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(54) **SQUEEZING CAST METAL VIA WEDGE MECHANISM**

(57) The invention relates to an apparatus (10) for applying a force to a metal component in a casting mold (12), the apparatus (10) comprising: a drive arrangement (14, 14') at least in part movable in a drive direction (D); and a squeeze arrangement (16, 16') at least in part movable in a squeeze direction (S) for applying the force to the metal component in the casting mold (12); wherein the apparatus (10) is configured such that a force can be mechanically transferred from the drive arrangement (14, 14') to the squeeze arrangement (16, 16') via a force deflection mechanism (20, 20'); and wherein the force deflection mechanism (20, 20') is based on a wedge mechanism. The invention also relates to a method and a use of the apparatus.

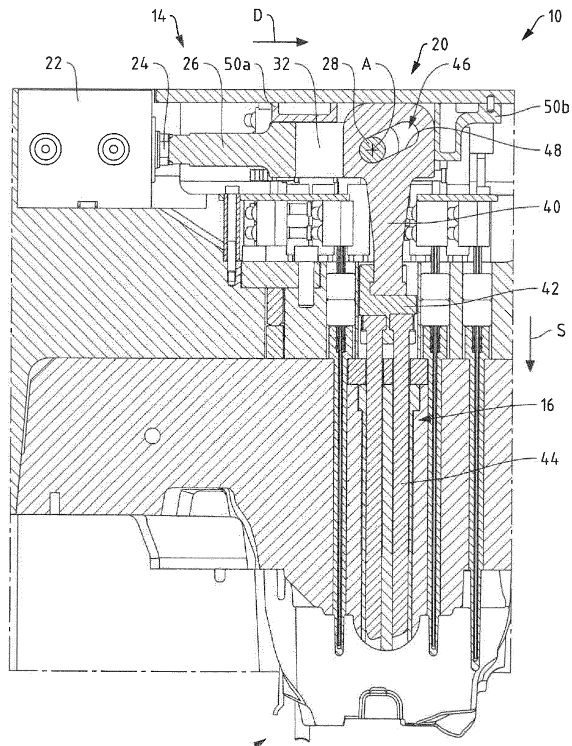

Fig.2

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Description

[0001] The present invention relates to an apparatus for applying a force to a metal component in a casting mold. The present invention also relates to a use of such an apparatus and to a method for applying a force to a metal component in a casting mold.

[0002] During metal casting of components in a casting mold, there exists the known problem of air inclusions in certain areas of the cast metal component. These inclusions can remain in the component during solidification of the metal and can result in a porosity of the cast meal component. This affects the mechanical properties of the component in the respective areas. More specifically, such porosity potentially impairs the yield strength and the ultimate tensile strength in the component. This is particularly critical for stressed areas of the component, such as the bearing area of cylinders of an engine block. Low mechanical properties in the cast component are one of the main problems particularly in high pressure die casting (HPDC). At the same time higher and higher mechanical properties are demanded in critical areas such as the mentioned bearing areas of cylinders of engine blocks. Thus, there is the need for manufacture mechanisms which reduce the risk of porosity.

[0003] In order to reduce the occurrence of air inclusions and the resulting risk of porosity, a possible approach is to use so called "squeeze pins" for exerting a pressure on the (partially solidified) cast component at the end of the filling of the casting mold.

[0004] In a first known approach, a cylinder piston rod is aligned axially with a squeeze pin without any transmission there between and the cylinder piston and piston rod move in the same direction as the squeeze pin. The issue here is to squeeze sufficiently large volumes because this requires sufficiently large forces. However, if this approach is used in an HPDC tool, the available space and thus the size of the cylinder is limited.

[0005] Thus, either the required forces cannot be achieved or the casting tool would need to be redesigned and allowed to take up more space.

[0006] An example of a pin-squeeze system without a transmission according to this first approach described above is illustrated in Fig. 1A. When a piston in cylinder is moved by the action of a fluid delivered to the cylinder, a clutch rigidly mounted on the end of the piston rod pushes a core pin, which then squeezes the metal. When the piston in the cylinder is moved back by the action of a fluid delivered to the cylinder, the core pin is returned to the initial position.

[0007] Alternatively, according to a second known approach, a transmission is used, which enables the use of a smaller cylinder. This method has the potential risk of higher maintenance costs. Also, it may be problematic to use this approach in existing tools, because of the size of the transmission, which also requires a lot of space.

[0008] An example of a pin-squeeze system with a transmission according to this second approach described above is illustrated in Fig. 1B. When a piston in a cylinder is moved by the action of a fluid delivered to the cylinder, the back-and-forth linear motion is translated into a rotational motion in the first gearing arrangement. In the second gearing arrangement, the rotational motion is translated back to a back-and-forth linear motion. A clutch links the toothed gear rack with the core pin, which squeezes the metal. When the piston in the cylinder is moved back by the action of a fluid delivered to the cylinder, the core pin is returned to the initial position.

[0009] An example of a system utilizing such a pressure pin is given in EP 0 465 947 B1 describing a method and apparatus for casting an engine block with an aluminum alloy for an automobile having a plurality of cylinders. The engine block casting apparatus comprises a squeeze pin extendible to a cavity between the main oil gallery mold releases pin and the sand core. The pin is reciprocated by a squeeze cylinder. At the end of molten metal filling, the squeeze pin extends to squeeze and eliminate the product cavity.

[0010] EP 3 015 194 A1 describes a method for manufacturing a cylinder block comprising a semicircular bearing section, wherein the method comprises pressure-injecting molten metal into a cavity formed inside a metal mold and sliding a pressure pin disposed in the metal mold after the pressure-injecting of the molten metal and thereby applying a pressure to the molten metal injected in the cavity.

[0011] Further examples are described in EP 0 694 358 B1, GB 2 209 015 B and US 6,629,558.

[0012] The above described pin-squeeze system without a transmission according to the first approach generally allows the application of a force to the metal during the solidification of the metal and can provide a reduction of the volume of porosity. Due to the fact that this mechanism does not require the use of a transmission, this simplifies the maintenance. However, as already explained above, using such an approach may be problematic when the compression of a large metal volumes is required. In this case, the pin squeeze system without a transmission would require the use of a comparably large cylinder or a doubling of the cylinder, which is connected with the necessity of providing a larger space for the implementation of this solution. For most casting tool constructions, it is not possible to provide for such additional space.

[0013] The use of a pin squeeze system with a transmission according to the second approach does also allow the compression of a large metal volume. As explained above, the disadvantage of this second approach is that there is often no possibility of adding such a system to an existing casting tool without significant rebuilding. Due to the dimensions of the transmission, the construction of the casting tool must be considered and adapted already at the beginning of the design stage. Another disadvantage of this second approach are the potentially higher costs of maintenance.

[0014] In view of the prior art, the present invention is faced with the problem of suggesting an apparatus which allows for applying a sufficiently high force to a metal component in the casting mold, while at the same time a compact size and an as low as possible maintenance effort shall be achieved. Further, a corresponding method and an advantageous use are suggested.

[0015] According to an exemplary aspect of the invention, there is disclosed an apparatus for applying a force to a metal component in a casting mold, the apparatus comprising: a drive arrangement at least in part movable in a drive direction; and a squeeze arrangement at least in part movable in a squeeze direction for applying the force to the metal component in the casting mold; wherein the apparatus is configured such that a force can be mechanically transferred from the drive arrangement to the squeeze arrangement via a force deflection mechanism; and wherein the force deflection mechanism is based on a wedge mechanism.

[0016] According to a further exemplary aspect of the invention, there is disclosed a method for applying a force to a metal component in a casting mold, the method comprising: at least in part moving a drive arrangement in a drive direction; thereby mechanically transferring a force from the drive arrangement to a squeeze arrangement via a force deflection mechanism, wherein the force deflection mechanism is based on a wedge mechanism; and thereby at least in part moving the squeeze arrangement in a squeeze direction for applying the force to the metal component.

[0017] According to yet a further exemplary aspect of the invention, there is disclosed a use of an apparatus according to the invention for applying a force to a metal component, in particular an engine cylinder block, in a casting mold, in particular for squeezing a bearing area of the engine cylinder block.

[0018] The use of a wedge mechanism for squeezing a metal component (in particular a bearing area of the cast metal component, such as the bearing area of an engine cylinder block) in a cast mold provides for a sufficient compression of the metal during its solidification and thus the ability to eliminate or reduce the volume of porosity. This solution does not only provide the ability to compress large volumes of metal, but also to maintain a very compact size of the mechanism. In addition the suggested solution does not require any special maintenance. As a result, the proposed solution can be used in critical areas (such as bearing areas of an engine cylinder block), where other solutions only achieve too small squeeze pressures or have too large dimensions and are thus impossible to implement in the respective casting tool. As a result, a metal component with improved mechanical properties, in particular a reduced potential risk of low yield strengths and ultimate tensile strengths can be provided in an efficient manner.

[0019] The casting method used may in particular be pressure casting or high pressure die casting (HPDC). Accordingly, the apparatus may be a high pressure die casting apparatus or a part thereof and the casting mold used may be a die-cast suitable for high pressure die casting. The force is in particular applied to the metal component at least for a certain time during solidification of the metal. The force may be kept applied until the solidification of the metal has completed. Accordingly, the term metal component is understood to cover the state of molten metal until completely solidified metal in the casting mold. Preferably, the metal may be aluminum or an aluminum alloy.

[0020] As already mentioned, the metal component may in particular be an engine cylinder block. The force applied to the metal component may in that case in particular be applied to a bearing area of the engine cylinder block.

[0021] The force applied to the metal component via the squeeze arrangement is set such that it is sufficient for reducing air inclusion and the porosity of the metal component. The specific force and pressure to be applied may depend on and determined based on various factors, such as the metal used, the casting method, the geometry of the metal component and/or the area of the component to be squeezed.

[0022] The drive arrangement and the squeeze arrangement (or a respective part thereof) may each be exclusively movable in the drive direction and the squeeze direction, respectively. Thus, the respective movement may be a translational or linear movement. The movement may an axial movement along an axis of the respective arrangement (such as a piston rod axis or a pin axis). That an arrangement may only in part be movable in a respective direction is understood to mean that the respective arrangement may comprise parts which are fixed or not movable. For instance, the drive arrangement may comprise a cylinder which is not moving in the drive direction, but only serves for driving a piston or piston rod in the drive direction. Likewise the squeeze arrangement comprises parts, such as e.g. one or more squeeze pins moving in the squeeze direction, but may also comprise parts, such as e.g. guides or sleeves, which may not necessarily move into the squeeze direction.

[0023] The force deflection mechanism may be realized with components of the drive arrangement and the squeeze arrangement. However, the force deflection mechanism may also comprise additional parts or elements.

[0024] A force deflection mechanism utilizing a wedge mechanism is understood to be a mechanism utilizing one or more wedge surfaces (i.e. inclined, or tilted surfaces in particular with respect to the drive direction and/or the squeeze direction) so as to deflect the direction of an input force to a direction of an output force. At the same time, the mechanism may realize a transmission, for instance, as will be explained in more detail below.

[0025] The drive arrangement is understood to be positioned on the drive side, while the squeeze arrangement is understood to be positioned on the driven (or drive end) side. Thus, as seen in the direction of power transmission there is the order "drive arrangement" - "force deflection mechanism" - "squeeze arrangement".

[0026] In the context of the invention, the exemplary method may further comprise steps before and after the application of a squeeze force to the metal component. For instance, the exemplary method may further comprise the action of pressure injecting metal into the casting mold. For instance, the exemplary method may further comprise the action of removing the metal component from the casting mold after solidification of the metal.

[0027] The method may in particular be performed by an apparatus according to the invention.

[0028] According to an exemplary embodiment of all aspects of the invention, the drive direction is transverse, preferably substantially perpendicular to the squeeze direction. As already mentioned the drive arrangement and the squeeze arrangement or the respective part thereof may only be movable in the drive direction and the squeeze direction, respectively. An configuration of the drive arrangement and the squeeze arrangement, such that the respective directions are transverse or perpendicular to each other, allows a specifically compact design, as it can be avoided that the drive arrangement (typically comprising lengthy components such as cylinder, piston, piston rod etc.) extends too much from the casting mold or the rest of the casting tool.

[0029] While it is generally conceivable that the force deflection mechanism provides a force transmission ratio of 1, it is preferred, according to an exemplary embodiment of all aspects of the invention, that the force deflection mechanism provides a force transmission ratio from the drive arrangement to the squeeze arrangement smaller or larger than 1. This allows for the provision of a tailored force and thus pressure for squeezing the metal component. At the same time, the drive arrangement can be kept comparably small, because the force and pressure to be applied to the metal component can be adjusted (and in particular increased) via the force deflection mechanism, if needed. The path transmission ration behaves inversely, i.e. if the force transmission ratio is larger than 1, then the path transmission ratio is smaller than 1 and vice versa. Preferably, the force transmission ratio from the drive arrangement to the squeeze arrangement (i.e. the output force $F_{squeeze}$ at the squeeze arrangement divided by the input force F_{drive} at the drive arrangement, i.e. $F_{squeeze}/F_{drive}$) is larger than 1 and more preferably larger than 2 (and correspondingly the path transmission ratio is smaller than 1 or even smaller than 0.5, respectively).

[0030] The desired force and path transmission ratio can be adjusted by accordingly designing the wedge mechanism. For instance, the inclination or tilting of a wedge surface can be adjusted so as to obtain the desired transmission ratios, which will be described in more detail below.

[0031] According to an exemplary embodiment of all aspects of the invention, the force deflection mechanism is a gear-free mechanism. It has been found out that a sufficient force deflection and in particular transmission can be achieved solely by a wedge mechanism without the need of any further gears or cog wheels. A gear-free mechanism allows for a particularly compact design and also provides a low-maintenance or even maintenance-free solution. However, it is noted that the utilized wedge mechanism may nevertheless employ rotating members or parts, such as the pivot member described further below.

[0032] According to an exemplary embodiment of all aspects of the invention, the force deflection mechanism directly transfers a translational motion of the drive arrangement in the drive direction into a translational motion of the squeeze arrangement in the squeeze direction. Since there is no further intermediate force transfer, the properties with regard to compactness and low-maintenance can be further improved in this case. As already mentioned above, it may nevertheless be possible that a rotational motion of e.g. a pivot element is provided, as described further below. However, there is still a direct transfer of the translational motion of the drive arrangement in the drive direction into the translational motion of the squeeze arrangement in the squeeze direction, as explained further below.

[0033] According to an exemplary embodiment of all aspects of the invention, the drive arrangement and/or the squeeze arrangement comprises a wedge member providing a wedge surface. The terms "a wedge member" and "a wedge surface" are understood to mean that there is at least one wedge member/surface and that there generally can also be provided multiple wedge members and/or surfaces. As already mentioned, a wedge surface is understood to be an inclined or tiled surface, in particular with respect to the drive direction and/or the squeeze direction. The wedge surface can be considered to be a force deflection surface, as its purpose is to deflect and mechanically transfer the force from the drive arrangement (at least partially moving in the drive direction) to the squeeze arrangement (at least partially moving in the squeeze direction) and as its geometry and properties define or at least influence the force deflection and transmission.

[0034] In a preferred embodiment, the squeeze arrangement comprises a wedge member (which is movable in the squeeze direction). However, it is also possible that alternatively or additionally the drive arrangement comprises a wedge member. For instance, in one example embodiment, a wedge surface of a wedge member of the drive arrangement and a wedge surface of a wedge member of the squeeze arrangement can abut and slide along each other. In another example embodiment, only one of the drive arrangement and the squeeze arrangement comprises a wedge member with a wedge surface and the respective other arrangement comprises a contact member abutting the wedge surface, as will be explained in more detail below.

[0035] With respect to the transmission ratio mentioned above, the wedge surface allows to set the transmission ratio. For instance, in case of a transmission ration equal to 1, the wedge surface will typically bisect the angle between the drive direction and the squeeze direction. In case of a (force) transmission ratio larger or smaller than 1, the wedge surface will have a correspondingly smaller or larger inclination with respect to the drive direction, respectively. The path transmission ration will behave inversely.

[0036] According to an exemplary embodiment of all aspects of the invention, either the squeeze arrangement or the drive arrangement comprises a wedge member providing a wedge surface and wherein the respective other arrangement of the drive arrangement and the squeeze arrangement comprises a mover (which does not have a wedge surface) cooperating with the wedge member. For instance, the mover may be pushed or pulled against the wedge member or is pushed or pulled by the wedge member. The mover may thus be referred to as a pusher. While it is preferred that the wedge member is comprised by the squeeze arrangement and the mover is comprised by the drive arrangement, it is also possible that it is the other way around.

[0037] In a preferred embodiment, the wedge member comprises one or more cutouts so as to provide respective wedge surfaces. A pin or pivot member of the mover, as will be explained further below, can traverse the cutout to securely provide the interaction between the mover and the wedge member.

[0038] According to an exemplary embodiment of all aspects of the invention, the mover comprises a pivot member rotatable around an axis of the pivot member and abutting the wedge member. The pivot member can be received or fixed in the mover, i.e. the pivot member may move translationally together with the mover in a respective direction, i.e. the drive direction or the squeeze direction. However, the pivot member is free to rotate around its axis. The pivot member may be a cylindrical member, for instance a bolt or a pin. The pivot member may rotate around its longitudinal axis. The pivot member may directly abut the wedge surface of the wedge member. The provision of a pivot member has the advantage that it can perform a rolling motion on the wedge surface when the mover and wedge member move in their respective direction, thereby reducing the undesired resistance or friction for the force deflection and transmission. In other words, the pivot member reduces the friction from a sliding friction to a rolling friction during the force deflection and transmission. The axis of rotation of the pivot member is preferably transverse, in particular substantially perpendicular to the drive direction and/or the squeeze direction.

[0039] According to an exemplary embodiment of all aspects of the invention, the mover comprises a bracket-like, in particular U-shaped section so as to encompass the wedge member. The bracket-like section can advantageously provide arms for encompassing the wedge member and also for holding the pivot member. Thus, the bracket-like section can also be a clam or support for the pivot member. For this, the pivot member can transverse the bracket-like section and is, for instance, received in through-holes of arms of the bracket-like section. In an alternative embodiment, it may also be the other way around, i.e. the wedge member comprises a bracket-like (e.g. u-shaped) section so as to encompass the mover. Each arm of the bracket like structure may in this case provide a wedge surface, for instance via a cutout in each of the arms.

[0040] According to an exemplary embodiment of all aspects of the invention, the wedge surface has an inclination with an angle with respect to the drive direction of at least 10°, preferably at least 20° and/or at most 40°, preferably at most 30°. These inclination angles of the wedge surface allow for high forces to be supplied to the squeeze arrangement and thus the metal component while maintaining a compact design. In a preferred embodiment the angle of inclination is substantially 25°.

[0041] According to an exemplary embodiment of all aspects of the invention, the apparatus comprises means for lubricating the force deflection mechanism in order to reduce friction and improve the efficiency of the apparatus. For instance, the lubrication may be provided to the wedge member and/or the mover contacting the wedge member, thus lubricating the contacting surface between the wedge member and the mover. For instance, the means for lubricating comprises at least a lubrication element or plate. A respective lubrication element or plate may be movable relative to and/or contact the wedge member and/or the mover. The means for lubrication, such as the lubrication element or plate, but also the wedge member and/or the mover, may each comprise a channel system with one or more lubrication channels for guiding a lubricant to the surfaces to be lubricated. The channel system may provide a reservoir for a lubricant or may facilitate a continuous provision of a lubricant to the force deflection mechanism.

[0042] According to an exemplary embodiment of all aspects of the invention, the squeeze arrangement comprises one or more squeeze pins and/or a clutch. For instance, at least two, or precisely two squeeze pins are provided. The squeeze pins may be in direct contact with the metal component. For applying a force to the metal component, the squeeze pins and/or the clutch move in the squeeze direction.

[0043] According to an exemplary embodiment of all aspects of the invention, the drive arrangement comprises: a cylinder; and/or a piston; and/or a piston rod. For applying a force to the metal component via the squeeze arrangement, the piston and piston rod move into the drive direction. For instance, the cylinder may be a pneumatic cylinder. For instance, the cylinder may be a hydraulic cylinder.

[0044] According to an exemplary embodiment of all aspects of the invention, the apparatus further comprises the casting mold. The casting mold may in particular be a casting mold for high pressure die casting (HPDC). The casting mold may comprise two or more casting mold parts, which define the geometry of the metal component.

[0045] With the apparatus and method as described above, it is in particular possible to achieve a squeeze volume of at least 1,000 mm^3 and preferably at least 2,000 mm^3. In exemplary embodiments the squeeze area may be at least 100 mm^2, preferably at least 200 mm^2. For instance, the squeeze pressure may be at least 1,000 bar, e.g. 2,000 - 3,000 bar. In exemplary embodiments, the squeeze force may be at least 50,000 N, preferably at least 60,000 N. However, in order to achieve the above squeeze volumes, squeeze forces and squeeze pressures, the force provided by drive arrangement (that is the cylinder force or the push or pull force) may only need to be in the order of 30,000 to 40,000 N.

[0046] The exemplary embodiments described in this description are also intended to be disclosed with respect to every aspect and in all combinations with one another. In particular, a method step is intended to also disclose respective means for performing the method step. Likewise, means for performing a certain method step are also intended to disclose the respective method step.

[0047] Further advantageous exemplary embodiments of the invention are indicated by the following detailed description of a number of practical examples of the present invention, in particular in connection with the figures.

[0048] The figures attached to the application, however, are only intended to be used for the purpose of clarification, and not to determine the scope of protection of the invention. The attached drawings are intended only as examples reflecting the general concept of the present invention. In particular, features shown in the figures should not in any way be considered an essential component part of the invention.

[0049] In the following, the invention will be described in more detail with reference to the figures.

Fig. 1A a cross-sectional view of a squeeze mechanisms of the prior art;

Fig. 1B a perspective view of a further squeeze mechanism of the prior art;

Fig. 2 a cross-sectional view of an exemplary apparatus according to the invention for performing an exemplary embodiment of the method according to the invention;

Fig. 3 the drive arrangement and the squeeze arrangement of the embodiment of Fig. 2 in a perspective view;

Fig. 4 the drive arrangement and squeeze arrangement of the embodiment of Fig. 2 in a side view;

Fig. 5 the mover of the drive arrangement of the embodiment of Fig. 2;

Fig. 6 the wedge member of the squeeze arrangement of the embodiment of Fig. 2;

Fig. 7 an alternative embodiment of the drive arrangement and the squeeze arrangement in a perspective view; and

Fig 8 top vie exemplary lubrication elements for the mover and the wedge member of the apparatus of Fig. 2 in a perspective view.

[0050] Fig. 1A is a cross-sectional view of a squeeze mechanisms of the prior art. As already discussed at the outset, in operation, the piston in cylinder 1 is first moved to the bottom by the action of a fluid delivered to the top end of the cylinder, the clutch 2 rigidly mounted on the end of the piston rod pushes the core pin 4, which then squeezes the metal. When the piston in the cylinder 1 is moved to the top by the action of a fluid delivered to the bottom end of the cylinder, the core pin 4 is returned to the initial position.

[0051] Fig. 1B is a perspective view of a further squeeze mechanism of the prior art. As discussed at the outset, for metal squeezing, the piston in cylinder 1 is first moved to the back right by the action of a fluid delivered to the front left end of the cylinder, the back-and-forth linear motion in the first gear 3a is translated into a rotational motion. In the second gear 3b, the rotational motion is translated back to a back-and-forth linear motion. A clutch links the toothed gear rack with the core pin 4, which squeezes the metal. When the piston in the cylinder 1 is moved to the front left by the action of a fluid delivered to the back right end of the cylinder, the core pin 4 is returned to the initial position.

[0052] Fig. 2 is a cross-sectional view of an exemplary apparatus according to the invention for performing an exemplary embodiment of the method according to the invention.

[0053] The apparatus 10 is a casting tool or system for high pressure die casting (HPDC) of an aluminum engine cylinder block.

[0054] The apparatus 10 is designed for applying a force to a metal component (not shown) in a casting mold 12. Apart from the casting mold 12, the apparatus 10 comprises a drive arrangement 14, which is in part movable in a drive direction D. The apparatus further comprises a squeeze arrangement 16, which is in part movable in a squeeze direction S for applying the force to the metal component in the casting mold 12. Here, the drive direction D is perpendicular to the squeeze direction S. By means of the drive arrangement 14 and the squeeze arrangement 16, the apparatus 10 is configured such that a force can be mechanically transferred from the drive arrangement 14 to the squeeze arrangement 16 via a force deflection mechanism 20. Therein and as will be explained in more detail below, the force deflection mechanism 20 is based on a wedge mechanism.

[0055] The drive arrangement 14 and the squeeze arrangement 16 of the embodiment of Fig. 2 are also shown in Fig. 3 in a perspective view and in Fig. 4 in a side view.

[0056] The drive arrangement 14 comprises a cylinder 22 and a piston (not shown) inside the cylinder 22 for driving a piston rod 24. The piston rod is connected to a mover 26. The mover is also shown in an isolated perspective view in Fig. 5. As illustrated, the mover 26 comprises a cylindrical pivot member 28, which is rotatable around its longitudinal axis A. The axis A is perpendicular to the drive direction D and the squeeze direction S. The mover 26 has a section 30 with two arms 32 forming a bracket-like, U-shaped geometry (see in particular Fig. 5). Each arm has a hole or cutout 34 for receiving the pivot member 28. The arms 32 of the mover 26 form a recess for receiving or encompassing a wedge member 40 of the squeeze arrangement 16, as described below.

[0057] Turning now back to Figs. 2 and 3, the squeeze arrangement 16 comprises, in addition to the mentioned wedge member 40, a clutch 42 and two squeeze pins 44. The wedge member 40 is also shown in an isolated perspective view in Fig. 6. As illustrated, the wedge member 40 comprises a cutout 46 so that a wedge surface 48 is provided (see in particular Fig. 6). More specifically, pivot member 28 of mover 26 abuts wedge surface 48 and can roll on wedge surface 48 upon movement of the drive arrangement 14 and the squeeze arrangement 16. In order to reduce friction, the drive arrangement 14 and the squeeze arrangement 16 each comprise means 50a, 50b for lubricating the force deflection mechanism 20.

[0058] By setting the slope or inclination of the wedge surface, the (force and path) transmission ratio of the wedge mechanism and thus of the force deflection mechanism 20 can be adjusted. In the embodiment shown in Figs. 2 - 6, the wedge surface 48 has an inclination angle with respect to the drive direction D of 25°, as can in particular be seen in Fig. 4. While this may be a preferred inclination, other inclination angles are possible, as well.

[0059] As a result, the force deflection mechanism provides a force transmission ratio from the drive arrangement to the squeeze arrangement ($F_{squeeze}/F_{drive}$) larger than 1 and even larger than 2 (and, accordingly, a path transmission ratio smaller than 1). This has the advantage of increasing the squeeze force without the need for a large drive force, which would require a large cylinder for instance.

[0060] When the piston in cylinder 22 is moved in the drive direction D, e.g. by the action of a fluid delivered to the end of the cylinder 22, mover 26 mounted rigidly on the end of the piston rod 24, wedge member 40 is pushed by pivot member 28. Wedge member 40 in turn is linked over clutch 42 with squeeze pins 44, which move in the squeeze direction and squeeze the metal component, such as an engine cylinder block in its bearing area. When the piston in cylinder 22 is moved back against the drive direction, e.g. again by the action of a fluid deliver to the other end cylinder 22, the squeeze pins are returned to their initial position. Afterwards, the metal component can be removed from the casting mold.

[0061] With reference to Fig. 7, a force deflection mechanism 20' realized by an alternative embodiment of a drive arrangement and a squeeze arrangement is now described. Generally, it can be referred to the embodiment already described with respect to Fig. 2 - 6. However, in contrast to the embodiment described above, in the alternative embodiment of Fig. 7, instead of the mover the wedge member 40' has a bracket-like, U-shaped section with two arms 32', which provide a recess for receiving or encompassing a mover 26' with a pivot member 28'. Each of the arms 32' has a cutout 46', which provide a respective wedge surface 48'. The working principle of this embodiment, however, is the same as described above.

[0062] As can be seen, the force deflection mechanism 20, 20' utilizing the above described wedge mechanism can directly transfer a translational motion of the drive arrangement 14,14' in the drive direction D into a translational motion of the squeeze arrangement 16, 16' in the squeeze direction S. Advantageously, this can be achieved with a compact, gear-free mechanism. Rather the force deflection mechanism 20, 20' can essentially be realized by the mover 26, 26' with the pivot member 28, 28' on the one hand and the wedge member 40, 40' on the other hand.

[0063] Fig 8 shows the exemplary lubrication element 50a implemented into the apparatus of Fig. 2 in a perspective view. The lubrication element 50a is in this case a planar plate and it is adjacent to and contacts the mover 26, more specifically the arms 32 of the bracket-like, U-shaped section 30 of mover 26. The lubrication plate comprises a channel system 52a for guiding a lubricant to the mover for lubricating the force deflection mechanism 20, and in particular for lubricating pivot member 28 and wedge surface 48.

[0064] Fig. 8 also shows the exemplary lubrication element 50b for the wedge member of the apparatus of Fig. 2 in a perspective view, which may be provided in addition or in alternative to lubrication element 50a. The lubrication element 50b is an angled plate and abuts wedge member 40 on the side opposite the drive arrangement 14. Similar to lubrication element 50a, the lubrication element 50b comprises a channel system 52b for guiding a lubricant to the wedge member for lubricating the force deflection mechanism 20, and in particular for lubricating pivot member 28 and wedge surface 48.

[0065] In each case, the lubricant may be or may be based on mineral oil, synthetic oil, a solid lubricant or an aequeous lubrication. For instance, the lubricant may be grease, such as high performance grease, e.g. based on Lithium 12-hydroxystearate.

[0066] In the following, an exemplary force calculation is provided for the embodiment shown in Fig. 2 - 7 to further illustrate that a comparably small cylinder can achieve a sufficient squeeze volume. Assuming that a squeeze pressure of 3,000 bar is required for achieving a sufficient squeeze volume. With a squeeze area (area of the squeeze pins) of 226 mm^2, one obtains a required squeeze force $F_{squeeze}$ of 67,800 N. With an angle of inclination of the wedge surface of about 25° with respect to the drive direction D, the force, which needs to be provided by cylinder 22 in the drive arrangement is $F_{drive} = F_{squeeze} * \tan(25°) = 31{,}616$ N. Thus, a compact hydraulic cylinder with a push force of around 43,000 N and a pull force with 35,000 N for 140 bar would be sufficient for reducing the porosity of an aluminum engine cylinder block with the above apparatus.

[0067] The advantages of the described approach can be summarized as follows:

- allowing a metal compression during solidification for reducing the volume of porosity and
- thereby improving the mechanical properties of (yield strength, ultimate tensile strength, elongation) of the metal component
- thereby scrap production
- achieving a compact size of the mechanism
- avoiding costly and special maintenance
- easily implementing approach into existing casting tools

List of reference signs:

[0068]

1	cylinder
2	clutch
3a,b	gearing arrangement
4	core pin
10	apparatus
12	casting mold
14, 14'	drive arrangement
16, 16'	squeeze arrangement
20, 20'	force deflection mechanism
22	cylinder
24	piston rod
26, 26'	mover
28, 28'	pivot member
30	bracket-like, U-shaped section
32, 32'	arms
34	hole, cutout
40, 40'	wedge member
42	clutch
44	squeeze pins
46, 46'	cutout
48, 48'	wedge surface
50a,b	lubrication elements
52a,b	channel system
A	longitudinal axis of pivot member
D	drive direction
S	squeeze direction

Claims

1. An apparatus (10) for applying a force to a metal component in a casting mold (12), the apparatus (10) comprising:

   - a drive arrangement (14, 14') at least in part movable in a drive direction (D); and
   - a squeeze arrangement (16, 16') at least in part movable in a squeeze direction (S) for applying the force to the metal component in the casting mold (12);

   wherein the apparatus (10) is configured such that a force can be mechanically transferred from the drive arrangement (14, 14') to the squeeze arrangement (16, 16') via a force deflection mechanism (20, 20'); and
   wherein the force deflection mechanism (20, 20') is based on a wedge mechanism.

2. The apparatus according to claim 1, wherein the drive direction (D) is transverse, preferably substantially perpendicular to the squeeze direction (S).

3. The apparatus according to claim 1 or 2, wherein the force deflection mechanism (20, 20') provides a force transmission ratio from the drive arrangement (14,14') to the squeeze arrangement (16, 16') smaller or larger than 1.

4. The apparatus according to any of claims 1 to 3, wherein the force deflection mechanism (20, 20') is a gear-free mechanism.

5. The apparatus according to any of claims 1 to 4, wherein the force deflection mechanism directly transfers a translational motion of the drive arrangement (14,14') in the drive direction (D) into a translational motion of the squeeze arrangement (16, 16') in the squeeze direction (S).

6. The apparatus according to any of claims 1 to 5, wherein the drive arrangement (14,14') and/or the squeeze arrangement (16, 16') comprises a wedge member (40, 40') providing a wedge surface (48, 48').

7. The apparatus according to any of claims 1 to 6, wherein either the squeeze arrangement (16,16') or the drive arrangement (14, 14') comprises a wedge member (40, 40') providing a wedge surface (48, 48') and wherein the respective other arrangement of the drive arrangement (14,14') and the squeeze arrangement (16, 16') comprises a mover (26, 26') cooperating with the wedge member (40, 40').

8. The apparatus according to claim 7, wherein the

mover (26, 26') comprises a pivot member (28, 28') rotatable around an axis (A) of the pivot member (28, 28') and abutting the wedge member (40, 40').

9. The apparatus according to claim 7 or 8, wherein the mover (26) comprises a bracket-like, in particular U-shaped section (30) so as to encompass the wedge member (40).

10. The apparatus according to any of claims 6 to 9, wherein the wedge surface (48, 48') has an inclination with an angle with respect to the drive direction (D) of at least 10°, preferably at least 20° and/or at most 40°, preferably at most 30°.

11. The apparatus according to any of claims 1 to 10, wherein the apparatus comprises means (50a, 50b) for lubricating the force deflection mechanism (20, 20').

12. The apparatus according to any of claims 1 to 11, wherein the squeeze arrangement (16, 16') comprises:

- one or more squeeze pins (44); and/or
- a clutch (42).

13. The apparatus according to any of claims 1 to 12, wherein the drive arrangement (14,14') comprises:

- a cylinder (22); and/or
- a piston; and/or
- a piston rod (24).

14. The apparatus according to any of claims 1 to 13, wherein the apparatus further comprises the casting mold (12).

15. A method for applying a force to a metal component in a casting mold, the method comprising:

- at least in part moving a drive arrangement in a drive direction;
- thereby mechanically transferring a force from the drive arrangement to a squeeze arrangement via a force deflection mechanism, wherein the force deflection mechanism is based on a wedge mechanism; and
- thereby at least in part moving the squeeze arrangement in a squeeze direction for applying the force to the metal component.

16. Use of an apparatus according to any of claims 1 to 14 for applying a force to a metal component, in particular an engine cylinder block, in a casting mold, in particular for squeezing a bearing area of the engine cylinder block.

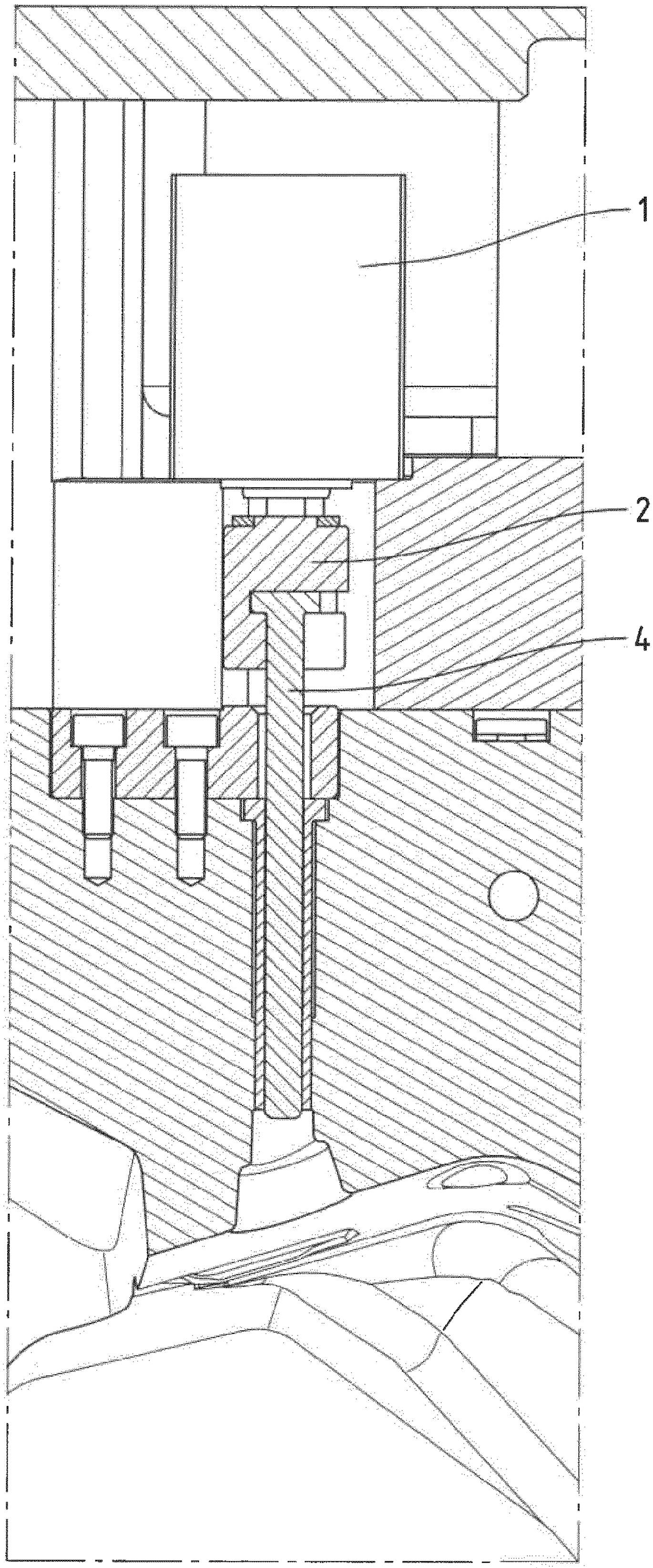

Fig.1A Prior Art

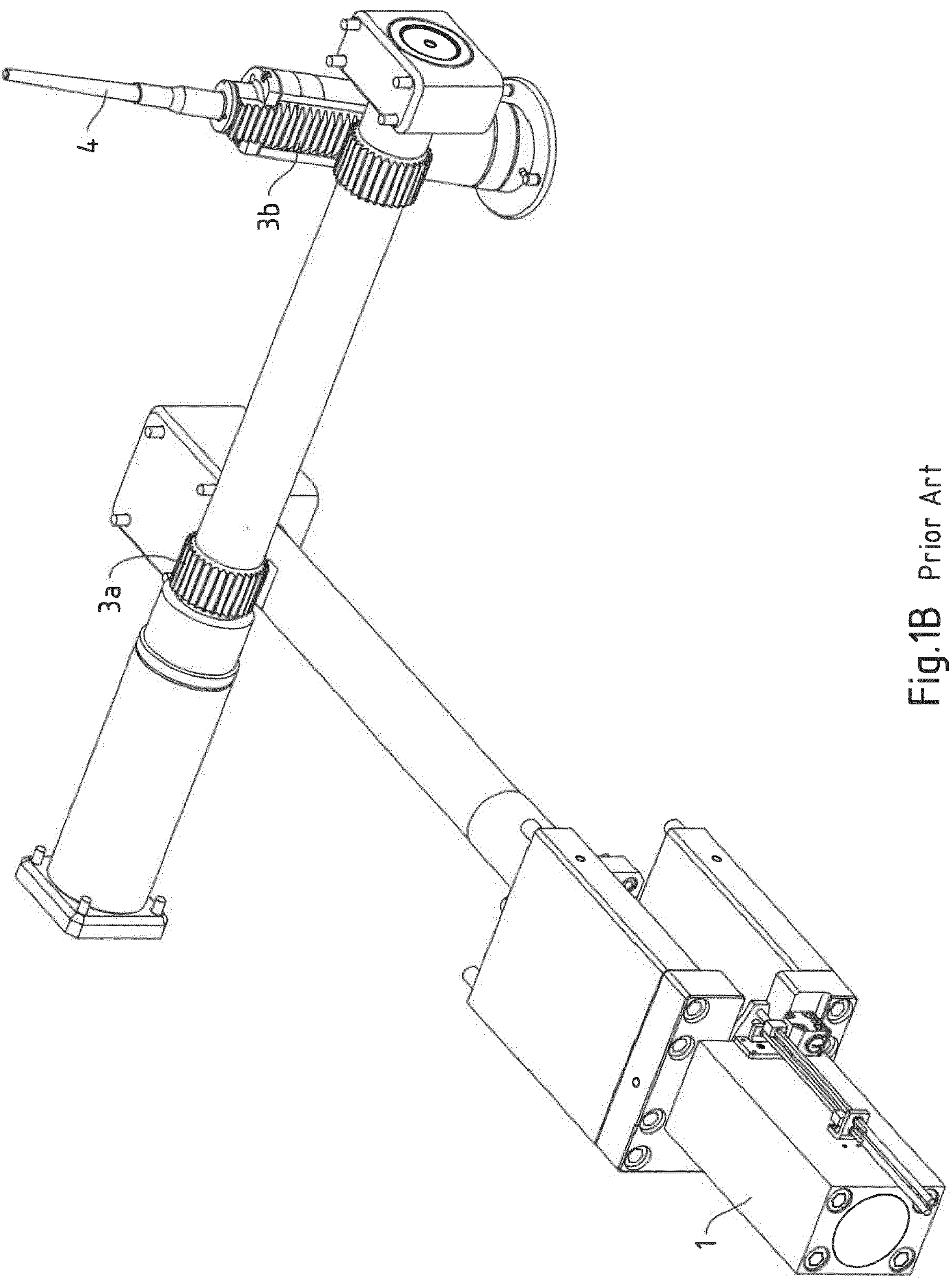

Fig.1B Prior Art

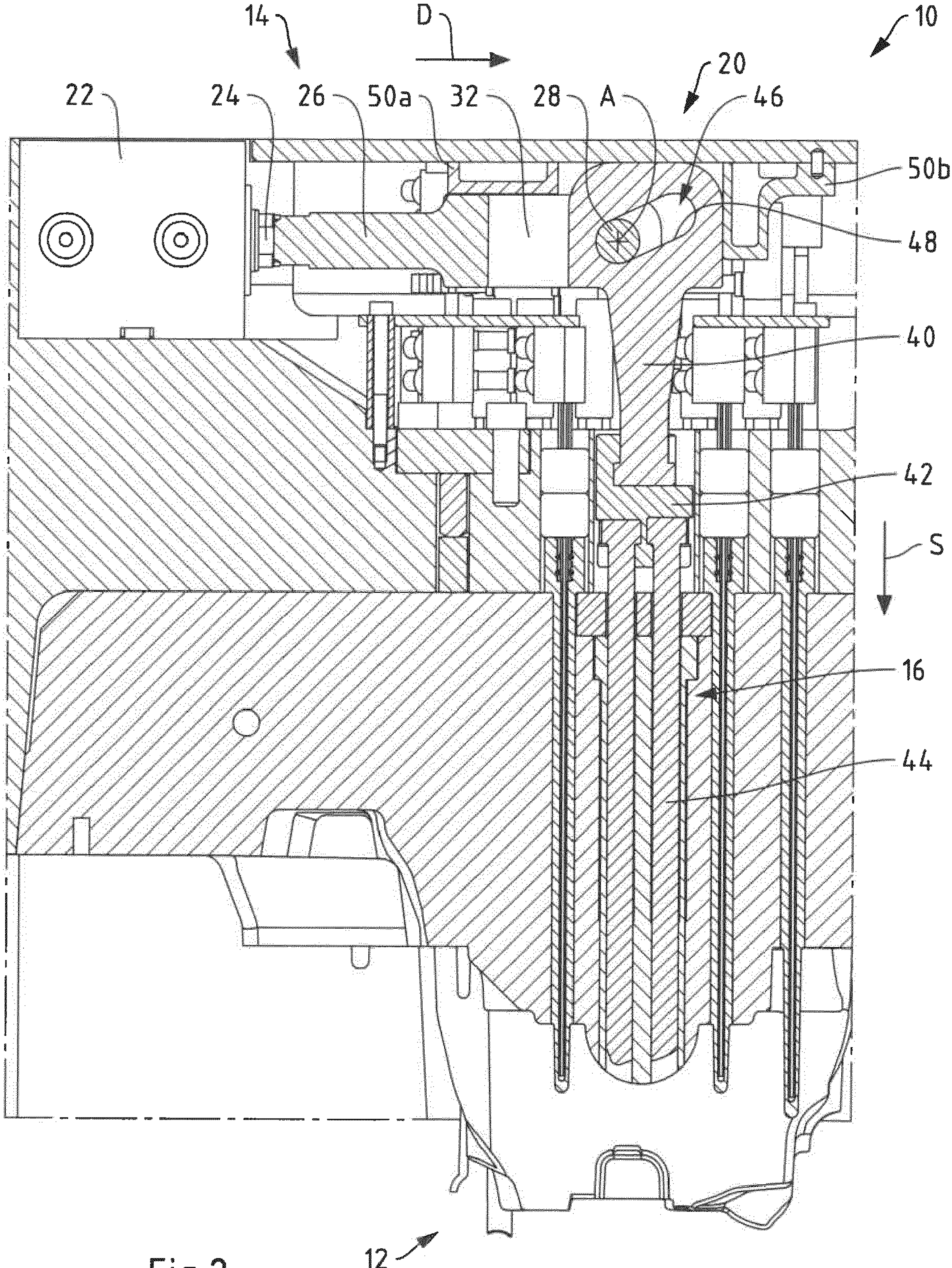

Fig.2

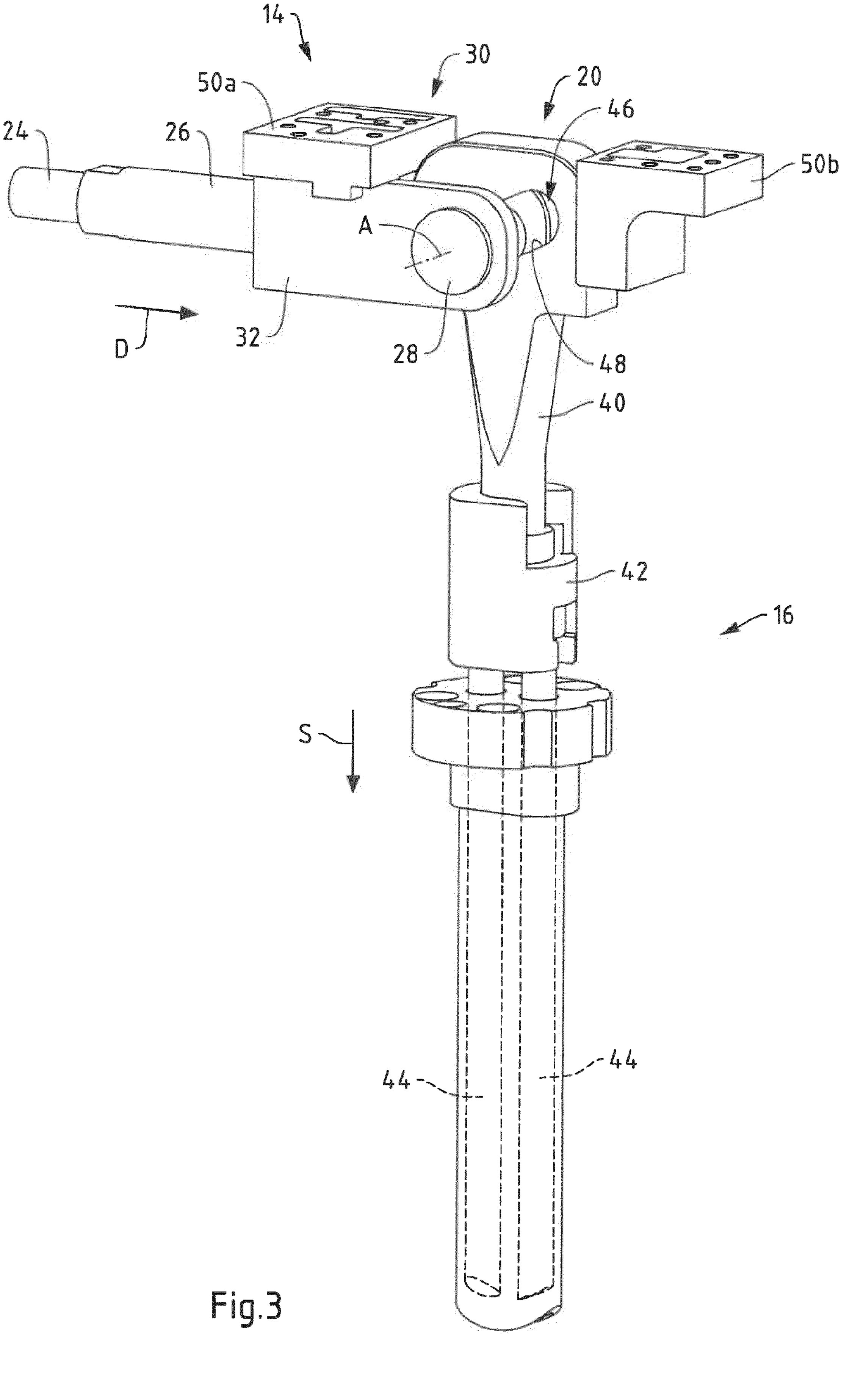

Fig.3

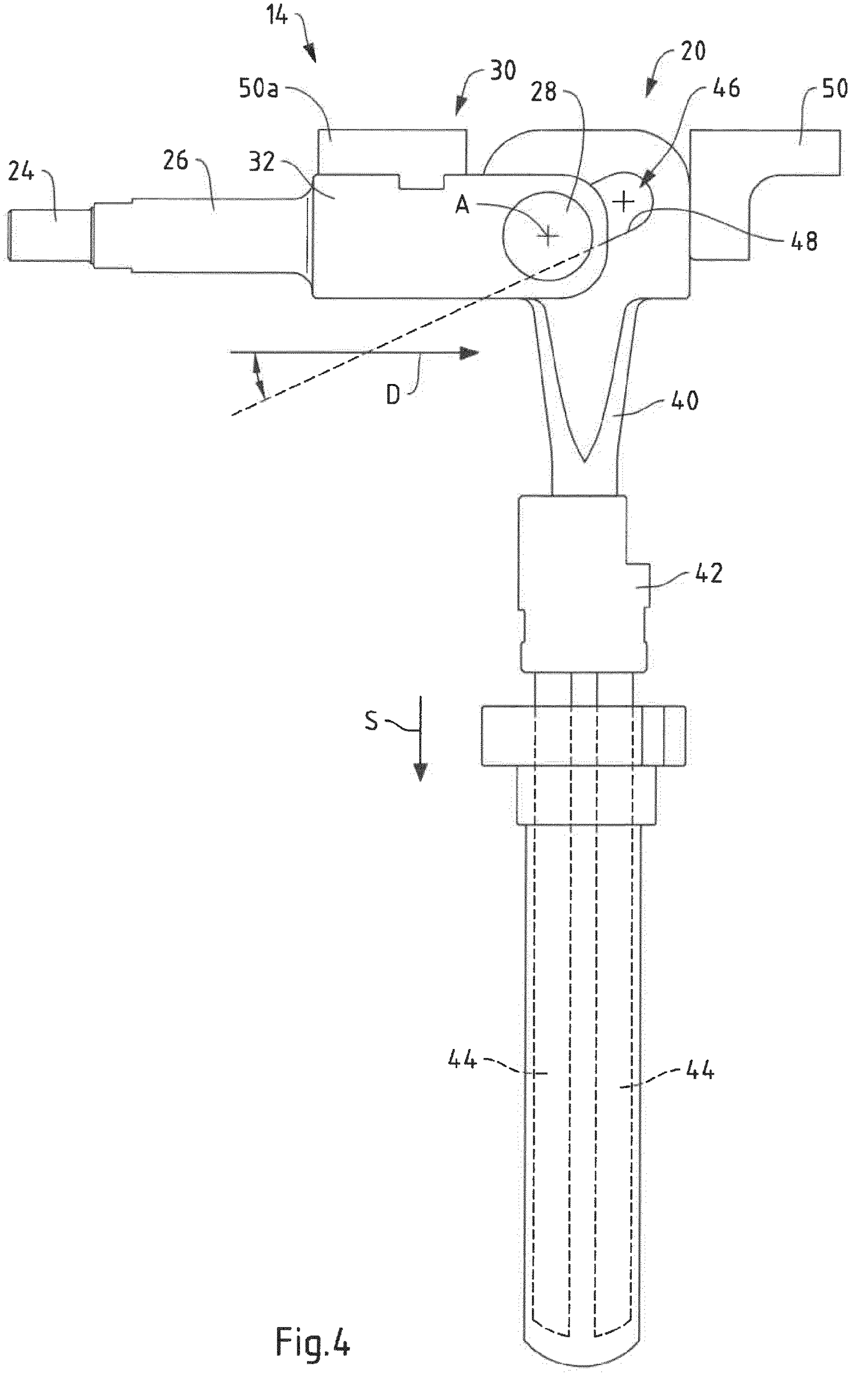

Fig.4

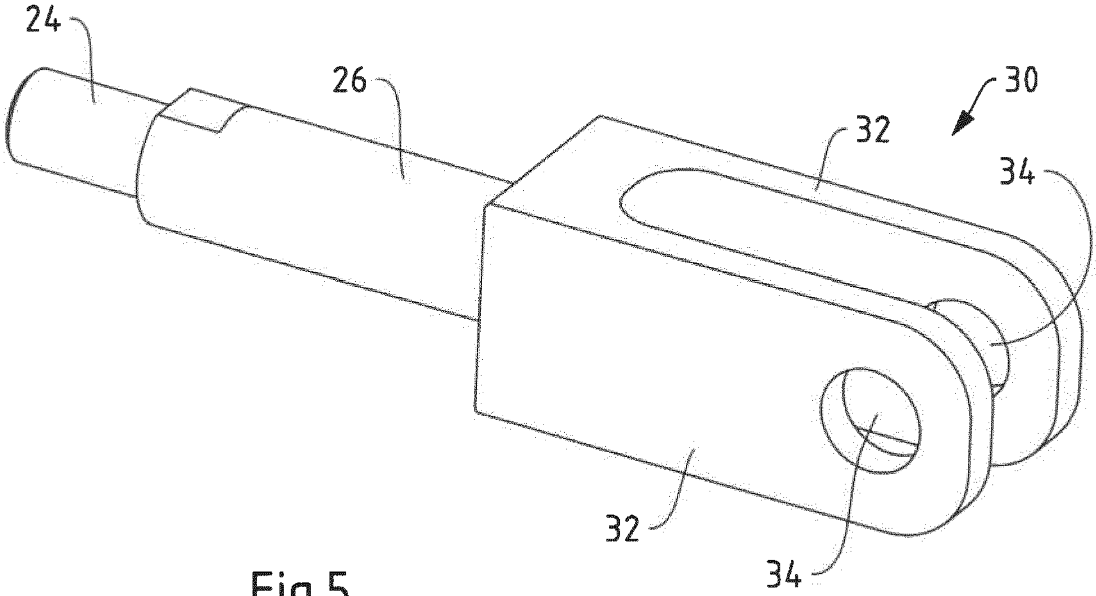

Fig.5

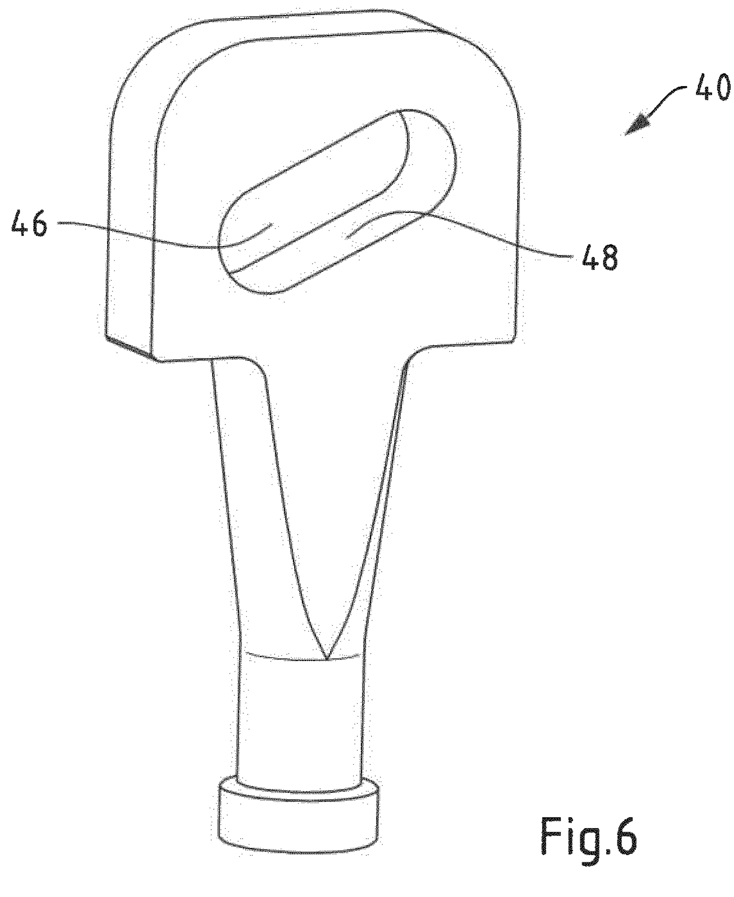

Fig.6

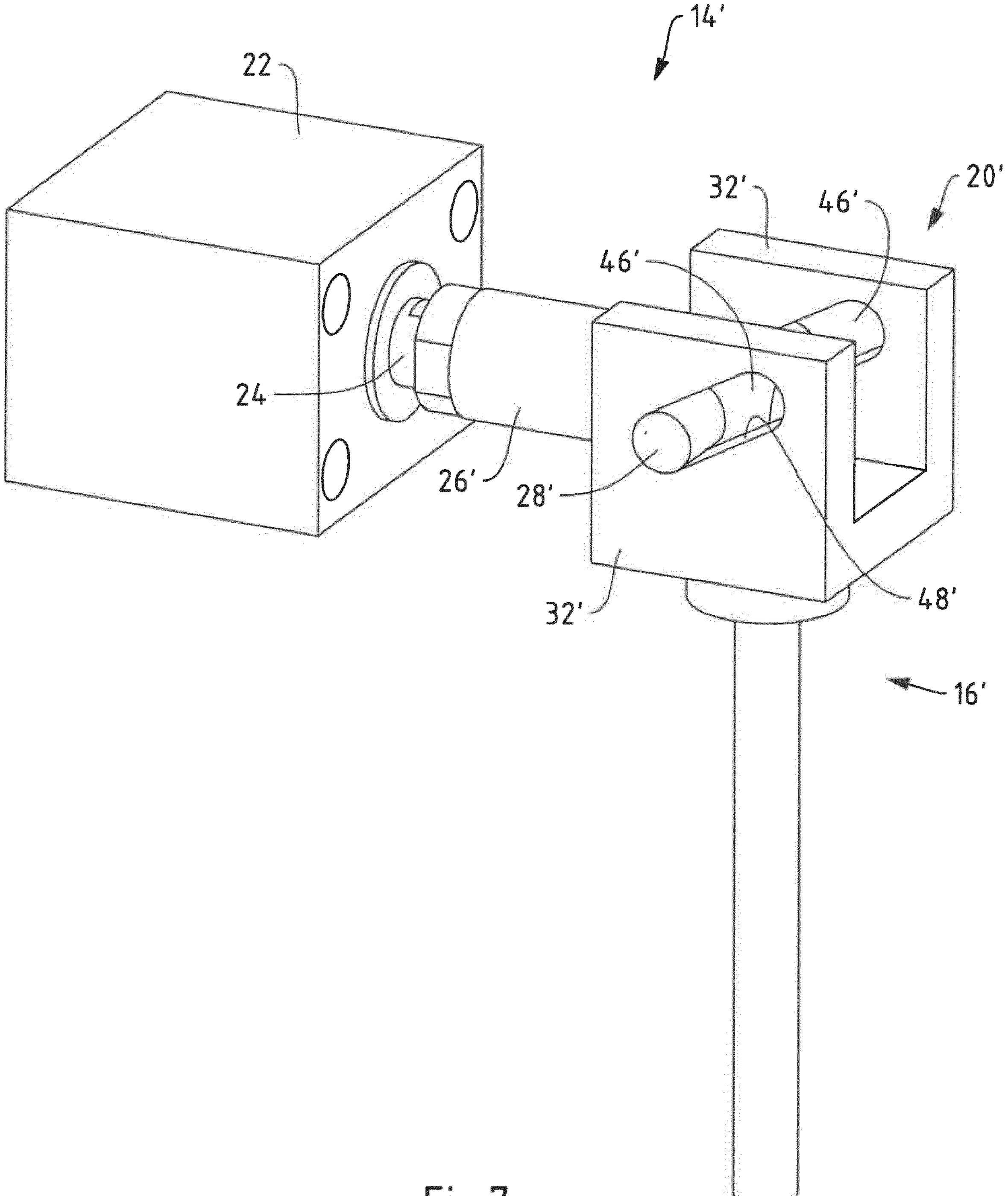

Fig.7

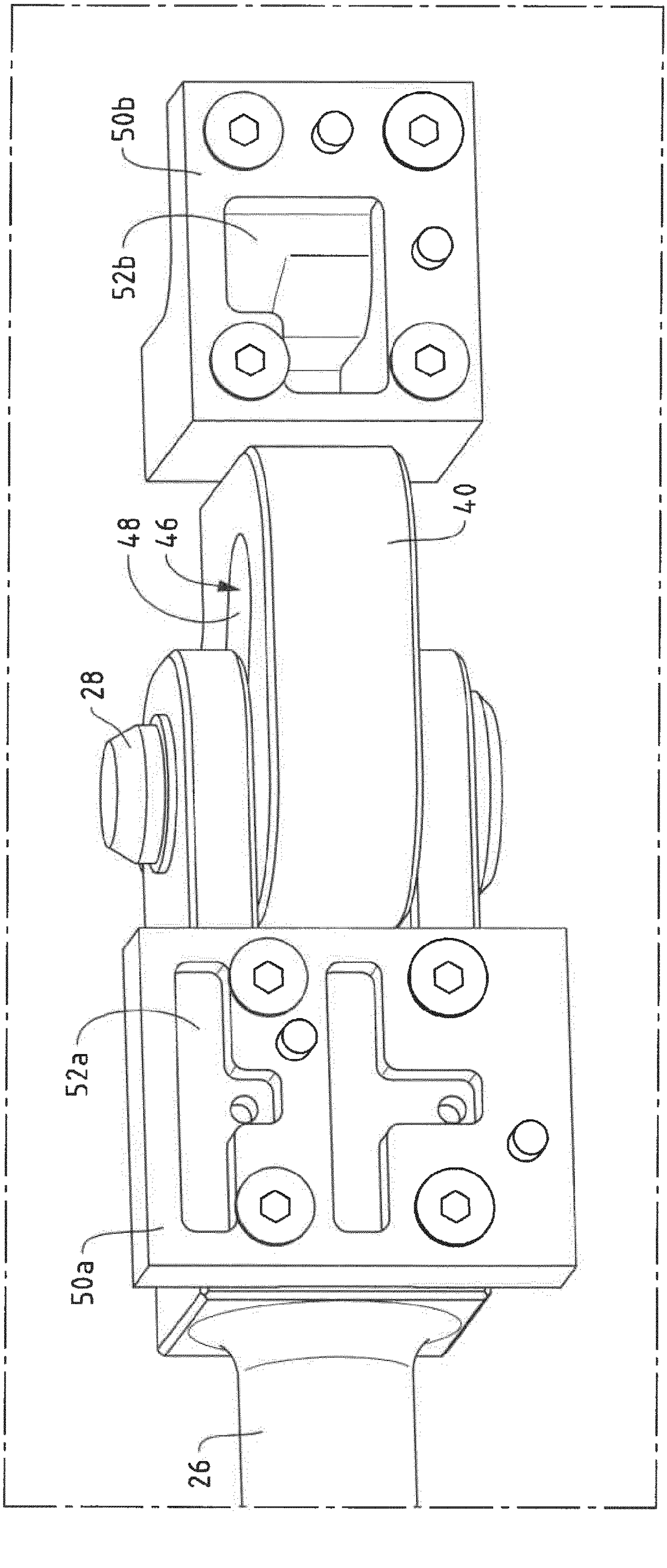

Fig.8

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EUROPEAN SEARCH REPORT

Application Number
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1

Place of search	Date of completion of the search	Examiner
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