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(54) **METHOD FOR MANUFACTURING A REINFORCED BI-METALLIC CASTING COMPOSITE AND APPARATUS FOR MANUFACTURING A REINFORCED BI METALLIC CASTING COMPOSITE**

(57) A method for manufacturing a reinforced bi-metallic casting composite is provided, wherein at least one metallic insert (2) is provided in a die (3) and a metal over casting step is performed, wherein, by means of said metal over-casting step, an over-cast metal (14) is casted at least partly over said at least one metallic insert (2). The method comprises the following steps: a) providing said at least one metallic insert (2) being in a preformed condition; b) introducing said at least one metallic insert (2) being in its preformed condition into said die (3); c) holding said at least one metallic insert (2) being in its preformed condition in a predetermined position in said die (3); d) performing a closing operation of said die by means of a closing element (9); e) performing a deformation operation, wherein, by means of said deformation operation, said at least one metallic insert (2) being in its preformed condition is deformed from its preformed condition into a casting condition; f) performing said metal over-casting step, wherein said over-cast metal (14) is casted at least partly over said at least one metallic insert (2) being in its casting condition; g) solidification of said over-cast metal (14); and h) extracting said at least one metallic insert (2) together with said over cast metal (14) from said die (3). An apparatus (1) for manufacturing a reinforced bi-metallic casting composite, preferably for performing said method, is also provided, comprising: a die (3), wherein said die comprises a moulding cavity (4); and a closing element (9) being movable in a closing direction (8) for closing said moulding cavity (4). The apparatus (1) further comprises: at least one actuator (11; 5) being adapted to perform a deformation operation to a metallic insert (2) when being arranged inside of said moulding cavity (4), wherein said at least one actuator (11; 5) is a mechanical actuator, a hydraulic actuator, a pneumatic actuator, a magnetic actuator or an electric actuator.

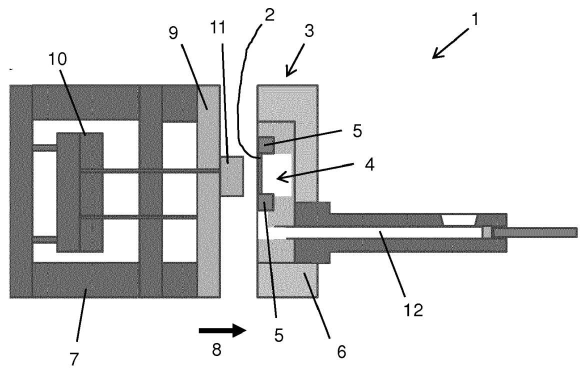

Fig. 2A

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method for manufacturing a reinforced bi-metallic casting composite. Furthermore, the present invention relates to an apparatus for manufacturing a reinforced bi-metallic casting composite.

STATE OF THE ART

[0002] Metallic casting composites are well-known in the state of the art and are used in a wide variety of applications. In particular, it is known to reinforce a metallic casting component in order to improve, by way of an example, the strength of such metallic casting component for its eventually intended purpose.

[0003] For example, it is known to reinforce a metallic casting component by another metallic component having a higher strength, or alternatively having another preferred characteristic, in order to eventually achieve a so-called bi-metallic casting composite of higher strength, or alternatively with another preferred characteristic, in comparison to the metallic casting component without said reinforcement.

[0004] In this context, in the present patent application, it is referred to a reinforced bi-metallic casting composite when a bi-metallic casting composite is meant which, in order to achieve a reinforcement, is manufactured by the steps of providing a first metallic component and, then, casting a metal at least partly around said first metallic component. In this manner, a reinforced bi-metallic casting composite is obtained which comprises said first metallic component as kind of an insert and which further comprises a casted second metallic component at least partly around said insert as kind of an overcasting second metallic component.

[0005] Several methods and apparatuses for manufacturing such reinforced bi-metallic casting composites are known. In GB 873012 A, a reinforced bi-metallic casting composite in terms of a brake drum or an engine cylinder is described. The reinforced bi-metallic casting composite is manufactured by two sequent casting processes. That is, in a first step, a metallic insert is manufactured by centrifugal casting and, in a second step, a light metal is casted on said metallic insert. Due to the two sequent casting steps, the method is highly time-consuming as well as cost-intensive. That is, after the first casting step, the casted metallic insert needs to cool down, to solidify and to be removed from a first mould before the second casting step can be realised in a second mould into which the casted metallic insert needs to be placed.

[0006] From WO 9002017 A1, it is known a method for manufacturing a reinforced bi-metallic casting composite in terms of a valve block wherein, in a first step, a cylinder is cold forged and, in a following step, said cold-forged cylinder is inserted into a mould in which metal is injection moulded around said cylinder. Said first step in terms of forming a pre-shaped cylinder to be moulded later in said second step requires several forming operations to be executed by at least one further apparatus. Accordingly, at least two different apparatuses are needed for the two steps in terms of forming a pre-shaped cylinder and injection moulding around said cylinder. Therefore, the method is extensive regarding the necessary apparatuses for manufacturing a reinforced bi-metallic casting composite and, moreover, the method is highly time-consuming as well as cost-intensive.

[0007] Similar methods and apparatuses for manufacturing a reinforced bi-metallic casting composite are known from US 2014290894 A1, US 2004222665 A1, as well as from US 2016137232 A1. It is known from said prior art to manufacture reinforced bi-metallic composites in at least two sequent main stages. That is, in a first step, a first metallic component in terms of a metallic insert is formed in a first apparatus and then is provided for the following step, wherein, in said following step, the metallic insert is placed into a mould and then a metal is casted at least partly around said metallic insert. Hence, at least two different apparatuses are needed for said at least two sequent main stages in terms of forming a metallic insert in a first apparatus and casting metal around said metallic insert in a second apparatus in terms of the mould. Therefore, the methods are extensive regarding the necessary apparatuses for manufacturing a reinforced bi-metallic casting composite and, moreover, the methods are highly time-consuming as well as cost-intensive.

[0008] Therefore, there is a need for manufacturing reinforced bi-metallic casting composites in a less time-consuming and less cost-intensive manner.

DESCRIPTION OF THE INVENTION

[0009] It is an object of the invention to provide a method for manufacturing a reinforced bi-metallic casting composite according to which reinforced bi-metallic casting composites can be manufactured in a less time-consuming and less cost-intensive manner.

[0010] This object is solved by a method for manufacturing a reinforced bi-metallic casting composite according to claim 1. Advantageous embodiments are described in the claims referring back to claim 1.

[0011] Furthermore, it is an object of the invention to provide an apparatus for manufacturing a reinforced bi-metallic casting composite by means of which apparatus reinforced bi-metallic casting composites can be manufactured in a less time-consuming and less cost-intensive manner.

[0012] This object is solved by an apparatus according to claim 14 and an advantageous embodiment is described in the claim referring back to claim 14.

[0013] In detail, according to the present invention, it is provided a method for manufacturing a reinforced bi-metallic casting composite, wherein at least one metallic insert is provided in a die and a metal over-casting step is performed, wherein, by means of said metal over-casting step, an over-cast metal is casted at least partly over said at least one metallic insert. The method is characterised in that it comprises the following steps: a) providing said at least one metallic insert being in a preformed condition; b) introducing said at least one metallic insert being in its preformed condition into said die; c) holding said at least one metallic insert being in its preformed condition in a predetermined position in said die; d) performing a closing operation of said die by means of a closing element; e) performing a deformation operation, wherein, by means of said deformation operation, said at least one metallic insert being in its preformed condition is deformed from its preformed condition into a casting condition; f) performing said metal over-casting step, wherein said over-cast metal is casted at least partly over said at least one metallic insert being in its casting condition; g) solidification of said over-cast metal; and h) extracting said at least one metallic insert together with said over-cast metal from said die.

[0014] In general, according to the present invention, the single steps of the described method are performed in the mentioned order, starting from step a) and proceeding until step h). However, to some extent, amendments of the order of said steps are possible as well. For instance, said steps d) and e), that is the closing operation and the deformation operation, can be performed in exchanged order or even at the same time. In other words, the deformation operation of the metallic insert can also be performed before the die is closed or while the die is being closed.

[0015] As material for the metallic insert, a material can be selected out of the group: steel, iron, aluminium, copper, magnesium, titanium alloy, or any alloy or combination of the mentioned metals. As material for the over-cast metal, a material can be selected out of the group: steel, iron, aluminium, copper, magnesium, titanium, zinc alloy, or any alloy or combination of the mentioned metals. In general, the materials of the metallic insert as well as of the over-cast metal can be the same. However, preferably, a material for the metallic insert is used that differs from the material being used for the over-cast metal in that the metallic insert material has a higher melting point than the over-cast metal material. In particular, the metallic insert can be a metallic sheet, preferably a steel sheet. Thus, a reinforced bi-metallic casting composite can be achieved that combines the positive effects of the different materials used for the insert and for the outer over-cast metal.

[0016] With a preformed condition of the metallic insert, it is meant an unfinished shape of the metallic insert, that is, the metallic insert has a shape differing from its intended final shape which it is supposed to have when being integrated into the reinforced bi-metallic casting composite to be manufactured. For instance, a substantially even, flat thin steel sheet corresponds to a metallic insert in a preformed condition.

[0017] Due to the deformation operation, the metallic insert is deformed from the preformed condition to a casting condition. The casting condition can correspond substantially to the finally intended shape of the metallic insert which it is supposed to have in the reinforced bi-metallic casting composite to be manufactured. Minor further amendments, for instance due to the following over-casting step, can still occur. Such further changes of the shape of the metallic insert due to the following over-casting step also can be considered already when performing the deformation operation for shaping the metallic insert into the casting condition. In this case, the casting condition of the metallic insert does not yet entirely correspond to the final intended shape of the metallic insert in the reinforced bi-metallic casting composite to be manufactured. However, due to the deformation operation, a substantial change of the shape of the metallic insert from its preformed condition to its casting condition is achieved. Accordingly, with the casting condition of the metallic insert, it is meant the finished or nearly finished shape of the metallic insert, that is, the metallic insert has a shape corresponding to or almost corresponding to its intended final shape which it is supposed to have in the reinforced bi-metallic casting composite to be manufactured and which is differing from the shape of the metallic insert in the preformed condition. For instance, the substantially even, flat thin steel sheet of the metallic insert in its preformed condition can be deformed in the casting condition to a not anymore even metallic insert comprising two shoulder sections at opposite ends of the metallic insert resulting in a metallic insert having a U-shaped cross-section.

[0018] The deformation operation can be a stamping operation and, in particular, a hot deformation operation such as hot stamping.

[0019] With a metal over-casting step, it is meant a common casting operation inside of the die, due to which casting operation melted metal is casted into a moulding cavity of the die. The metallic insert being arranged inside of the die, or in particular inside of the moulding cavity, is being moulded or over-casted by said metal over-casting step. That is, the metallic insert is being contacted at its outer surface at least partly with the melted metal. Also, the metallic insert can be entirely covered, that is entirely over-casted, within the metal over-casting step. The casting operation preferably corresponds to a high pressure die casting. However, the used casting machine can also be another die casting, squeeze, semi-permanent or low pressure casting machine. Depending on the casting process, the pressure over the metallic insert varies from a few bars till approximately 1.200 bars in a high pressure die casting and up to approximately 2.000 bars in a squeeze casting.

[0020] Under a solidification of said over-cast metal, the process is meant according to which the casted melted metal is solidified by cooling down at least below the melting point. The solidification according to the described method can be passive but can also be actively promoted for instance by actively cooling the die. The solidification of the over-cast metal can be entirely completed before the next step of the method, that is the extraction of the metallic insert together with the over-cast metal from said die (step g)), is performed. However, the next step (step g)) can also be performed when the solidification of the over-cast metal has not been completed yet. In this instance, the solidification of the over-cast metal has to have been proceeded already to a point that permits the metallic insert together with the over-cast metal to be extracted from said die. The step of extracting said at least one metallic insert together with said over-cast metal from said die usually also includes the step of opening the die.

[0021] According to the described method, at least one metallic insert can be used and finally integrated as reinforcement into the reinforced bi-metallic casting composite. However, it is also possible to use and integrate two or more metallic inserts.

[0022] As a result, after extracting the at least one metallic insert together with the over-cast metal from said die, the obtained product is a reinforced bi-metallic casting composite as kind of a metal matrix composite with a metallic insert in terms of, for instance, a sheet. All the mentioned steps of the method can be performed by one singular die. There is no necessity for further apparatuses to perform the deformation of the metallic insert into its finally intended shape as well as to perform the embedding of this metallic insert with the over-cast metal. Accordingly, a method for manufacturing a reinforced bi-metallic casting composite is achieved according to which reinforced bi-metallic casting composites can be manufactured in a less time-consuming and less cost-intensive manner. A reduction in space for the machinery, as well as a reduction of the machinery and the production cost and an increase of the process productivity is obtained.

[0023] In a preferred embodiment, said deformation operation is performed by at least one actuator, wherein said at least one actuator is a mechanical actuator, a hydraulic actuator, a pneumatic actuator, a magnetic actuator or an electric actuator. It is preferred to have two or more actuators. The actuators can be arranged inside or outside of the moulding cavity of the die but also, in case of being arranged outside of the moulding cavity, the actuators form a part of the die and are adapted to interact with the metallic insert in its preformed condition after being introduced into the moulding cavity. The actuators execute the deformation operation of the metallic inside due to their movements. The actuators can perform lineal, rotating or combined movements in order to permit the deformation. Furthermore, the actuators can guarantee the positioning of the insert in the die. Thus, the actuators can also be responsible to perform step c) of the method, that is, holding the metallic insert in a predetermined position in the die. Thereby, the actuators can also be positioners at the same time. The actuators can also have a retractile movement, that is they can be retractable, in order to leave enough space for the melted over-cast metal to flow into the moulding cavity of the die and to be casted around the metallic insert. The actuators or positioners can be spacer rods mounted retractably on springs, which press against the deformable section of the metallic insert. In general, the actuators can perform the deformation operation by means of magnetism, adhesion, extraction, vacuum, suction cups or gravity.

[0024] In a particular embodiment, said deformation operation is performed before said closing operation. In other words, step e) of the method in terms of the deformation operation is performed before step d), that is before the die is being closed.

[0025] In another particular embodiment, said deformation operation is performed after said closing operation. In other words, step e) of the method in terms of the deformation operation is performed after step d), that is after the die has been closed.

[0026] In a particular embodiment, said deformation operation is performed at least partly by means of said closing operation and, after said deformation operation, a retraction and closing operation is performed, wherein, by means of said retraction and closing operation, said closing element is reversed at least partly and a further closing operation of said die is performed. Accordingly, steps d) and e) of the method are performed kind of at the same time. The closing operation can, thereby, be responsible for the deformation operation of the metallic insert. In case of at least one actuator performing the deformation operation, the actuator can be integrated into the closing element, by means of which closing element the closing operation is performed. The deformation operation can be performed at least partly by means of the closing operation, that is, the deformation operation can additionally be performed by further operations such as actuator operations of actuators being additionally arranged inside of the moulding cavity. In this case, a combination of actuators inside of the moulding cavity and of the closing operation execute the intended deformation operation. A sequent retraction and closing operation is performed so that, first, the closing element is reversed at least partly again in order to leave enough space for the melted over-cast metal to later flow into the moulding cavity of the die and to be casted around the metallic insert. Second, after the closing element is reversed at least partly, the die may need to be closed again in order to allow the sequent over-casting step. Due to said particular embodiment, an effective method is achieved as the movement of the necessary closing operation can be combined with the necessary movement of the deformation operation, such as hot stamping. The closure force of the closing element can be used effectively to perform the deformation operation.

[0027] In a particular embodiment, said retraction and closing operation includes a sliding movement of said closing element to a side substantially perpendicular to a closing direction of said closing element. Due to the reverse movement of the closing element in combination with the sliding movement, it is left enough space for the melted over-cast metal to later flow into the moulding cavity of the die and to be casted around the metallic insert.

[0028] In another particular embodiment, said retraction and closing operation includes a rotation movement of said closing element around an axis being substantially parallel to a closing direction of said closing element. Due to the reverse movement of the closing element in combination with the rotation movement up to a predetermined angle, it is left enough space for the melted over-cast metal to later flow into the moulding cavity of the die and to be casted around the metallic insert.

[0029] In a particular embodiment, said die is a thermally regulated die, wherein said thermally regulated die can control a die temperature, in particular different die temperatures in different areas of the die, in a range from 80°C to 500°C, preferably from 200°C to 400°C, in particular by means of at least one temperature sensor and by means of at least one temperature controller, preferably a PID controller. It is preferred that the die can be heated, in particular heated differently in different areas or zones of the die. Thus, an effective heat transfer from the heated die surfaces to the metallic insert being placed into the die can be achieved. As a preparation of the deformation operation, it can be preferred that different areas of the metallic insert are heated in a different manner. Thus, the metallic insert can be deformed from its preformed condition to its casting condition effectively. Providing the thermally regulated die, accordingly, is advantageous for the deformation operation of the metallic insert. Also, finally intended properties of the reinforced bi-metallic casting composites can be influenced by regulating the temperature of the metallic insert before the over-casting step, in particular by providing different areas of the metallic insert with a different temperature. It is preferred that each area of the die to be heated differently has a single temperature sensor and a single temperature controller, preferably a PID controller, in order to control the temperatures of the different areas in an effective manner. In order to maintain the thermal control of the die effectively, a cooling system as well as a heating system can be employed into the die. The cooling and heating systems can be cartridge heaters, jet cooler, water and oil coolers and other temperature controlling systems or combinations thereof.

[0030] In another particular embodiment of the method, during the solidification of said over-cast metal, at least one actuator element, in particular at least one squeeze pin, squeezes said over-cast metal when said over-cast metal is in a semi-solid state. Accordingly, a final product in terms of the reinforced bi-metallic casting composite can be achieved with better properties in comparison to a product not having been squeezed in its semi-solid state, since, for example, the shrinkage porosity is reduced or, respectively, the union of the metallic insert and the over-cast metal is increased. As the at least one actuator element, also at least one of the actuators can be used that perform the deformation operation.

[0031] In another particular embodiment of the method, after step h), a finishing operation is performed to said at least one metallic insert together with said over-cast metal. Such finishing operation, after the reinforced bi-metallic casting composite has been removed from the die, can be, for instance, a trimming operation or any other machining or finishing process. Thus, a reinforced bi-metallic casting component of higher quality can be achieved.

[0032] In a particular embodiment of the method, after said at least one metallic insert together with said over-cast metal has been extracted from said die, inner surfaces of said die are cleaned at least partly and sprayed at least partly with a de-moulding agent. Thus, it can be avoided that some parts of the over-cast metal get stack in the die. This can be supported by a possible temperature control of the different zones inside of the die. As a result, an efficient method is achieved as the next production cycle for manufacturing a reinforced bi-metallic casting composite can be initiated faster. The spraying and a sequent drying process that is employed after the bi-metallic cast part is ejected from the die can be also employed to maintain a desired die temperature in every section of the die before starting a new manufacturing cycle.

[0033] In another particular embodiment, said at least one metallic insert being in a preformed condition is provided in a pre-heated condition. Thus, a more efficient method can be achieved as the time for the possible internal heating of the metallic insert before the step of performing the over-casting of the metallic insert can be reduced.

[0034] In a particular embodiment of the method, before step a), a pre-shaping operation is performed to said at least one metallic insert in order to achieve said preformed condition of said at least one metallic insert, preferably by means of cutting, cold or hot pressing, 3D prototyping, casting or machining of said at least one metallic insert. Thus, a reinforced bi-metallic casting composite comprising a metallic insert as reinforcement with an arbitrarily complex shape can be achieved. Potential limits to deform the shape of the metallic insert by the step of the deformation operation can be compensated by the fact that the final intended design of the metallic insert is achieved by a combination of the pre-shaping operation and the deformation operation.

[0035] According to another aspect of the invention, an apparatus for manufacturing a reinforced bi-metallic casting composite, preferably for performing a method according to any of claims 1 to 13, is provided, the apparatus comprising a die, wherein said die comprises a moulding cavity; and a closing element being movable in a closing direction for closing said moulding cavity. The apparatus is characterised in that it further comprises: at least one actuator being adapted to perform a deformation operation to a metallic insert when being arranged inside of said moulding cavity, wherein said at least one actuator is a mechanical actuator, a hydraulic actuator, a pneumatic actuator, a magnetic actuator or an electric actuator.

[0036] Thus, an apparatus is provided by means of which a reinforced bi-metallic casting composite can be manufactured with fewer machines, for instance in a single machine, without the necessity of a plurality apparatuses. No several apparatuses are needed for the necessary deformation operation of the metallic insert and the over-casting step.

[0037] According to the description of the method before, the actuator or the actuators can be integrated into the closing element or arranged inside or also outside of the moulding cavity of the die. They are adapted to interact with a metallic insert being arranged inside of the die in order to perform a deformation operation to the metallic insert. Advantages that have been described previously with regard to the method are correspondingly valid for the apparatus according to the invention.

[0038] In a particular embodiment of the apparatus, said die is a thermally regulated die, wherein said thermally regulated die can control a die temperature, in particular different die temperatures in different areas of the die, in a range from 80° C to 500° C, preferably from 200° C to 400° C, in particular by means of at least one temperature sensor and by means of at least one temperature controller, preferably a PID controller. Thus, an advantageous temperature control of the different parts of the die and, thereby, a thermal regulation of the metallic insert to be arranged inside of the moulding cavity of the apparatus can be performed according to the previous description of the corresponding features of the method.

[0039] The different aspects and embodiments of the invention defined in the foregoing can be combined with one another, as long as they are compatible with each other.

[0040] Additional advantages and features of the invention will become apparent from the detail description that follows and will be particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] To complete the description and in order to provide for a better understanding of the invention, a set of drawings is provided. Said drawings form an integral part of the description and illustrate an embodiment of the invention, which should not be interpreted as restricting the scope of the invention, but just as an example of how the invention can be carried out. The drawings comprise the following figures:

Figure 1 shows a flow diagram of a method for manufacturing a reinforced bi-metallic casting composite according to the present invention.

Figure 2A shows a principle sketch representing the method as well as the apparatus according to the present invention, with the method performing the steps of placing a metallic insert in the die and holding the metallic insert in the die.

Figure 2B shows a principle sketch corresponding to the reproduction in Fig. 2A, with the method this time performing the steps of the closing operation and the deformation operation.

Figure 2C shows a principle sketch corresponding to the reproductions in Fig. 2A and Fig. 2B, with the method this time performing a retraction movement of the actuators.

Figure 2D shows a principle sketch corresponding to the reproductions in Fig. 2A, Fig. 2B and Fig. 2C, with the method this time performing the metal over-casting step.

Figure 2E shows a principle sketch corresponding to the reproductions in Fig. 2A, Fig. 2B, Fig. 2C and Fig. 2D, with the method this time performing the step of die opening and part extraction.

Figure 3A shows a principle sketch representing the method as well as the apparatus according to the present invention in correspondence with the reproductions in Fig. 2A to 2E, with an alternative step for a retraction and closing operation of the closing element.

Figure 3B shows a principle sketch corresponding to the reproduction in Fig. 3A, with a further alternative step for a retraction and closing operation of the closing element.

DESCRIPTION OF A WAY OF CARRYING OUT THE INVENTION

[0042] The following description is not to be taken in a limiting sense but is given solely for the purpose of describing the broad principles of the invention. Embodiments of the invention will be now described by way of example, with reference to the above-mentioned drawings showing elements and results according to the invention.

[0043] In the following description, same reference signs refer to same elements and, respectively, same features. Accordingly, a description given with regard to a specific figure also is valid with regard to elements in other figures. Thereby, a repeated description is avoided. Furthermore, single features described with regard to a specific embodiment are also applicable in different embodiments.

[0044] Figure 1 shows a flow diagram of a method for manufacturing a reinforced bi-metallic casting composite according to the present invention. In a first step I), which is an optional step, a pre-shaping of a metallic insert can be performed. As material for the metallic insert, a material can be selected out of the group: steel, iron, aluminium, copper, magnesium, titanium alloy, or any alloy or combination of the mentioned metals. By said pre-shaping, for instance by means of cutting, cold or hot pressing, 3D prototyping, casting or machining, a metallic insert that is intended to be integrated to the final bi-metallic composite is provided in a preformed condition.

[0045] In the following two steps, the steps a) and b) as the first essential steps of the presented method, the metallic insert being in its preformed condition is provided and introduced into a die. In particular, the metallic insert is placed into a moulding cavity of the die where the metallic insert is held in a predetermined condition, for instance by positioners such as spacer rods mounted retractably on springs, which can press against the metallic insert. In general, the positioners can be adapted to perform the positioning operation by means of magnetism, adhesion, extraction, vacuum, suction cups or gravity. The metallic insert can optionally be provided in a preheated condition. The metallic insert can be by way of an example a flat steel sheet.

[0046] Then, in step d), a closing operation of the die by means of a closing element is performed, and, in step e), a deformation operation is performed. By means of said closing operation, it is assured that the subsequent casting operation in terms of the metal over-casting step can be performed since, therefore, the moulding cavity of the die needs to be closed. By means of said deformation operation, the metallic insert is deformed from its preformed condition into a casting condition. The deformation operation can be a stamping operation and, in particular, a hot deformation operation such as hot stamping. The deformation operation can be performed by at least one actuator, for instance by mechanical actuators, hydraulic actuators, pneumatic actuators, magnetic actuators or electric actuators, and the deformation operation can be performed by the positioners as well. In this case, the positioners correspond to the actuators.

[0047] Said steps d) and e), that is the closing operation and the deformation operation, can also be performed in exchanged order or even at the same time. In other words, the deformation operation of the metallic insert can also be performed before the die is closed or while the die is being closed.

[0048] Subsequently, in step f), the metal over-casting step is performed. Thereby, an over-cast metal is casted into the die at least partly over the metallic insert. A bond between the metallic insert and the over-cast metal is intended by performing said step in order to eventually achieve a reinforced bi-metallic casting composite.

[0049] As material for the over-cast metal, a material can be selected out of the group: steel, iron, aluminium, copper, magnesium, titanium, zinc alloy, or any alloy or combination of the mentioned metals. In general, the materials of the metallic insert as well as of the over-cast metal can be the same. However, preferably, a material for the metallic insert is used that differs from the material being used for the over-cast metal in that the metallic insert material has a higher melting point than the over-cast metal material. Thus, a reinforced bi-metallic casting composite can be achieved that combines the positive effects of the different materials used for the metallic insert and for the outer over-cast metal.

[0050] The casting operation preferably corresponds to a high pressure die casting. However, the used casting machine can also be another die casting, squeeze, semi-permanent or low pressure casting machine. Depending on the casting process, the pressure over the metallic insert varies from a few bars till approximately 1.200 bars in a high pressure die casting and up to approximately 2.000 bars in a squeeze casting.

[0051] In the subsequent step g), the solidification of the over-cast metal. Thereby, a bond between the metallic insert and the over-cast metal is achieved. The resulting part will be the intended reinforced bi-metallic casting composite. In order to improve the properties of the resulting reinforced bi-metallic casting composite, a squeezing operation can be performed during step g), that is, during the solidification of the over-cast metal. In particular, at least one squeeze pin can squeeze the over-cast metal when said over-cast metal is in a semi-solid state during the solidification of said over-cast metal. Thus, the shrinkage porosity can be reduced or, respectively, the union of the metallic insert and the over-cast metal can be increased. As the at least one actuator element for the squeezing operation, also at least one of the actuators or positioners can be used.

[0052] In a final essential step of the method, in step h), the metallic insert together with the over-cast metal is extracted from the die as the reinforced bi-metallic casting composite. Within this step, the die is also opened, that is, the closing element is opened and the closing operation of the die is undone again.

[0053] Optionally, as mentioned in step II) in figure 1, a finishing operation can be performed to the reinforced bi-metallic casting composite after it has been extracted from the die. For instance, the reinforced bi-metallic casting composite can be exposed to a trimming operation or any other machining or finishing process in order to further improve its properties.

[0054] Furthermore, after the reinforced bi-metallic casting composite has been extracted from said die, the inner surfaces of the die optionally can be cleaned at least partly and sprayed at least partly with a de-moulding agent. Thus, it can be avoided that some parts of the over-cast metal get stack in the die and an efficient method is achieved as the next production cycle for manufacturing a reinforced bi-metallic casting composite can be initiated faster.

[0055] The die being used in the described method preferably is a thermally regulated die. Thereby, the die temperature can be controlled. In particular, different die temperatures in different areas of the die can be set. This can be done by the heating of different areas of the die in a distinctive intense manner. The die or its different areas can be heated up to 500°C. During the method, when the metallic insert is placed in the die, the die or its different areas preferably have a temperature in a range from 200°C to 400°C. The temperature of the die or of its different areas is controlled by one temperature sensor as well as one temperature controller, preferably a PID controller, per different die area. Complementary, the die as well as its different die areas can be cooled down in a controlled manner. The cooling and heating systems can be cartridge heaters, jet cooler, water and oil coolers and other temperature controlling systems or combinations thereof.

[0056] After performing the method as shown in figure 1 and as described above at least in terms of the steps a) until h), the obtained product is a reinforced bi-metallic casting composite as kind of a metal matrix composite with a metallic insert, for instance a sheet. The mentioned steps can be performed by one singular die or machine. There is no necessity for further apparatuses to perform the deformation of the metallic insert into its finally intended shape as well as to perform embedding of this metallic insert with the over-cast metal. Accordingly, a method for manufacturing a reinforced bi-metallic casting composite is achieved according to which reinforced bi-metallic casting composites can be manufactured in a less time consuming and less cost-intensive manner. A reduction in space for the machinery, as well as a reduction of the machinery and the production cost and an increase of the process productivity is obtained.

[0057] Figure 2A shows a principle sketch representing the method as well as an apparatus 1 according to the present invention, with the method performing the steps of placing a metallic insert 2 in the die 3 and holding the metallic insert 2 in the die 3. The metallic insert 2 is placed inside of the die 3, in particular in a moulding cavity 4 of the die 3, where the metallic insert 2 is held by two lateral actuators 5. These lateral actuators 5, therefore, serve as positioners of the metallic insert 2. The two lateral actuators 5 are part of a fix part 6 of the die 3. The metallic insert 2 is in the shown embodiment a flat thin sheet and is provided to the die 3 in a preformed condition.

[0058] The die 3 comprises in addition to the fix part 6 also a mobile part 7 being arranged opposite to the fix part 6 and being movable in a closing direction 8. The closing direction 8 is the direction into which the mobile part 7 is moved so that the closing operation of the method is performed, that is, in order to close the die 3, in particular the moulding cavity 4 so that the metal over-casting step can be performed.

[0059] The mobile part 7 of the die 3 comprises a closing element 9 which is adapted to close the moulding cavity 4 of the die 3 by its movement to the closing direction 8. For said movement in the direction of the closing direction 8. The mobile part 7 of the die 3 further comprises an expulsion part 10 which is adapted to extract the finished part out of the die 3 or, respectively, out of the moulding cavity 4.

[0060] The closing element 9 further comprises an actuator in terms of a hot press actuator 11. The hot press actuator 11 is adapted to perform a hot stamping operation to the metallic insert 2 and the hot press actuator 11 is a part of the mobile part 7 of the die 3 as well as the closing element 9. Therefore, the hot press actuator 11 can also be moved forth and backwards along the closing direction 8. The movement along the closing direction 8 can be realised independent from the movement of the closing element 9 or, as well, in connection with the movement of the closing element 9. The movements of the closing element 9 and the hot press actuator 11 both substantially are lineal movements along the closing direction 8 independent from each other.

[0061] Moreover, a metal path 12 is provided in the apparatus 1, by means of which metal path 12 the melted over-cast metal can be casted into the die 3, in particular into the moulding cavity 4. Accordingly, the metal path 12 is connected to the moulding cavity 4 in a manner which allows the flow of liquid metal through the metal path 12 up to the moulding cavity 4.

[0062] Figure 2B shows a principle sketch corresponding to the reproduction in figure 2A, with the method this time performing the steps of the closing operation and the deformation operation. That is, the method or, respectively, the apparatus 1 is shown in a status according to the two steps subsequent to the status as shown before in figure 2A.

[0063] In figure 2B, the mobile part 7 has been moved along the closing direction 8 towards the fix part 6 of the die 3 in order to perform the closing operation. At the same time, the deformation operation of the metallic insert 2 has been performed so that the metallic insert 2 is shown in figure 2B in its casting condition which differs from its preformed condition in that the metallic insert 2 has been deformed from being a flat thin sheet to being a sheet comprising two lateral shoulder sections 13.

[0064] The deformation operation of the metallic insert 2 has been performed by means of the hot press actuator 11 which has moved into the closing direction 8 together with the closing element 9 or, respectively, the mobile part 7 of the die 3. Hence, the closure force has been used to perform the deformation operation. The deformation operation corresponds to a hot stamping operation as the metallic insert 2 inside of the die 3 is heated. This heating can be achieved by a preheating of the metallic insert 2 before placing it inside of the die 3 or by the heat existing inside of the die 3, for instance due to heated die surfaces. The deformation operation is supported by the two lateral actuators 5 or positioners.

[0065] According to the embodiment as shown in figure 2B, the closing operation of the die 3 as well as the deformation operation of the metallic insert 2 has been performed at the same time, in particular by the same step, namely by closing the die 3 due to the lineal movement of the closing element 9 and the hot press actuator 11. Alternately, the two steps, namely the closing operation and the deformation operation, can also be performed in subsequent manner. That is, the die 3 could be closed after a deformation operation has already been performed or, alternatively, before a deformation operation is performed later on.

[0066] Figure 2C shows a principle sketch corresponding to the reproductions in figure 2A and figure 2B, in a status in which, according to the method, a retraction movement of the actuators is performed. That is, the hot press actuator 11 as well as the two lateral actuators 5 are retracted back or away from their positions of before, as shown in figure 2B. Accordingly, the hot press actuator 11 is moved back away from the fix part 6 of the die 3 along the closing direction 8 or, in other word, against the closing direction 8. The two lateral actuators 5 are moved laterally away from the two lateral shoulder sections 13 of the metallic insert 2. Said retraction movements of the actuators is indicated in an exaggerated manner in figure 2C by means of dotted arrows.

[0067] Due to said retraction movements of the actuators, the moulding cavity 4 is released again in a manner that allows the flow of liquid metal through the metal path up to the moulding cavity 4. Before the retraction movements, the metallic insert 2 was contacted by the actuators, in particular by the hot press actuator 11 as well as the two lateral actuators 5 (cf. figure 2B) and, accordingly, a flow of melted over-cast metal had not been able to reach its destination in terms of the metallic insert 2. At the same time, the retraction movement of the hot press actuator 11 does not lead to an opening of the die 3 or, respectively, the moulding cavity 4. In other words, the closing operation of the die 3 is not undone. This is due to the fact that the hot press actuator 11 can be moved against the closing direction 8 independently from the closing element 9 which closing element 9 still serves for keeping the die 3 and the moulding cavity 4 closed.

[0068] However, it would also be possible to open the die 3 or, respectively, the moulding cavity 4 again by said retraction operation so that a new closing operation of the die 3 is needed. This case is referred to as a retraction and closing operation.

[0069] Figure 2D shows a principle sketch corresponding to the reproductions in figure 2A, figure 2B and figure 2C, in a status of the method according to which the metal over-casting step is performed. The moulding cavity 4 of the die 3 is still closed by the closing element 9 although the hot press actuator 11 is in a retracted condition. Melted over-cast metal 14 has been casted into the moulding cavity 4 after having passed through the metal path 12. The melted over-cast metal 14 is surrounding the metallic insert 2 at its entire inside surfaces. Furthermore, the outer surfaces of the two lateral shoulder sections 13 are also contacted with the melted over-cast metal 14 due to the previous retraction movement of the lateral actuators 5.

[0070] Figure 2E shows a principle sketch corresponding to the reproductions in figure 2A, figure 2B, figure 2C and figure 2D, in a status of the method according to which the step of die opening and part extraction is performed. After the solidification of the over-cast metal 14, the metallic insert 2 can be extracted together with the over-cast metal 14 being bonded to the metallic insert 2. Thus, the reinforced bi-metallic casting composite is removed from the die 3 or, respectively, from the moulding cavity 4. The extraction operation of the reinforced bi-metallic casting composite is combined with an opening operation of the die 3. In particular, the mobile part 7 of the die 3 is moved away from the fic part 6 of the die 3 and, at the same time, the expulsion part 10 of the die 3 extracts the reinforced bi-metallic casting composite, that is the metallic insert 2 together with the over-cast metal 14, out of the moulding cavity 4. The laterally retracted position of the two lateral actuators 5 allow this movement of the metallic insert 2 together with the over-cast metal 14 as the two lateral actuators 5 or positioners are not holding anymore the metallic insert 2 inside of the moulding cavity 4.

[0071] After the extraction of the reinforced bi-metallic casting composite, also a final finishing operation, for instance a machining operation, of the reinforced bi-metallic casting composite can be performed. Furthermore, the moulding cavity 4 or the inner surfaces of the die 3 can be treated with a de-moulding agent for subsequent production processes.

[0072] Figure 3A as well as figure 3B both show a principle sketch representing the method as well as the apparatus according to the present invention in correspondence with the reproductions in figures 2A to 2E, with an alternative step for a retraction and closing operation of the closing element 9. In the status as shown in figure 3A as well as in figure 3B, the deformation process of the metallic insert 2 has already been performed. Accordingly, the metallic insert 2 comprises its two lateral shoulder sections 13. However, the metal over-casting step has not been performed yet and the metallic insert 2 is arranged in the moulding cavity 4 without any over-cast metal yet being present.

[0073] Both, in figure 3A and figure 3B, a retraction and closing operation is performed, wherein, by means of a retraction and closing operation, the closing element 9 is reversed at least partly and a further closing operation of the die 3 is performed. The further closing operation of the die 3 has not been performed yet in the embodiments as shown in figure 3A and figure 3B. However, the type of retraction movement of the closing elements 9 are shown.

[0074] In figure 3A, the retraction movement of the closing element 9 includes a sliding movement of the closing element 9 as indicated by arrow 15 to a side substantially perpendicular to the closing direction 8. In contrast to this, in figure 3B, the retraction movement of the closing element 9 includes a rotation movement of the closing element 9 as indicated by arrow 16 around an axis being substantially parallel to the closing direction 9.

[0075] In both cases, after the retraction movements of the closing elements 9, that is after the moulding cavity 4 of the die 3 has been opened, a new closing operation of the die 3 has to be performed in order to close the moulding cavity 4 again so that it is prepared for the subsequent metal over-casting step as described above in connection with the previous embodiments. Accordingly, the closing element 9 does not serve for the final closing of the moulding cavity 4 but another additional, subsequent closing element and, therefore, the closing element 9 can be regarded as a mobile deformation tool.

[0076] In the context of the present invention, the term "comprises" and its derivations (such as "comprising", "including", "includes", etc.) should not be understood in an excluding sense, that is, these terms should not be interpreted as excluding the possibility that what is described and defined may include further elements, steps, etc.

[0077] In the context of the present invention, the term "approximately" and terms of its family (such as "approximate", etc.) should be understood as indicating values very near to those which accompany the aforementioned term. That is to say, a deviation within reasonable limits from an exact value should be accepted, because a skilled person in the art will understand that such a deviation from the values indicated is inevitable due to measurement inaccuracies, etc. The same applies to the terms "about" and "around" and "substantially".

[0078] The invention is obviously not limited to the specific embodiment(s) described herein, but also encompasses any variations that may be considered by any person skilled in the art (for example, as regards the choice of materials, dimensions, components, configuration, etc.), within the general scope of the invention as defined in the claims.

Claims

1. A method for manufacturing a reinforced bi-metallic casting composite, wherein at least one metallic insert (2) is provided in a die (3) and a metal over-casting step is performed, wherein, by means of said metal over-casting step, an over-cast metal (14) is casted at least partly over said at least one metallic insert (2),
characterised in that the method comprises the following steps:

a) providing said at least one metallic insert (2) being in a preformed condition;
b) introducing said at least one metallic insert (2) being in its preformed condition into said die (3);
c) holding said at least one metallic insert (2) being in its preformed condition in a predetermined position in said die (3);
d) performing a closing operation of said die by means of a closing element (9);
e) performing a deformation operation, wherein, by means of said deformation operation, said at least one metallic insert (2) being in its preformed condition is deformed from its preformed condition into a casting condition;
f) performing said metal over-casting step, wherein said over-cast metal (14) is casted at least partly over said at least one metallic insert (2) being in its casting condition;
g) solidification of said over-cast metal (14); and
h) extracting said at least one metallic insert (2) together with said over-cast metal (14) from said die (3).

2. The method of claim 1, wherein said deformation operation is performed by at least one actuator (11; 5), wherein said at least one actuator (11; 5) is a mechanical actuator, a hydraulic actuator, a pneumatic actuator, a magnetic actuator or an electric actuator.

3. The method of claim 1 or 2, wherein said deformation operation is performed before said closing operation.

4. The method of claim 1 or 2, wherein said deformation operation is performed after said closing operation.

5. The method of claim 1 or 2, wherein said deformation operation is performed at least partly by means of said closing operation and, after said deformation operation, a retraction and closing operation is performed, wherein, by means of said retraction and closing operation, said closing element (9) is reversed at least partly and a further closing operation of said die is performed.

6. The method of claim 5, wherein said retraction and closing operation includes a sliding movement (15) of said closing element (9) to a side substantially perpendicular to a closing direction (8) of said closing element (9).

7. The method of claim 5, wherein said retraction and closing operation includes a rotation movement (16) of said closing element (9) around an axis being substantially parallel to a closing direction (8) of said closing element (9).

8. The method of any of claims 1 - 7, wherein said die (3) is a thermally regulated die, wherein said thermally regulated die can control a die temperature, in particular different die temperatures in different areas of the die (3), in a range from 80°C to 500°C, preferably from 200°C to 400°C, in particular by means of at least one temperature sensor and by means of at least one temperature controller, preferably a PID controller.

9. The method of any of claims 1 - 8, wherein, during the solidification of said over-cast metal (14), at least one actuator element, in particular at least one squeeze pin, squeezes said over-cast metal (14) when said over-cast metal (14) is in a semi-solid state.

10. The method of any of claims 1 - 9, wherein, after step h), a finishing operation is performed to said at least one metallic insert (2) together with said over-cast metal (14).

11. The method of any of claims 1 - 10, wherein, after said at least one metallic insert (2) together with said over-cast metal (14) has been extracted from said die, inner surfaces of said die (3) are cleaned at least partly and sprayed at least partly with a de-moulding agent.

12. The method of any of claims 1 - 11, wherein said at least one metallic insert (2) being in a preformed condition is provided in a pre-heated condition.

13. The method of any of claims 1 - 12, wherein, before step a), a pre-shaping operation is performed to said at least one metallic insert (2) in order to achieve said preformed condition of said at least one metallic insert (2), preferably by means of cutting, cold or hot pressing, 3D prototyping, casting or machining of said at least one metallic insert (2).

14. An apparatus (1) for manufacturing a reinforced bi-metallic casting composite, preferably for performing a method according to any of claims 1 to 13, comprising:

- a die (3), wherein said die comprises a moulding cavity (4); and
- a closing element (9) being movable in a closing direction (8) for closing said moulding cavity (4),

characterised in that the apparatus (1) further comprises:
at least one actuator (11; 5) being adapted to perform a deformation operation to a metallic insert (2) when being arranged inside of said moulding cavity (4), wherein said at least one actuator (11; 5) is a mechanical actuator, a hydraulic actuator, a pneumatic actuator, a magnetic actuator or an electric actuator.

15. The apparatus (1) of claim 14, wherein said die (3) is a thermally regulated die, wherein said thermally regulated die can control a die temperature, in particular different die temperatures in different areas of the die (3), in a range from 80° C to 500° C, preferably from 200° C to 400° C, in particular by means of at least one temperature sensor and by means of at least one temperature controller, preferably a PID controller.

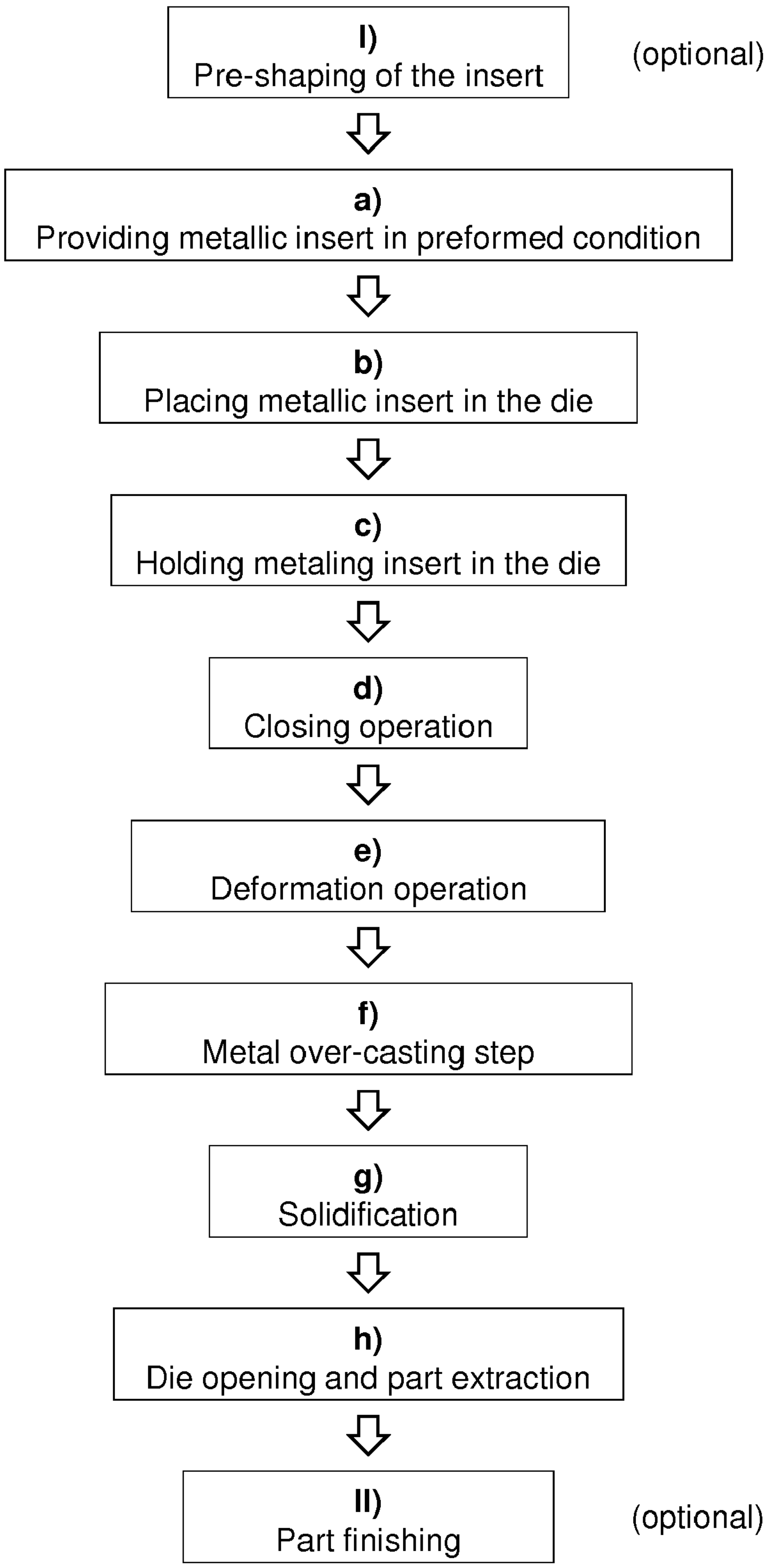
I)
Pre-shaping of the insert
(optional)
a)
Providing metallic insert in preformed condition
b)
Placing metallic insert in the die
c)
Holding metaling insert in the die
d)
Closing operation
e)
Deformation operation
f)
Metal over-casting step
g)
Solidification
h)
Die opening and part extraction
II)
Part finishing
(optional)

Fig. 1

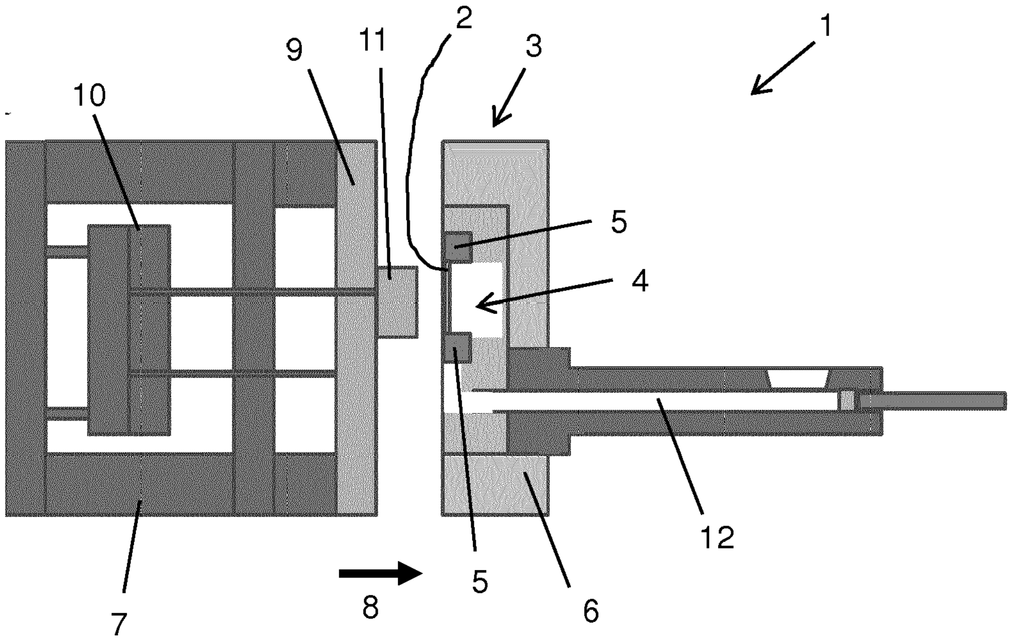

Fig. 2A

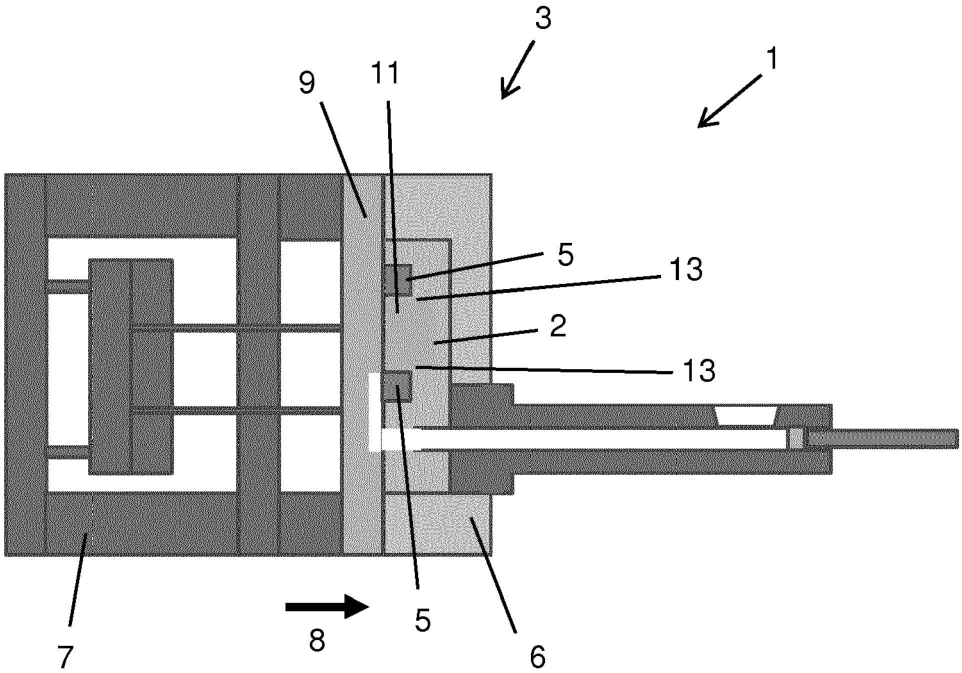

Fig. 2B

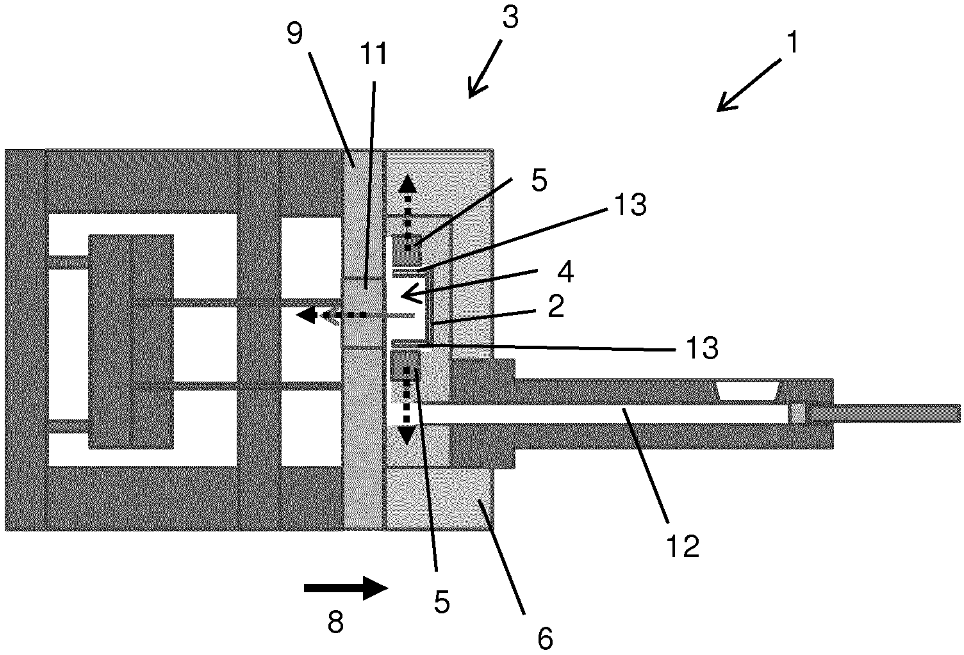

Fig. 2C

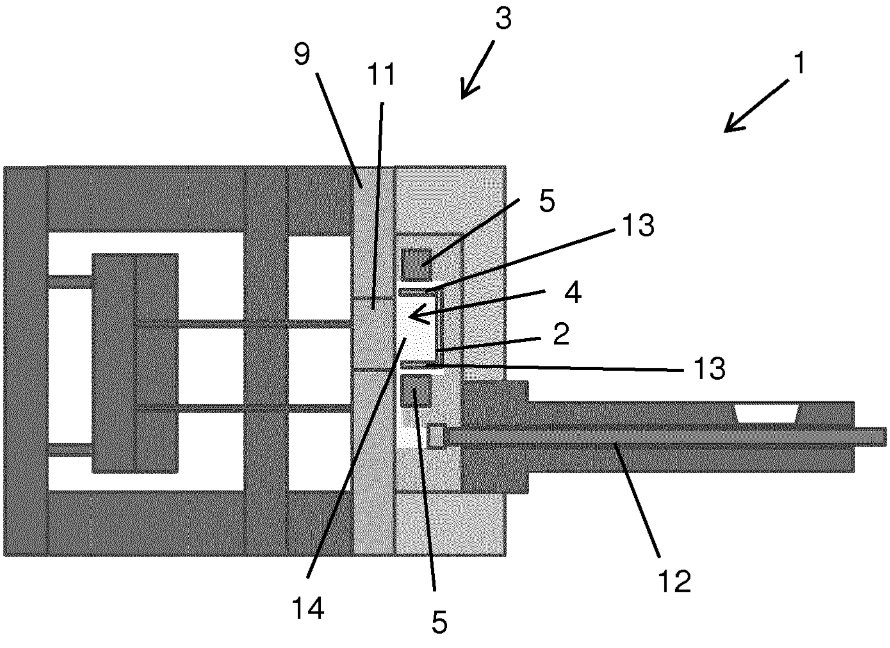

Fig. 2D

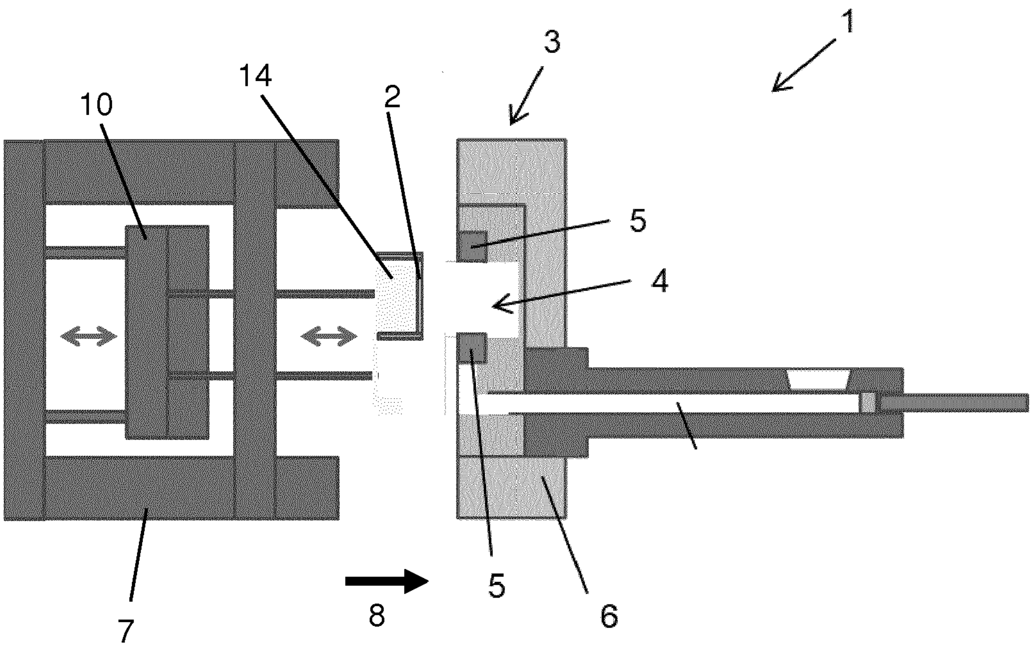

Fig. 2E

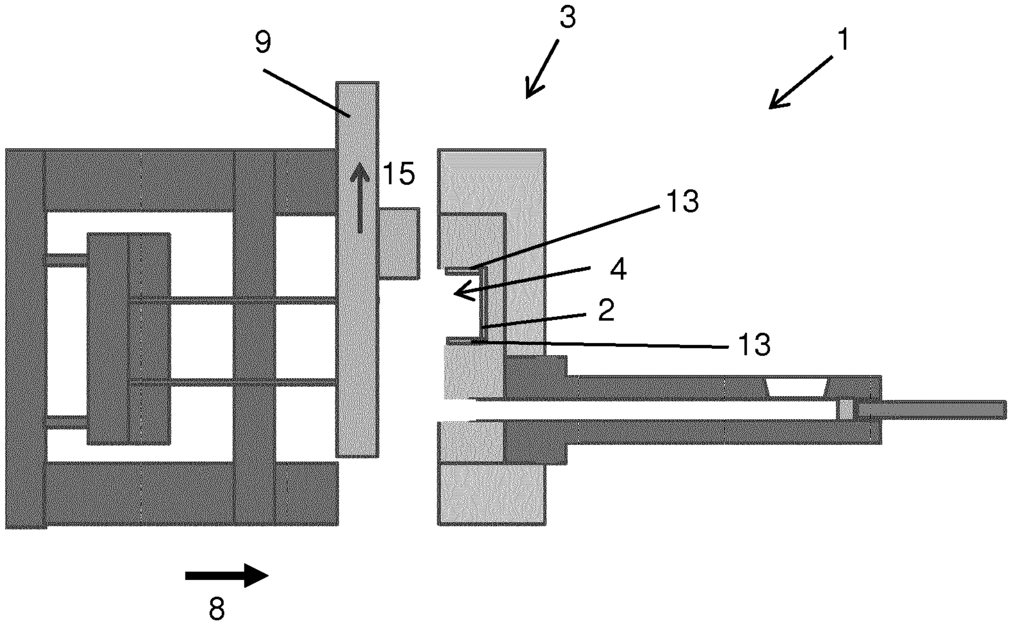

Fig. 3A

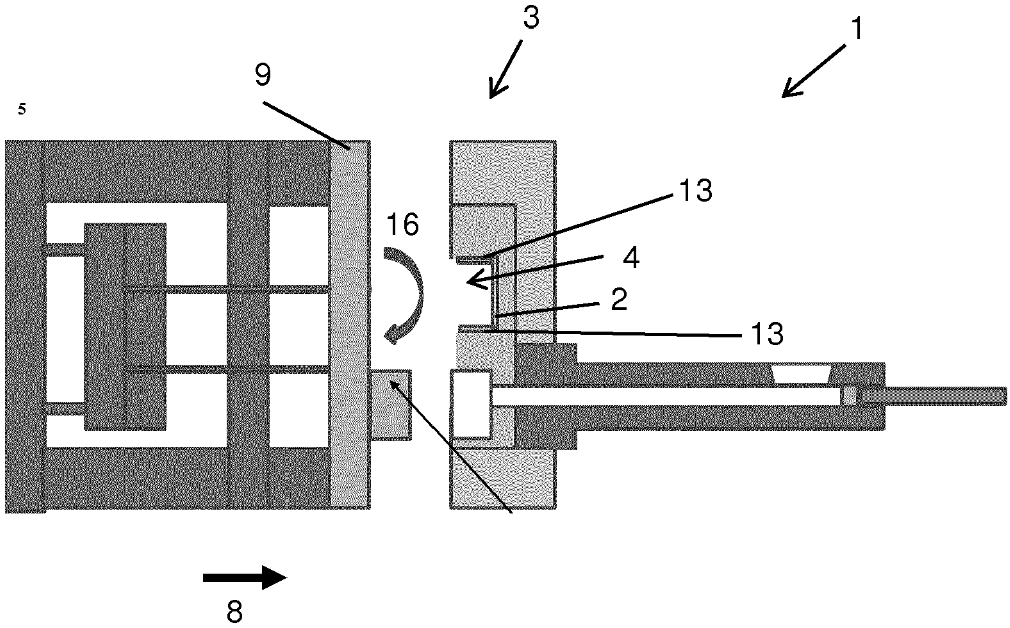

Fig. 3B

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EUROPEAN SEARCH REPORT

Application Number
EP 18 38 2480

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

B22D
B29C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	6 August 2018	Porté, Olivier

CATEGORY OF CITED DOCUMENTS

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