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(54) **SEMI-SOLID DIE-CASTING MACHINE AND METHOD**

(57) A semi-solid die-casting machine (1) comprising a die-casting mould (2), inside which a moulding chamber (3) is made, an injection container (8) in which a chamber (9) is made suitable to contain molten metal (25) in the semi-solid state, a feeding channel (13) of the jet of metal suitable to place in fluidic communication the injection container (8) with the moulding chamber (3) and a piston (10) to push the molten metal (25) in the semi-solid state contained in the injection container (8) into the moulding chamber (3) through the feeding channel (13). The semi-solid die-casting machine (1) further comprises a filter (11), which is placed in the feeding channel (13) of the jet of metal and is structured in such a way that when the molten metal in the semi-solid state passes through the filter (11), the metal is subjected to a swirling mixing.

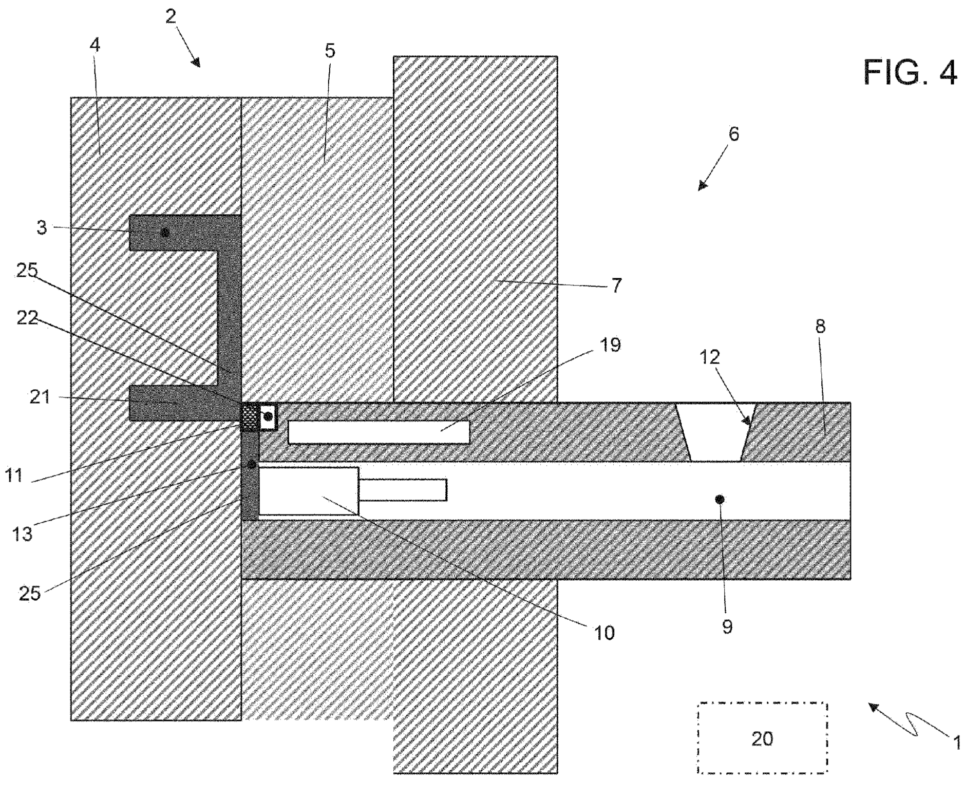

FIG. 4

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Description

PRIORITY CLAIM

[0001] *This application claims priority from Italian Patent Application No.* 102017000008841 filed on 27/01/2017*, the disclosure of which is incorporated by reference.*

[0002] The present invention relates to a semi-solid die-casting machine and method.

[0003] It is known that in die-casting processes, the main advantages resulting from the use of a molten metal alloy in the semi-solid state are now widely known and concern both the product and the process.

[0004] In particular, it is known that to obtain a microstructure with thixotropic properties it is necessary to achieve a "multiplication of dendrites" through rapid cooling of the metal alloy and simultaneous stirring during the first stages of solidification.

[0005] Some die-casting processes are essentially based on the immediate use of thixotropic material ("slurry on demand"). In particular, these processes are essentially based on the idea of performing a rapid cooling of the metal bath to promote the increase of solidification nuclei and to simultaneously perform adequate mixing to apply however only in the first stages of solidification to promote dendritic multiplication in the phases where the dendrites are extremely thin and unstable given the high ratio between surface and volume and, above all, the thermal homogenisation of the semi-solid load in formation.

[0006] This technique is generally capable of generating metallic material with a globular microstructure and allows its immediate use in known semi-solid forming processes.

[0007] More in detail in some of the above mentioned processes it is provided to take a molten material from a waiting furnace to pour it into an intermediate semi-solid preparation recipient (1st transfer) and to then transfer the semi-solid metal from said recipient into an injection container of a series of presses (2st transfer).

[0008] In this process, the transfer operations of the metal material significantly detract from the metallurgical characteristics and increase the metal defects. In fact, each transfer of metal corresponds to an incorporation of oxides ("bi-films") which have deleterious effects on the integrity and the mechanical characteristics of the final pieces. If the metal, after mixing, must necessarily be transferred into an injection container of the die-casting machine, it is obvious that the solid fraction (depending on the extent of the thermal transfer applied) must necessarily be limited. Otherwise, the 2nd transfer would not be practicable with the consequence of adversely affecting the amount of solidification shrinkage within the jets.

[0009] In order to reduce the aforesaid criticalities, processes have been devised in which the metal is prepared directly inside the injection container of the press. This way, the second transfer is avoided and consequently there are no constraints to the extent of the solid fraction, which can be injected.

[0010] More in detail, some processes, such as that described in the European patent EP 2 709 781 A1 provide for using a mechanical stirrer in the injection container of the press to accelerate the preparation of the semi-solid. Other processes are also known of where the mixing of the metal in the injection container of the press is performed using electromagnetic systems or ultrasonic systems.

[0011] These technologies, however, require mixing devices, which weigh heavily on the complexity and cost of the machine.

[0012] Most of these processes also do not guarantee perfect metallurgical hygiene which is necessary for the quality of the final jet. Each step between the formation of the semi-solid material and the realisation of the jet creates conditions for possible pollution from oxides, bi-films, gas of the container detachment agent, inclusions, etc.

[0013] Methods for producing aluminium components described in DE10231888, US6564854 and JPH0938758 are also known.

[0014] The purpose of the present invention is to provide a semi-solid die-casting machine and method that is easy and economical to make.

[0015] According to the present invention, a semi-solid die-casting machine and method as claimed in the appended claims is provided.

[0016] The present invention will now be described with reference to the appended drawings, which illustrate some non-limiting embodiments, wherein:

- Figure 1 is a schematic view of a semi-solid die-casting machine made according to the present invention;
- Figures 2-5 are schematic views of the semi-solid die-casting machine in Figure 1 during subsequent phases of the die-casting process; and
- Figures 6 to 12 are as many schematic views of some types of a filter installable in the semi-solid die-casting machine according to the present invention.

[0017] The present invention will now be described in detail with reference to the appended figures to enable a person skilled in the art to make and use it. Various modifications to the embodiments described will be immediately apparent to the person skilled in the art, the general principles described may be applied to other embodiments, and applications while remaining within the sphere of protection of the present invention, as defined in the appended claims. The present invention should not therefore, be considered limited to the embodiments described and illustrated, but given a broader scope of protection according to the principles and characteristics described and claimed herein.

[0018] In Figure 1, reference numeral 1 globally denotes a semi-solid die-casting machine.

[0019] The semi-solid die-casting machine 1 comprises a die casting mould 2, inside which a moulding chamber 3 is made. The semi-solid die-casting machine 1 further comprises an injection container 8 in which a chamber 9 is made suitable to contain the molten metal 25, a feeding channel 13 of the jet suitable to place the injection container 8 in communication with the moulding chamber 3, and an injection die 6 suitable to inject under pressure the molten metal 25, in the semi-solid state, contained in the injection container 8 into said moulding chamber 3 through said feeding channel 13.

[0020] The moulding chamber 3 reproduces the negative of the shape of the piece to be made and is intended to receive the jet of molten metal in the semi-solid state for the subsequent completion of the solidification of said jet.

[0021] According to a possible exemplary embodiment shown in the schematic example of Figure 1, the die-casting mould 2 may preferably be composed of a mobile die 4 and a fixed die 5. During the feeding of the jet of molten metal in the semi-solid state, the mobile and fixed dies 4, 5 can be mechanically coupled to form/constitute the moulding chamber 3. Once the jet of injected metal is sufficiently solidified, the mobile die 4 can preferably be distanced, in a known manner, from the fixed die 5 to allow the piece to be extracted from the die-casting mould 2.

[0022] According to a possible embodiment, the die-casting mould 2 can be supported by the injection press 6. The injection press 6 can be structured to feed under pressure the jet of molten metal in the semi-solid state inside the moulding chamber 3 through the feeding channel 13.

[0023] According to a possible exemplary embodiment shown in Figure 1, the injection press 6 may include for example a support surface 7, to which a die of the mould 2 can be mechanically coupled/attached, preferably the fixed die 5. Although the press 6 shown schematically in Figure 1 is of the horizontal type and the support surface 7 is vertical, it is understood that the present invention may provide, alternatively, for the use of a vertical press 6 with a horizontal support surface 7.

[0024] According to a possible embodiment shown in Figure 1, the injection press 6 may comprise a preferably cylindrical tubular injection container 8. According to a possible exemplary embodiment the container 8 can be placed preferably through a corresponding cavity made in the support surface 7 and preferably, but not necessarily, through a corresponding cavity made through the fixed die 5 of the die-casting mould 2.

[0025] Within the injection container 8 a preferably cylindrical preparation chamber 9 may be made into which the molten metal is poured in the liquid state before injecting the molten metal in the semi-solid state into the moulding chamber 3 through the feeding channel 13.

[0026] According to a possible embodiment shown in Figure 1, the preparation chamber 9 may be bounded by an injection piston 10 which is axially mounted along said preparation chamber 9 so as to vary the internal volume thereof.

[0027] According to a possible embodiment shown in Figure 1, the feeding channel 13 of the jet is made in the mould 2 so as to place in fluidic communication the preparation chamber 9 with the moulding chamber 3.

[0028] According to a possible embodiment shown in Figure 1, the feeding channel 13 of the jet is made in the mould 2 so as to present an inlet communicating with the preparation chamber 9 on the opposite side to the injection piston 10 and an outlet communicating with the moulding chamber 3. Preferably, the feeding channel 13 may be made in the fixed die 5 of the mould 2 and may be communicating with the inlet mouth of the moulding chamber 3.

[0029] According to a possible exemplary embodiment shown in Figure 1, the injection container 8 also has a feed opening 12, which is made through a wall, preferably upper, of the injection container 8 and in use is used to feed the molten metal in the liquid state into the preparation chamber 9.

[0030] Unlike the known solutions, the die-casting machine 1 is also provided with at least one filter 11, which is arranged stably (rigidly) in the feeding channel 13 of the jet, and is structured in such a way as to: receive in input molten metal in the semi-solid state, causing a swirling mixing of the molten metal in the semi-solid state during the passage through the filter 11 of the molten metal in the semi-solid state, and to provide in output the molten metal in the mixed semi-solid state.

[0031] The Applicant has found that the swirling mixing imparted by the filter 11 on the molten metal in the semi-solid state crossing the channel 13 determines the technical effect of advantageously producing a mechanical fluid stirring which in turn causes the formation of the thixotropic globular microstructure.

[0032] In the example illustrated, the filter 11 is also structured so that the flow of molten metal in the semi-solid state in output from the filter 11 is itself an approximately laminar flow. The Applicant has found that the use of a filter capable of generating a laminar flow of metal in the semi-solid state conveniently makes it possible to reduce the formation of turbulence in the metal fed to the chamber 3, which would tend to incorporate oxides, causing deleterious effects on the integrity and the mechanical characteristics of the piece.

[0033] In the example illustrated the filter 11 is also structured in such a way as to filter, i.e. retain, during the crossing of the molten metal in the semi-solid state, impurities of predetermined dimensions contained in the metal itself. The Applicant has found that the placement of the filter 11 in the feeding channel 13 advantageously makes it possible to retain the oxides, films, inclusions and other impurities, which contribute to prejudicing the metal hygiene of the metal forming the piece 21.

[0034] In the example illustrated, the filter 11 is also internally structured so as to determine on the flow of metal in the semi-solid state passing through it a refining of the metal beads.

[0035] According to a preferred exemplary embodiment shown in Figures 6-9, the filter 11 may consist of a thin perforated plate-shaped element, such as a net/mesh or perforated sheet, which is permanently placed inside the feeding channel 13 on a lying plane approximately transverse to the injection/forward direction of the metal in a semi-solid state into the channel 13 itself towards the chamber 3.

[0036] Preferably, the plate-shaped element or net/mesh is structured in such a way as to: receive in input the molten metal in the semi-solid state, causing a swirling mixing of the molten metal in the semi-solid state during the passage through the filter 11 of the molten metal in a semi-solid state, and to supply in output the molten metal in the mixed semi-solid state.

[0037] Preferably, the plate-shaped element or net/mesh can be made in a metal alloy characterized by a melting temperature of higher than about 650°C. Preferably, the metal alloy of the perforated sheet or of the net/mesh forming the filter 11 may be aluminium and/or iron-based. The holes or openings through the filter 11 may have a diameter greater than about 1 mm and a density greater than or equal to about 50% of the area. Preferably, the perforated sheet and the net/mesh may have a thickness determined along a direction orthogonal to said lying plane greater than or equal to about 1 mm.

[0038] The Applicant has found that the use of a filter 11 made of a perforated plate-shaped element or net/mesh in metal (metal grating flat filter") (Figure 7) in metal material, preferably an aluminium alloy, is particularly convenient since following the solidification of the metal in the chamber 3, the filter 11 remains completely embedded in the solidified biscuit of the piece 21, and can therefore be easily and fully recovered in a subsequent phase of recasting the biscuit, thereby reducing waste. This type of filter 11, in addition to being economical, is particularly effective in filtering the inclusions contained in the metal, exploiting the opportunity to superpose various ones until the result is achieved.

[0039] The Applicant has also found it particularly convenient to use a second type of filter 11 called "cloth flat filter". This second type of filter 11 differs from that described above in that the filter 11 is composed of/made from fabrics in refractory material, suitably perforated. Preferably, the refractory fabric of the filter 11 is structured in such a way as to: receive in input the molten metal in the semi-solid state, causing a swirling mixing of the molten metal in the semi-solid state during the passage through the filter 11 of the molten metal in a semi-solid state, and to supply in output the molten metal in the mixed semi-solid state.

[0040] Preferably, the refractory fabric of the filter 11 may be impregnated with one or more low-thermal capacity resins in such a way as to adequately increase the filtering efficiency. The low thermal capacity impregnating resins may include for example phenolic resins or similar resins. Figure 6 schematically shows a possible example of filter 11 belonging to the second type.

[0041] The filters 11 belonging to the second type are conveniently suitable to be installed in the feeding channel 13 in a cascade configuration, in which a plurality of filters 11 are placed one after the other in the feeding channel 13 at a given distance from each other, to perform, on the one hand, the consecutive multiple filtering of the impurities present in the metal and on the other to facilitate the separation of the filling elements (biscuits) from the piece 21 obtained. The Applicant has found that this configuration makes it possible to conveniently simplify the separation of the casting branch from the piece.

[0042] The Applicant has also found it particularly convenient to use a third type of filter 11 in which the filters 11 are volumetric ("volume filters"). The volume filters are structured in such a way as to: receive in input the molten metal in the semi-solid state, causing a swirling mixing of the molten metal in the semi-solid state during the passage through the filter 11 of the molten metal in a semi-solid state, and to supply in output the molten metal in the mixed semi-solid state.

[0043] These filters 11 are each provided with a body in ceramic material on which through holes are made defining inner channels suitable to be crossed in use by molten metal in the semi-solid state.

[0044] A first category of volume filters that can be installed in the machine 1 may correspond to strainer core filters 11 (Figure 8). The strainer core filter 11 is provided with a filtering body formed of a monolithic body, i.e. a monobloc, preferably of a parallelepiped or cylindrical or any other similar shape sized to be placed in the channel 13. Preferably, the filter 11 is shaped so as to present the same cross-section as the channel 13 so that it can be housed internally.

[0045] The through holes of the first strainer core category of volume filter 11 can be made in the monobloc of the filter 11 so as to form filtering channels adjacent to each other. The channels can be made in the monobloc so that the surface arrangement of the holes is substantially of the reticular or matrix type, i.e. in rows and columns. Each hole can be aligned or offset from adjacent holes. The through channels can also be made in the monobloc of the strainer core volume filter 11 so as to be substantially rectilinear, approximately parallel to each other. The through holes of the strainer core volume filter 11 can also be made in the monobloc of the filter 11 itself so as to be facing the channel 13 and each have a preferably approximately circular, elliptical or similar cross-section.

[0046] The through holes of the strainer core volume filter 11 can also be made in the monobloc so as to have a diameter between about 4 and about 10 mm, and a depth along the relative axis between about 6 and about 20 mm. Preferably, the strainer core volume filter 11 may conveniently be placed in the channel 13 at the inlet mouth of the chamber 3. Preferably, in the feeding channel 13, a plurality of strainer core volume filters 11 may be stably arranged in cascade, suitably spaced apart from each other. In this case, each filter 11 may have holes with a smaller diameter than the diameter of the holes of another filter 11 placed immediately upstream and greater than the diameter of the holes of another filter 11 placed immediately downstream of said filter 11 along the crossing direction of the channel 13 by the jet of metal. The Applicant has found that the use of the strainer core volume filter 11 is particularly advantageous as it is economical, allows efficient filtering of impurities and has a high mechanical strength. It should be clarified that the strainer core volume filters 11 in addition to being able to retain impurities having a significant thickness (coarse impurities), are conveniently structured to (accelerate) improve the filling of the chamber 3 by making the flow of metal in the semi-solid state more laminar, and simultaneously preventing the formation of vortices in the space of the channel 13 between the outlet of said filter 11 and the chamber 3 so as to conveniently reduce the turbulence of the jet of metal injected into the mould 2.

[0047] A second category of volume filters that can be installed in the machine 1 may correspond to pressed volume filters 11 (Figure 9). The pressed volume filters 11 differ from the strainer core volume filter in that they are made using semi-dry ceramic mixtures pressed into moulds, at elevated pressures. Subsequently the pressed filter is placed in the oven and subjected to a cooking process, which, together with the mixture, determines the characteristics of thermal and mechanical resistance. The flow is determined by the size of the holes and by the density.

[0048] Preferably, the diameter of the channels/through holes of the pressed volume filter 11 can be between about 1 mm and about 3 mm. Preferably, the thickness of the pressed volume filter 11 determined along the crossing direction of the filter 11 by the metal can conveniently be between about 10 mm and about 22 mm.

[0049] Preferably, the filtering area of the surface of the pressed volume filter 11 which in use is affected by the flow/jet of molten metal in the semi-solid state can be between about 45% and about 58% of the total surface area of the pressed volume filter 11, which in use comes into contact with the metal. The type of pressed semi-dry ceramic mixtures used for the filter 11 depends on the type of alloy/metal that passes through it. For example, semi-dry ceramic mixtures are used for aluminium, bronze, brass, and steels, based on the mixtures and the cooking.

[0050] A third category of volume filters that can be installed in the machine 1 may correspond to extruded volume filters 11 (an example of which is shown in Figure 11.) The extruded volume filters 11 are structured in such a way as to: receive in input the molten metal in the semi-solid state, causing a swirling mixing of the molten metal in the semi-solid state during the passage through the filter 11 of the molten metal in a semi-solid state, and to supply in output the molten metal in the mixed semi-solid state. The extruded volume filters 11 have a structure substantially similar to that of the strainer core volume filters described above and differ from the latter in that they are produced using an extrusion process of ceramic materials with plastic behaviour using a mould. In addition, the extruded volume filters 11 have through channels/holes having an approximately rectangular cross-section. The Applicant has found that the use of the extruded volume filters 11 makes it possible to increase the filtering area and thus obtain a greater flow rate of the metal flowing through the cross-section, compared to the strainer core filters. The Applicant has found that the square or rectangular shape allows a higher flow of aluminium. In other words, the filtering area of the surface of the extruded volume filter 11, which in use is affected by the flow/jet of molten metal in the semi-solid state, is about 65% of the total area of the filter surface 11 that comes into contact with the metal, for a lower thermal capacity. It should be specified that a greater density of the holes entails fewer thermal effects. The Applicant has also found that the square cross-section of the holes/channels increases the filtering capacity compared to holes with a circular cross-section.

[0051] The Applicant has also found the use of filters 11 made from ceramic foam (Figure 12) particularly advantageous.

[0052] The ceramic foam filters 11 are structured in such a way as to: receive in input the molten metal in the semi-solid state, causing a swirling mixing of the molten metal in the semi-solid state during the passage through the filter 11 of the molten metal in a semi-solid state, and to supply in output the molten metal in the mixed semi-solid state. The ceramic foam filters 11 are made of ceramic material and comprise a substantially cellular structure formed of open cells. The cells are connected to each other so as to form in the filter body 11 a plurality of paths/channels through the filter. The paths/channels can be made in the filter 11 so that in use the flow of metal passing through the filter is diverted a series of times within the filter itself so that, on the one hand, swirling motions are generated inside the filter (random), and on the other the impurities are retained therein.

[0053] It should be clarified that the ceramic foam filter 11 is particularly convenient for performing deep filtrations i.e. particularly effective, since in use the flow of metal crossing the filter is subject to localized turbulence and sudden changes of direction that encourage the entrapment of metal impurities in the filter 11 itself. It is also appropriate to specify that the dimensions of the trapped inclusions are significantly lower than the internal size of the cells. In other words, in the loops of the path of semi-solid aluminium inside the filter 11, small impurities are deposited. In this regard, the Applicant has found that, in use, the trapped particles accumulate in the channels, forming therein bridges/obstructions that result in a progressive reduction in the flow rate of the filter. As a result, the filter must be sized according to the volume of metal that must pass through it, to the impurities that must be filtered before the filter itself is occluded. It is understood that the flow rate of the metal flowing through the filter 11 depends on several variables, such as the amount of inclusions present in the metal alloy, the internal dimension of the holes/channels of the filter 11, the cohesion force existing between the particles of individual impurities or that present in the filter walls, which in turn depends on the material of the filter 11 itself. The Applicant has found that a thickness of the ceramic foam filter 11 transverse to the lying plane of the filter 11, particularly conveniently is between about 12 mm and about 50 mm.

[0054] The Applicant has also found that the use of ceramic foam filters 11 is particularly advantageous since on the one hand it makes for high efficiency in the depth of metal filtration, and on the other is available in multiple shapes and sizes. Laboratory tests have shown that by varying the size and/or the shape of the ceramic foam filter 11 it is possible to achieve high mechanical strength, low apparent density, high melting temperature, high filtering efficiency, and high casting capacity.

[0055] The Applicant has lastly found that alternatively or in addition to the filters described above it is possible to use volumetric filters formed of a series of overlapping metal meshes (Figure 10) or metal wire pad.

[0056] According to a preferred embodiment shown in Figures 1-5, the machine 1 may further comprise a cooling system to cool down the molten metal contained in the preparation chamber 9. In the example illustrated, the cooling system comprises a cooling device 19, which is placed near the preparation chamber 9 and is suitable to cool the molten metal in the liquid state contained in the preparation chamber 9 to ensure that the molten metal passes from the liquid state to the semi-solid state. According to an exemplary embodiment shown schematically in Figures 1 to 5, the cooling device 19 may be placed/integrated/embedded inside the injection container 8. For example, the cooling device 19 may have an annular shape and could therefore be arranged all around the preparation chamber 9.

[0057] According to a preferred embodiment shown in Figures 1-5, the semi-solid die-casting machine 1 may further comprise a control unit 20, which controls the operation of the semi-solid die-casting machine 1 itself. It is therefore understood that the operating steps implemented by the machine 1 are preferably controlled by the control unit 20.

[0058] According to a preferred embodiment shown in Figures 1-5, the semi-solid die-casting machine 1 may further comprise a heating device 22, which is suitable to heat the filter 11 preferably under the control of the control unit 20. The heating device 22 may be an electrical device, such as a thermo-resistance, which is placed near the feeding channel 13 in a position adjacent to the filter 11 and is suitable to be activated by the control unit 20 to heat the filter 11 itself.

[0059] According to a possible exemplary embodiment shown in the attached Figures 1-5, the heating device 22 may be embedded inside the injection container 8 at/next to the filter 11. For example, the heating device 19 may have an annular shape and may therefore be arranged around the channel 13 so as to surround the filter 11.

[0060] The functioning of the semi-solid die-casting machine 1 for the production of a mechanical part 21 (illustrated in Figure 5) is described below. The Applicant has found that the machine and therefore the method are particularly effective for making pieces 21 corresponding to brake callipers in aluminium alloy for motor vehicles.

[0061] Merely by way of example, the metal used to make the mechanical part 21 may be an aluminium and silicon alloy, for example, the A356 or A357 alloy having a liquidus temperature of 617 °C.

[0062] Initially, as illustrated in Figure 1, the semi-solid die-casting machine 1 is completely empty (i.e., free of molten metal) and the injection piston 10 is fully retracted to give the preparation chamber 9 the maximum size, while the filter 11 is stably placed in the feeding channel 13, preferably at the inlet mouth of the chamber 3.

[0063] Subsequently, as illustrated in Figure 2, the molten metal 25 in the fully liquid state is fed inside the preparation chamber 9 through the feed opening 12. For example, the molten metal 25 can be taken in the fully liquid state from a waiting furnace at about 650°C and may preferably, but not necessarily, be cast by means of a generic casting cup (not illustrated) inside the injection container 8 through the feed opening 12.

[0064] Subsequently and as shown in the example of Figure 3, the injection piston 10 may be moved at a controlled speed, preferably a low speed, and axially along the preparation chamber 9 to reduce the axial dimension of the preparation chamber 9 and thereby concentrate the molten metal 25 next to the feeding channel 13 in contact with the filter 11. In essence, the injection piston 10 may preferably advance at low speed to reduce the volume of the preparation chamber 9 until the molten metal 25 substantially occupies a predetermined useful space of the preparation chamber 9 and is in contact with the filter inlet surface 11.

[0065] Once the molten metal 25 is concentrated in the chamber 9 and partially in the feeding channel 13 of the jet so as to be in contact with the inlet surface of the filter 11 as shown in Figure 3, a partial solidification operation of the metal 25 is performed so that it passes from the fully liquid state to the semi-solid state. In the example shown in Figure 3, the machine 1 can activate the cooling device 19 to reduce the temperature of the metal 25 in a controlled manner until it reaches a predetermined temperature threshold of about 580°C.

[0066] For example, the achievement of the semi-solid state by the metal 25 may occur due to the cooling effect induced by the contact of the metal 25 with the walls of the preparation chamber 9 (i.e., with the walls of the injection container 8), suitably cooled by the cooling device 19 controlled by the control unit 20 based on one or more temperatures measured by respective temperature sensors (not shown) suitably arranged in the container 8.

[0067] In the example shown in Figure 3, the machine

1 can also activate the heating device 22 to ensure that the filter temperature 11 is increased in a controlled manner until it reaches a predetermined temperature. Preferably, the predetermined heating temperature of the filter 11 may be approximately equal to the predetermined temperature threshold of the metal. The Applicant has found that heating the filter 11 results in the technical effect of limiting the impact force of the incoming metal and preventing the breakage of the filter 11 itself.

[0068] After completion of the semi-solidification phase of the molten metal 25, which is achieved at the predetermined temperature threshold, the injection piston 10 can be further axially moved along the preparation chamber 9 (as illustrated in Figure 4) to further reduce the axial dimension of the preparation chamber 9 and thereby push (inject) the metal 25 in the semi-solid state through the filter 11 contained in the feeding channel 13 of the jet, to ensure that the metal 25 in the semi-solid state in output from the filter 11 is injected into the moulding chamber 3.

[0069] In this phase, the molten metal in the semi-solid state at the temperature corresponding to the predetermined temperature threshold is pushed with a certain pressure into the channel 13 so as to cross the holes/channels of the filter 11, preferably continuously, i.e. without interruption.

[0070] The technical effect of the filter 11 on the molten metal in the semi-solid state that passes through it, is to cause localized swirling movements. In particular, the effect of the channels/holes of the filter 11 on the flow of metal, is to temporarily break down/divide the latter into a series of micro-flows (micro-jets) and to change the speed/flow rates and lines/directions of the micro-flows thereby causing a plurality of swirling movements inside the filter 11 itself. In this regard it should be clarified that laboratory tests carried out by the Applicant have shown that the localized swirling movements imparted to the metal inside the filter 11 make it possible to achieve an overall stirring of the metal sufficient to obtain a globular microstructure material, i.e. the mixing of the molten metal in the semi-solid state. This globular microstructure will then be able to give the molten metal 25 in the semi-solid state in output from the filter 11 and injected into the chamber 3 marked rheological characteristics. It should also be clarified that laboratory tests performed by the Applicant have also shown that the behaviour of the metal in the semi-solid state as it crosses the filter 11 when the temperature of the metal itself corresponds to the predetermined temperature threshold, is substantially similar to that of a metal in the liquid state. As a result, although the metal is partially slowed and mixed internally by the filter 11 as described above, it is able to easily cross the holes/channels of the filter 11 despite its semi-solid state, if subjected to a certain pressure and a temperature corresponding to the aforementioned temperature threshold.

[0071] It is understood that the thrust and pressure of the molten metal in the semi-solid state in the channel 13 and through the filter 11 may conveniently be adjusted/controlled by the control unit 20 by controlling the displacement of the piston 10 in the chamber 9.

[0072] The control unit 20 can control the piston 10 in the chamber 9 to adjust the speed of the metal 25 in the semi-solid state passing through the filter 11. Laboratory tests performed by the Applicant have shown that if the molten metal in the semi-solid state crosses the filter 11 with a speed of between 0.2 metres/second and 5 metres/second, on the one hand the mixing of the semi-solid metal in the filter 11 is conveniently achieved and on the other the semi-solid state of the metal in output from the filter 11 is conveniently maintained following its mixing. The control unit 20 is thus configured to control the displacement of the piston 10 based on an injection control parameter (stored) indicative of the crossing speed of the metal in the filter, wherein this parameter is fixed/stored so that in use, the metal 25 in the semi-solid state enters the filter 11 and leaves the same in the semi-solid state so as to then be injected into the moulding chamber 3.

[0073] In this phase, the filter 11 receives in input the metal 25 in the semi-solid state, mixes it with swirling movements thanks to its internal structure and to the thrust which the metal 25 is subjected to during crossing, and provides in output the metal 25 in the semi-solid state. It is understood that the filter 11 is structured so that it does not cause a change to the state of the metal 25 that passes through but keeps it in the semi-solid state in output also.

[0074] Once the filling of the moulding chamber 3 with metal 25 in the semi-solid state is completed and once an appropriate cooling time has elapsed such as to allow the molten metal 25 to cool enough to acquire a solid state (i.e. to assume a form that is no longer modifiable), the die-casting mould 2 can be opened for example by moving the mobile die 4 to extract the finished mechanical part 21 (as shown in Figure 5).

[0075] The above-described semi-solid die-casting machine 1 has numerous advantages.

[0076] First, the semi-solid die-casting machine 1 described above is extremely economical to construct, since it simply requires the installation of a filter and of a heating device 22 of the filter 11.

[0077] In addition, the above-described semi-solid die-casting machine 1 makes it possible to proceed directly with the injection of metal in the semi-solid state inside the die-casting mould without the need for any additional transfer since, as described, the metal in the semi-solid state is mixed/stirred/prepared in the channel of the mould itself. The known processes instead provide that the mixing phase is carried out in dedicated recipients or equipment and it is only at the end of this operation that the paste material can be poured into the injection container. Consequently, the fraction of solid may not exceed values to the order of 10-15% otherwise the high viscosity of the semi-solid might prevent the very casting operation.

[0078] It has therefore been shown that the present invention makes it possible to achieve the objectives indicated above.

[0079] Finally, it is clear that modifications and variants may be made to the die-casting machine and the method described and illustrated herein while remaining within the scope of the present invention defined by the appended claims.

Claims

1. A semi-solid die-casting machine (1);
the semi-solid die-casting machine (1) comprises:

a die-casting mould (2) inside which a moulding chamber (3) is made to receive a molten metal (25) in the semi-solid state;
an injection container (8) provided with a preparation chamber (9) designed to contain said molten metal (25) in the semi-solid state;
a feeding channel (13) of the jet of molten metal in the semi-solid state designed to place in fluidic communication said injection container (8) with said moulding chamber (3);
pressing means (10) designed to push the molten metal (25) in semi-solid state contained in said injection container (8) into said moulding chamber (3) through said feeding channel (13);
at least one filter (11), which is placed in said feeding channel (13) of the jet of metal, and is structured so as to receive in input the molten metal (25) in the semi-solid state and to supply in output the molten metal in the semi-solid state to feed it to said moulding chamber (3) .

2. The machine (1) according to claim 1, wherein:

said channel (13) feeds the molten metal (25) in the semi-solid state in input to the filter (11) so that the molten metal (25) in the semi-solid state passes through the filter (11) at a predetermined speed, and receives in output from the filter (11) the molten metal (25) in the semi-solid state;
said filter (11) being structured so as to cause a swirling mixing of the molten metal in the semi-solid state without altering the semi-solid state, when it is crossed by the molten metal in the semi-solid state at said predetermined speed.

3. The semi-solid die-casting machine (1) according to claim 2, comprising control means (20) configured to control said pressing means (10) so that the molten metal in the semi-solid-state crosses said filter (11) at said predetermined speed.

4. The semi-solid die-casting machine (1) according to any one of the preceding claims, wherein said feeding channel (13) of the jet of molten metal in the semi-solid state is made at least partially in said die-casting mould (2) .

5. The semi-solid die-cast machine (1) according to any one of the claims from 1 to 3, wherein said filter (11) is arranged stably in said feeding channel (13) immediately against the inlet of said moulding chamber (3).

6. The semi-solid die-casting machine (1) according to any one of the claims from 3 to 5, comprising cooling means (19) designed to cool the molten metal in the liquid state contained in said preparation chamber (9) in a controlled manner; said control unit (20) being configured so as to control said cooling means (19) to perform a partial solidification operation (25) of the metal so that it passes from the fully liquid state to said semi-solid state.

7. The semi-solid die-casting machine (1) according to any one of the preceding claims, wherein said filter (11) is structured so as to provide in output a flow of molten metal in the semi-solid state with an approximately laminar flow.

8. The semi-solid die-casting machine (1) according to any one of the claims from 3 to 7, comprising heating means (22) designed to heat said filter (11).

9. The semi-solid die-casting machine (1) according to any one of the preceding claims, wherein said filter (11) comprise: a thin perforated plate-shaped element and/or a cloth flat filter and/or volume filter and/or a strainer core filter and/or an extruded filter and/or a ceramic foam filter.

10. A semi-solid die-casting method;
the semi-solid die-casting method comprises the steps of:

feeding the molten metal (25) in a completely liquid state into a preparation chamber (9) made in an injection container (8);
carrying out a semi-solidification of the liquid molten metal (25) inside said preparation chamber (9) so as to transform it into a molten metal in the semi-solid state;
feeding the molten metal (25) in a semi-solid state contained in said preparation chamber (9) into a moulding chamber (3) made in a die-casting mould (2), through a feeding channel (13),
placing a filter (11) in said feeding channel (13) of the jet of metal so that the filter (11) receives in input the molten metal (25) in the semi-solid state and supplies in output the molten metal in the semi-solid state to feed it to said moulding chamber (3).

11. The semi-solid die-casting method according to claim 10, wherein said channel (13) feeds the molten metal (25) in the semi-solid state in input to the filter (11) so that the molten metal (25) in the semi-solid state passes through the filter (11) at a predetermined speed, and receives in output from the filter (11) the molten metal (25) in the semi-solid state;
said filter (11) being structured so as to cause a swirling mixing of the molten metal in the semi-solid state without altering the semi-solid state, when it is crossed by the molten metal in the semi-solid state at said predetermined speed.

12. The semi-solid die-casting method according to any of the claims 10 or 11, wherein said feeding channel (13) of the jet of molten metal cast in the semi-solid state is obtained at least partially in said die casting mould (2).

13. The semi-solid die-cast method according to any of the claims 10 or 11, wherein said filter (11) is arranged stably in said feeding channel (13) immediately against the inlet of said moulding chamber (3).

14. The semi-solid die-casting method according to any of the claims from 10 to 13 wherein said filter (11) is structured so as to provide in output a flow of molten metal in the semi-solid state with an approximately laminar flow.

15. The semi-solid die-casting method according to any of the claims from 10 to 14, wherein said filter (11) may comprise: a thin perforated plate-shaped element and/or a cloth flat filter and/or volume filter and/or a strainer core filter and/or an extruded filter and/or a ceramic foam filter.

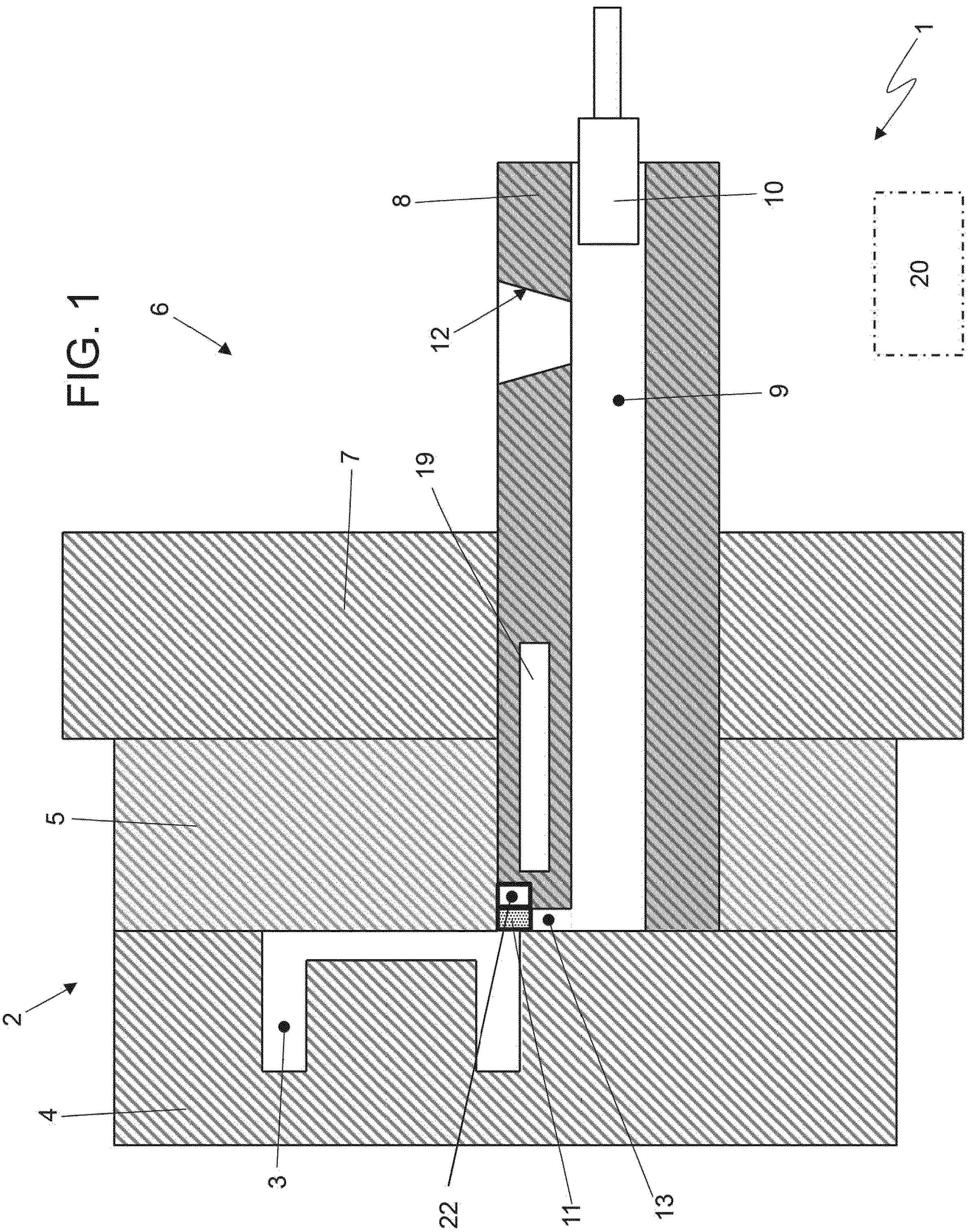


FIG. 1

FIG. 2

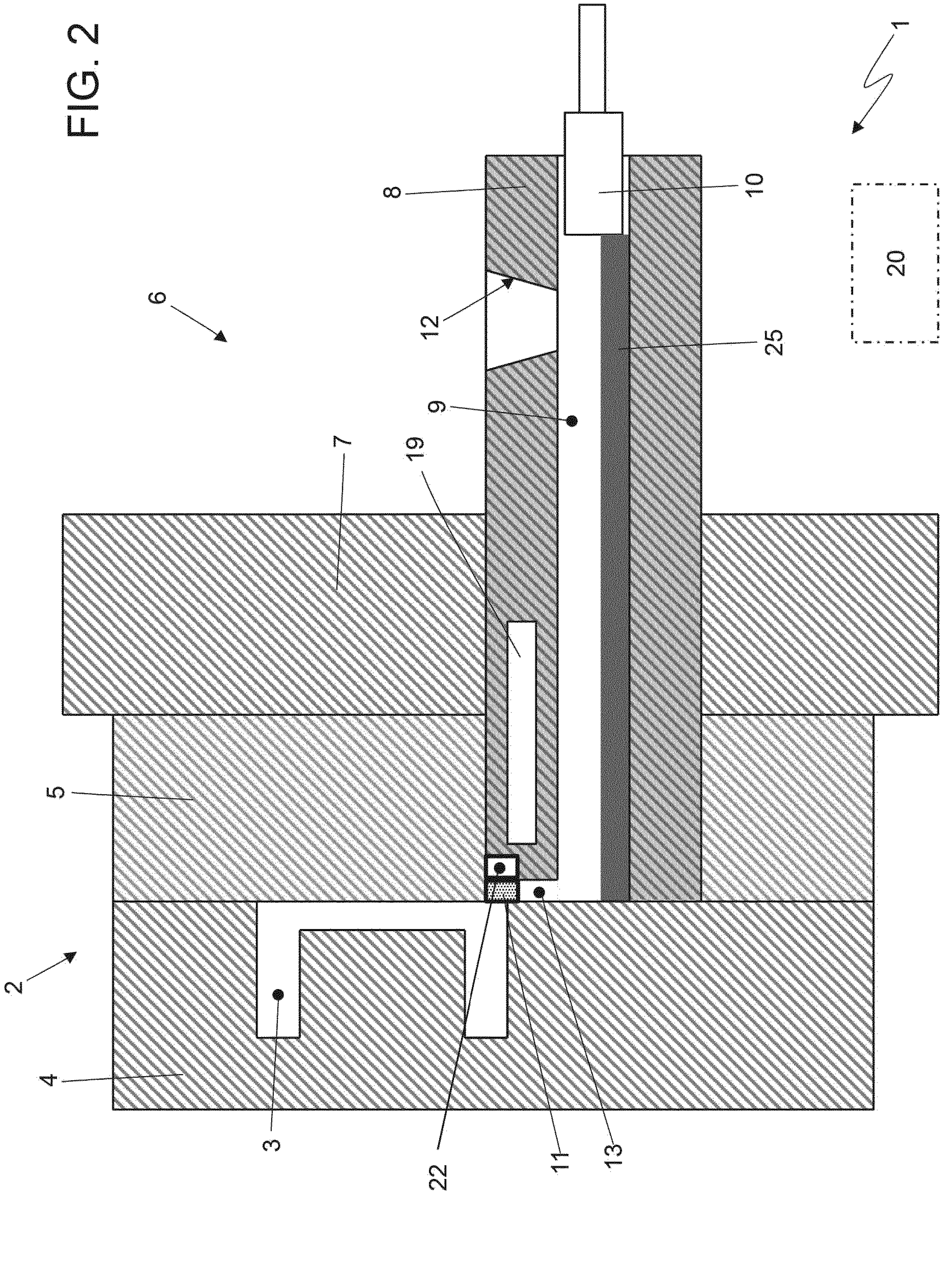
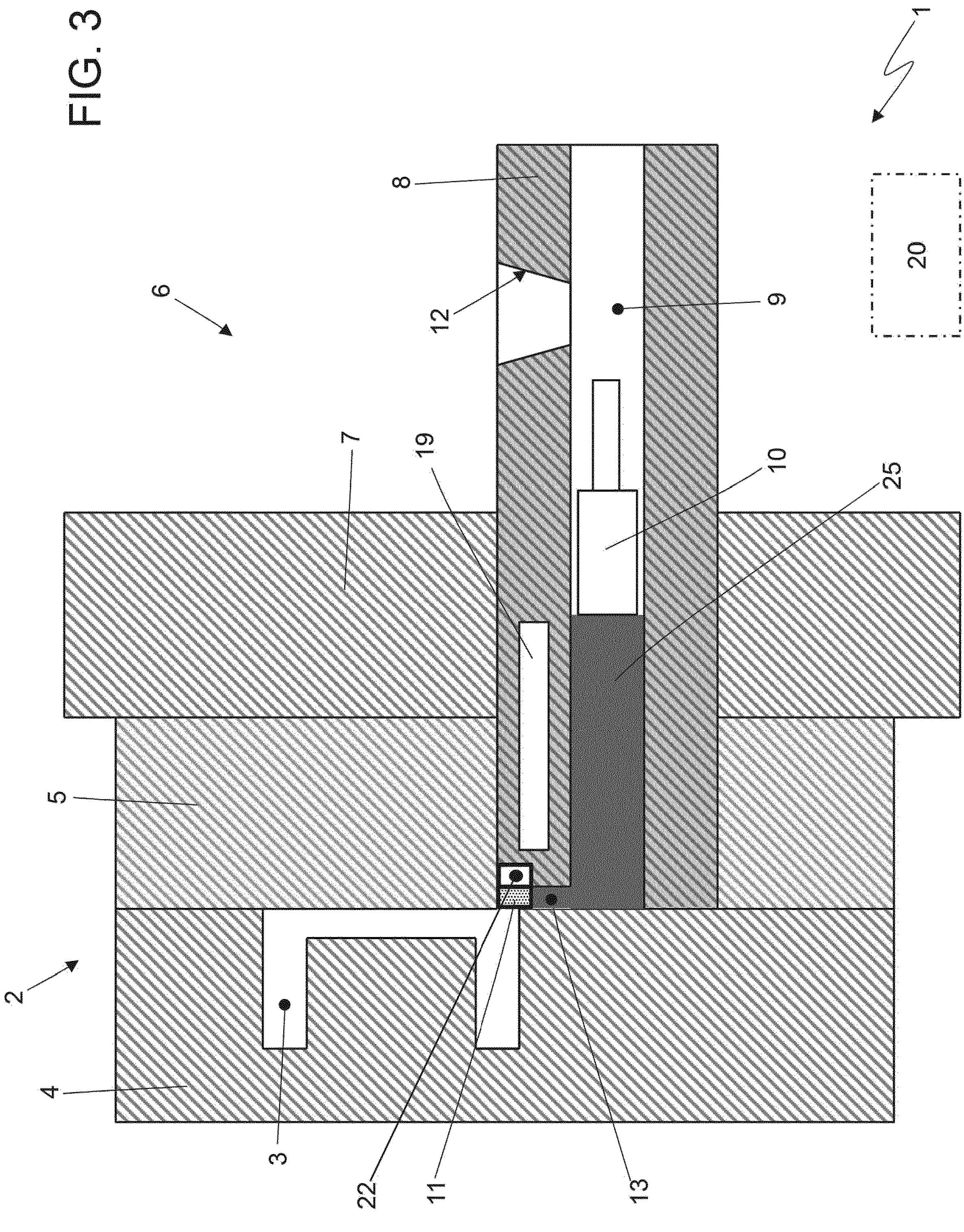


FIG. 3



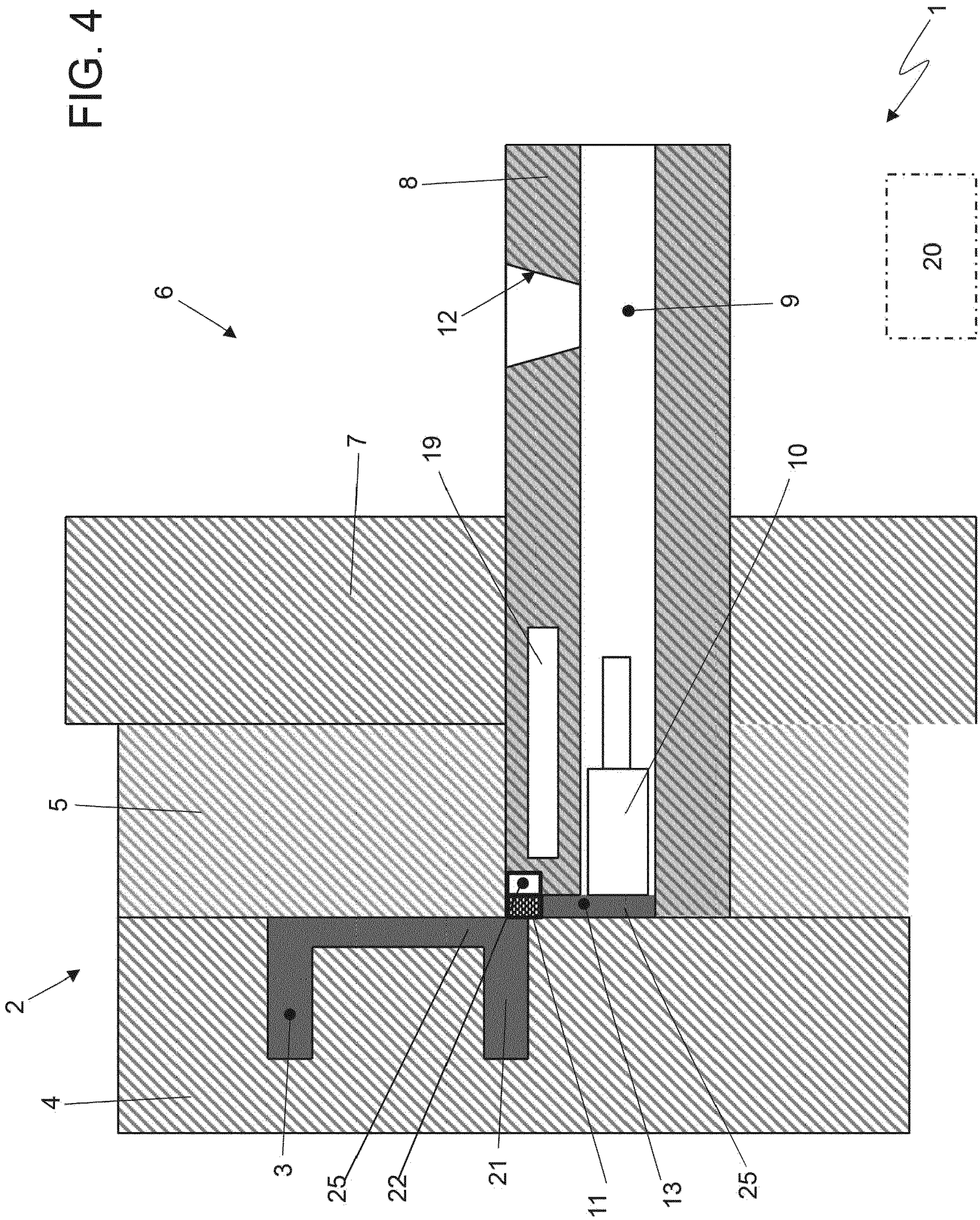


FIG. 4

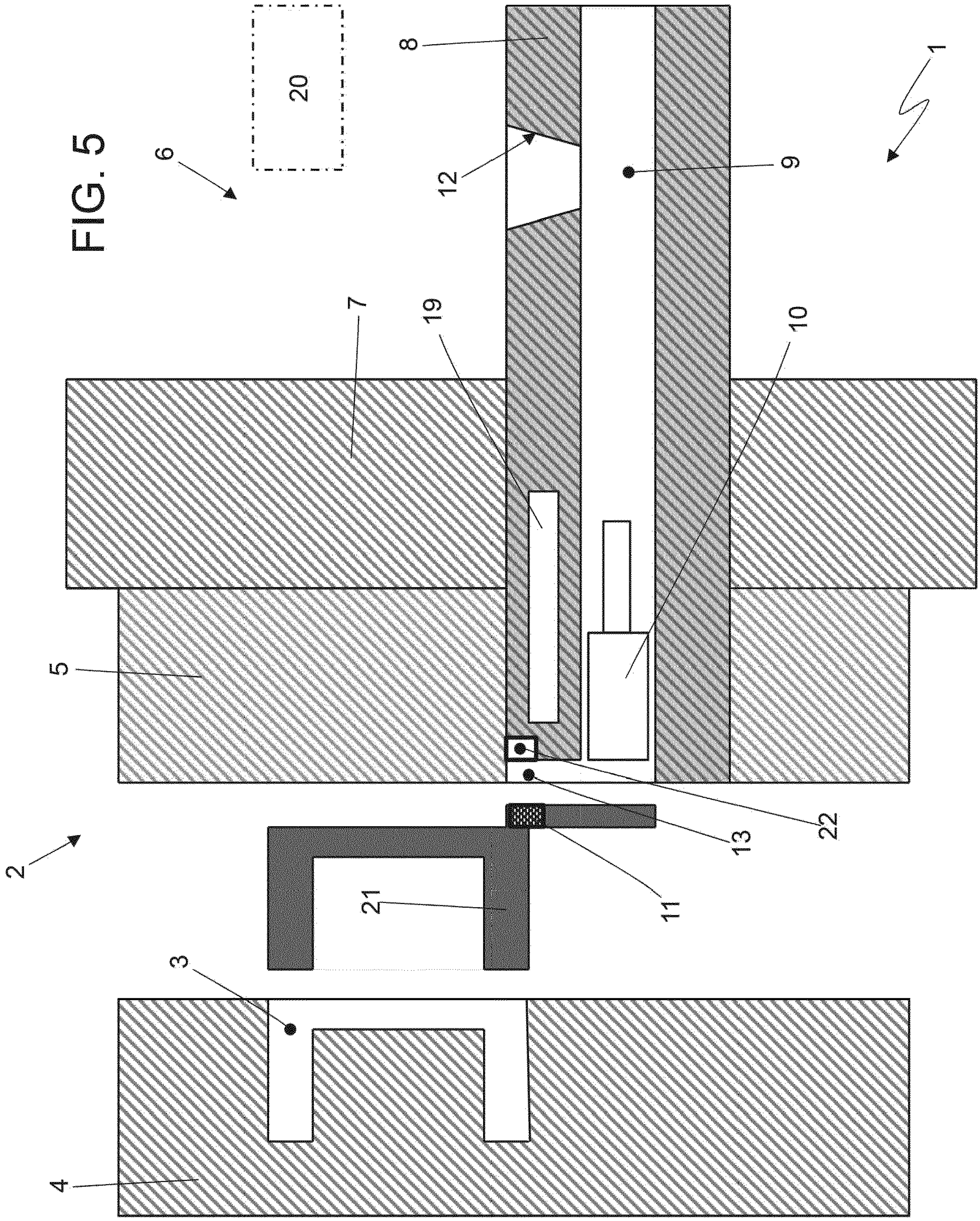


FIG. 5

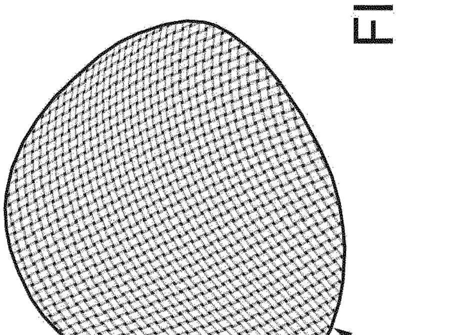


FIG. 6

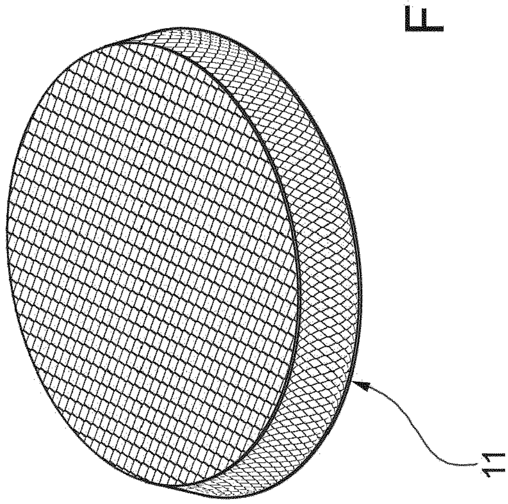


FIG. 7

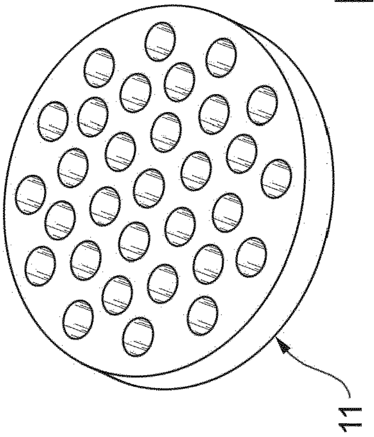


FIG. 8

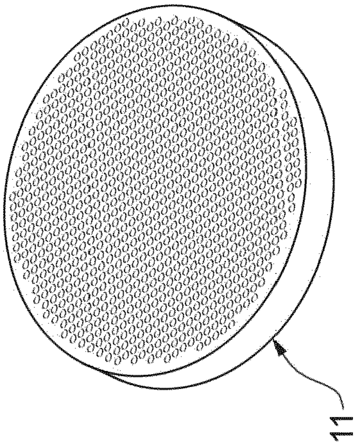


FIG. 9

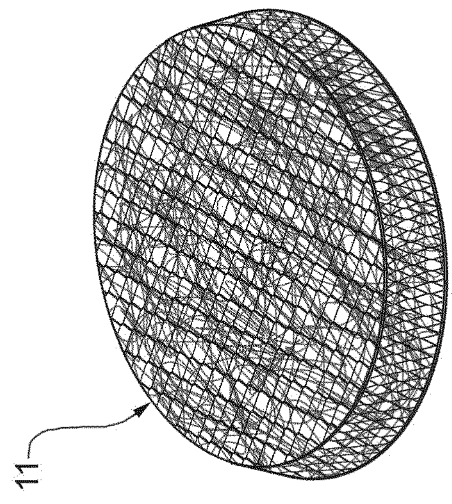


FIG. 10

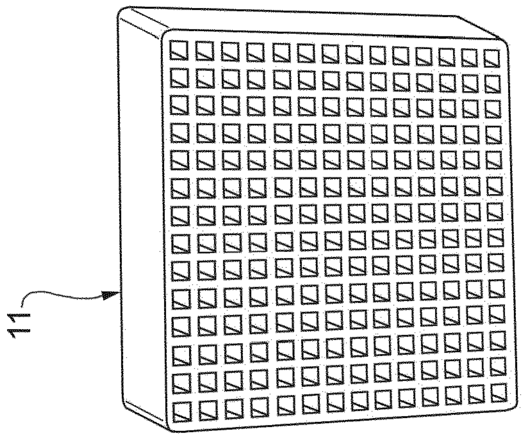


FIG. 11

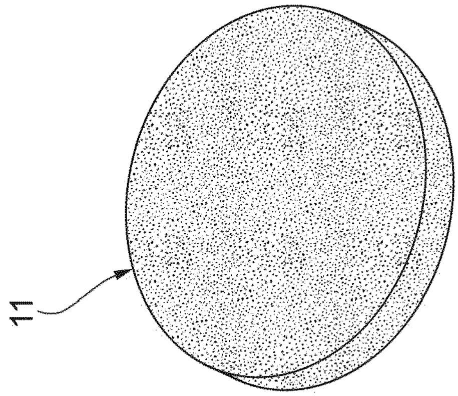


FIG. 12

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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 3765

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	8 May 2018	Baumgartner, Robin

CATEGORY OF CITED DOCUMENTS

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