUM, ALLIAGES D'ALUMINIUM, ALLIAGES LÉGERS, LAITON ET MATIÈRES ANALOGUES

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## Description

**[0001]** The present invention relates to a method and an apparatus for casting objects made of aluminum, aluminum alloys, light alloys, brass and the like.

**[0002]** As is known, in the casting of objects made of aluminum or aluminum alloys or brass, there are problems which are due to the possibility of making pieces that do not include porosity inside them and which make it possible to obtain high-performing mechanical characteristics and a considerable reduction of the process.

**[0003]** The patent application MI2003A002186 describes an apparatus that consists of a lower die and an upper die which delimit a region for containing a dosed quantity of liquid metal that comes from a duct which is connected to a furnace and originates from below.

**[0004]** In such patent application the upper die is provided with a flow control element which acts on the connecting opening to the liquid metal delivery duct, and a compactor punch which defines a portion of the upper impression of the die.

**[0005]** The die is then overfilled with the liquid metal, with the drawback, however, of not knowing exactly how much metal is necessary to complete the piece.

**[0006]** Furthermore, the dosing of the metal may not be correct since in the initial step the die is not fully filled, and instead the liquid metal is brought flush with the overflow line; the die is fully filled only after the connecting opening to the liquid metal delivery duct is closed, and the compactor punch has descended, making the liquid metal rise back up to complete the casting cavity.

**[0007]** The solution explained above, which has been found to be effective in many ways, is however susceptible of improvements, especially with regard to the method of filling of the die.

**[0008]** EP 3170582 discloses an apparatus for casting objects of aluminum and US 5562147 discloses a multistage casting plant and a method of forming castings.

**[0009]** The aim of the present invention, as defined in the appended claims, is to provide a method and an apparatus for casting objects made of aluminum, aluminum alloys, light alloys, brass and the like, in which the filling of the die is done without overflow and without specific dosing of the liquid metal.

**[0010]** Within this aim, an object of the present invention is to provide a method and an apparatus that make it possible to obtain cast pieces that are free from gas or air impurities and with precision shape, and with all types of aluminum alloys including plastic deformation alloys.

**[0011]** Another object of the present invention is to provide a method and an apparatus for casting objects made of aluminum, aluminum alloys, light alloys, brass and the like, which can be used even if a sand core or the like is inserted into the casting cavity.

**[0012]** Another object of the present invention is to provide a method and an apparatus that are highly reliable, easily and practically implemented and of low cost.

**[0013]** This aim and these and other objects which will become better apparent hereinafter are achieved by a method for casting objects made of aluminum, aluminum alloys, light alloys, brass and the like, as defined in the appended claims.

**[0014]** Further characteristics and advantages of the invention will become better apparent from the detailed description of a preferred, but not exclusive, embodiment of the method and of the apparatus according to the invention, which is illustrated by way of non-limiting example in the accompanying drawings, wherein:

Figure 1 is a cross-sectional view of the apparatus according to the invention in the configuration with the die open;

Figure 2 is a cross-sectional view of the apparatus in Figure 1 in the configuration with the die closed;

Figure 3 is a cross-sectional view of the apparatus in Figures 1 and 2 in the step of feeding liquid metal, indicating the system for creating the void in the casting cavity;

Figure 4 is a cross-sectional view of the apparatus in the previous figures, with the supply duct in the closed condition and the liquid metal supply hole depressurized;

Figure 5 is a cross-sectional view of the apparatus according to the invention in the step of forging the metal in the semisolid state in the casting cavity;

Figure 6 is a cross-sectional view of the apparatus according to the invention with the die open and the cast piece extracted;

Figure 7 shows the introduction of inert gas which has a specific weight that exceeds the weight of air in order to enable it to remain in the riser tube until the next cycle.

Figure 8 shows the control of temperatures on the shapes of the die, both with cooling using pressurized water and proportional valves and also with an electric heating system. In both cases, each region of the casting is controlled by a thermocouple and the temperatures of the die can vary from 250C° to 380C°.

Figure 9 shows the constant level of the metal in the chamber of the pressurized furnace and in the riser tube; the temperatures of the metal in the pressurized chamber will be approximately 70-150C° higher than the temperature of initial solidification of the alloy used.

**[0015]** With reference to the figures, the apparatus according to the invention, generally designated by the reference numeral 100, comprises a lower platen 1 and an upper platen 2.

**[0016]** A lower die 3 is arranged on the lower platen 1 and defines one or more lower impressions.

**[0017]** At the lower die 3 there is a duct 10 for introducing liquid metal 19, which is provided with an opening 11 which is connected with the pressed metal accumulation region and the casting cavity.

**[0018]** The liquid metal 19 originates from below with a low pressure exerted in a furnace 13 which is arranged in a position below the apparatus 100; such furnace contains the liquid metal 19 at a temperature approximately 70-150C° higher than the temperature of initial solidification of the alloy used. The metal then goes from the furnace 13 through the duct 10 and enters the casting cavity and an accumulation chamber 18 for forging metal.

**[0019]** The delivery duct 10 is typically provided with conventional heating means for maintaining the metal in the liquid phase, and in consideration of the fact that when the casting cavity and accumulation chamber 18 is filled the delivery duct 10, which has an upper opening 11, is closed mechanically by way of a flow control element 9, which is better described below. This makes it possible to make the diameter of the duct considerably larger than in systems used at low pressure, and in particular the diameter of the opening 11 can vary from 40 to 100mm.

**[0020]** An upper die 4 is provided at the upper platen 2 and can be coupled with the lower die 3 so as to define a cast piece 15, and is provided with one or more upper impressions that can engage in the corresponding lower impressions of the lower die 3.

**[0021]** There are one or more inserts 14 at the lower die 3 which are adapted to define the piece 15 to be provided. The inserts 14 are conveniently provided with electrical resistance heaters 20 for their heating, which are paired with thermocouples 21.

**[0022]** The inserts 14 are kept in position by a containment ring 17, which is integral with a die holder 5, in order to prevent their opening during the forging step.

**[0023]** The upper die 4, in its central portion, has a flow control element 9 which is controlled by a piston 7 which is concentric to a compactor punch 8 which in turn is controlled by a forging piston 6.

**[0024]** At least one impression of the casting cavity is connected to an accumulation chamber 21 for liquid metal 19 in the compactor punch 8.

**[0025]** The upper die 4 is supported by the die holder 5 which is connected to the upper platen 2 where the vacuum is applied.

**[0026]** The method for casting using the apparatus described above is as follows.

**[0027]** With reference to the figures, Figure 1 shows the condition of the apparatus with the die open and heated by the electrical resistance heaters 20, the temperature of which is controlled by the thermocouples 21, and cooled with pressurized water, through channel systems 22 and proportional valves 40 (see Figure 8), the temperature of which is controlled by thermocouples 23.

**[0028]** In this step the containment ring 17 is upward and the inserts 14 are open.

**[0029]** In the subsequent step, shown in Figure 2, the upper die 4 is brought to close against the lower die 3 and with the forging piston 6 upward at a preset height and the flow control element 9 flush with the forging piston 6.

**[0030]** In this step, the inserts 14 are closed and the containment ring 17 holds them clamped, being coupled with the inserts 14.

**[0031]** In this step, the liquid metal 19 has not yet been introduced into the casting cavity.

**[0032]** Figure 3 shows the third step of casting of the method according to the invention, in which the liquid metal 19 is injected, through the duct 10 and the opening 11, into the casting cavity defined by the lower die 3 and by the upper die 4 which were brought to close against each other in the previous step.

**[0033]** Filling the casting cavity with the liquid metal 19 occurs at low pressure, in order not to create turbulence and with the casting cavity containing no air because a vacuum has been created both in the casting cavity defined by the coupling of lower die 3 and upper die 4 and also in the liquid metal accumulation chamber.

**[0034]** During the filling of the casting cavity the compactor punch 8, as shown in Figure 3, is in an upper region at a programmed height and the chamber 18 containing liquid metal 19 for the forging is filled at low pressure together with the casting cavity.

**[0035]** The chamber 18 which contains liquid metal 20 is filled with an amount of metal equal to 6-10% of the weight of the piece to be cast.

**[0036]** During the step of filling with liquid metal 19, in the casting cavity and in the accumulation chamber 18 for liquid metal of the compactor punch 8, the pressure of the liquid metal varies for example from 300 mbar to 2,000 mbar while during the step of compaction/solidification the pressure in the casting cavity varies from 500 $kg/cm^2$ (490 bar) up to 1,500 $kg/cm^2$ (1470 bar).

**[0037]** When the compactor punch 8 is at a programmed height upward from the rim of the cavity of the upper die 4 as illustrated in Figure 1 and in

**[0038]** Figure 2, the flow control element 9 is in the maximum raised condition, i.e. at the maximum upward stroke, and is flush with the compactor punch 8.

**[0039]** In the step shown in Figure 4 therefore, the flow control element 9 moves to close the opening 11 of the duct 10, after which the pressure is immediately cut in the supply duct 10, as illustrated, under the die; the liquid metal 19 that is in the duct 10 goes back down to the position 12, while a dosed quantity of metal remains in the casting cavity and in the compaction chamber 18.

**[0040]** Conveniently, there is a liquid metal presence sensor for detecting the level of the metal inside the casting cavity and the chamber of the compactor punch 8.

**[0041]** The temperature of the die and the temperature of the metal are preset and the furnace is preset to a pressure level that varies as a function of the position of the liquid metal in the furnace and in the casting cavity.

**[0042]** Once the delivery duct 10 is closed, the descent of the compactor punch 8 is actuated by the piston 6 at a variable pressure, for example from 500 $kg/cm^2$ up to 1500 $kg/cm^2$ and at a speed programmable for example from 3 mm/sec a 15 mm/sec.

**[0043]** This operation in practice carries out a forging of the material which is still in the semi-solid state, trans-

ferring the liquid metal 19 accumulated in the chamber 18 of the compactor punch 8 to the casting cavity through the connection between the chamber 18 and the casting cavity.

**[0044]** This step is illustrated in Figure 5, which shows the descent of the compactor punch 8 which comes to directly press on the liquid metal 19 contained in the casting cavity.

**[0045]** When the piece 15 has been extracted and the apparatus is opened in the feeding duct 10, by way of a duct 16, an inert gas is introduced with a specific weight that exceeds that of air, such as for example argon, in order to eliminate or reduce the oxides that could form during the rise of the liquid metal.

**[0046]** Figure 8 shows the control of temperatures on the shapes of the die, both with cooling using pressurized water and proportional valves and also with an electric heating system. In both cases, each region of the casting is controlled by a thermocouple and the temperatures of the die can vary from 250C° to 380C°.

**[0047]** In particular, there is a tower (tank) 60 for containing water, at least one pump 61 for pumping the water (with a variable pressure configurable for example from 4 to 20 kg/ $cm^2$) to a manifold 62 from which, by means of the solenoid valves 40 and the thermocouples 23, the temperature of the various different areas of the die is controlled.

**[0048]** The apparatus further comprises a vacuum system 50 (see Figure 3) which makes it possible to aspirate the air contained in the casting cavity through air vents which are created on the die and which are closed by the liquid metal during the step of filling under low pressure. In this manner, during the forging step it is not necessary to install a valve for closing the vacuum duct.

**[0049]** In practice it has been found that the method and the apparatus according to the invention achieve the intended aim and objects, in that they make it possible to fill the die without overflowing and without needing to specifically adjust the dosage of the liquid metal.

**[0050]** Furthermore, the material necessary for compaction during solidification is accumulated in the compactor punch at a preset height.

**[0051]** The method and the apparatus according to the invention make it possible to produce pieces that are free from gas or air impurities and with precision in shape.

**[0052]** Furthermore, the pieces obtained have high-performing mechanical characteristics and solidify faster than similar pieces obtained with conventional methods and apparatuses; furthermore, they are obtained with all the aluminum alloys available on the market, including those used with the plastic deformation process i.e. with a low percentage of silicon or without silicon and more precisely the alloys of the series 2000, 6000, 7000.

**[0053]** The method and the apparatus, thus conceived, are susceptible of numerous modifications and variations, all of which are within the scope of the appended claims.

**[0054]** Moreover, all the details may be substituted by other, technically equivalent elements.

**[0055]** In practice the materials employed, and the contingent dimensions and shapes, may be any according to requirements and to the state of the art.

**[0056]** The disclosures in Italian Patent Application No. 102018000007754 from which this application claims priority.

## Claims

1. A method for casting objects made of aluminum, aluminum alloys, light alloys, brass and the like, by way of a casting apparatus (100) which comprises a lower platen (1) adapted to support a lower die (3) which is connected to a duct (10) for feeding liquid metal (20), an upper platen (2) at which an upper die (4) is arranged, a compactor punch (8) which is arranged so that it can move coaxially with respect to said upper die (4), and a flow control element (9) which is arranged concentrically inside said compactor punch (8), the method being **characterized in that** it comprises the steps of:

   - closing said upper die (4) onto said lower die (3) in order to define a casting cavity;
   - introducing liquid metal (19) through said duct (10) into said casting cavity;
   - placing the compactor punch (8) upward at a preset height with respect to the lower rim of the upper die (4);
   - accumulating a quantity of liquid metal (19) which is equal to 6-10% of the weight of the piece to be cast in a chamber (18) for accumulating liquid metal for forging;
   - closing the duct (10) for supplying liquid metal (19) by moving said flow control element (9) downward and depressurizing the liquid metal supply duct (10), thus causing the return of said liquid metal (19) into said duct (10);
   - forging said liquid metal inside said casting cavity by moving said compactor punch (8) downward, the temperature of said die varies from 250 to 380°C, with control provided by way of electrical resistance heaters (20) with thermocouples (21) and a cooling system (22, 23).

2. The method according to claim 1, **characterized in that** in the step in which said die is open, said compactor punch (8) is flush with said upper die (4).

3. The method according to claim 1 or 2, **characterized in that** said forging step is performed with said compactor punch (8) acting directly on said liquid metal (20) contained in said casting cavity.

4. The method according to one or more of the preceding claims, **characterized in that** said liquid metal

(19) is fed at low pressure into said supply duct (10).

**5.** The method according to one or more of the preceding claims, **characterized in that** said liquid metal (19) is arranged in a supply furnace (13) at low pressure, which is arranged in a position below said apparatus, the temperature of the metal in said furnace (13) being 70-150°C higher than the temperature at which solidification of the metal begins.

**6.** The method according to one or more of the preceding claims, **characterized in that** the forging pressure on said compactor punch (8) varies from 500 kg/cm$^2$ (490 bar) to 1500 kg/cm$^2$ (1470 bar).

**7.** The method according to one or more of the preceding claims, **characterized in that** it comprises, when said apparatus is open and the cast piece (15) has been extracted, a step of introducing a neutral gas into said supply duct (10), in order to eliminate the formation of oxides.

**8.** The method according to one or more of the preceding claims, **characterized in that** inserts (14) are provided which are adapted to define the piece to be cast, said inserts being adapted to be moved from an open position, when said die is in the open condition, to a closed position, when said die is in the closed condition, a containment ring (17) being provided in order to keep said inserts in the closed condition.

**9.** An apparatus (100) for casting objects made of aluminum, aluminum alloys, light alloys, brass and the like, which comprises a lower platen (1) adapted to support a lower die (3) into which a duct (10) for feeding liquid metal (19) leads, an upper platen (2) at which an upper die (4) is defined which is supported by a die holder (5), and a compactor punch (8) which is arranged coaxially to said upper die (4), said compaction punch having, internally and concentrically thereto, a flow control element (9) which is adapted to open and close an opening (11) of said duct (10) for supplying liquid metal (19), **characterized in that** said compactor punch (8) can move from a position in which said compactor punch (8) is flush with said upper die (4) to a position in which said compactor punch (8) is moved upward with respect to said upper die (4), in order to define a chamber (18) for accumulating liquid metal for forging, and **in that** electrical resistance heaters (20) with thermocouples (21) and a cooling system (22, 23) are provided in order to control the temperature of said die.

**10.** The apparatus according to claim 9, **characterized in that** said compactor punch (8) is moved by a piston (6) and said flow control element (9) is also moved by a corresponding piston (7).

**11.** The apparatus according to one or more of claims 9 to 10, **characterized in that** said lower die (3) defines at least one impression and said upper die (4) likewise defines at least one impression.

**Patentansprüche**

**1.** Verfahren zum Gießen von Objekten, die aus Aluminium, Aluminiumlegierungen, Leichtlegierungen, Messing und dergleichen bestehen, mittels einer Gießvorrichtung (100), die eine untere Platte (1) aufweist, die dazu ausgelegt ist, eine untere Gussform (3) zu stützen, die mit einem Kanal (10) zum Zuführen von flüssigem Metall (20) verbunden ist, eine obere Platte (2), an der eine obere Gussform (4) angeordnet ist, einen Verdichterstempel (8), der so angeordnet ist, dass er sich bezüglich der oberen Gussform (4) koaxial bewegen kann, und ein Fließsteuerelement (9), das konzentrisch im Inneren des Verdichterstempels (8) angeordnet ist, wobei das Verfahren **dadurch gekennzeichnet ist, dass** es die folgenden Schritte aufweist:

- Schließen der oberen Gussform (4) auf der unteren Gussform (3), um einen Gießhohlraum zu definieren;
- Einführen von flüssigem Metall (19) durch den Kanal (10) in den Gießhohlraum;
- Platzieren des Verdichterstempels (8) oben an einer vorgegebenen Höhe bezüglich des unteren Rands der oberen Gussform (4);
- Ansammeln einer Menge von flüssigem Metall (19), die gleich 6-10% des Gewichts des zu gießenden Teils ist, in einer Kammer (18) zum Ansammeln von flüssigem Metall zum Schmieden;
- Schließen des Kanals (10) zum Zuführen flüssigen Metalls (19) durch Bewegen des Fließsteuerelements (9) nach unten und Entfernen des Drucks von dem Zuführkanal (10) für flüssiges Metall, wodurch das Rückführen des flüssigen Metalls (19) in den Kanal (10) veranlasst wird;
- Schmieden des flüssigen Metalls im Inneren des Gießhohlraums durch Bewegen des Verdichterstempels (8) nach unten, wobei die Temperatur der Gussform von 250 bis 380°C variiert, wobei Steuerung mittels elektrischer Widerstandsheizvorrichtungen (20) mit Thermoelementen (21) und einem Kühlsystem (22, 23) bereitgestellt wird.

**2.** Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** in dem Schritt, in dem die Gussform offen ist, der Verdichterstempel (8) mit der oberen Gussform (4) bündig ist.

**3.** Verfahren nach Anspruch 1 oder 2, **dadurch ge-**

**kennzeichnet, dass** der Schmiedeschritt durchgeführt wird, wobei der Verdichterstempel (8) direkt auf das flüssige Metall (20), das in dem Gießhohlraum enthalten ist, einwirkt.

**4.** Verfahren nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das flüssige Metall (19) mit niedrigem Druck in den Zuführkanal (10) zugeführt wird.

**5.** Verfahren nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das flüssige Metall (19) in einem Zuführofen (13) mit niedrigem Druck angeordnet wird, der in einer Position unterhalb der Vorrichtung angeordnet ist, wobei die Temperatur des Metalls in dem Ofen (13) um 70-150°C höher als die Temperatur ist, bei der die Verfestigung des Metalls beginnt.

**6.** Verfahren nach einem oder mehreFormular_Europaeische_Uebersetzung_V1_1ren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Schmiededruck auf den Verdichterstempel (8) von 500 kg/cm$^2$ (490 bar) bis 1500 kg/cm$^2$ (1470 bar) variiert.

**7.** Verfahren nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** es, wenn die Vorrichtung offen ist und das Gussteil (15) extrahiert worden ist, einen Schritt des Einführens eines neutralen Gases in den Zuführkanal (10) aufweist, um die Bildung von Oxiden zu eliminieren.

**8.** Verfahren nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** Einsätze (14) bereitgestellt werden, die dazu ausgelegt sind, das zu gießende Teil zu definieren, wobei die Einsätze dazu ausgelegt sind, von einer offenen Position, wenn sich die Gussform im offenen Zustand befindet, in eine geschlossene Position, wenn sich die Gussform im geschlossenen Zustand befindet, bewegt zu werden, wobei ein Einschlussring (17) bereitgestellt wird, um die Einsätze im geschlossenen Zustand zu halten.

**9.** Vorrichtung (100) zum Gießen von Objekten, die aus Aluminium, Aluminiumlegierungen, Leichtlegierungen, Messing und dergleichen bestehen, die eine untere Platte (1) aufweist, die dazu ausgelegt ist, eine untere Gussform (3) zu stützen, in die ein Kanal (10) zum Zuführen von flüssigem Metall (19) führt, eine obere Platte (2), an der eine obere Gussform (4) definiert ist, die von einem Gussformhalter (5) gestützt wird, und einen Verdichterstempel (8), der koaxial zu der oberen Gussform (4) angeordnet ist, wobei der Verdichterstempel innen und konzentrisch dazu ein Fließsteuerelement (9) hat, das dazu ausgelegt ist, eine Öffnung (11) des Kanals (10) zum Zuführen von flüssigem Metall (19) zu öffnen und zu schließen, **dadurch gekennzeichnet, dass** sich der Verdichterstempel (8) von einer Position, in der der Verdichterstempel (8) mit der oberen Gussform (4) bündig ist, in eine Position, in der der Verdichterstempel (8) bezüglich der oberen Gussform (4) nach oben bewegt ist, bewegen kann, um eine Kammer (18) zum Ansammeln von flüssigem Metall zum Schmieden zu definieren, und dass elektrische Widerstandsheizvorrichtungen (20) mit Thermoelementen (21) und einem Kühlsystem (22, 23) bereitgestellt sind, um die Temperatur der Gussform zu steuern.

**10.** Vorrichtung nach Anspruch 9, **dadurch gekennzeichnet, dass** der Verdichterstempel (8) von einem Kolben (6) bewegt wird und das Fließsteuerelement (9) ebenfalls von einem korrespondierenden Kolben (7) bewegt wird.

**11.** Vorrichtung nach einem der Ansprüche 9 bis 10, **dadurch gekennzeichnet, dass** die untere Gussform (3) wenigstens eine Prägung definiert und die obere Gussform (4) ebenfalls wenigstens eine Prägung definiert.

**Revendications**

**1.** Procédé pour couler des objets en aluminium, alliages d'aluminium, alliages légers, laiton et analogue, au moyen d'un appareil de coulée (100) qui comporte un plateau inférieur (1) adapté pour supporter une matrice inférieure (3) qui est reliée à un chenal (10) pour transférer du métal liquide (20), un plateau supérieur (2) sur lequel une matrice supérieure (4) est agencée, un poinçon compacteur (8) qui est agencé de sorte qu'il peut se déplacer coaxialement par rapport à ladite matrice supérieure (4), et un élément de commande d'écoulement (9) qui est agencé de manière concentrique à l'intérieur dudit poinçon compacteur (8), le procédé étant **caractérisé en ce qu'**il comporte les étapes consistant à :

- fermer ladite matrice supérieure (4) sur ladite matrice inférieure (3) afin de définir une cavité de coulée,
- introduire du métal liquide (19) par ledit chenal (10) dans ladite cavité de coulée,
- placer le poinçon compacteur (8) vers le haut à une hauteur préréglée par rapport au rebord inférieur de la matrice supérieure (4),
- accumuler une quantité de métal liquide (19) qui est égale à 6 à 10 % du poids de la pièce à couler dans une chambre (18) pour accumuler le métal liquide en vue d'un forgeage,
- fermer le chenal (10) pour fournir du métal li-

quide (19) en déplaçant ledit élément de commande d'écoulement (9) vers le bas et supprimer la pression dans le chenal d'alimentation en métal métallique (10), en entraînant ainsi le retour dudit métal liquide (19) dans ledit chenal (10),
- forger ledit métal liquide à l'intérieur de ladite cavité de coulée en déplaçant ledit poinçon compacteur (8) vers le bas, la température de ladite matrice varie de 250 à 380 °C, avec une commande assurée au moyen de résistances électriques chauffantes (20) avec des thermocouples (21) et un système de refroidissement (22, 23).

**2.** Procédé selon la revendication 1, **caractérisé en ce qu'**à l'étape pendant laquelle ladite matrice est ouverte, ledit poinçon compacteur (8) est affleurant à ladite matrice supérieure (4).

**3.** Procédé selon la revendication 1 ou 2, **caractérisé en ce que ladite étape de forgeage est** réalisée avec ledit poinçon compacteur (8) agissant directement sur ledit métal liquide (20) contenu dans ladite cavité de coulée.

**4.** Procédé selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit métal liquide (19) est transféré à basse pression dans ledit chenal d'alimentation (10).

**5.** Procédé selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** ledit métal liquide (19) est agencé dans un four d'alimentation (19) à basse pression, qui est agencé dans une position au-dessous dudit appareil, la température du métal dans ledit four (13) étant de 70 à 150 °C plus élevée que la température à laquelle la solidification du métal débute.

**6.** Procédé selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** la pression de forgeage sur ledit poinçon compacteur (8) varie de 500 kg/cm$^2$ (490 bar) à 1 500 kg/cm$^2$ (1470 bar) .

**7.** Procédé selon une ou plusieurs des revendications précédentes, **caractérisé en ce qu'**il comporte, lorsque ledit appareil est ouvert et que la pièce coulée (15) a été extraite, une étape consistant à introduire un gaz neutre dans ledit chenal d'alimentation (10), afin d'éliminer la formation d'oxydes.

**8.** Procédé selon une ou plusieurs des revendications précédentes, **caractérisé en ce que** des inserts (14) sont prévus qui sont adaptés pour définir la pièce à couler, lesdits inserts étant adaptés pour être déplacés d'une position ouverte, lorsque ladite matrice est à l'état ouvert, à une position fermée, lorsque ladite matrice est à l'état fermé, un anneau de confinement (17) étant prévu afin de maintenir lesdits inserts à l'état fermé.

**9.** Appareil (100) pour couler des objets en aluminium, alliages d'aluminium, alliages légers, laiton et analogue, qui comporte un plateau inférieur (1) adapté pour supporter une matrice inférieure (3) dans laquelle débouche un chenal (10) pour transférer du métal liquide (19), un plateau supérieur (2) sur lequel une matrice supérieure (4) est définie qui est supportée par un porte-matrice (5), et un poinçon compacteur (8) qui est agencé coaxialement à ladite matrice supérieure (4), ledit poinçon compacteur ayant, de manière interne et concentrique à celui-ci, un élément de commande d'écoulement (9) qui est adapté pour ouvrir et fermer une ouverture (11) dudit chenal (10) pour fournir du métal liquide (19), **caractérisé en ce que** ledit poinçon compacteur (8) peut se déplacer depuis une position dans laquelle ledit poinçon compacteur (8) est affleurant à ladite matrice supérieure (4) jusqu'à une position dans laquelle ledit poinçon compacteur (8) est déplacé vers le haut par rapport à ladite matrice supérieure (4), afin de définir une chambre (18) pour accumuler du métal liquide en vue d'un forgeage, et **en ce que** des résistances électriques chauffantes (20) avec des thermocouples (21) et un système de refroidissement (22, 23) sont prévus afin de commander la température de ladite matrice.

**10.** Appareil selon la revendication 9, **caractérisé en ce que** ledit poinçon compacteur (8) est déplacé par un piston (6) et ledit élément de commande d'écoulement (9) est également déplacé par un piston (7) correspondant.

**11.** Appareil selon une ou plusieurs des revendications 9 à 10, **caractérisé en ce que** ladite matrice inférieure (3) définit au moins une empreinte et ladite matrice supérieure (4) définit de façon analogue au moins une empreinte.

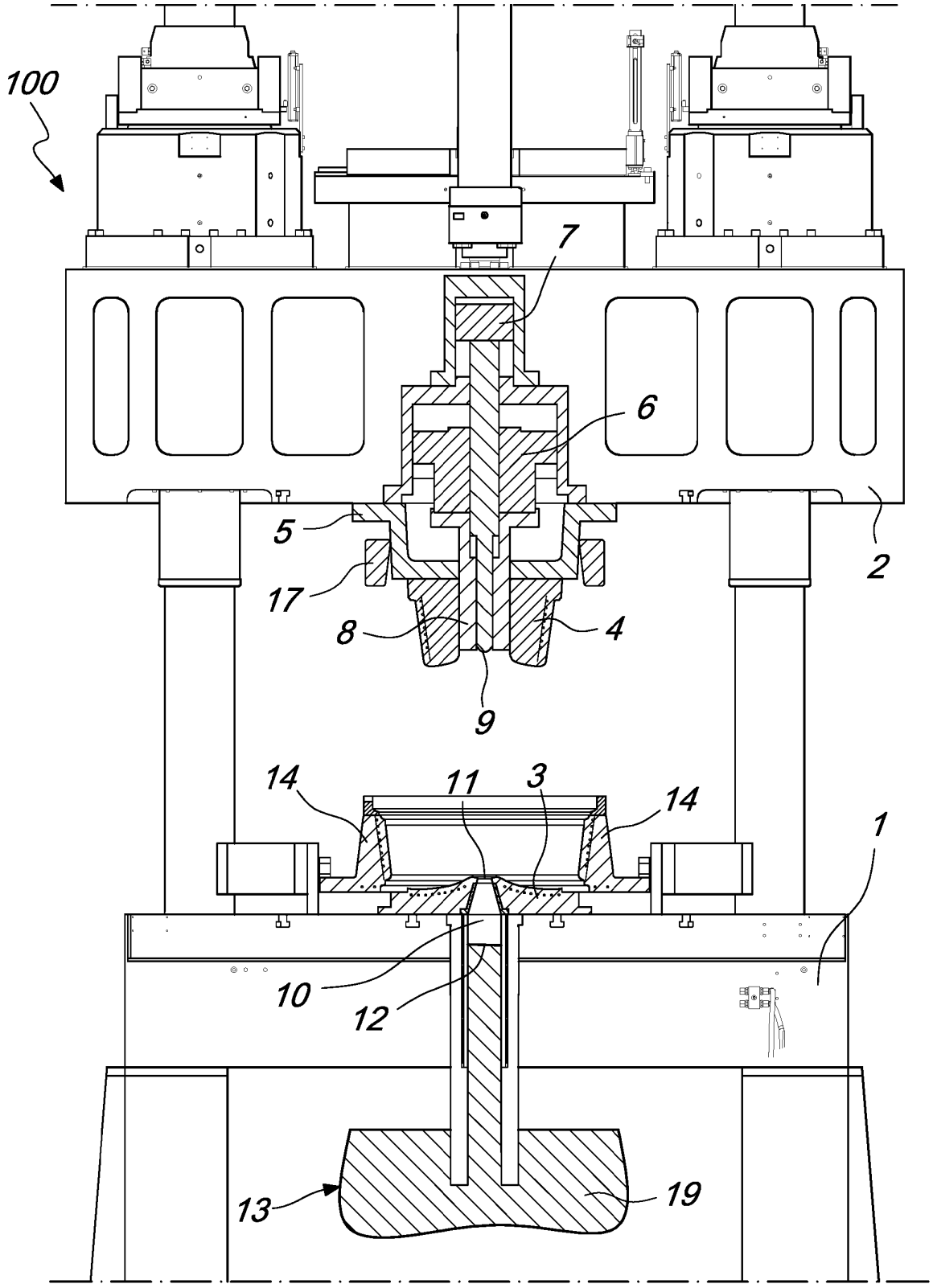


Fig. 1

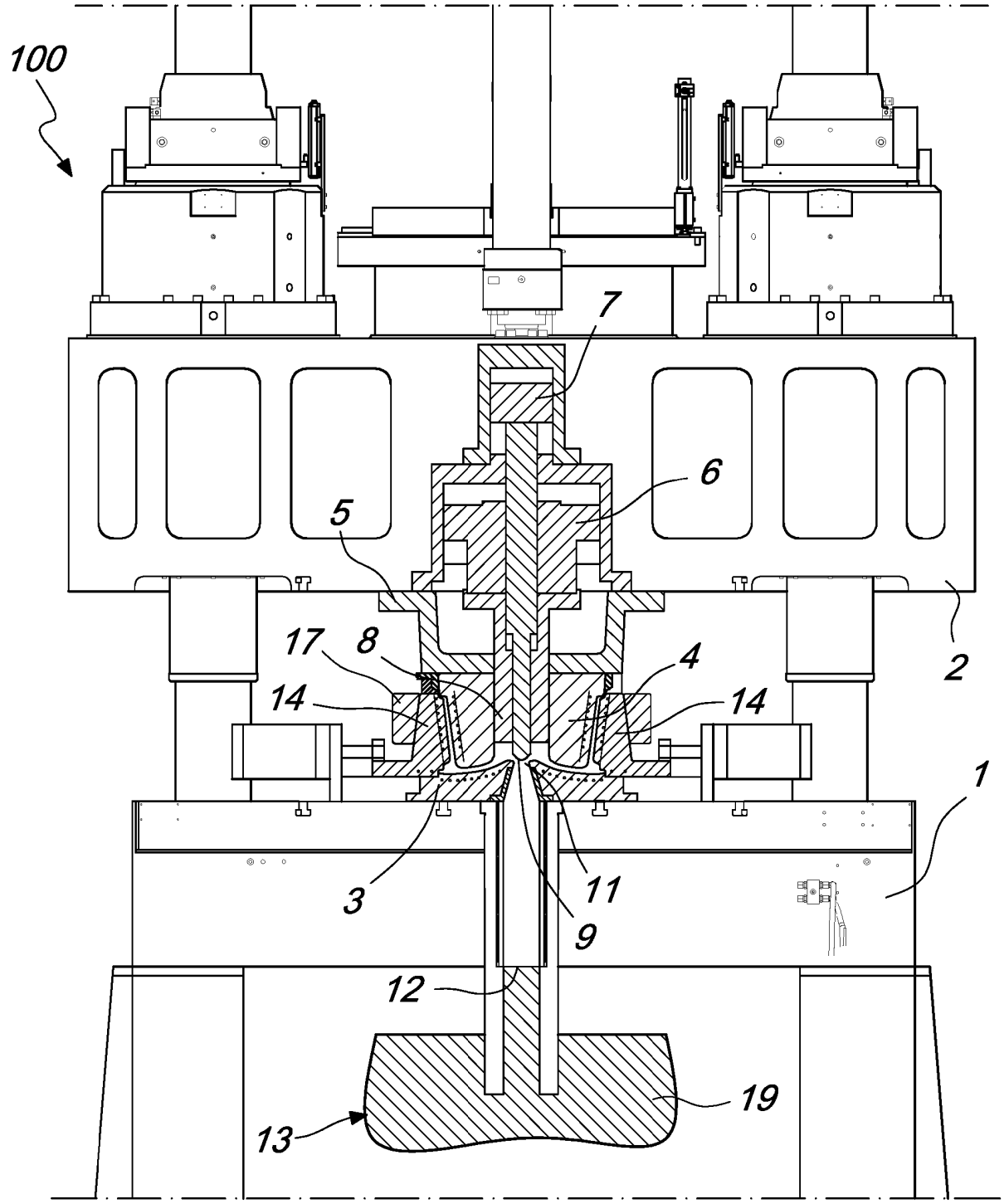


Fig. 2

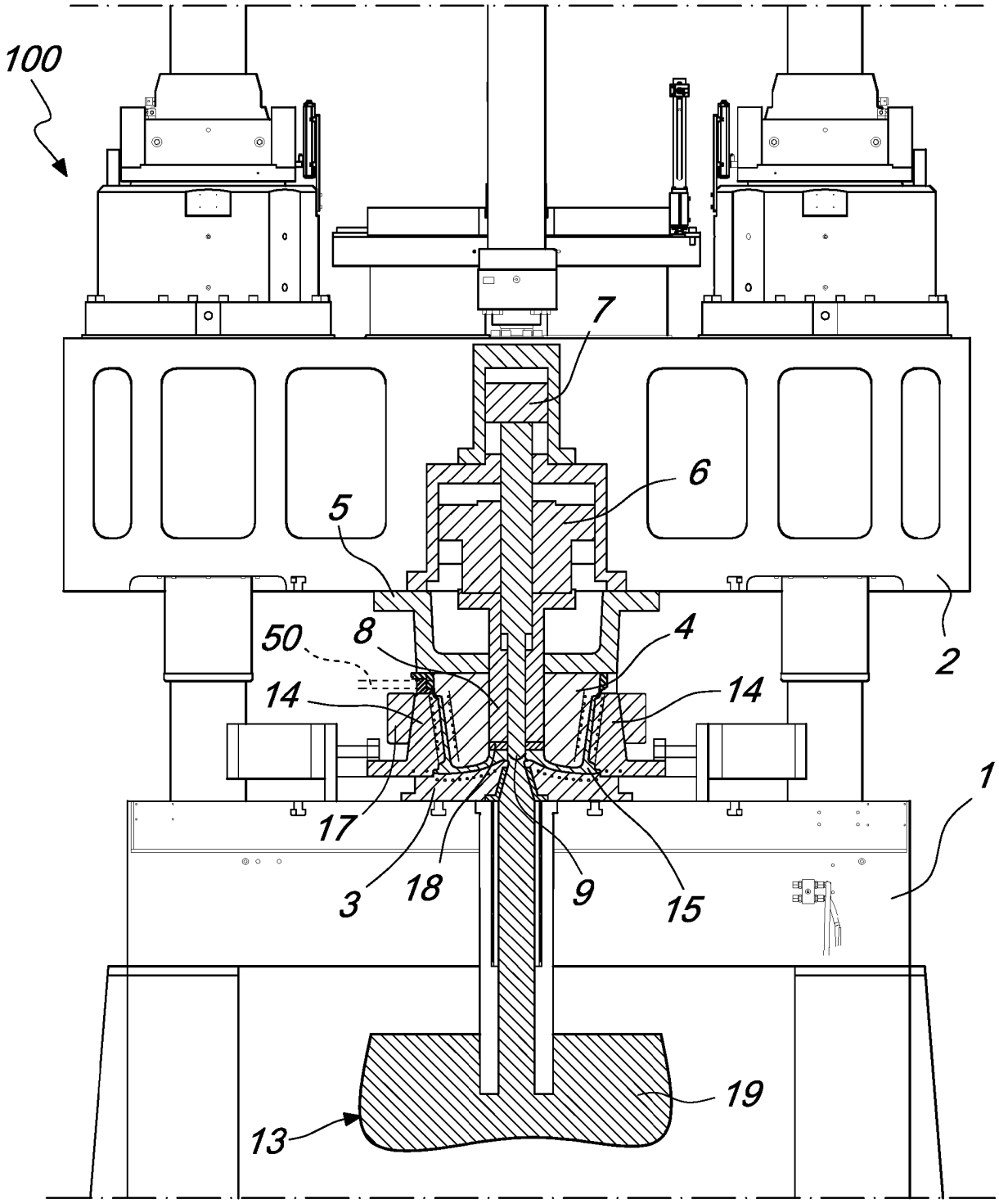


Fig. 3

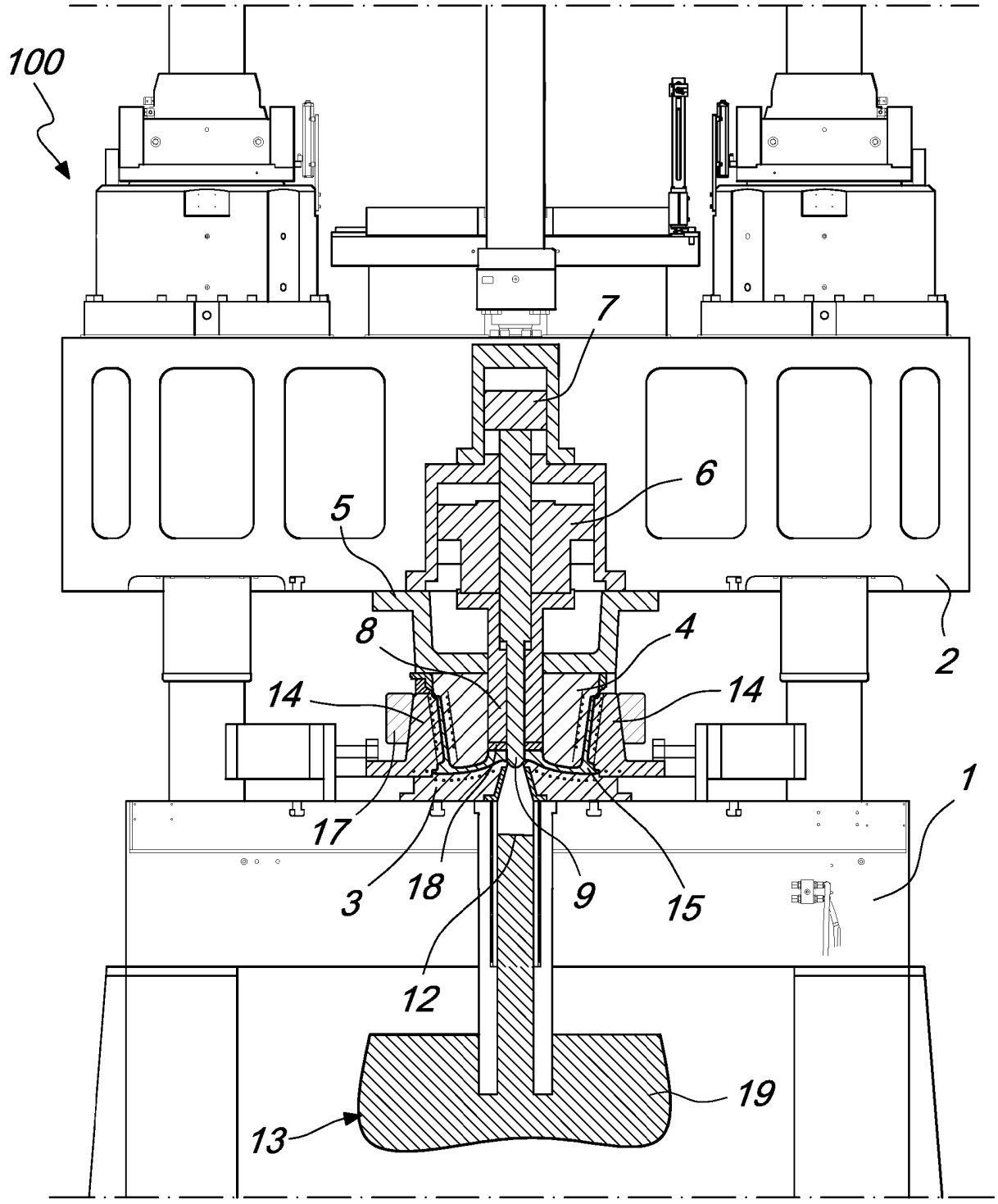


Fig. 4

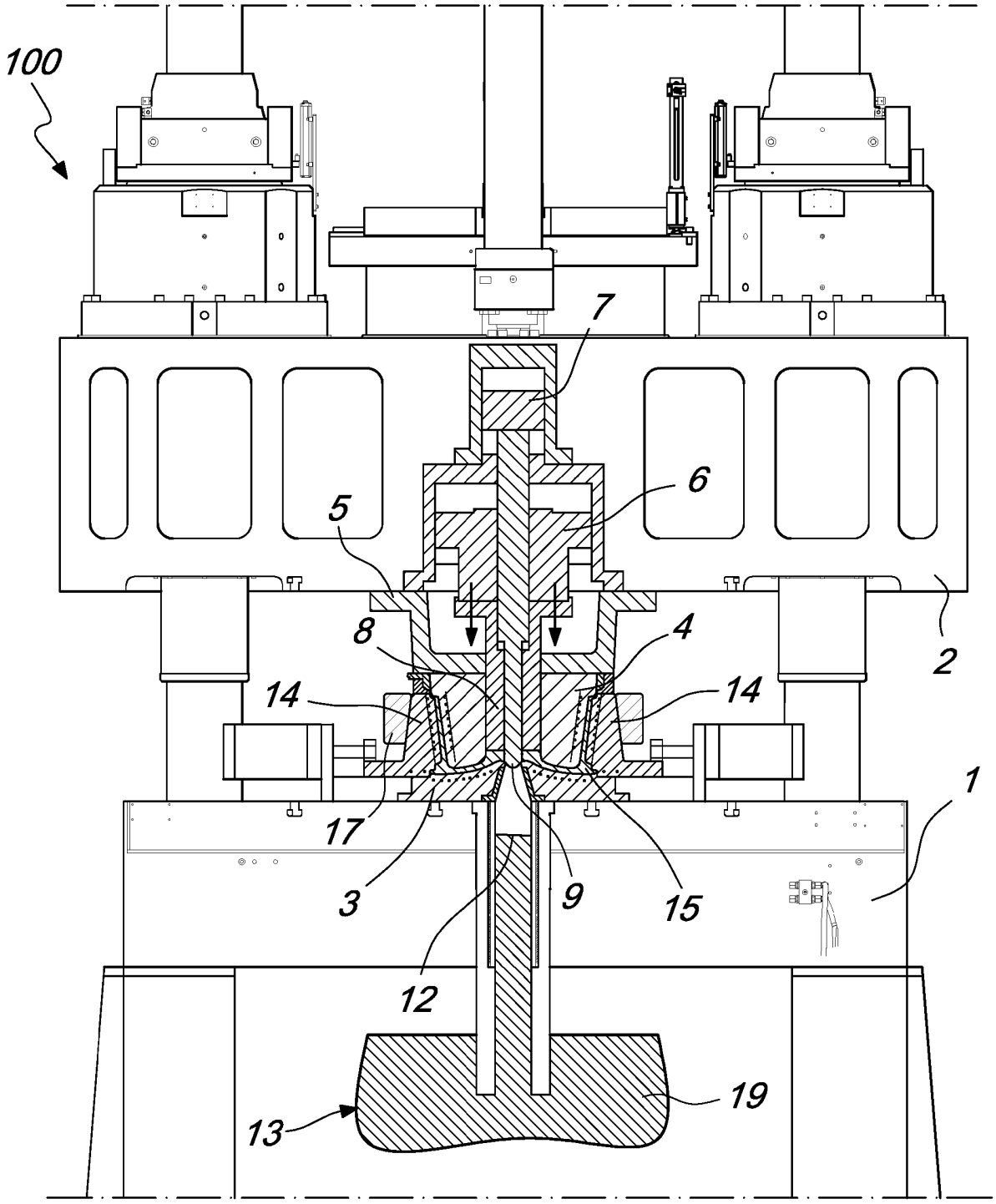


Fig. 5

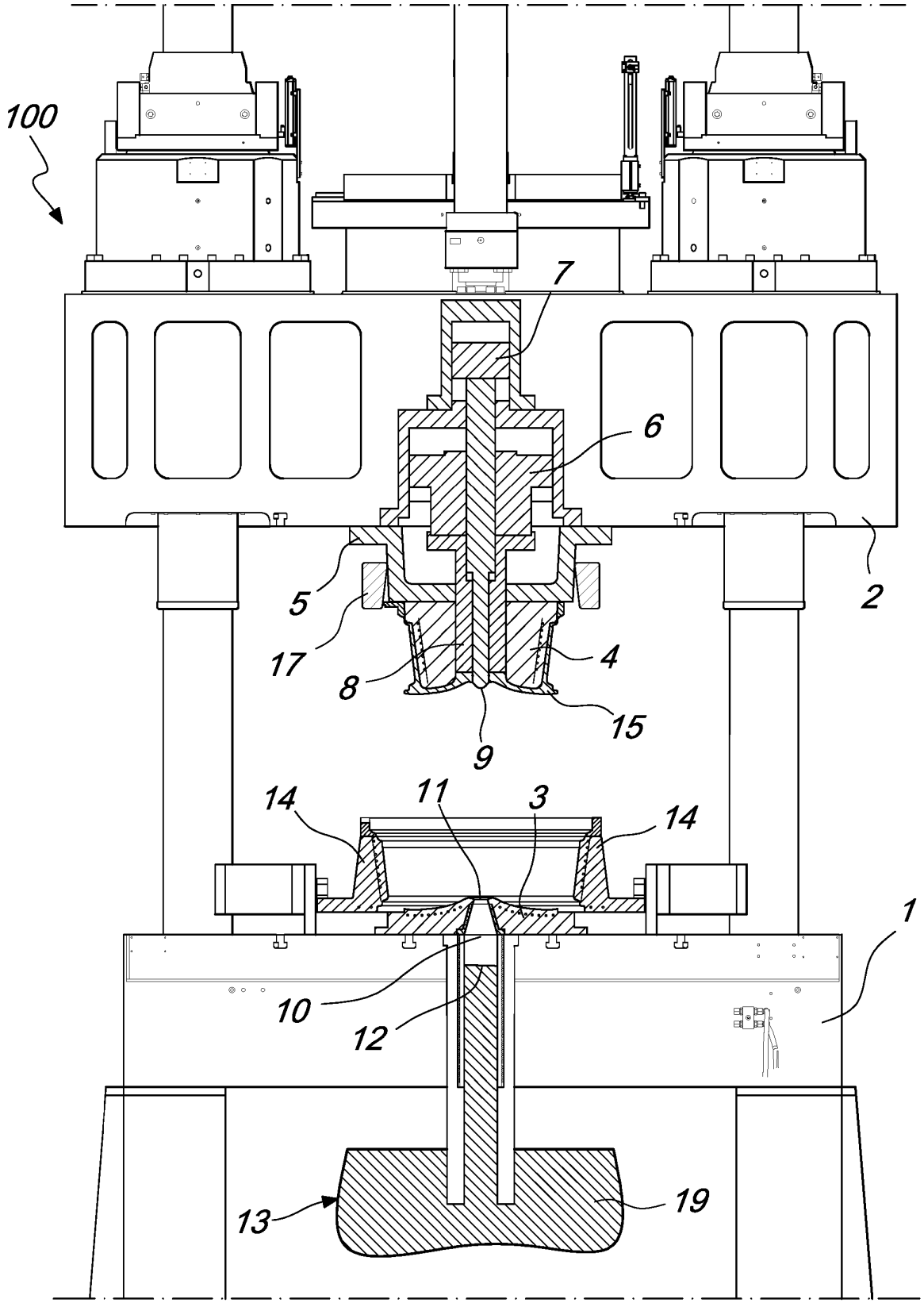


Fig. 6

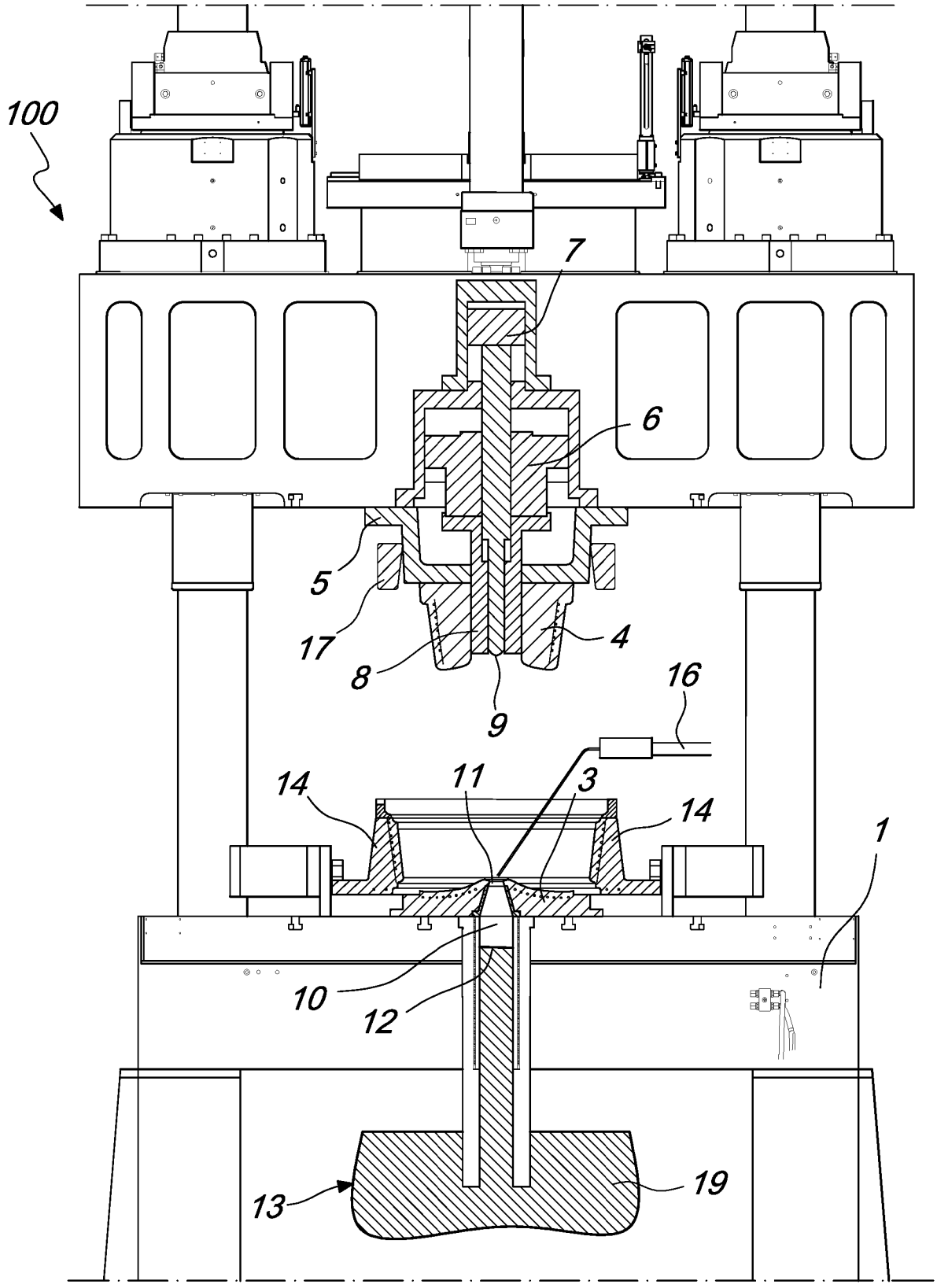


Fig. 7

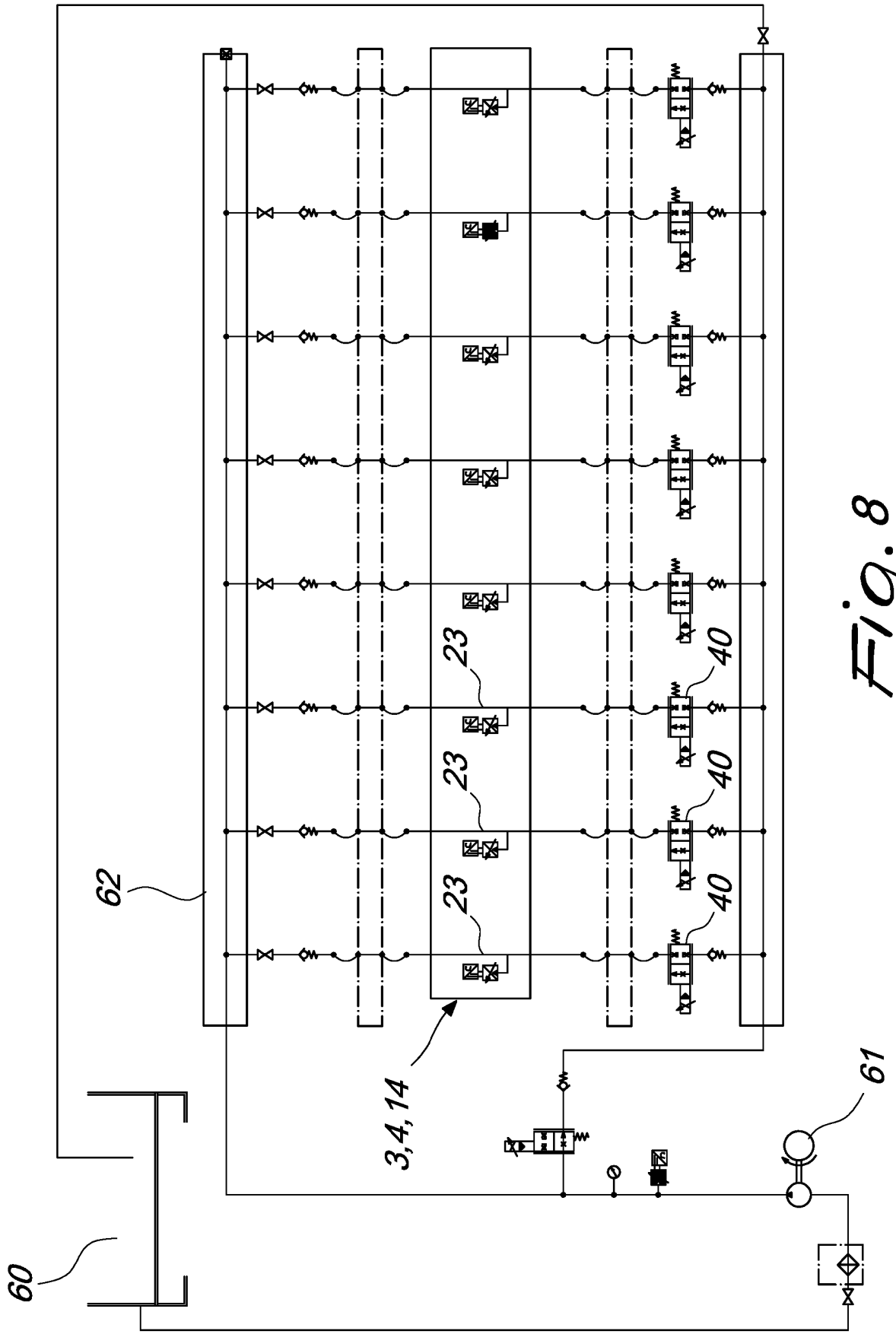


Fig. 8

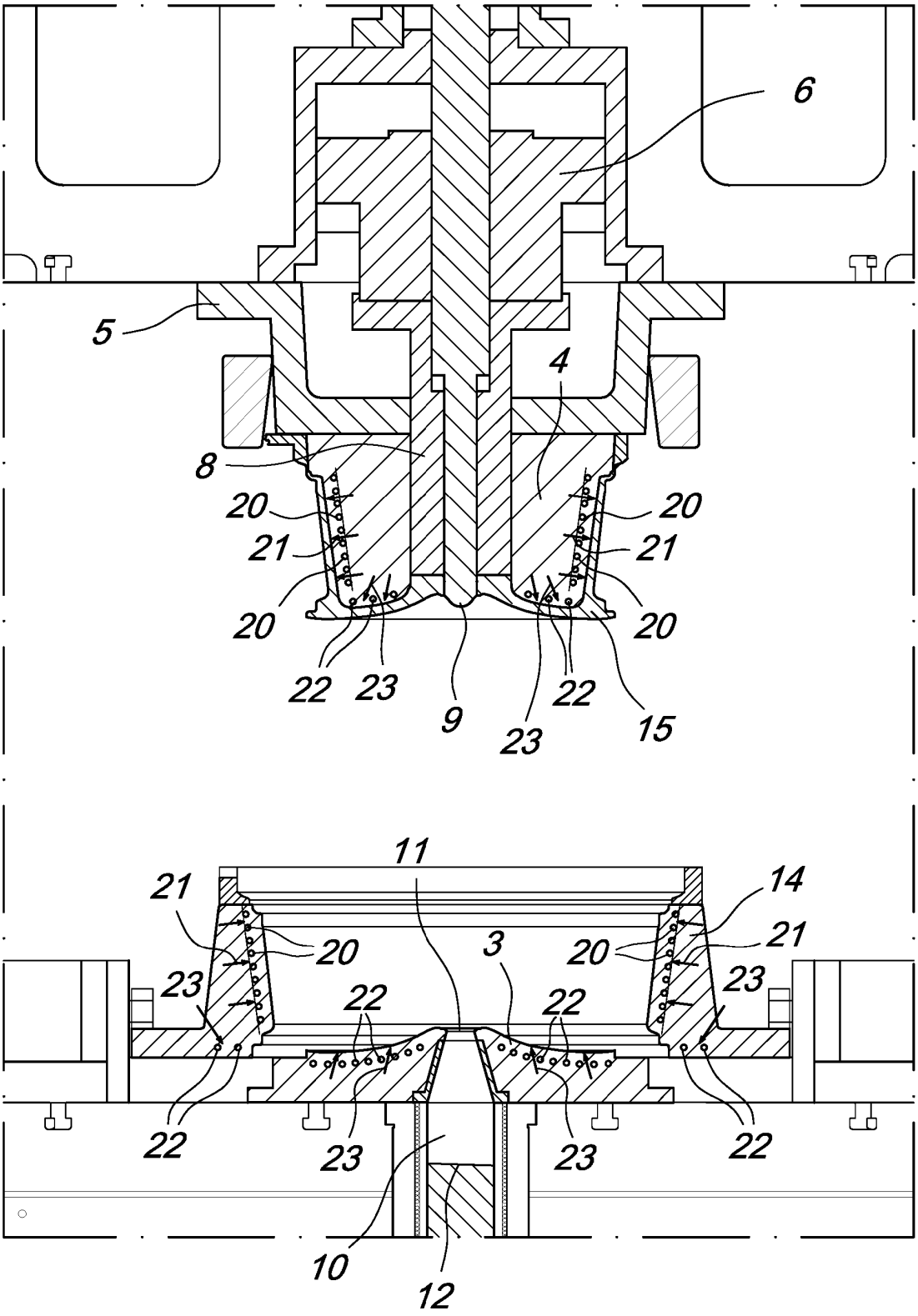
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Fig. 9

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


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