US 20250256440A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2025/0256440 A1
GIBSON
(43) Pub. Date: Aug. 14, 2025

(54) **METHOD AND APPARATUS RELATING TO MANUFACTURE OF MOLD HALVES FOR FORMING CONTACT LENSES**

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(21) Appl. No.: **18/997,187**

(22) PCT Filed: **Jul. 19, 2023**

(86) PCT No.: **PCT/GB2023/051901**

§ 371 (c)(1),
(2) Date: **Jan. 21, 2025**

Related U.S. Application Data

(60) Provisional application No. 63/391,332, filed on Jul. 22, 2022.

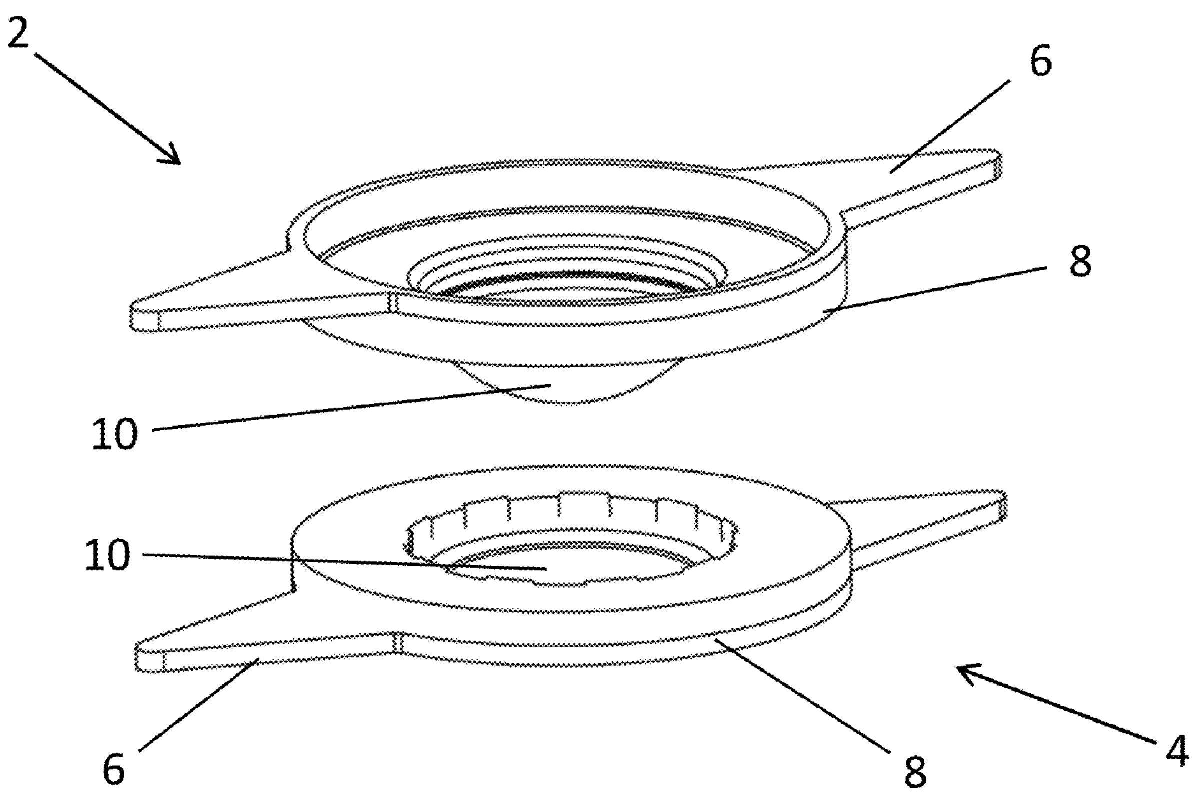
Publication Classification

(51) **Int. Cl.**
B29C 45/17 (2006.01)
B29C 45/26 (2006.01)
B29L 31/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B29C 45/1756*** (2013.01); ***B29C 45/26*** (2013.01); *B29L 2031/757* (2013.01)

(57) **ABSTRACT**

An apparatus (**60**) for injection molding of mold halves (**2**, **4**) for use in the manufacture of contact lenses comprises one or more first tool halves (**22**) mounted on a first support (**80**), and one or more second tool halves (**24**) releasably mounted on a second support (**82**). With the second support (**82**) in an operative orientation, the first and second supports (**80**, **82**) are movable between a closed position in which the first and second tool halves (**22**, **24**) engage one another to provide corresponding mold cavities (**54**) therebetween, and an open position in which the first and second tool halves (**22**, **24**) are aligned with one another across a part removal gap (**86**). The second support (**82**) is movable between the operative orientation, and a reloading orientation in which the second tool halves (**24**) are located in a tool change area (**64**) that is out of alignment with the first tool halves (**22**).



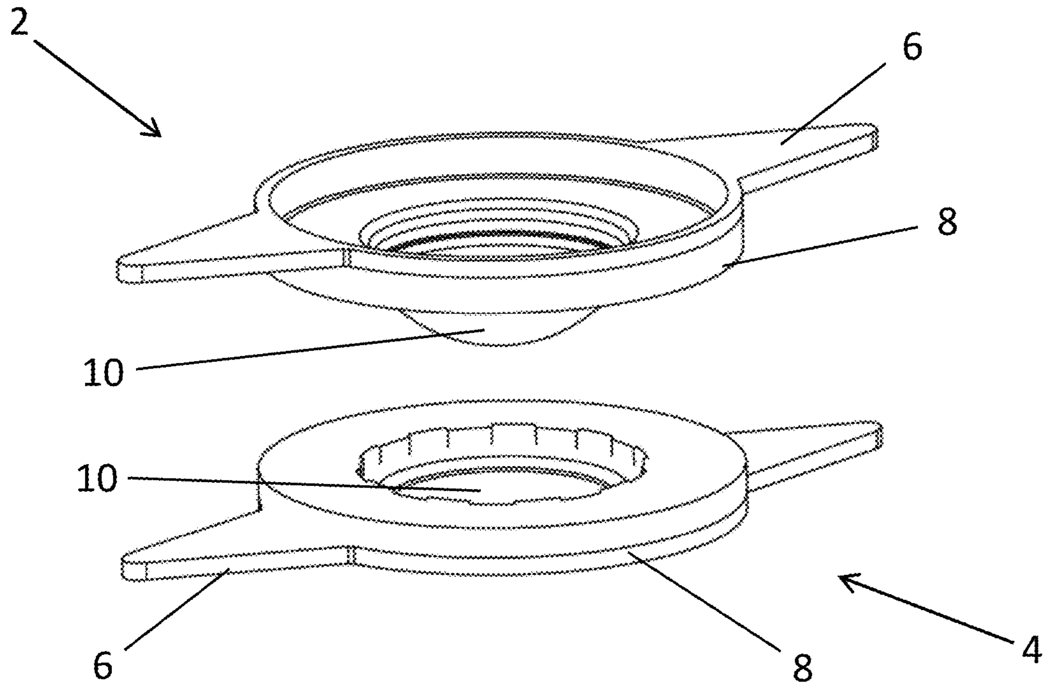


FIG. 1A

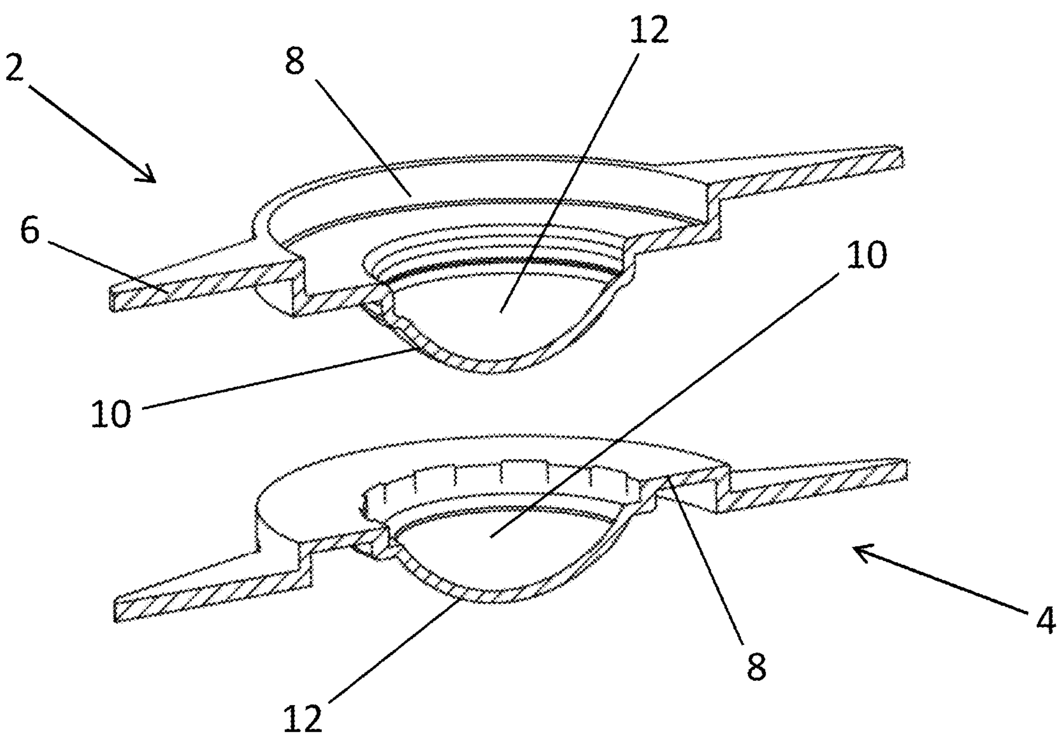


FIG. 1B

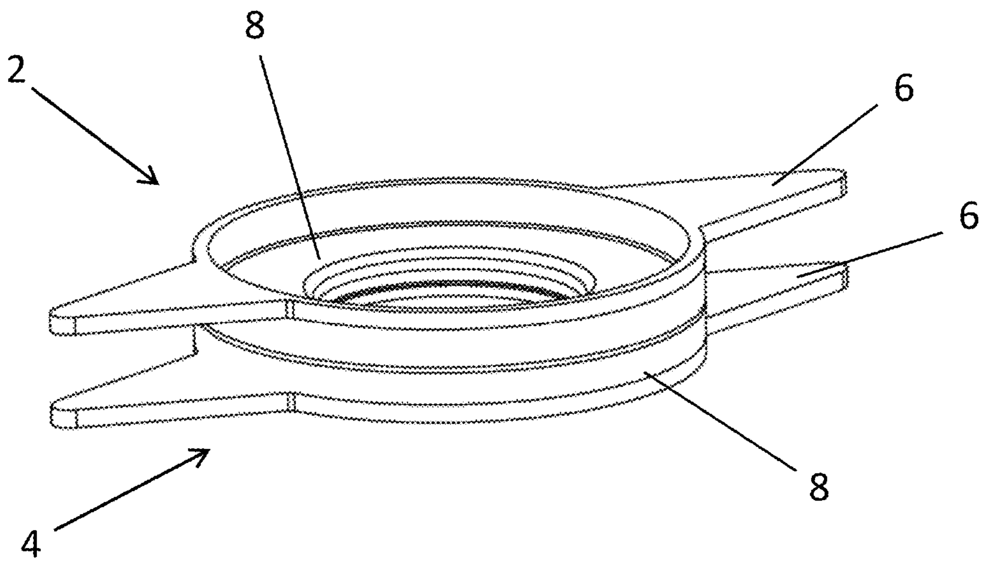


FIG. 2A

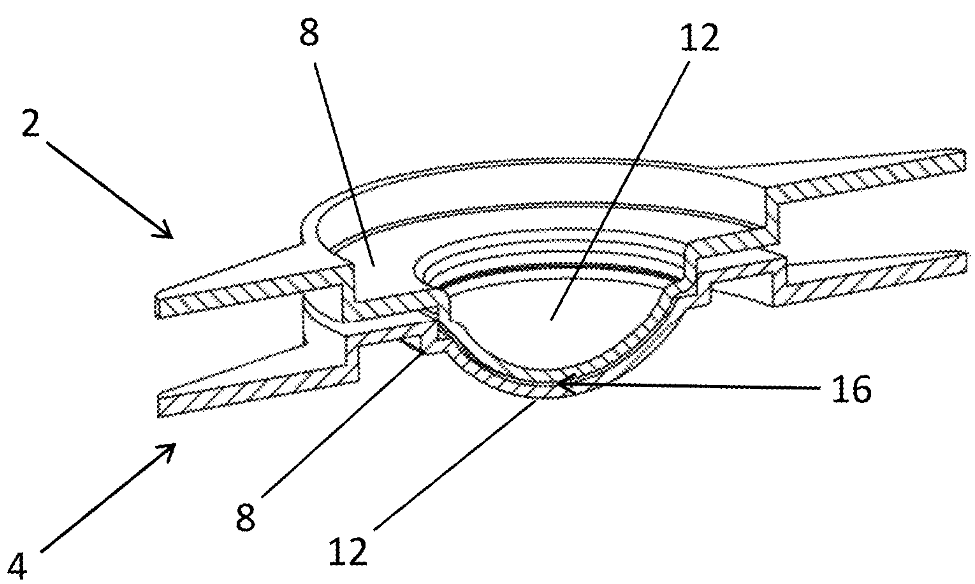


FIG. 2B

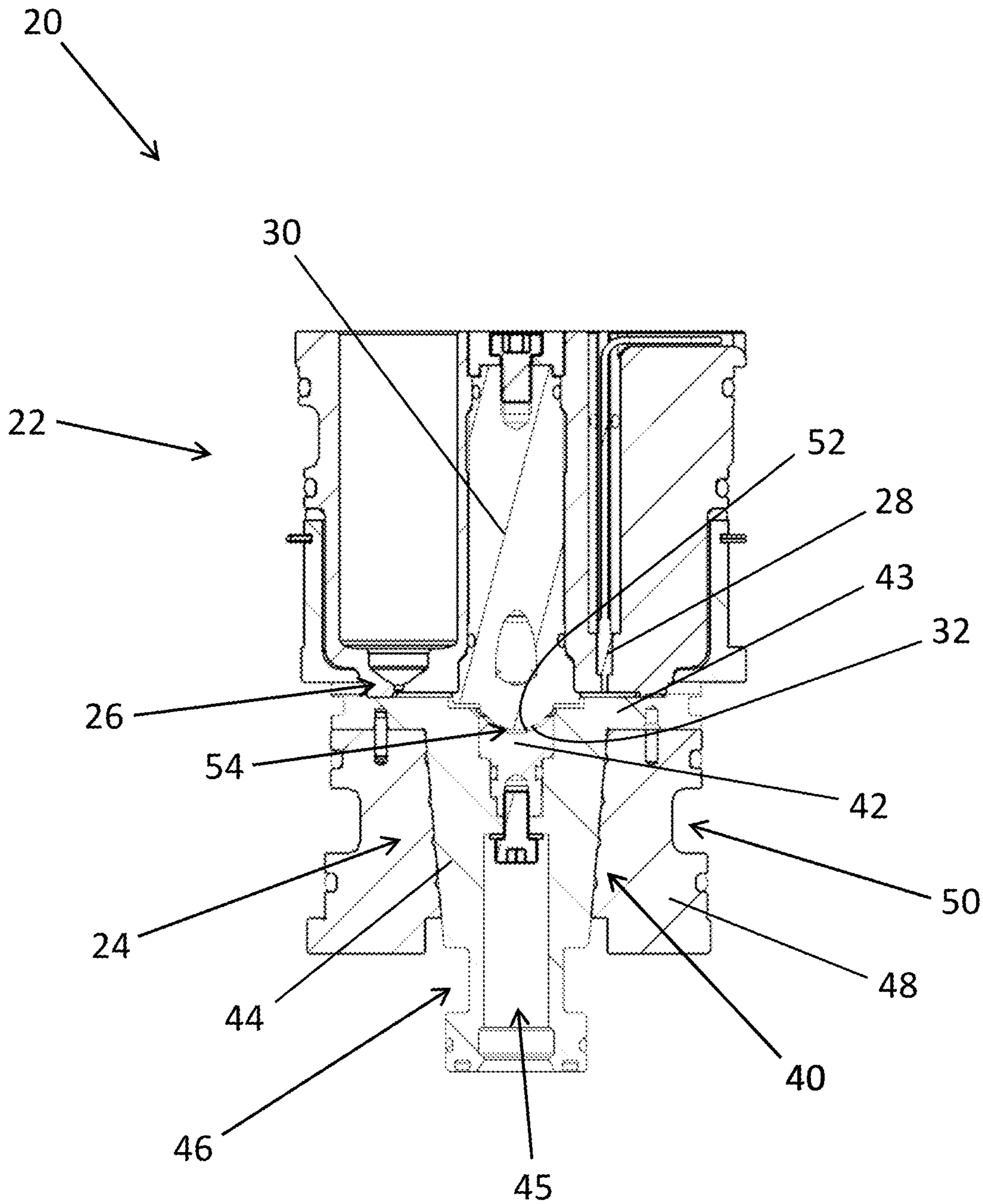


FIG. 3

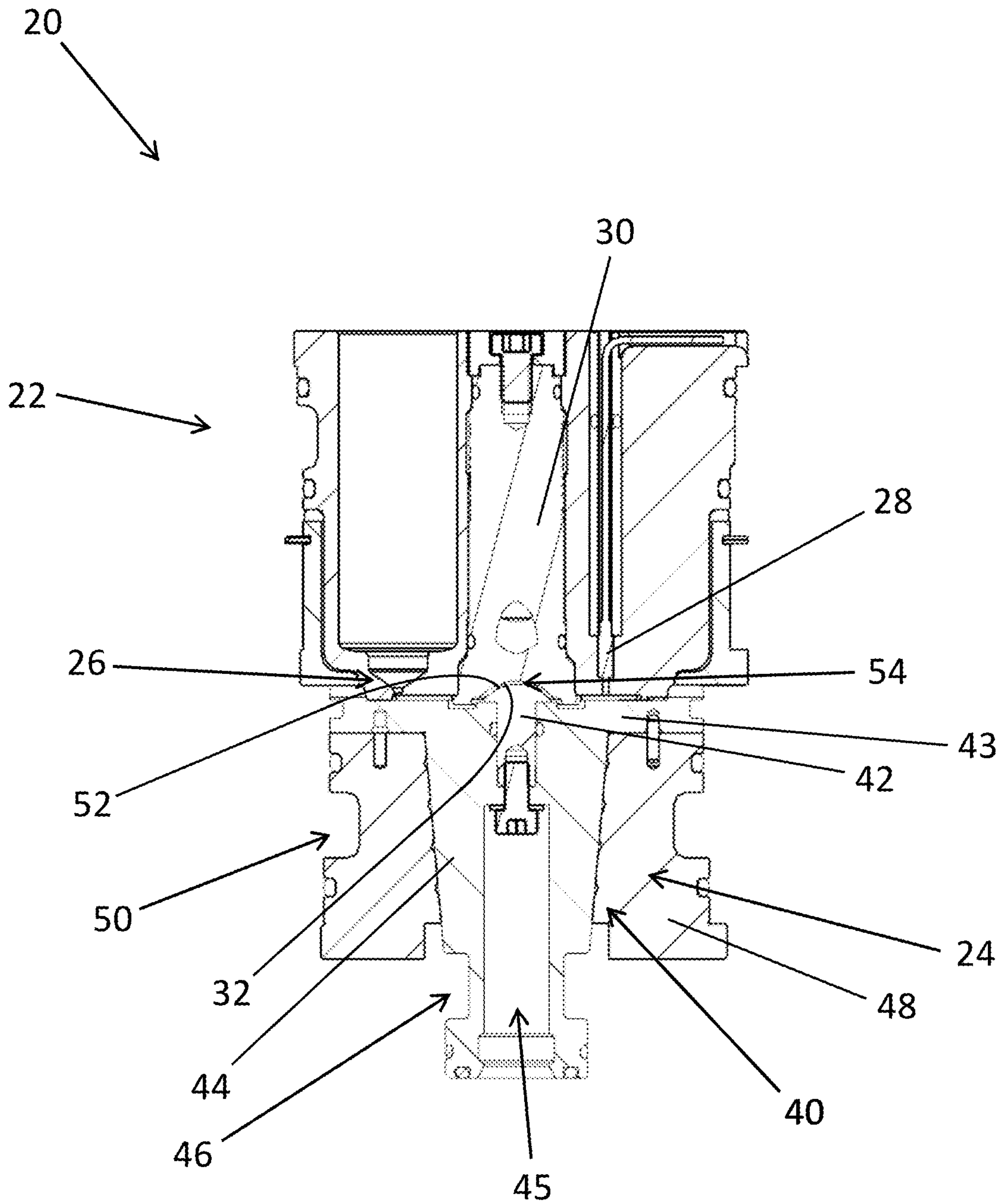


FIG. 4

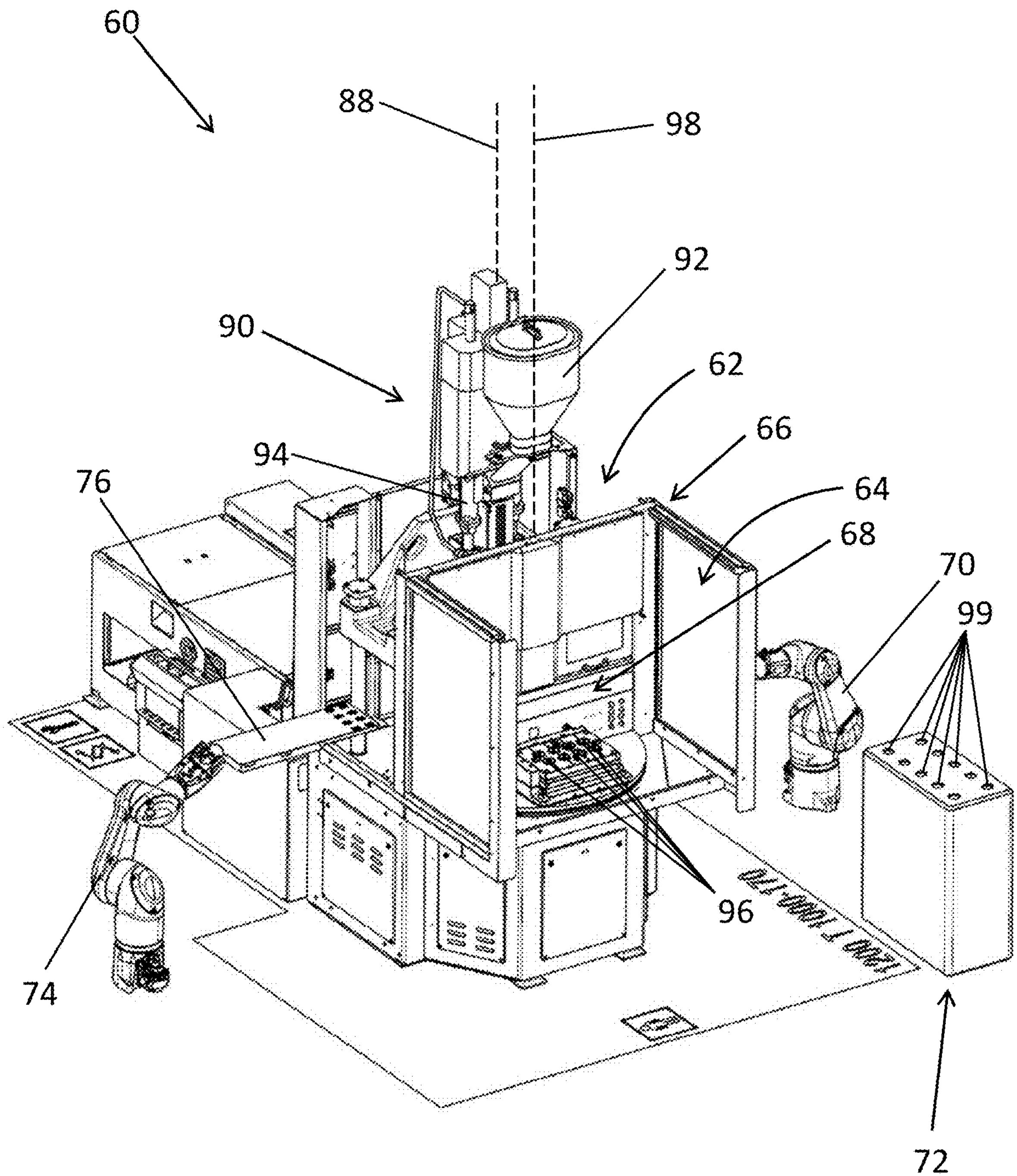


FIG. 5

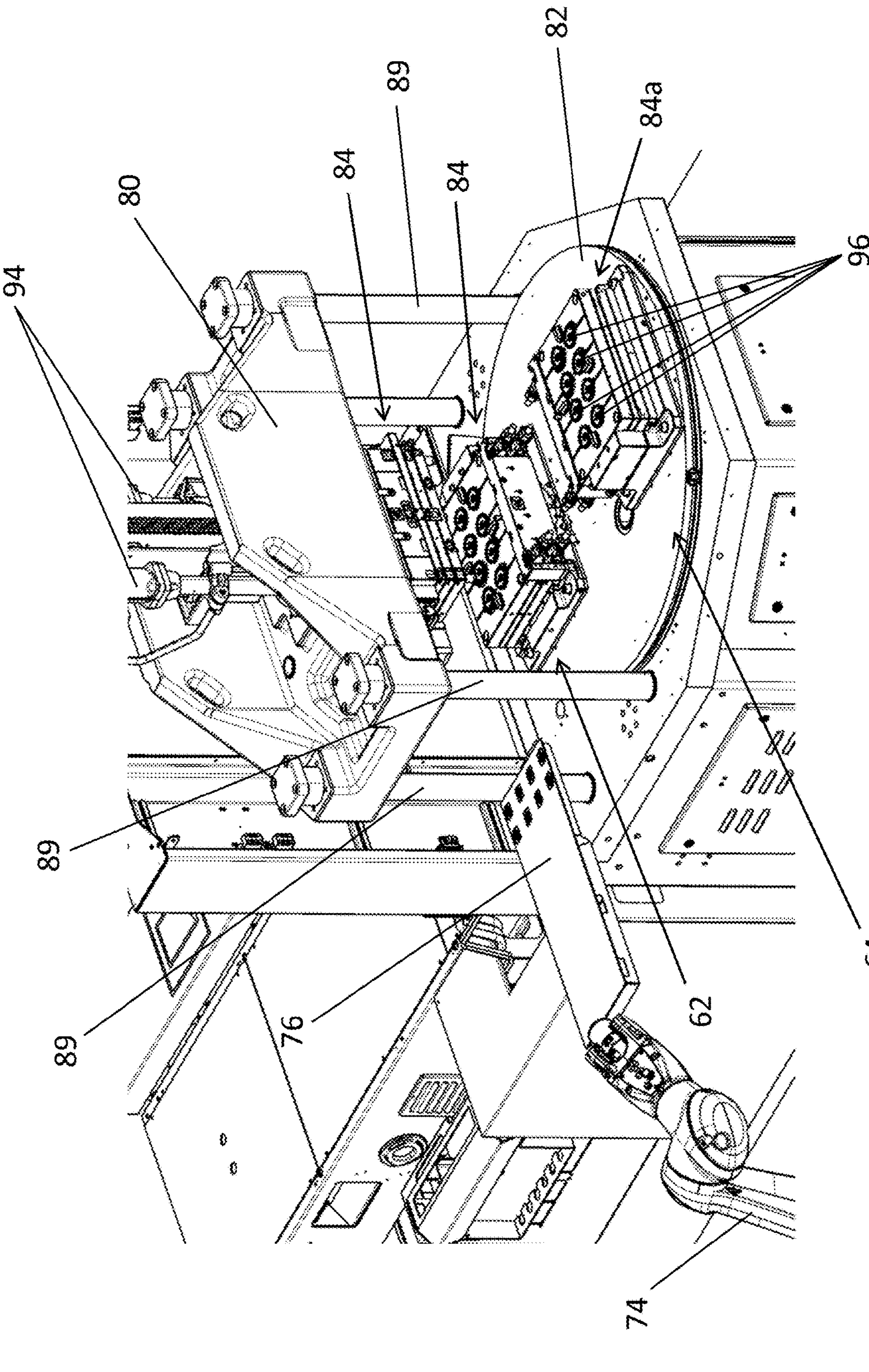


FIG. 6

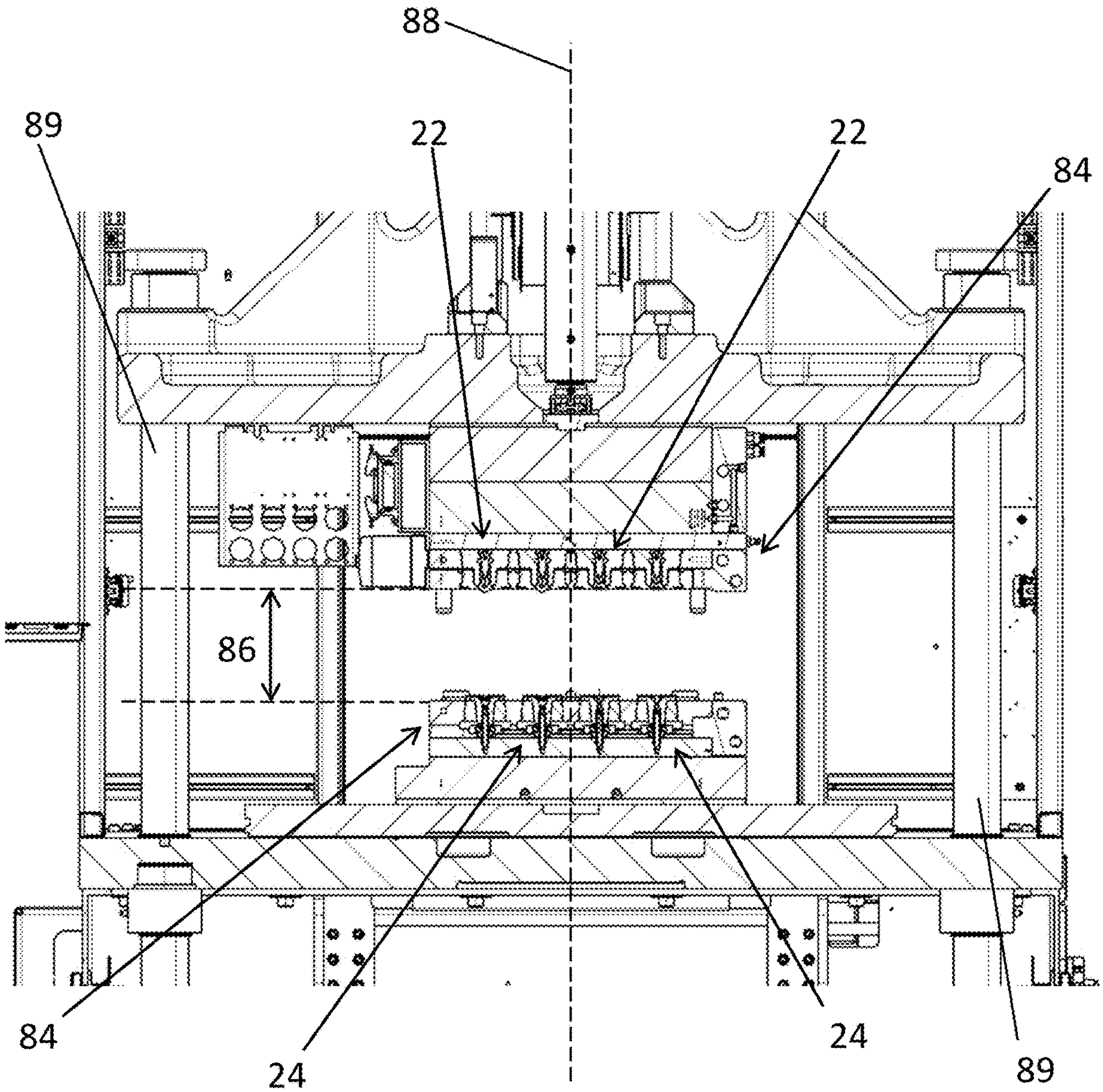


FIG. 7

METHOD AND APPARATUS RELATING TO MANUFACTURE OF MOLD HALVES FOR FORMING CONTACT LENSES

FIELD

[0001] The present disclosure relates to the field of contact lens manufacture, using mold halves produced by injection molding. In particular, it relates to apparatus and methods for rapidly inspecting, replacing or exchanging tools in injection molding machines in order to manufacture said mold halves.

BACKGROUND

[0002] Various methods of manufacturing contact lenses are known, including spin casting, lathing (for example, by diamond turning) and cast molding (for example, using injection molded mold halves). In particular, cast molding of contact lenses involves forming a pair of mold halves (i.e., a first mold half and a second mold half), placing a volume of a contact lens formulation on an optical quality surface of one of the two mold halves, and placing the two mold halves in contact with each other to form a contact lens mold assembly that has a contact lens-shaped cavity containing the contact lens formulation. The contact lens mold assembly is then exposed to conditions to cause the contact lens formulation to polymerize or cure in the contact lens mold assembly. Using high speed manufacturing lines, contact lenses can be manufactured in very large numbers, for example, tens of thousands each day. Increases in the rate of manufacture of contact lenses can be expected to bring down the cost of each lens. It is important, however, that increased rates of manufacture do not compromise the quality of the lenses produced.

[0003] When contact lenses are formed by cast molding using injection molded contact lens mold halves, the process includes many steps. For example, the process of producing the mold halves can include closing two injection molding tool halves provided in plates of an injection molding machine, forming the contact lens mold halves in the closed injection molding tool halves, opening the tool halves containing the injection molded mold halves, removing the injection molded mold halves from the opened tool halves and optionally transferring the newly formed mold halves to a transporter for further processing. As understood by persons skilled in the art, and as used herein, an injection molding tool half refers to the (usually metallic) inserts used to form curved surfaces of the contact lens mold halves. The inserts are typically provided in plates of an injection molding machine. One or both of the inserts, or tool halves, will have an optical quality surface used to form a lens-forming surface of a contact lens mold half.

[0004] The mold halves, and in particular the optical surfaces thereof, must be produced to high manufacturing tolerances. Accordingly, the tool halves used to mold them are usually subject to frequent inspection and are replaced or repaired at the first sign of wear or damage. In addition, the same injection molding machine is normally used to produce a range of shapes of mold halves, each shape of mold half producing a contact lens of corresponding shape (and thus optical characteristics). Conventionally, the tool halves are changed by discontinuing use of the injection molding machine, changing out the tool halves (for instance using a robotic arm) and then recommencing use of the machine. The machine down-time necessary to change over the tools can add considerably to the overall production costs of mold halves, and thus the contact lenses produced therewith.

[0005] It is an object of the invention to mitigate or obviate one of the aforesaid disadvantages, and/or to provide an improved or alternative apparatus or part of apparatus for injection molding of mold halves, method for injection molding mold halves, mold half for manufacturing a contact lens, method for manufacturing a contact lens, or contact lens.

SUMMARY

[0006] According to a first aspect of the present disclosure there is provided an apparatus for injection molding of mold halves for use in the manufacture of contact lenses, the apparatus comprising one or more first tool halves mounted on a first support, and one or more second tool halves releasably mounted on a second support. With the second support in an operative orientation, the first and second supports are movable between a closed position in which the first and second tool halves engage one another to provide corresponding mold cavities therebetween, and an open position in which the first and second tool halves are aligned with one another across a part removal gap. The second support is movable between the operative orientation, and a reloading orientation in which the second tool halves are located in a tool change area that is out of alignment with the first tool halves.

[0007] According to a second aspect of the present disclosure there is provided a part of an apparatus according to the first aspect of the disclosure, said part comprising the first support, the second support, and a drive mechanism for moving the first and second supports between the open and closed positions and moving the second support between said orientations.

[0008] According to a third aspect of the present disclosure there is provided a method of injection molding mold halves for use in the manufacture of contact lenses. The method comprises moving a second support to an operative orientation, and then moving a first support and the second support to a closed position such that one or more first tool halves supported on the first support and one or more second tool halves releasably supported on the second support engage one another to provide corresponding mold cavities therebetween. The method further comprises injecting molten polymer into the mold cavities, then allowing the polymer to solidify in the mold cavities and form mold halves. Further, the method comprises moving the first and second supports to an open position such that the first and second tool halves are aligned with one another across a part removal gap. The method also comprises removing said mold halves through the part removal gap. In addition, the method comprises moving the second support to a reloading orientation in which the second tool halves are located in a tool change area which is out of alignment with the first tool halves. The method further comprises removing the second tool halves from the second support.

[0009] According to a fourth aspect of the present disclosure there is provided a mold half for manufacturing a contact lens, injection molded using the apparatus of the first aspect of the disclosure and/or the method of the third aspect of the disclosure.

[0010] According to a fifth aspect of the present disclosure there is provided a method of manufacturing a contact lens.

The method comprises injection molding a male mold half and injection molding a female mold half, at least one of said mold halves being a mold half according to the fourth aspect of the disclosure. The method further comprises engaging the male and female mold halves with one another, with a quantity of a contact lens formulation located in a cavity defined therebetween. The method further comprises curing the contact lens formulation to form said contact lens. The method further comprises separating the male and female mold halves and removing the contact lens.

[0011] According to a sixth aspect of the present disclosure there is provided a contact lens manufactured using the method of the fifth aspect of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIGS. **1**A and **1**B are a perspective and cross-sectional views of two mold halves for use in the production of a contact lens.

[0013] FIGS. **2**A and **2**B are perspective and cross-sectional views of the two mold halves of FIGS. **1**A and **1**B engaging one another to define a cavity therebetween.

[0014] FIG. **3** is a cross-sectional view through a pair of tool halves used to produce the male mold half of FIGS. **1**A to **2**B.

[0015] FIG. **4** is a cross-sectional view through a pair of tool halves used to produce the female mold half of FIGS. **1**A to **2**B.

[0016] FIG. **5** is a perspective view of an apparatus for injection molding the mold halves of FIGS. **1**A to **2**B, using the pairs of tool halves shown in FIGS. **3** and **4**.

[0017] FIG. **6** is a perspective view of the apparatus of FIG. **5**, with a divider removed.

[0018] FIG. **7** is a cross-sectional view of first and second supports of the apparatus of FIGS. **5** and **6**.

DETAILED DESCRIPTION

[0019] According to a first aspect of the present disclosure there is provided an apparatus for injection molding of mold halves for use in the manufacture of contact lenses, the apparatus comprising one or more first tool halves mounted on a first support, and one or more second tool halves releasably mounted on a second support, wherein:

[0020] with the second support in an operative orientation, the first and second supports are movable between a closed position in which the first and second tool halves engage one another to provide corresponding mold cavities therebetween, and an open position in which the first and second tool halves are aligned with one another across a part removal gap; and the second support is movable between the operative orientation, and a reloading orientation in which the second tool halves are located in a tool change area that is out of alignment with the first tool halves.

[0021] The second support being movable between the operative and reloading orientations, thereby moving the second tool halves between alignment with the first tool halves and non-alignment with the first tool halves in the tool change area, can allow the second tool halves to be removed from and/or attached to the second support easily. For instance, the tool change area can be a location more accessible to a worker or robot tasked with removal of the second tool halves from the second support (e.g. for inspection, repair or replacement) and/or attachment of the second tool halves to the second support (e.g. after said inspection, repair or replacement). This ease of access can translate to reduced downtime, and therefore to reduced overall cost of production for a given number of mold halves.

[0022] For the avoidance of doubt, reference to the first and second supports moving between the open and closed positions is intended to refer to them moving relative to one another. Accordingly, when moving between positions the first support may move relative to a stationary second support, the second support may move relative to a stationary first support, or both first and second supports may move. Embodiments where the second support remains stationary when the first and second supports move between positions may be beneficial in that the mechanism required may be simpler than if the second plate had to be movable both between said orientations, and also movable to move the supports between positions.

[0023] The supports may be movable between said open and closed positions along an upright axis.

[0024] This may reduce the 'footprint' of the apparatus (i.e. floor-space taken up by the apparatus), in comparison to an arrangement where the supports move between positions along a horizontal axis, for example. Instead or as well, it may allow gravity to assist with removal of the second tool halves from the second support and/or attachment of the second tool halves to the second support.

[0025] The apparatus may further comprise one or more third tool halves releasably mounted on the second support, wherein with the second support in the reloading orientation the first and second supports are movable between a further closed position in which the first and third tool halves engage one another to provide corresponding mold cavities therebetween, and a further open position in which the first and third tool halves are aligned with one another across a part removal gap.

[0026] This can allow the apparatus to continue injection molding mold halves, using the first tool halves and the third tool halves, while the second tool halves are in the tool change area (for instance being removed from or attached to the second support).

[0027] As an alternative, the apparatus may comprise no other tool halves save for the first tool halves and second tool halves. In such an arrangement, with the second support in the reloading orientation a blank area of the second support may be located in alignment with the first tool halves. Such a blank area may further be located in the tool change area when the second support is in the operative orientation.

[0028] Where the apparatus comprises third tool halves, the third tool halves may be substantially the same shape as the second tool halves (whereupon mold halves produced using the first and second tool halves would be substantially the same shape as mold halves produced using the first and third mold halves), or may have a different shape to the second tool halves (whereupon mold halves produced using the first and second tool halves would have a different shape to those produced using the first and third mold halves).

[0029] With the second support in the operative orientation, the third tool halves may be located in the tool change area.

[0030] This can allow the apparatus to continue injection molding mold halves, using the first tool halves and the second tool halves, while the third tool halves are in the tool change area (for instance being removed from or attached to the second support). In other words, the machine can be run using the first and second tool halves while removing or attaching the third tool halves, and can also be run using the first and third tool halves while removing or attaching the second tool halves.

[0031] As an alternative, with the second support in the operative orientation the third tool halves may be located outside the tool change area, for instance in an intermediate location between the tool change area and the location in which they would be aligned with the first tool halves. In such an arrangement, the second support may be movable to a further orientation in which the third tool halves are located in the tool change area.

[0032] The apparatus may further comprise one or more fourth tool halves releasably supported on the second support.

[0033] This may improve the versatility of the apparatus. For instance where the second, third and fourth tool halves are of different shapes to one another, the apparatus may be capable of producing mold halves of three different shapes simply by moving the support between orientations.

[0034] With the second support in the operative orientation, the fourth mold halves may also be located in the tool change area. The fourth tool halves can therefore be accessible while mold halves are being produced using the first and second tool halves, in a similar manner as described above in relation to the third tool halves.

[0035] The supports may be movable between the open and closed positions by moving them along a molding axis (the molding axis can be understood to refer to an axis along which the mold halves are moved to contact each other to form a mold assembly), and the second support may be movable between the operative and reloading orientations in a direction normal to the molding axis. For instance, the second support may be rotatable between the operative and reloading orientations about an axis which is parallel to the molding axis.

[0036] This can allow the mechanism used to move the second support between orientations to be advantageously simple and/or robust, in comparison to an arrangement where the second support moves in a direction with a component parallel to the molding axis (such as an arrangement where the second support has a shape akin to an escalator, where each 'step' supports a different set of tool halves).

[0037] The second tool half or each second tool half may be configured to form an optical surface of said mold half.

[0038] The optical surfaces being provided on the second tool halves, which may be advantageously easy to remove/attach as outlined above, may be of particular benefit since the tool halves which provide the optical surfaces are particularly likely to need to be removed for inspection (since the optical surface forms a surface of the mold half which will then form a surface of the finished contact lens) or to be replaced with different tool halves (since different mold halves usually need different optical surfaces but may have the same shape on the reverse).

[0039] The apparatus may further comprise one or more alternative tool halves which are configured to be releasably mounted on the second support in place of the second tool halves.

[0040] The apparatus being able to use alternative tool halves in place of the second tool halves can increase the versatility of the apparatus, allowing some mold halves to be produced using the first and second tool halves (and/or first and third tool halves and/or first and fourth tool halves, where present), and different mold halves to be produced using the first tool halves and the alternative tool halves.

[0041] As an alternative, the apparatus may be configured to function using only the first tool halves and second tool halves (and third and fourth tool halves, where present) only, with individual tool halves being removed and replaced for inspection or repair when necessary.

[0042] According to a second aspect of the present disclosure there is provided a part of an apparatus according to the first aspect of the disclosure, said part comprising the first support, the second support, and a drive mechanism for moving the first and second supports between the open and closed positions and moving the second support between said orientations.

[0043] The part may be used to manufacture an apparatus according to the first aspect of the disclosure, thereby providing one or more of the benefits discussed above.

[0044] The drive mechanism may comprise an electric, hydraulic or pneumatic motor. Such a motor may be arranged to move the second support between said orientations. Where the drive mechanism comprises such a motor it may further comprise a transmission such as a chain drive, belt drive or gearbox driven by that motor.

[0045] Instead, or as well, the drive mechanism may comprise a pneumatic cylinder, a hydraulic cylinder, a solenoid and/or or an electric linear actuator. The drive mechanism may comprise more than one of said components, for instance two, three, four or more. Said component or components may be arranged to move the first and second plates between the open and closed positions.

[0046] According to a third aspect of the present disclosure there is provided a method of injection molding mold halves for use in the manufacture of contact lenses, the method comprising:

- **[0047]** moving a second support to an operative orientation, and then moving a first support and the second support to a closed position such that one or more first tool halves supported on the first support and one or more second tool halves releasably supported on the second support engage one another to provide corresponding mold cavities therebetween;
- **[0048]** injecting molten polymer or molten plastic into the mold cavities, then allowing the polymer or plastic to solidify in the mold cavities and form mold halves;
- **[0049]** moving the first and second supports to an open position such that the first and second tool halves are aligned with one another across a part removal gap;
- **[0050]** removing said mold halves through the part removal gap;
- **[0051]** moving the second support to a reloading orientation in which the second tool halves are located in a tool change area which is out of alignment with the first tool halves; and
- **[0052]** removing the second tool halves from the second support.

[0053] Moving the second support between the operative and reloading orientations, thereby moving the second tool halves between alignment with the first tool halves and non-alignment with the first tool halves in the tool change area, can allow the step of removing the second tool halves, and or a step of (re-)attaching second tool halves, to be performed with advantageous ease. For instance, the tool change area can be a location more accessible to a worker or robot tasked with removal of the second tool halves (e.g. for inspection, repair or replacement) and/or (re)attachment of the second tool halves to the second support (e.g. after said inspection, repair or replacement). This ease of access can translate to reduce downtime, and therefore to reduced overall cost of production for a given number of mold halves.

[0054] The method may use the apparatus according to the first aspect of the disclosure.

[0055] Moving the supports to the closed position and moving them to the open position may each comprise moving the supports along an upright axis.

[0056] The first and second supports being movable along an upright axis may reduce the 'footprint' of the apparatus (i.e. floor-space taken up by the apparatus), in comparison to an arrangement where the supports move between positions along a horizontal axis, for example. Instead or as well, it may allow gravity to assist with removal of the second tool halves from the second support and/or attachment of the second tool halves to the second support.

[0057] The step of moving the second support to the reloading orientation may also move one or more third tool halves, which are also releasably supported by the second support, into alignment with the first tool halves, and the method may further comprise:

- **[0058]** moving the first and second supports to a further closed position, with the second support in the reloading orientation, such that the first tool halves and the third tool halves engage one another to provide corresponding mold cavities therebetween;
- **[0059]** injecting molten polymer or plastic into the mold cavities, then allowing the polymer or plastic to solidify in the mold cavities and form additional mold halves;
- **[0060]** moving the first and second supports to a further open position such that the first and third tool halves are aligned with one another across a part removal gap; and
- **[0061]** removing said additional mold halves through the part removal gap.

[0062] This can allow the apparatus to continue injection molding mold halves, using the first tool halves and the third tool halves, while the second tool halves are in the tool change area (for instance being removed from or attached to the second support).

[0063] As an alternative, the apparatus may comprise no other tool halves save for the first tool halves and second tool halves. In such an arrangement, moving the second support to the reloading orientation may move a blank area of the second support into alignment with the first tool halves. Such a blank area may further be moved to the tool change area when the second support is moved to the operative orientation.

[0064] Moving the second support to the operative orientation may also move the third tool halves to the tool change area.

[0065] This can allow the apparatus to continue injection molding mold halves, using the first tool halves and the second tool halves, while the third tool halves are in the tool change area (for instance being removed from or attached to the second support). In other words, the machine can be run using the first and second tool halves while removing or attaching the third tool halves, and can also be run using the first and third tool halves while removing or attaching the second tool halves.

[0066] As an alternative, moving the second support to the operative orientation may move the third tool halves to a location outside the tool change area, for instance in an intermediate location between the tool change area and the location in which they would be aligned with the first tool halves.

[0067] Such a method may further comprise a step of moving the second support to a further orientation in which the third tool halves are located in the tool change area.

[0068] The step of moving the second support to the operative orientation may also move one or more fourth tool halves, which are also releasably supported by the second support, into the tool change area.

[0069] This may improve the versatility of the apparatus. For instance where the second, third and fourth tool halves are of different shapes to one another, the apparatus may be capable of producing mold halves of three different shapes simply by moving the support between orientations.

[0070] The step of moving the second support to the operative orientation may also move the fourth mold halves to the tool change area. The fourth tool halves can therefore be accessible while mold halves are being produced using the first and second tool halves, in a similar manner as described above in relation to the third tool halves.

[0071] Optionally:

- **[0072]** moving the first and second supports to the closed position and moving them to the open position each comprises moving them along a molding axis; and
- **[0073]** moving the second support to the operative orientation and moving it to the reloading orientation each comprises moving it in a direction normal to the molding axis, for example rotating it about an axis which is parallel with (for instance collinear with) the molding axis.

[0074] This can allow the mechanism used to move the second support between orientations to be advantageously simple and/or robust, in comparison to an arrangement where the second support moves in a direction with a component parallel to the molding axis (such as an arrangement where the second support has a shape akin to an escalator, where each 'step' supports a different set of tool halves).

[0075] Optionally:

- **[0076]** moving the first and second supports to the closed position and moving them to the open position each comprises moving them along a molding axis; and
- **[0077]** moving the second support to the operative orientation and moving it to the reloading orientation each comprises rotating it about an axis which is parallel to the molding axis.

[0078] The step of allowing the polymer or plastic to solidify in the mold cavities and form mold halves may comprise allowing some of said polymer or plastic to solidify against optical surfaces provided by said second tool halves so as to form optical surfaces of said mold halves.

[0079] The optical surfaces being provided on the second tool halves, which may be advantageously easy to remove/attach as outlined above, may be of particular benefit since the tool halves which provide the optical surfaces are particularly likely to need to be removed for inspection (since the optical surface forms a surface of the mold half which will then form a surface of the finished contact lens) or to be replaced with different tool halves (since different mold halves usually need different optical surfaces but may have the same shape on the reverse).

[0080] The method may further comprise attaching second tool halves to the second support, for instance re-mounting second tool halves previously removed from the second support, or attaching replacements of one or more of the second tool halves (for instance where a second tool half has become worn or damaged). As an alternative, the method may further comprise the step of replacing the second tool halves removed from the second support with one or more alternative tool halves.

[0081] The apparatus being able to use alternative tool halves in place of the second tool halves can increase the versatility of the apparatus, allowing some mold halves to be produced using the first and second tool halves (and/or first and third tool halves and/or first and fourth tool halves, where present), and different mold halves to be produced using the first tool halves and the alternative tool halves.

[0082] As an alternative, the apparatus may be configured to function using only the first tool halves and second tool halves (and third and fourth tool halves, where present) only, with individual tool halves being removed and replaced for inspection or repair when necessary.

[0083] According to a fourth aspect of the present disclosure there is provided a mold half for manufacturing a contact lens, injection molded using the apparatus of the first aspect of the disclosure and/or the method of the second aspect of the disclosure.

[0084] A mold half so produced may be cheaper to produce, for instance due to reduced downtime as discussed above.

[0085] According to a fifth aspect of the present disclosure there is provided method of manufacturing a contact lens, the method comprising:

- **[0086]** injection molding a male mold half and injection molding a female mold half, at least one of said mold halves being a mold half according to the fourth aspect of the disclosure;
- **[0087]** engaging the male and female mold halves with one another, with a quantity of a contact lens formulation located in a cavity defined therebetween;
- **[0088]** curing the contact lens formulation to form said contact lens; and separating the male and female mold halves and removing the contact lens.

[0089] It can be understood that the curing of the contact lens formulation takes place by polymerization. The method using mold halves according to the fourth aspect of the disclosure may reduce the cost associated with that mold half for the reasons given above, thereby reducing the cost of production of said contact lens.

[0090] The method may comprise further steps, for instance washing or rinsing the contact lens and/or hydrating the contact lens.

[0091] According to a sixth aspect of the present disclosure there is provided a contact lens manufactured using the method of the fifth aspect of the disclosure.

[0092] Such a contact lens may be cheaper to produce for the reasons given above.

[0093] The skilled person will understand that specific features of embodiments of the disclosure described herein that are not incompatible with each other can be present in in any combination in example embodiments of the disclosure. Optional or preferred features described in relation to one aspect of the disclosure may be applicable to other aspects of the disclosure, where appropriate.

[0094] Herein, reference is made to mold halves, but it is to be understood that, although two mold halves may complement each other and together form a mold assembly, each mold half is not necessarily half of, or 50% of, the mold assembly. One mold half can comprise 20%, 30%, 40%, 45%, or the like, of a mold assembly while the other mold half can comprise 80%, 70%, 60%, 55%, or the like, of the mold assembly. Accordingly, while the two mold halves can make one whole mold assembly, it is to be understood that the two mold halves neither have to be of the same size nor do they have to be mirror images of one another. Similarly, while reference is made herein to tool halves, it is to be understood that two tool halves, that complement each other and together define a mold cavity, do not have to be of the same size or mirror images of one another.

[0095] With reference to the drawings, FIGS. **1**A and **1**B (as well as FIGS. **2**A and **2**B) show to mold halves, a male mold half **2** and a female mold half **4**, for use in the manufacture of a contact lens. Each mold half **2**, **4** has alignment tabs **6**, a rim portion **8**, an optical surface **10** and a non-optical surface **12**. The optical surface **10** of the male mold half **2** is convex and its non-optical surface **12** is concave, whereas the optical surface **10** of the female mold half **4** is concave and its non-optical surface **12** is convex.

[0096] The male and female mold halves **2**, **4** can engage with one another as shown in FIGS. **2**A and **2**B. With the mold halves **2**, **4** so engaged, they seal against one another and the convex optical surface **10** of the male mold half **2** projects into the concave optical surface **10** of the female mold half **4**. The two optical surfaces **10** thereby form a cavity **16** within which a contact lens can be molded.

[0097] To manufacture a contact lens using the mold halves **2**, **4** a quantity of a contact lens formulation is placed into or onto the concave optical surface **10** of the female mold half **4**, and the male and female mold halves **2**, **4** are then engaged with one another. As the mold halves **2**, **4** are engaged, the contact lens formulation is spread out and substantially fills the cavity **16**. The mold halves **2**, **4** containing the contact lens formulation are then treated, for instance using heat or UV light, to cure the formulation into a polymer contact lens. The mold halves **2**, **4** can then be separated to release the contact lens, which is then washed to remove any residual chemicals that do not form part of the polymerized contact lens, such as unreacted monomer and the like. The lens is then hydrated, and packaged ready for use.

[0098] The mold halves **2**, **4** are each produced by injection molding into a cavity formed between a pair of tool halves. FIG. **3** shows the pair **20** of tool halves used to produce the male mold half **2**, and FIG. **4** shows the pair **20** of tool halves used to produce the female mold half **4**. Each pair comprises a first tool half **22** and a second tool half **24**.

[0099] Each first tool half **22** includes an injection nozzle **26**, a thermocouple **28**, a tool portion **30**, and an ejection mechanism (not visible) arranged to eject formed mold halves. Coolant flow passages (not visible) are provided behind tool portion **30**, passing approximately 4 mm from its outermost surface **32** at their closest approach. The injection nozzles **26** and thermocouples **28** of the first tool halves **22** are located away from the centers of tool portions **30**. This makes room for the coolant passages to pass close to the outer surface **32** of the tool portion **30**, where the surface of the contact lens mold half used to cast-mold the optic zone of a contact lens is formed.

[0100] Each second tool half **24** of this example takes the form of a collet **40** carrying a tool insert **42**. Each collet **40** has a front disc portion **43** and a frustoconical body portion **44**. Frustoconical body portion **44** has a coolant passage **45** down its centre, up to the rear of the tool insert **42** and back, and includes toward its rear an annular groove **46**. As discussed in more detail later, each second tool half **24** is supportable on a second support. More particularly, in this example each second tool half **24** is supportable in a respective bushing **48** of the second support. The bushings **48** in this example also have coolant passages **50** running around them.

[0101] The first tool halves **22** can be clamped in place in the bushings **48**, and thus attached to the second support, by respective clamps (not shown) which engage the grooves **46** of the collets **40** to prevent withdrawal of the frustoconical body portions **44** from the bushings **48**. Each second tool half **24** can be unclamped, removed, and replaced independently of other second tool halves, enabling flexible interchange of second tool halves **24**. Furthermore, each collet **40** can carry a different tool insert **42**.

[0102] The second tool half **24** of each pair **20** provides an optical surface **52**. In the case of the second tool half **24** of FIG. **3**, the optical surface **52** of the second tool half is concave and defines the convex optical surface **10** of the male mold half **2**. In the case of the second tool half **24** of FIG. **4**, the optical surface **52** of the second tool half is convex and defines the concave optical surface **10** of the female mold half **4**. In each case, in this example the optical surfaces **52** of the second tool halves **24** are provided on the tool inserts **42**. The shapes of the optical surfaces **52** of the second tool halves **24**, and thus the shapes of the optical surfaces **10** of the mold halves **2**, **4** (and therefore the shape and optical properties of a contact lens produced therewith) can therefore be changed by changing the tool inserts **42** of the second tool halves **24**.

[0103] In the first tool half **22** of each pair **20**, the outermost surface **32** of the tool portion **30** provides a surface of complementary shape to the optical surface **52** of the associated second tool half **24**. Thus, the outermost surface **32** of the tool portion **30** of the first tool half **22** in FIG. **3** is convex, and the outermost surface **32** of the tool portion **30** of the first tool half **22** in FIG. **4** is concave. Since these surfaces do not form surfaces of the mold halves **2**, **4** which form surfaces of the contact lens, their precise shapes are less crucial. Accordingly, the same first tool half **22** may be used with a plurality of different second tool halves (e.g. with a plurality of different tool inserts **42** fitted to the same collets **40**, and/or with a plurality of different sets of collets **40** each with different tool inserts **42**).

[0104] FIGS. **3** and **4** show the pairs **20** of tool halves **22**, **24** engaged with one another. So engaged, the first and second tool halves **22**, **24** form mold cavities **54** into which molten polymer or plastic can be injected (through the injection nozzles **26**) and allowed to cool to form the respective mold halves **2**, **4**.

[0105] FIG. **5** shows an example of an apparatus **60** for injection molding mold halves which utilizes first and second tool halves **22**, **24** as described above. The apparatus includes an injection molding area **62** and a tool change area **64**, separated from one another by a divider **66** which includes a sliding door **68**. The apparatus **60** also includes a tool exchange robot **70**, a tool store **72**, and a take-off robot **74** with plate **76**. Further, as shown in FIG. **6**, the apparatus comprises a first support **80** and a second support **82**.

[0106] FIG. **6** shows the apparatus **60** with the divider **66** removed, showing the first and second supports **80**, **82** more clearly, and FIG. **7** shows a cross-section of this area. Mounted to the first support **80** are a set of first tool halves **22** of the type shown in FIGS. **3** and **4**. Mounted to the second support **82**, more particularly removably mounted as discussed below, are a set of second tool halves **24** of the type shown in FIGS. **3** and **4**. In this specific example the first support **80** has four first tool halves **22** of the type shown in FIG. **3** and four first tool halves **22** of the type shown in FIG. **4**. Similarly, the second support **82** has four second tool halves **24** of the type shown in FIG. **3** and four second tool halves **24** of the type shown in FIG. **4**. The first and second supports **80**, **82** hold the first and second tool halves **22**, **24** in respective mounting plate assemblies **84**. The same component numbers in FIGS. **5-7** refer to the same components as described herein.

[0107] FIGS. **5** to **7** show the second support **82** in an operative orientation. With the second support **82** in this orientation, the first and second supports **80**, **82** are movable relative to one another between an open position (as shown in FIGS. **5** to **7**) and a closed position. With the supports **80**, **82** in the open position the first and second tool halves **22**, **24** are aligned with one another across a part removal gap **86**. With the supports **80**, **82** in the closed position, the aligned first and second tool halves **22**, **24** engage one another in the manner shown in FIGS. **3** and **4**.

[0108] In this example, the supports **80**, **82** are movable between the open and closed positions by moving the first support **80** along a vertically-aligned molding axis **88**, guided by a set of guide rods **89** which run parallel to the molding axis **88**. The first support is mounted to a stationary feed unit **90**, which also supports a hopper **92** holding polymer or plastic granules to be injection molded, by a pair of hydraulic cylinders **94** of a drive mechanism of the apparatus. To move the first support **80** to the closed position, the cylinders **94** are extended to lower the first support **80** down along the molding axis **88** towards the second support **82**, and to move the first support **80** to the open position, the cylinders **94** are retracted to lift the first support **80** up along the molding axis **88** away from the second support **82**.

[0109] In this example, the second support **82** also has a set of third tool halves **96** removably mounted thereon in another mounting plate assembly **84***a*. The third tool halves **96** are generally the same as the first tool halves **22**, except that the tool inserts **42** are of slightly different shapes such that the mold halves **2**, **4** produced thereby also have slightly different shapes. Accordingly, the contact lenses produced using those mold halves **2**, **4** would also have a slightly different shape and thus slightly different optical properties. With the second support **82** in the operative orientation, as illustrated, the third tool halves are located in the tool change area.

[0110] The second support **82** is movable between the operative orientation and a reloading orientation. More particularly, in this example the second support forms a turntable which can rotate under action of an electric motor (not visible) of a drive mechanism of the apparatus **60**. The second support **82** is rotatable about an axis **98** which in this example is parallel to the molding axis **88**. The sliding door **68** in the divider **66** can be lifted when the second support

82 is to be rotated, providing sufficient clearance for the plate assemblies **84** to pass under the divider **66**.

[0111] With the second support **82** in the reloading orientation, the second tool halves **24** are positioned in the tool change area, i.e., out of alignment with the first tool halves **22**, and the third tool halves **96** are positioned in the injection molding area **62** in alignment with the first tool halves **22**. The second tool halves **24** being in the tool change area **64** makes them more accessible. In this example the tool change robot **70** is configured to remove the second tool halves **24** from the second support **82** and place them in the tool store **72**, then replace the second tool halves **24** with a set of alternative tool halves **99** previously stored in the tool store **72**. In other examples, however, no alternative tool halves **99** may be provided and the tool change robot may remove one second tool half **24** at a time, for instance for inspection or changing of its tool insert, before re-attaching it to the second support **82**).

[0112] Just as moving the second support **82** from the operative orientation to the reloading orientation moves the second tool halves **24** from alignment with the first tool halves **22** to non-alignment with the first tool halves in the tool change area **64**, it also moves the third tool halves **96** from the tool change area into alignment with the first tool halves **22** in the injection molding area **62**. With the second support **82** in this position, the first and second supports **80**, **82** are movable between a further open position in which the first and third tool halves **22**, **96** are aligned with one another across a part removal gap, and a closed position in which the first and third tool halves **22**, **96** engage one another in the same manner as described above in relation to the first and second tool halves **22**, **24**.

[0113] Accordingly, with the second support **82** in the reloading orientation, the apparatus **60** can continue making mold halves **2**, **4** while the second tool halves **24** are being removed for inspection or replacement. Thus, the only machine down time required for the second tool halves **24** to be inspected/replaced is the time taken for the drive mechanism of the apparatus **60** to rotate the second support **82** from the operative orientation to the reloading orientation (which in this example is around four seconds).

[0114] In corresponding fashion, when the second support **82** is in the operative orientation, i.e. the second tool halves **24** are aligned with the first tool halves **22** in the injection molding area and the third tool halves **96** are in the tool change area **64**, the tool exchange robot **70** can remove the third tool halves **96** for inspection or replacement.

[0115] To injection mold the mold halves **2**, **4**, the second support **82** is moved to the operative orientation and the first and second supports **80**, **82** are moved to the closed position so that the first and second tool halves **22**, **24** define mold cavities **54** as described above. Polymer or plastic pellets from the hopper **92** are heated beyond their melting point and the resultant liquid polymer/plastic flows into a manifold (not visible) and then into the cavities **54** through the injection nozzles **26** of the first tool halves **22** (see FIGS. **3** and **4**). Further heating is provided by a coil (not visible) around each injection nozzle **26**. Thermocouples **28**, arranged on the opposite sides of the first tool halves **22** from the injection nozzles **26**, are used to monitor the temperature of the injected polymer/plastic. Heating of nozzles **26** is controlled to ensure that the liquid polymer/plastic is injected into each of the eight cavities **54** at the same temperature, and hence at the same flow rate. Non-constant flow rates result in stresses in the formed mold, which in turn result in deformations and inconsistencies in contact lenses formed from the molds, for example, different levels of fit, different radii, and hence, different powers. Careful control of pressure and cooling gives consistency and uniformity; in contrast, poor control can result in a need to stop injection, selectively, into cavities for which the flow rate has deviated too far from a target value.

[0116] Once the cavities **54** are full of polymer or plastic and a desired hold pressure profile applied, stopper pins (not shown) in the injection nozzles **26** are moved forward to shut off the injection nozzles **26** from the cavities **54**, which stops the flow of polymer/plastic. Coolant, for example, water, is circulated through coolant passages **45**, **50** to cool the polymer/plastic and thereby form the mold halves, with polymer/plastic solidifying against the optical surfaces **52** of the tool inserts **42** and forming the optical surfaces **10** of the mold halves **2**, **4**. The coolant passages **45**, **50** in tool halves **22**, **24** pass close to the outermost surfaces **32** of the tool portions and the optical surfaces **52** of the tool inserts **42**. Such an arrangement provides direct cooling in the portions of the mold halves **2**, **4** that form the optic zone of the lens as the mold halves **2**, **4** form in the cavity (rapid cooling of nucleated material results in good quality, uniform molds; without nucleation, slower cooling in the middle of the material can result, forming bigger crystals in the middle of the material).

[0117] Once the polymer/plastic has solidified and the mold halves **2**, **4** have therefore been formed, the hydraulic cylinders **94** lift the first support **80** to move the supports **80**, **82** to the open position, separating the die halves **22**, **24** and opening the cavities **54**. The newly formed mold halves **2**, **4** remain on the first tool halves **22** as the first support **80** is lifted. The take-off robot **74** then inserts the plate **76** into the part removal gap **86**. The ejector mechanism (not visible) then pushes the mold halves **2**, **4** off the first tool halves **22** so that they can be collected onto the plate **76** using high airflow vacuum. The take-off robot **74** then transports the mold halves **2**, **4** on the plate out through the part removal gap **86** and away from the injection molding area **62** for further processing (such as further cooling, quality inspection, or immediate use in the manufacture of contact lenses as described above).

[0118] The above process can be followed to make further mold halves **2**, **4**. Whenever inspection or replacement of the second tool halves **24** is needed, or when it is desired to manufacture mold halves **2**, **4** of the shape that will be produced by the third tool halves **96**, the second support **82** is moved to the reloading orientation so as to place the second tool halves **24** in the tool change area **64** and the third tool halves **96** in alignment with the first tool halves **22**. The tool exchange robot **70** can then remove the second tool halves **24** or replace them with alternative tool halves **99** as described above. While this is taking place, the apparatus can continue to injection mold further mold halves **2**, **4** using the first and third tool halves **22**, **96** using the same process above but moving the supports **80**, **82** between the further open position and the further closed position.

[0119] Similarly, whenever inspection or replacement of the third tool halves **96** is needed, or when it is desired to manufacture mold halves **2**, **4** of the shape that will be produced by the first tool halves **24** (or the alternative tool halves **99**, where these have been placed onto the second support **82**), the second support **82** is moved to the operative orientation so as to place the third tool halves **96** in the tool change area **64** and place the second tool halves **24** (or alternative tool halves **99**) in alignment with the first tool halves **22**.

[0120] In this example, production monitoring software logs whenever the set of tool halves **24**, **96** being used in conjunction with the first tool halves **22** to manufacture mold halves **2**, **4** is changed by changing the orientation of the second support **82**. By doing so, the output of mold halves **2**, **4** from the apparatus **60** can be managed autonomously. This can avoid the need for different batches of mold halves **2**, **4**, produced using different sets of mold halves **24**, **96**, to be segregated physically (for instance packaging them onto different containers for future processing).

[0121] While the present disclosure has been described and illustrated with reference to particular embodiments, it will be appreciated by those of ordinary skill in the art that the disclosure lends itself to many different variations not specifically illustrated herein. By way of example only, in a modification of the above apparatus, the second support may include a set of fourth tool halves as well as the second tool halves and third tool halves. In this example, the divider may be shaped so that with the second support oriented with any one of said sets of tool halves in alignment with the first tool halves, one or both of the other sets of tool halves on the second support may be positioned in the tool change area. As another example, whilst the above example has two different types of first tool half, two different types of second tool half, etc., other arrangements may have first tool halves which are all identical to one another and second tool halves which are all identical to one another (whereupon a tool changeover would need to be performed before both male and female mold halves could be produced). As an alternative, other examples may have four different types of first tool halves, four different types of second tool halves, etc., so that complete sets of mold halves for two different shapes of contact lens could be produced at once.

[0122] For the avoidance of doubt, the names 'first tool half', 'second tool half' etc. should not be construed as having any limitations beyond those recited in the appended claims. There is no intended implication in terms of structure of said tool halves or order of use. For instance, the second tool halves and third tool halves may be identical to one another in some examples, and/or the first use of the apparatus may utilize the third tool halves before the second tool halves. Furthermore, it should be understood that although the apparatus described above has eight first tool halves mounted on the first support (and eight second tool halves and eight third tool halves mounted on the second support), this should not be construed as limiting. In a modification of the apparatus there may be fewer than eight (for instance one, two or four) first tool halves mounted on the first support or there may be more than eight first tool halves mounted on the first support, with a corresponding number of second tool halves (and a corresponding number of third tool halves if applicable) mounted on the second support.

[0123] In the foregoing description, where integers or elements are mentioned which have known, obvious or foreseeable equivalents, then such equivalents are herein incorporated as if individually set forth. Reference should be made to the claims for determining the true scope of the present disclosure, which should be construed so as to encompass any such equivalents. It will also be appreciated by the reader that integers or features of the disclosure that are described as preferable, advantageous, convenient, or the like, are optional and do not limit the scope of the independent claims. Moreover, it is to be understood that such optional integers or features, while of possible benefit in some embodiments of the disclosure, may not be desirable, and can therefore be absent, in other embodiments.

1. An apparatus for injection molding of contact lens mold halves for use in the manufacture of contact lenses, the apparatus comprising one or more first tool halves mounted on a first support, and one or more second tool halves releasably mounted on a second support, wherein:

with the second support in an operative orientation, the first and second supports are movable between a closed position in which the first and second tool halves engage one another to provide corresponding mold cavities therebetween, and an open position in which the first and second tool halves are aligned with one another across a part removal gap; and

the second support is movable between the operative orientation, and a reloading orientation in which the second tool halves are located in a tool change area that is out of alignment with the first tool halves.

2. The apparatus according to claim **1**, wherein the first support and the second support are movable between said open and closed positions along an upright axis.

3. The apparatus according to claim **1**, further comprising one or more third tool halves releasably mounted on the second support, wherein with the second support in the reloading orientation the first support and the second support are movable between a further closed position in which the first tool halves and the third tool halves engage one another to provide corresponding mold cavities therebetween, and a further open position in which the first tool halves and the third tool halves are aligned with one another across a part removal gap.

4. The apparatus according to claim **3**, wherein with the second support in the operative orientation, the third tool halves are located in the tool change area.

5. The apparatus according to claim **3**, further comprising one or more fourth tool halves releasably supported on the second support.

6. The apparatus according to claim **1**, wherein the first support and second support are movable between the open and closed positions by moving them along a molding axis, and the second support is rotatable between the operative and reloading orientations about an axis which is parallel to the molding axis.

7. The apparatus according to claim **1**, wherein the second tool half or each second tool half is configured to form an optical surface of said mold half.

8. The apparatus according to claim **1**, further comprising one or more alternative tool halves which are configured to be releasably mounted on the second support in place of the second tool halves.

9. A part of an apparatus according to claim **1**, said part comprising the first support, the second support, and a drive mechanism for moving the first support and the second support between the open and closed positions and moving the second support between the operative and reloading orientations.

10. A method of injection molding mold halves for use in the manufacture of contact lenses, the method comprising:

moving a second support to an operative orientation, and then moving a first support and the second support to a closed position such that one or more first tool halves supported on the first support and one or more second tool halves releasably supported on the second support engage one another to provide corresponding mold cavities therebetween;

injecting a molten polymer into the mold cavities, then allowing the molten polymer to solidify in the mold cavities and form mold halves;

moving the first support and the second support to an open position such that the one or more first tool halves and the one or more second tool halves are aligned with one another across a part removal gap;

removing said mold halves through the part removal gap;

moving the second support to a reloading orientation in which the one or more second tool halves are located in a tool change area which is out of alignment with the one or more first tool halves; and

removing the one or more second tool halves from the second support.

11. The method according to claim **10**, wherein moving the first support and the second support to the closed position and moving the first support and the second support to the open position each comprises moving the first support and the second support along an upright axis.

12. The method according to claim **10**, wherein the step of moving the second support to the reloading orientation also moves one or more third tool halves, which are also releasably supported by the second support, into alignment with the one or more first tool halves, and the method further comprises:

moving the first support and the second support to a further closed position, with the second support in the reloading orientation, such that the one or more first tool halves and the one or more third tool halves engage one another to provide corresponding mold cavities therebetween;

injecting a molten polymer into the mold cavities, then allowing the molten polymer to solidify in the mold cavities and form additional mold halves;

moving the first support and the second support to a further open position such that the one or more first tool halves and the one or more third tool halves are aligned with one another across a part removal gap; and

removing said additional mold halves through the part removal gap.

13. The method according to claim **12**, wherein moving the second support to the operative orientation also moves the one or more third tool halves to the tool change area.

14. The method according to claim **12**, wherein the step of moving the second support to the operative orientation also moves one or more fourth tool halves, which are also releasably supported by the second support, into the tool change area.

15. The method according to claim **10**, wherein:

moving the first support and the second support to the closed position and moving them to the open position each comprises moving the first support and the second support along a molding axis; and

moving the second support to the operative orientation and moving the second support to the reloading orientation each comprises rotating the second support about an axis which is parallel to the molding axis.

16. The method according to claim **10**, wherein the step of allowing the molten polymer to solidify in the mold cavities and form mold halves comprises allowing some of said molten polymer to solidify against optical surfaces provided by said one or more second tool halves so as to form optical surfaces of said mold halves.

17. The method according to claim **10**, further comprising the step of replacing the one or more second tool halves removed from the second support with one or more alternative tool halves.

18-20. (canceled)

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