



(51) International Patent Classification:

B22D 11/049 (2006.01) B22D 11/07 (2006.01)  
B22D 11/055 (2006.01)

(21) International Application Number:

PCT/IB2023/053832

(22) International Filing Date:

14 April 2023 (14.04.2023)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

22168449.1 14 April 2022 (14.04.2022) EP

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(81) Designated States (unless otherwise indicated, for every kind of national protection available):

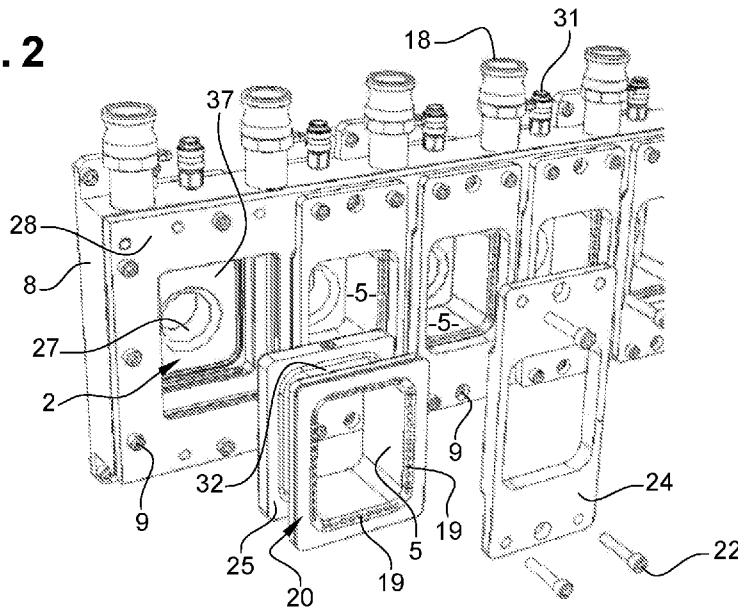
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(84) Designated States (unless otherwise indicated, for every kind of regional protection available):

ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: MOLD FOR CONTINUOUS CASTING OF METAL STRANDS

Fig. 2



(57) Abstract: Mold (1) for semi-continuous casting of metal strands from liquid metal, comprising a mold body (8) provided with at least one mold cavity (2), said mold cavity comprising: - a liquid metal inlet (3) defined by a nozzle plate (25), - an insert (20), said insert (3) defining a perimeter wall (5) intended to be in contact with the metal leaving said liquid metal inlet (3), - a mold outlet (4), - a plurality of spray nozzles (19) for spraying cooling fluid onto said metal strand, said spray nozzles being preferably provided in said insert (20), characterized in that said mold body (8) is provided with a channel (39) for cooling fluid, and in that said insert (20) is removable and is made from a metallic material. This mold is useful for casting aluminium strands.



**Published:**

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

## Mold for continuous casting of metal strands

### Technical field of the invention

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The invention relates to the field of casthouse technology, and more precisely to machines for casting metal strands by direct chill (DC) casting. DC casting is a continuous (or more precisely, semi-continuous) casting process, and is of widespread use, in particular for casting certain non-ferrous metals and alloys. In particular the present invention relates to a novel mold for semi-continuous casting machines for casting strands or ingots in non-ferrous metals and alloys that are neither precious metals nor refractory metals, and in particular in aluminium and aluminium alloys.

The invention also relates to a method of casting a metal strand or ingot using such a mold, and to metal strands obtained by this method. The invention also relates to a method for maintaining or repairing said mould.

### Prior art

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Casting machines for transforming molten metal into a solid, elongated body of metal are known for a long time. Open ended, cooled moulds with an inner perimeter wall are used for a so-called continuous (or rather semi-continuous) casting process. At the beginning of this casting process, liquid metal is poured through said open ended mold, which is closed by a starting block, also called bottom block. As the metal is solidifying in the neighborhood of the inner perimeter wall of the mould, the bottom plate advances into the casting direction, which may be vertical (and in this case downwards) or horizontal, while the emerging metal strand is cooled. Cooling of the emerging metal strand is usually achieved by water that is sprayed over the metal strand as it emerges from the mould outlet; for this reason, this process is also called « chill casting ». When emerging from the mold outlet, the metal strand may still be liquid or semi-solid in its centre and will completely solidify in a few seconds under the effect of water-chilling as it moves away from the mould outlet. Such a process and related equipment are described in many patent documents, such as US 2002/0148593 A1 and EP 4 035 786 A1 (Rusal)

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This process allows to produce metal strands with a substantially constant cross section; their length is limited by the dimensions of the equipment (namely the depth of the casting

pit, in the case of vertical casting, or the length of the structure supporting the horizontally emerging metal strand), by the available quantity of liquid metal, and by the overall stability of the casting process. For increased productivity, multiple strands can be cast in one run from liquid metal: to this end, a plurality of molds is provided in a so-called casting table. For billet casting, casting tables with several dozens of molds are used, depending on the diameter of the billets.

Molds for continuous casting are usually complex tools made from chemically resistant materials with good thermal conductivity; they comprise a perimeter wall that is in contact with the liquid and solidifying metal, as well as cooling means. Cooling of the metal is usually achieved by water that is sprayed over the metal strand as it emerges from the outlet of mold.

Perimeter walls have a contact surface that experiences friction with the outer surface of the solidifying metal strand; they need to be lubricated in order to minimize wear and tear. When the surface state of a perimeter wall is terminally degraded such that the mold does no longer allow to cast billets with the required surface quality, the mold can be disabled in the casting table; this allows to continue the use of the casting table, but with decreased productivity.

Perimeter walls can be made from various materials. They can be made from metallic materials such as steel and will then need to be lubricated. They can also be made from graphite, which is a chemically inert, auto-lubricating material resisting to fairly high temperatures. Additional lubrication by appropriate lubricants can be provided, as graphite is porous and will let pass a certain amount of lubricant or gas, depending on the applied pressure, on the temperature, and on the effective contact surface. Such graphite perimeter walls can be made as inserts (sleeves) which can be replaced if necessary.

Certain prior art continuous billet casting systems for liquid aluminium are provided with a permeable or porous graphite perimeter wall through which lubricant and gas are distributed to the inside surface of the mold. This has been described in US 4,598,763 (Wagstaff). WO 95/23044 (Wagstaff) discloses various embodiments of molds for casting rolling ingots; these molds have graphite rings provided with channels for cooling liquid sprayed onto the outer surface of the emerging metal strand. Conduits for delivery of oil or gas may be circumferential groove-shaped conduits, and/or they may be holes partially drilled through the perimeter wall. US 2007/0163746 describes an improved

perimeter wall lubrication system for molten aluminium molds using for billet casting, achieving a more even flow of lubricant through the peripheral wall. Permeable cavity rings, separated from each other by a gasket or sealing material, are described in WO 01/00353 (Norsk Hydro).

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One objective of the present invention is to provide a mold for ingot casting that has improved lifetime, and that can be cleaned, repaired or renovated easily.

Another objective of the present invention is to provide a casting table and mold for multiple strand ingot casting that have improved lifetime.

Another objective of the invention is to improve the overall process stability of multiple strand ingot casting, while increasing casting speed (expressed, for a given cross section, in length of the metal strand per time unit), and in particular to improve the stability of the lubrication at the interface between the mold and the emerging metal surface.

Yet another objective of the invention is to improve the process control of multiple strand ingot casting.

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Yet another objective of the invention is to decrease the quantity of lubricant used in multiple strand ingot casting, while ensuring sufficient and stable lubrication at the interface between the mold and the emerging metal surface.

## 25 **Objects of the invention**

According to the invention, these problems are solved by several means that cooperate with each other.

30 One essential feature of the invention is cooling of the mold body. According to prior art, during continuous casting a cooling fluid, usually water, is sprayed on the emerging strand of solidifying metal. As a result of the mold design according to the invention, there are at least two independent means of cooling.

35 Primary cooling is achieved through the mold body which is cooled from its inside during the casting operation. More precisely, the mold body is cooled by a cooling liquid

circulating in cooling channels arranged in the wall of the mold; this allows efficient cooling of the peripheral wall of the mold which is in contact with the solidifying metal.

Secondary cooling is achieved by a water spray: The surface of the emerging metal strand is cooled by cooling fluid sprayed in an annular zone all over the surface of the  
5 strand.

In addition to these primary and secondary cooling means, the surface of the peripheral wall of the mold which is in contact with the solidifying metal is lubricated by an appropriate lubricant, such as oil or a mixture of oil and water. The use of a lubricant  
10 improves the surface quality of the emerging metal strand throughout the continuous casting process which proceeds under dynamic and steady state conditions.

Another essential feature of the invention is the use of a removable insert defining the perimeter wall which will be in contact with the solidifying metal. This allows efficient  
15 inspection, maintenance and repair of the mold, without disabling defective mold cavities in the case of multiple-strand molds. This insert may be a copper insert, but is advantageously made from aluminium or aluminium alloy. Surprisingly, the contact between the solidifying and moving aluminium skin of the metal strand being cast and the solid aluminium insert allows to obtain an excellent surface quality, especially if a  
20 lubricant is used.

The present invention is particularly useful for horizontal casting.

A first object of the invention is a mold for semi-continuous casting of metal strands from  
25 liquid metal, comprising a mold body provided with at least one mold cavity, said mold cavity comprising:

- a liquid metal inlet defined by a nozzle plate,
- an insert, said insert defining a perimeter wall intended to be in contact with the metal leaving said liquid metal inlet,
- 30 - a mold outlet comprising a plurality of spray nozzles for spraying cooling fluid onto said metal strand,

characterized in that said mold body is provided with a channel for cooling fluid, and in that said protective insert is removable, and is made from a metallic material.

35 During casting operation, liquid metal will be admitted to the mold through said nozzle plate and flows through said insert, which is arranged downstream of said liquid metal inlet. Said insert is cooled by a cooling fluid circulating in said channel. Said channel for

cooling fluid is in fluid connection with a connection interface for cooling fluid. The liquid metal solidifies in contact with the cooled insert, and when leaving the mold outlet, at least the surface of the metal strand will be solid. At the mold outlet, cooling fluid is sprayed onto the surface of the metal strand as it leaves the mold.

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Said nozzle plate is advantageously made from a non-metallic inorganic material, and preferably from a ceramic material.

Said insert is advantageously made from copper or copper alloy, or, preferably, from aluminium or aluminium alloy. These materials have a high thermal conductivity, are fully recyclable and easy to machine. Machinability is a significant asset here because it allows to provide the insert with a plurality of spraying nozzles by which the cooling fluid used for primary cooling of the insert is sprayed onto the merging metal strand. The inner perimeter wall of said insert, which is in contact with the cast metal, is advantageously made from copper or copper alloy, or, preferably, from aluminium or aluminium alloy. It has preferably a flat surface.

According to advantageous embodiments of the invention:

- said mold body is provided with a removable front plate;
- 20 - said channel for cooling fluid is arranged in said mold body or adjacent to said mold body;
- said mold body, said insert and said front plate define a waterbox, said waterbox preferably comprising said channel for cooling fluid;
- said channel for cooling fluid is arranged in said mold body or between said mold body and said insert, or between said mold body, said insert and said front plate.

The mold according to the invention can further comprise a removable insert clamping plate, fixed onto said front plate and capable of clamping said insert against said nozzle plate.

30 Said insert can be clamped between said nozzle plate, using a nozzle clamping plate, and said mold body, using an insert clamping plate. This allows easy removal of the insert, for inspection, repair, maintenance and/or replacement. Said insert has a noncircular cross section, allowing to cast metal strands with a cross section that is noncircular, such as foundry ingots.

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According to an advantageous embodiment, said mold further comprises at least one conduit provided in said insert which is in fluid connection with a connection interface for a lubricant fluid. In particular, said conduit is designed for admitting a lubricant fluid between said insert and said nozzle plate.

5 The mold according to the invention can comprise a plurality of mold cavities, each of which showing the inventive features mentioned above. Said mold cavities can be identical or not. They are advantageously aligned on one single axis (i.e., arranged in a row), and in this case, the front plate forms advantageously one single piece, and the back plate advantageously forms one single piece, too. Said waterbox extends  
10 substantially over the whole mold.

In an advantageous embodiment the number of mold cavities is comprised between five and twenty, preferably arranged in a row.

In an advantageous embodiment each mold cavity has its own means of adjustment for the pressure and/or the throughput of said lubricant fluid.

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Another object of the invention is the use of a mold according to any of the embodiments of the invention for casting of metal strands with a noncircular cross section, said metal strands being preferably foundry ingots. During casting, cooling fluid is circulated in said cooling channels and/or said waterbox, and/or cooling fluid is sprayed onto the metal  
20 strand emerging from the mold outlet using said nozzles, and/or lubricant fluid is admitted through said conduits surface of said metal strand.

Another object of the invention is a method for casting a metal strand from liquid metal, in particular a metal strand for use as a foundry ingot, using said mold according to the invention, with the proviso that said metal strand does not have a circular cross section.

25 In this method, the temperature of the cooling water is typically between about 5 °C and about 50 °C, the volume of cooling water per cast mass of aluminium is between about 5 Nm<sup>3</sup>/t and about 40 Nm<sup>3</sup>/t, the volume of lubrication agent per cast mass of aluminium is comprised between about 5 mL/t and about 400 mL/t, the volume of lubrication agent per strand and hour is comprised between about 0.5 mL/h and 18.5 mL/h, and the casting  
30 speed was between about 0.1 mm/s and about 15 mm/s. Said lubrication agent can typically be used in a concentration of between about 0.05 L/m<sup>3</sup> and about 2 L/m<sup>3</sup> of water, preferably between about 0.1 L/m<sup>3</sup> and about 0.8 L/m<sup>3</sup> of water, and more preferably between about 0.14 L/m<sup>3</sup> and about 0.6 L/m<sup>3</sup> of water. If there is not enough  
35 lubrication, the surface of the metal strand shows increased surface roughness; if there is too much lubrication the surface of the metal strand may show ripples.

Another object of the invention is a method of maintaining or repairing a mold according to the invention, wherein said insert clamping plate is removed, said insert is removed for inspection and/or maintenance and/or repair and/or replacement, another or the same insert is inserted, and said insert clamping plate is put in place again and fastened. Said maintenance or repair can comprise polishing of the perimeter surface prior to putting in place the insert again.

**Brief description of the figures**

10 Figures 1 to 5 represent various aspects and embodiments of the invention. They are given for illustration only and are not meant to limit the scope of the invention.

Figure 1 shows a perspective front view of a multiple-strand mold for ingots with substantially rectangular cross section according to the invention, capable of producing up to ten cast bars.

Figure 2 shows an exploded and enlarged perspective front view of the multiple-strand mold of figure 1.

Figure 3 shows a perspective rear view of the mold of figure 1.

Figure 4 shows an exploded and enlarged perspective rear view of the mold of figure 1.

20 Figure 5 shows a cross section of the mold according to figure 1.

The following reference numbers are used on the figures and in the description:

1	Mold according to the invention	2	Mold cavity
3	Liquid metal inlet	4	Mold outlet
5	Inner surface of the perimeter wall of the mold	6	Solidified metal strand
8	Mold body	9	Assembling or fixation means
18	Connection interface for water circuit	19	Spray nozzles for cooling fluid
20	Protective insert	22	Assembly or fixation means
24	Insert clamping plate	25	Nozzle plate
26	Nozzle clamping plate	27	Perimeter wall of 3
28	Front plate	29	Back plate
30	Water box	31	Connection interface for oil circuit
32	Outer perimeter wall of insert 20	35	Front surface of 25
36	Rear surface of 20	37	Bottom portion of 25

38	Conduit	39	Channel for cooling fluid
40	O-ring		

### Detailed description

5 The term “aluminium” as used herein includes aluminium alloys, and the term “copper” as used herein includes copper alloys.

Typical molds according to the invention will be described here in relation with figures 1 to 5.

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The mold **1** shown on figure 1 in a perspective front view comprises ten mold cavities **2** arranged in a row. Figure 3 shows the corresponding perspective rear view. In this embodiment the mold cavities **2** are identical, and in particular have an identical cross section, but in other embodiments they can have different cross sections and/or sizes.

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Each mold cavity **2** has a liquid metal inlet **3** (visible on figure 3) and a mold outlet **4**. During the continuous casting process, liquid metal will be introduced into the mould cavity **2** through its inlet **3**, and a solidified metal strand (not shown on the figures) will emerge from said mold outlet **4**.

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The mold **1** comprises several parts, namely a front plate **28** and a back plate **29**, arranged parallel to each other, and each manufactured from a single piece. Said front plate **28** and back plate **29** are pressed against a body **8**, held together by appropriate means **9** for fastening or assembling, such as bolts. The back plate **29** comprises the liquid metal inlet **3**, whereas the front plate **28** comprises the mold outlet **4**. Said body **8**,

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front plate **28** and back plate **29** are typically made from metallic materials having a good thermal conductivity. As an example, the following metals and their alloys can be used: aluminium, copper, titanium, as well as stainless steel. As an example, if the mold **1** is intended to be used for casting aluminium or aluminium alloys, the back plate **29** is typically made from steel, and the front plate **28** is typically made from copper or

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aluminium, whereas the body **8** is advantageously made from copper.

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The inner surface (called here « contact surface ») of a mold is in contact with liquid metal and solid metal and is subject to friction and wear. According to the invention, at least part of the contact surface is the inner surface of a sleeve which can be replaced if needed. This sleeve takes the form of an insert **20**, which protects at least part of the

mold cavity. In particular, said insert forms the perimeter wall **32** of the mold cavity **2**, the inner, flat surface **5** of said perimeter wall being in contact with the molten metal during the casting operation.

5 Said insert **20** is substantially rectangular in cross section; its edges may be rounded. The insert **20** is fixed with an insert clamping plate **24** against the front plate **28** using fixing means such as bolts **22**. This can be seen from figure 1, as well as from figure 2 which shows an enlarged exploded perspective front view of the mold of figure 1. As can be seen, the insert **20** can be removed by unlocking said fixing means **22** and removing  
10 the clamping plate **24**.

According to the invention, any direct contact between the inner surface of the mold body **8** and the liquid metal is avoided. Instead, it is the inner surface **5** of the perimeter wall of the protective insert **20** that will be in contact with the liquid metal. Said protective  
15 insert **20** is in thermal contact with a cooling fluid. Said protective insert **20** being subject to wear, it can be replaced if necessary. Protective inserts **20** with a cross section that is substantially rectangular are shown in figures 1 to 5 for a first embodiment; protective inserts having a cross section that is substantially circular can be used for billet casting (not shown of the figures).

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On the rear of the mold **1**, the insert **20** is completed by a nozzle plate **25**. This can be seen from Figure 3 which shows a perspective rear view of the mold of figure 1. The liquid metal enters the liquid metal inlet **3** through the nozzle plate **25** having a substantially circular perimeter wall **27**. The nozzle plate **25** is fixed against the back  
25 plate **29** of the mold body **8** by nozzle clamping plate **26** using a fixation means **22** such as bolts. Said nozzle clamping plate **26** advantageously has the same height as the mold body **8**. Said nozzle plate **25** and said nozzle clamping plate **26** are typically arranged parallel to each other, and parallel with respect to the front plate **28** and the back plate **29**. As can be seen from figure 4, nozzle plate **25** can be replaced very easily by  
30 removing the nozzle clamping plate **26**.

Figure 4 shows an enlarged exploded perspective rear view of the mold of figure 1. Insert **20** has been introduced from the front side, and nozzle plate **25** is inserted from the rear side, abutting against the insert **20**; the back plate **29** is then pressed against nozzle  
35 plate **25** using said fixation means **22**.

This can be seen from figure 5 which shows a cross section of a mold cavity **2** similar to that shown on figures 1 to 4. Said nozzle plate **25** has an opening acting as the liquid metal inlet **3**, delimited by a perimeter wall **27**, and a substantially flat bottom portion **37**, the front surface **35** of which abuts against the rear surface **36** of the insert **20**. One or more O-rings **40** can be used to ensure tightness of this abutment.

According to the invention, the mold **1** is provided with cooling means. Said cooling means are of at least two kinds: the mold itself is cooled by a cooling fluid that circulates in cooling channels **39** (so-called primary cooling means), and a plurality of spray nozzles **19** are provided in the protective insert **20** at the mold outlet **4** for spraying a cooling fluid onto the emerging metal strand are provided (so-called secondary cooling means). This will now be explained in more detail.

Said primary and secondary cooling means are provided in the form of at least one cooling fluid circuit. A circuit for cooling fluid is provided in the mold body **8**, said circuit comprising cooling fluid channels **39** and/or a cooling fluid box **30** (as in the embodiment of figure 1). An appropriate connection interface **18** is provided to connect said cooling fluid circuit to an external supply of cooling fluid. Said cooling circuit carries the cooling fluid through channels **39** arranged in the mold body **8**, and in particular in the outlet part of the mold, in order to cool said mold body **8** and in particular said outlet part. As the most frequently used cooling fluid is water, the cooling circuit will here also be called a « water circuit » and the cooling fluid box **30** will here also be called a “water box”, which does however not imply that other fluids cannot be used (such as water – glycol mixtures).

Figure 5 shows the water box circuit **39**, which ensures primary cooling of the mold. Said cooling fluid channel **39** (called here also « water channel ») is provided in vicinity of the mold body **8** and preferably, as in figure 5, adjacent to the mold body **8**, so as to ensure excellent thermal contact with the perimeter wall **32**, said perimeter wall **32** being itself in thermal contact with the hot metal being cast. The cooling fluid circulating in said fluid channel **39** is therefore a means to cool the liquid metal during casting, as it passes through the insert **20**: in contact with the perimeter wall the liquid metal will solidify at least in a certain thickness from its surface, said thickness in a given portion of metal being increasing as said metal portion is passing through the insert **20**.

The length of said perimeter wall **32** in the direction of advancement of the metal during casting is advantageously comprised between about 10 mm and about 60 mm,

preferably at least 15 mm, more preferably at least 20 mm, and still more preferably at least 25 mm. If the length is too small, the cooling effect is insufficient. If the length is too high, lubrication of the interface between the metal strand and the perimeter wall **32** may become unstable, leading to an insufficient surface quality of the cast metal strand.

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In the embodiment of figure 5, said cooling fluid box **30** is defined by the front plate **28** of the mold **1**, by the mold body **8**, and by the outer perimeter wall **32** of metallic insert **20**. Cooling fluid enters and leaves the mold **1** through appropriate connection interfaces **18**. One or more O-rings **40** can be used to ensure tightness of the various conduits of the waterbox circuit. As these O-rings are inserted in a cooled zone of the mold, they can be made of elastomeric materials such as synthetic rubber.

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In other embodiments (not shown on the figures) the water box **30** can be defined also by the back plate **29** of the mold **1**, and/or the water channel **39** can be provided in the mold body **8**.

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In addition to primary cooling of the mold itself, and in particular of its perimeter wall, means for secondary cooling of the solid surface of the solidifying metal strand are provided by a set of spray nozzles **19** provided in an annular zone around the outlet of the insert **20**. They are configured such as to spray cooling fluid in an annular zone over the surface of the metal strand as it emerges from the mold outlet.

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Typically, one single cooling circuit is provided for both primary and secondary cooling means, as in the figures, and the cooling fluid used for cooling the mold will leave the mold through the spray nozzles **19** which are provided in the insert **20**. In the embodiment of figures 1 to 4, the waterbox circuit **39** as well as said spray nozzles **19** are in fluid connection with the connection interfaces **18** for the fluid circuit. It would however be within the scope of the invention to use separate cooling fluid circuits for the primary cooling means and the secondary cooling means; in this case said cooling fluids can be identical or different.

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According to an advantageous feature of the invention, the surface of the perimeter wall **5** of the mold is lubricated during casting. To this end, the mold **1** comprises a dedicated circuit (called here « oil circuit ») that carries a separating agent, said circuit comprising at least one channel. This separating agent (also called « lubrication agent » or simply « oil ») has two functions: it lubricates the interface between said metal surface and the inner perimeter wall **5** of the insert **20**, and it contributes (as a so-called “tertiary

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cooling means”) to cooling the emerging metal surface of the cast strand. Lubrication should be permanent and stable, in order to avoid ripples and other defects on the surface of the metal strand. To this end, openings are provided in the insert **20** and/or the mold body **8**, allowing oil to penetrate and to access to the surface of the emerging metal strand. Said separating agent can be an oil or an oily liquid such as an oil-water mixture. For example, said oil can be selected from the group formed by vegetable oil(s), refined vegetable oil(s), refined mineral oil(s), synthetic oil(s), mixtures of the mentioned oils.

More precisely, as can be seen from figure 5, the mold body **8** is provided with conduits **38** which extend into the insert **20**, until close to the perimeter wall **5**. Said conduits **38**, which are in fluid connection with a specific connection interface **31**, extend until close to the edge **40** or interface between the mold body **8** and the nozzle plate **25**; a small opening (not shown on the figures) may be provided to allow oil to penetrate until the edge **40** or close to said edge of the perimeter wall **5**, where it can access to the surface of the emerging metal strand. Said opening advantageously has a diameter comprised between 0.1 mm and 1.0 mm, preferably between 0.25 mm et 0.75 mm. There may be provided more than one of such conduits **38** for each mold cavity **2**, preferably on each of the sides of the cross section. This system of conduits is used to inject oil at a remote position of the perimeter wall **5**, namely close to, or at, said edge **40**. Said oil will form a continuous and homogeneous thin film on the whole surface of the emerging metal strand, as soon as it will solidify in contact with the perimeter wall **5**. This continuous and homogeneous lubrication leads to an excellent surface quality of the as-cast metal strands.

Said oil circuit is in fluid connection with an oil pump (not shown on the figures). One single oil pump can be used for the mold. According to an advantageous embodiment of the invention, each mold cavity **2** has its own means of adjustment (not shown on the figures) for the oil pressure and/or the oil throughput. This single strand lubrication approach allows to adjust the lubrication individually for each mold cavity, taking into account in particular the surface aspect of the emerging metal strands. Said adjustment can be carried manually or automatically. A camera coupled with appropriately configured image analysis software run on a control computer can be used to identify any significant surface defecets that could be avoided by improving lubrication; a feedback loop can be provided between the camera and the means of adjustment for oil pressure and/or oil throughput.

In a variant of the invention, air cooling can be provided as an additional cooling means, as an additional air circuit (not shown on the figures) for supplying compressed air blown on the mold and/or on the emerging metal strand. This air circuit is optional.

5 The protective insert **20** is made from a material that is relatively inert with respect to the liquid metal and which does not stick to the liquid metal. Graphite can be used as a material for said protective insert **20**, as it is chemically inert and self-lubricating. According to a particularly advantageous embodiment of the invention, the insert **20** is a metallic insert. An insert made in aluminium or copper is preferred for molds intended to  
10 be used for casting aluminium. Although metallic materials based on aluminium or copper are not auto-lubricating like graphite, they have significant advantages over graphite: their thermal conductivity is much higher than that of graphite, they have a significantly longer lifetime, they are less expensive, and can be recycled. Said metallic inserts can be manufactured by casting and/or by machining, or by additive techniques  
15 (so-called 3D printing). Cast perimeter surfaces need to be machined prior to their first use. All machined perimeter surfaces are advantageously polished, preferably after each use. After removal of the insert from the mold, the insert can be inspected and repaired if needed, or discarded for recycling if repair is not possible. Discarded metal inserts can be recycled (usually by remelting), which is hardly possible with graphite.

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The lifetime of perimeter walls made from graphite is usually of the order of 250 h to 500 h. The inventors have found that perimeter walls made from aluminium alloys have a lifetime that is significantly higher than that of graphite, and in particular the lifetime of the metallic insert **20** can be in excess of 1 000 hours. The nozzle plate **25** needs to be  
25 changed typically after 60 h to 80 h.

We will describe now in relation with figure 4 a method for changing the nozzle plate **25**. In a first step the fixation means **22** of the nozzle clamping plate **26** are unlocked. In a second step the nozzle clamping plate **26** is removed. In a third step the nozzle plate **25**  
30 is removed. In a fourth step a new or renovated nozzle plate **25** is put in place. In a fifth step the nozzle clamping plate **26** is reinstalled. In a sixth step the nozzle clamping plate **26** is fixed by fastening the fixation means **22**. During nozzle plate change all other components of the mold can remain mounted, only the nozzle clamping plate **26** and the fixation means **22** have to be dismantled to allow change of the nozzle plate **25**. The  
35 surfaces of the removed nozzle clamping plate **26** are cleaned before it is put in place in the third step, or another cleaned, new or renovated nozzle clamping plate is used. The

visible surface of the back plate **29** is cleaned between the second and the fourth step, as well as all accessible surfaces of the mold cavity.

We will describe now in relation with figure 2 a method for changing the mold insert **20**.

5 In a first step the fixation means of the insert clamping plate **24** are unlocked. In a second step the insert clamping plate **24** is removed. In a third step all accessible surfaces of the mold cavity are cleaned. In a fourth step a new (or renovated) mold insert **20**, and preferably a new O-ring, are installed. In a fifth step the insert clamping plate **24** is reinstalled. In a sixth step the insert clamping plate **24** is fixed by fastening the fixation  
10 means. During insert plate change all other components of the mold can remain mounted, only the insert clamping plate **24** and the fixation means have to be dismantled.

The invention has many advantages. One of the advantages of the invention is that the  
15 body **8** is not subject to wear, but only the insert **20** and the nozzle plate **25**, both of which can be exchanged individually if necessary, using a simple and fast method. The insert **20** and the nozzle plates **25** are metallic parts that can be manufactured easily, and which are rather inexpensive; moreover, they can be recycled easily after having been discarded. The perimeter wall **5** is made from metal, such as aluminium alloy, which has  
20 a higher thermal conductivity than graphite, thereby allowing better cooling of the whole surface of the perimeter wall **5**. Lubrication is efficient and is limited to the part of the interface where it is absolutely necessary; this allows to use a small amount of lubrication agent (such as oil) only. The lubrication agent is used in a mixture with water, which acts as coolant. The quantity coolant (water – lubrication agent mixture) and / or lubrication  
25 agent can be adjusted for each individual mold cavity, according to what is needed to ensure sufficient lubrication.

The mould **1** according to the invention can have one single mold cavity, or preferably a plurality of mold cavities. Figures 1 and 3 show a typical embodiment with ten identical  
30 mold cavities **2** arranged in a row. The mold cavities **2** can be different, although this would not be a preferred embodiment of the invention.

### Examples

35 The mold and casting process according to the invention has been used for horizontal casting of foundry ingots (so-called HDC ingots or Horizontal Direct Chilled ingots) in various aluminium alloys, with a width of about 55 mm and a height of about 75 mm or

90 mm, which can be used for remelting in various casting processes, such as die casting. During these industrial casting tests, the temperature range of the cooling water was between about 5 °C and about 50 °C, the volume of cooling water per cast mass of aluminium was between about 5 Nm<sup>3</sup>/t and about 40 Nm<sup>3</sup>/t, the volume of cooling water per strand and hour was comprised between about 2.3 Nm<sup>3</sup>/h and 18.2 Nm<sup>3</sup>/h, the volume of lubrication agent per cast mass of aluminium was comprised between 10 mL/t and 400 mL/t, the volume of lubrication agent per strand and hour was comprised between about 0.5 mL/h and 18.5 mL/h, and the casting speed was between about 0.1 mm/s and about 15 mm/s. Said lubrication agent can typically be used in a concentration of about 0.2 L/m<sup>3</sup> of water.

15

## CLAIMS

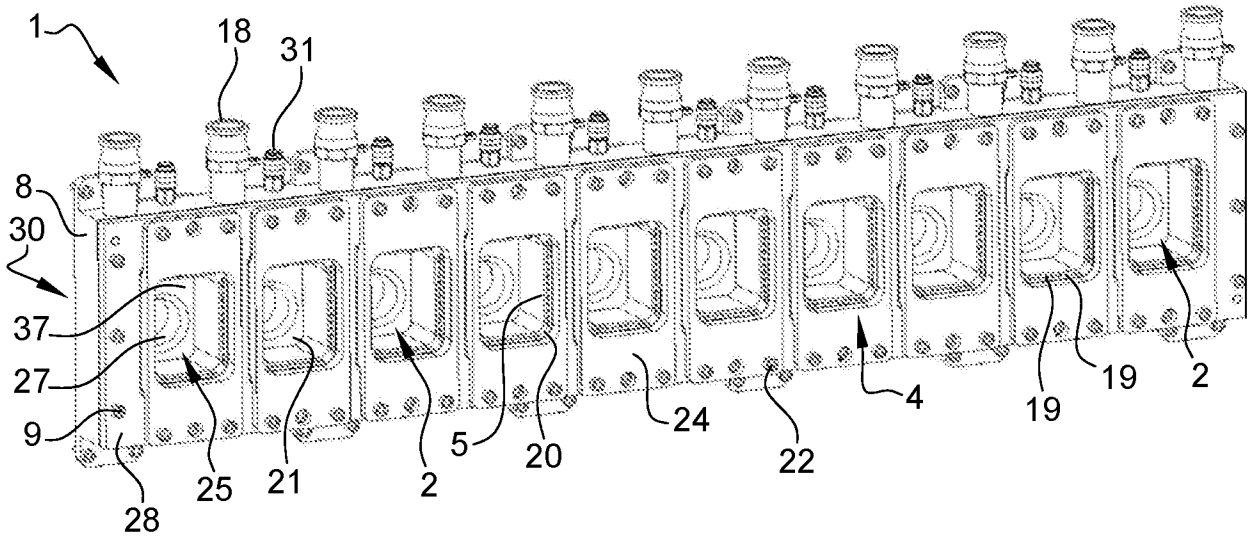
1. Mold (1) for semi-continuous casting of metal strands from liquid metal, comprising a mold body (8) provided with at least one mold cavity (2), said mold cavity comprising:
- 5 - a liquid metal inlet (3) defined by a nozzle plate (25),  
- an insert (20), said insert (20) defining a perimeter wall (5) intended to be in contact with the metal leaving said liquid metal inlet (3),  
- a mold outlet (4),  
- a plurality of spray nozzles (19) for spraying cooling fluid onto said metal strand, said
- 10 spray nozzles being preferably provided in said insert (20),  
characterized in that said mold body (8) is provided with a channel (39) for cooling fluid, and in that said insert (20) is removable, and is made from a metallic material, which is preferably selected from the groupe formed by: aluminium, aluminium alloys, copper, copper alloys.
- 15
2. Mold (1) according to claim 1, wherein said mold body (8) is provided with a removable front plate (28).
3. Mold (1) according to any of claims 1 or 2, characterized in that said channel (39)
- 20 for cooling fluid is arranged in said mold body (8) or adjacent to said mold body (8).
4. Mold according to any of claims 2 or 3, wherein said mold body (8), said insert (20) and said front plate (28) define a waterbox (30), said waterbox preferably comprising said channel (39) for cooling fluid.
- 25
5. Mold (1) according to any of claims 2 to 4, characterized in that said channel (39) for cooling fluid is arranged in said mold body (8) or between said mold body (8) and said insert (20), or between said mold body (8), said insert (20) and said front plate (28).
- 30
6. Mold according to any of claims 1 to 5, further comprising a removable insert clamping plate (24), fixed onto said front plate (28) and capable of clamping said insert against said nozzle plate (25).
- 35
7. Mold (1) according to any of claims 1 to 4, characterized in that said insert (20) is clamped between said nozzle plate (25), using a nozzle clamping plate (26), and said mold body (8), using an insert clamping plate (24).

8. Mold (1) according to any of claims 1 to 7, characterized in that said nozzle plate (25) is made from a non-metallic inorganic material, and preferably from a ceramic material.
- 5
9. Mold (1) according to any of claims 1 to 8, further comprising at least one conduit (38) provided in said insert which is in fluid connection with a connection interface (31) for a lubricant fluid.
- 10
10. Mold (1) according to claim 9, wherein said conduit (38) is designed for admitting a lubricant fluid between said insert (20) and said nozzle plate (25).
11. Mold (1) according to any of claims 1 to 11, comprising a plurality of mold cavities (2).
- 15
12. Mold (1) according to claim 11 depending on any of claims 4 to 10, characterized in that said waterbox (30) extends substantially over the whole mold.
13. Mold (1) according to any of claims 11 to 12, characterized in that each mold cavity (2) is provided with its own means for adjustment for the oil pressure and / or the oil throughput.
- 20
14. Use of a mold (1) according to any of claims 1 to 13 for casting of metal strands with a noncircular cross section, said metal strands being preferably foundry ingots.
- 25
15. Use of a mold according to any of claims 1 to 13, comprising a plurality of mold cavities arranged in a row, for horizontal casting of metal strands.
16. Use according to any of claims 14 or 15 for casting metal strands in aluminium or aluminum alloys.
- 30
17. Use according to any of claims 14 to 16, characterized in that during casting:
- cooling fluid is circulated in said cooling channels (39) and/or said waterbox (30), and/or
  - 35 - cooling fluid is sprayed onto the metal strand emerging from the mold outlet (4) using said spray nozzles (19), and/or
  - lubricant fluid is admitted through said conduits on the surface of said metal strand.

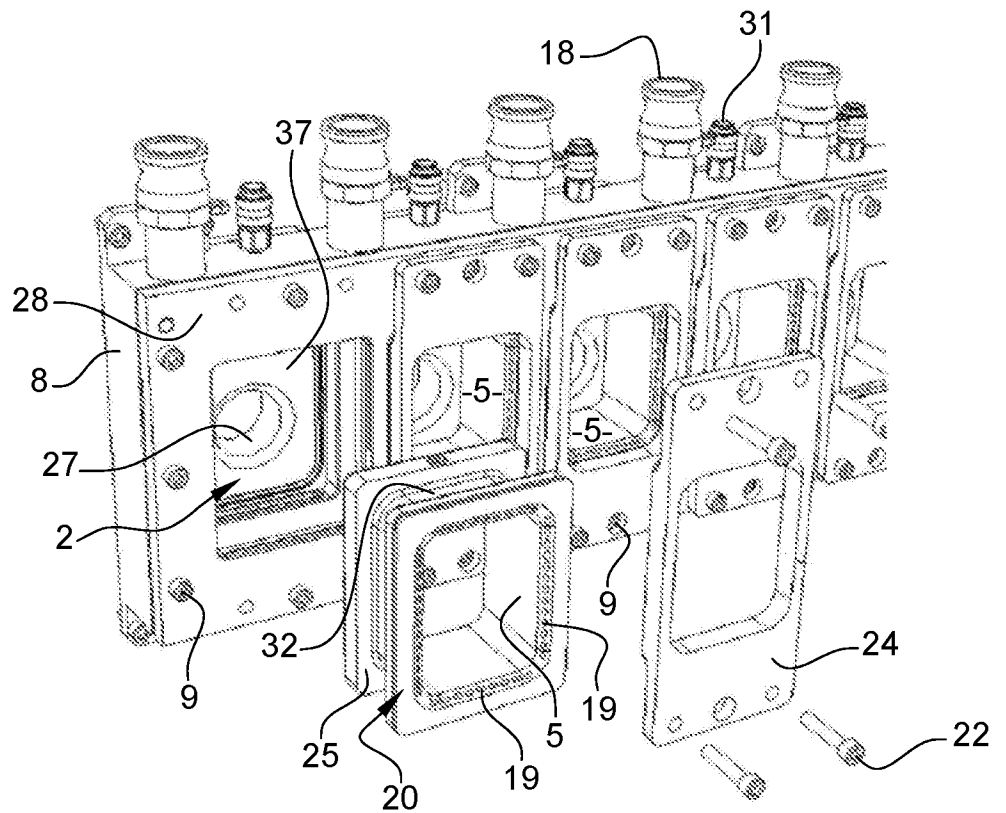
18. Method of maintaining or repairing a mold (1) according to any of claims 7 to 13, wherein said insert clamping plate (24) is removed, said insert (20) is removed for maintenance, repair or replacement, another or the same insert is inserted, and said insert clamping plate (24) is put in place again and fastened.
19. Method according to claim 18 for changing the mold insert (20), wherein in a first step the fixation means of the insert clamping plate (24) are unlocked, in a second step the insert clamping plate (24) is removed, in a third step the accessible surfaces of the mold cavity are cleaned, in a fourth step a new or renovated mold insert (20), and preferably a new O-ring, are installed, in a fifth step said insert clamping plate (24) is resintalled, in a sixth step said insert clamping plate (24) is fixed by fastening the fixation means.
20. Method for changing a nozzle plate (25) in a mold according to any of claims 7 to 13, wherein in a first step fixation means (22) of said nozzle clamping plate (26) are unlocked, in a second step said nozzle clamping plate (26) is removed, in a third step said nozzle plate (25) is removed, in a fourth step a new or renovated nozzle plate (25) is put in place, in a fifth step said nozzle clamping plate (26) is reinstalled, in a sixth step said nozzle clamping plate (26) is fixed by fastening the fixation means (22).

25

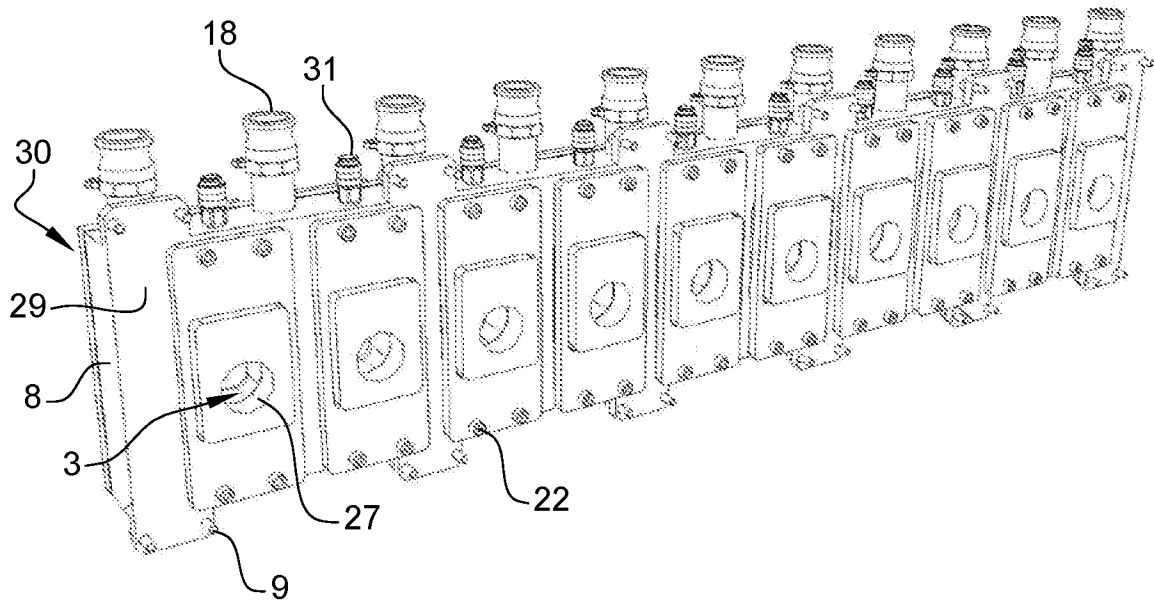
**Fig. 1**



**Fig. 2**



**Fig. 3**



**Fig. 4**

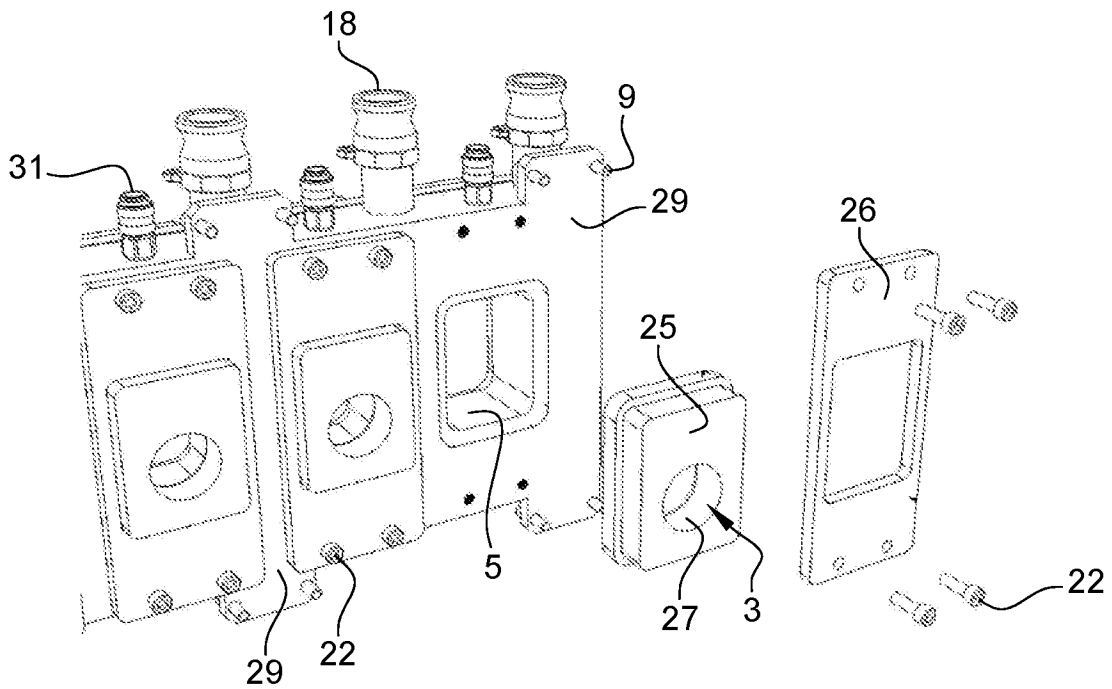
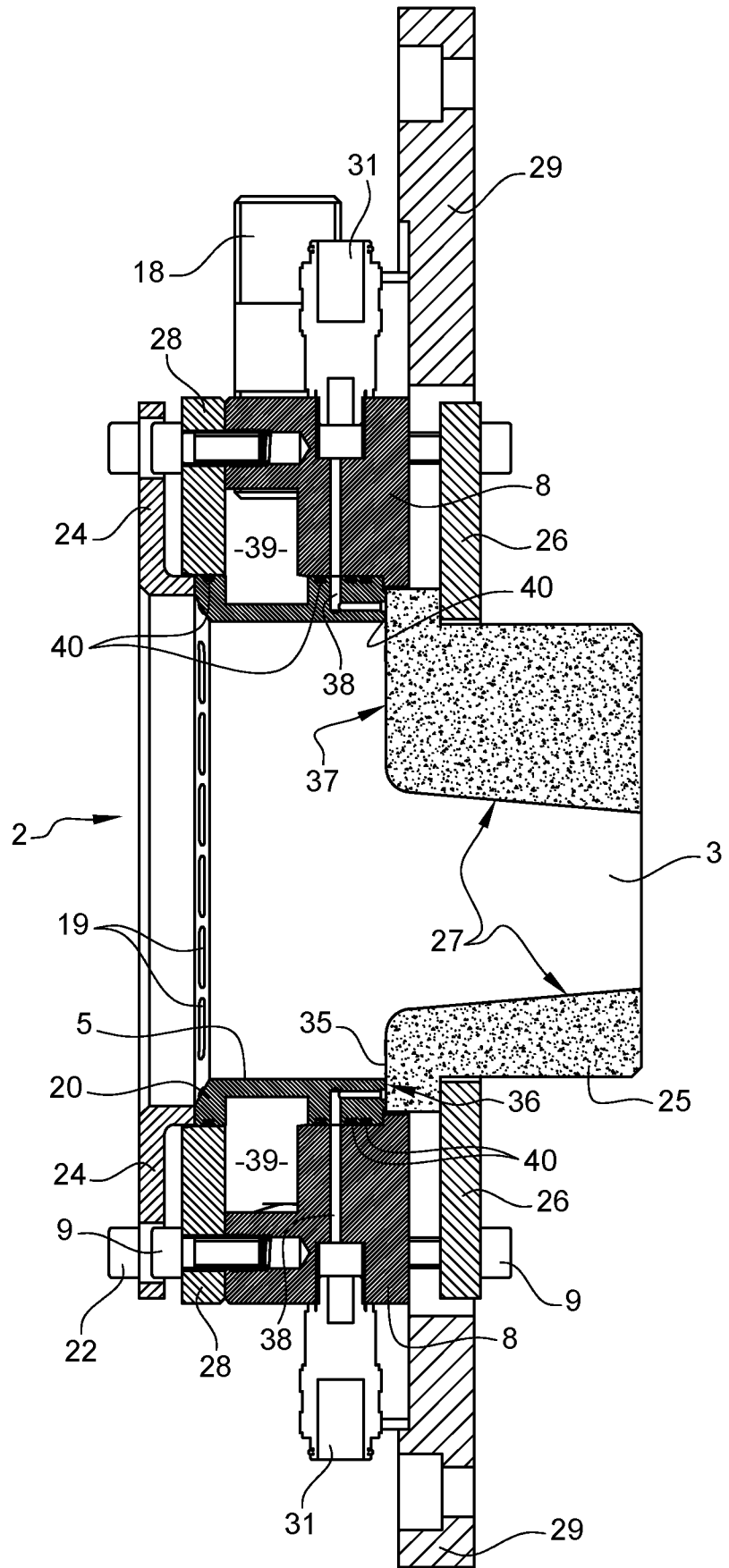


Fig. 5



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/IB 2023/053832

A. CLASSIFICATION OF SUBJECT MATTER IPC: <b>B22D 11/049</b> (2006.01); <b>B22D 11/055</b> (2006.01); <b>B22D 11/07</b> (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) <b>B22D</b>		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) <b>wpi, epodoc, fulltext-databases</b>		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 1455403 A (KAISER ALUMINIUM CHEM CORP) 10. November 1976 (10.11.1976)  fig. 6; page 4: lines 7-64	1-3, 5, 9-10, 14, 16-17, 20
X	US 5785112 A (CARRUPT ET AL.) 28. Juli 1998 (28.07.1998)  abstract; fig. 3; column 9: lines 34-54	1, 3, 5, 9, 10
X	EP 0247768 A2 (ALCAN INT LTD) 02. Dezember 1987 (02.12.1987)  abstract; fig. 2; page 5: line 1 - page 6: line 33	1-3, 5, 8-10, 20
Further documents are listed in the continuation of Box C.		<input checked="" type="checkbox"/> See patent family annex.
* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance		"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date		"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		"&" document member of the same patent family
Date of the actual completion of the international search 10 August 2023 (10.08.2023)		Date of mailing of the international search report 10 August 2023 (10.08.2023)
Name and mailing address of the ISA/AT Austrian Patent Office Dresdner Straße 87, A-1200 Vienna Telephone No. +43 (1) 53424 342		Authorized officer Pavdi Christian Telephone No. +43 1 534 24 374

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
PCT/IB 2023/053832

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GB 1455403 (A)	GB 1455403 (A)	1976-11-10
US 5785112 (A)	AT 195677 (T) CA 2171790 (A1) CH 689446 (A5) EP 0733420 (A1) EP 0733420 (B1) IS 4331 (A) US 5785112 (A)	2000-09-15 1996-09-25 1999-04-30 1996-09-25 2000-08-23 1996-09-25 1998-07-28
EP 0247768 (A2)	AU 598542 (B2) AU 7338787 (A) BR 8702699 (A) CA 1275781 (C) CN 1008609 (B) CN 87103804 (A) EG 17997 (A) EP 0247768 (A2) EP 0247768 (A3) EP 0247768 (B1) ES 2016358 (B3) JP H06104268 (B2) JP S62279054 (A) NO 169218 (B) NO 169218 (C) NZ 220068 (A) US 4709744 (A) ZA 872942 (B)	1990-06-28 1987-12-03 1988-03-01 1990-11-06 1990-07-04 1987-12-09 1991-06-30 1987-12-02 1988-03-02 1990-07-25 1990-11-01 1994-12-21 1987-12-03 1992-02-17 1992-05-27 1989-01-06 1987-12-01 1987-10-19