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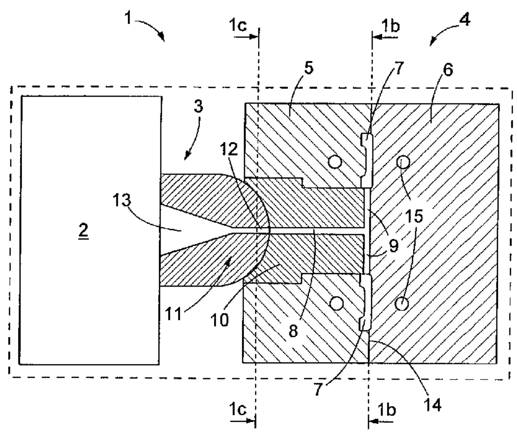
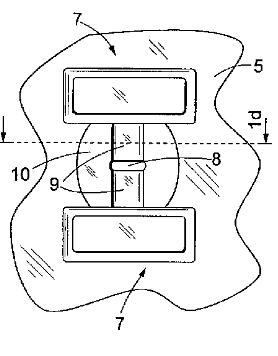
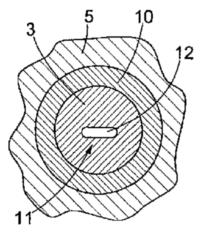
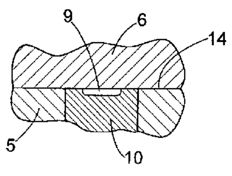
(54) Title: INJECTION MOULDING METHOD, MOULD AND DIE









(57) Abstract: A method for reducing cycle time in injection moulding, an injection mould, and a nozzle of an injection-moulding machine. The ratio of the surface area of the cross-section of feed conduits (8, 9) to their outer surface area is arranged in relation to the capacity and shape of a mould cavity (7) such that injected moulding material left in the conduits (8, 9) hardens at the latest substantially simultaneously with the moulding material that fills the mould cavity (7).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INJECTION MOULDING METHOD, MOULD AND DIE

[0001] The invention relates to a method for reducing cycle time in injection moulding, the method comprising
- arranging moulding material into an injection unit;
- injecting the moulding material through flow conduits into a mould cavity of an injection mould;
- hardening the moulding material that is in the mould cavity and the moulding material that is left in the flow conduits;
- removing the hardened moulding material from the mould.

[0002] The invention further relates to an injection mould, particularly to an injection mould for manufacturing thin-walled injection-moulded products, the mould comprising a mould cavity and a feed system for supplying the moulding material from an injection unit to the mould cavity.

[0003] The invention further relates to a nozzle of an injection-moulding machine, the nozzle comprising a flow conduit arranged to guide moulding material from an injection unit to a sprue of an injection mould.

[0004] The invention relates to the injection moulding of plastic products. In particular, the invention relates to the feed system of the injection mould and to the nozzle of the injection-moulding machine. In this context, the feed system of the injection mould refers to the system conveying fluid plastic material from the injection-moulding machine nozzle to the mould cavity. The feed system typically comprises a sprue, into which the moulding material flows from the moulding machine nozzle, and a runner for guiding the material into the mould cavity.

[0005] Injection moulding is one of the primary techniques for manufacturing thermoplastic products, and it is also used for making thermosetting plastic products. When thermoplastic products are injection-moulded, the mould is cooled so as to harden the moulding material by lowering its temperature, whereas when thermosetting plastics are concerned, the mould is heated so as to harden the material by raising its temperature. It should be noted that unless otherwise specified, the following disclosure refers to the manufacture of thermoplastic products, although it is obvious that the invention may be also applied in the manufacture of thermosetting plastic products.

[0006] Injection moulding is a technique which has conventionally been used for producing relatively massive, i.e. thick-walled, products. Their injection moulding cycle time is long and they require high holding-pressure of long duration to avoid shrinkage during the cooling of the moulding material and to prevent subsequent product deficiencies, such as sink marks or the like. For holding-pressure to be provided the plastic mass in the feed system must remain fluid, i.e. it must be kept at a sufficiently elevated temperature, during the entire holding-pressure period. The construction of the mould cavity and the feed system is optimally dimensioned when the moulding material hardens first in the mould cavity parts furthest away from the feed system and last in the feed system. To ensure this, an attempt has been made in prior art feed systems to minimize the ratio of the outer surface area of the feed system conduits to their cross-sectional area by using conduits of mainly circular, quadratic, or similar, cross-section. As a result, injected material left in a conduit cools down slowly because of the small outer surface area of the cooling conduit per mass unit of material. Cooling is typically the most time-consuming phase in an injection moulding process, and in practice the length of the entire process depends on it.

[0007] Since the injection-moulding machine nozzle and its flow conduit must fit tightly with the sprue of the mould, in prior art the flow conduit of the nozzle has been provided with a cross-sectional shape that minimizes the ratio of the outer surface area of the conduit to its cross-sectional area.

[0008] Today injection moulding is used ever increasingly for manufacturing thin-walled products for example for the needs of electronics industry, pharmaceutical industry and automobile industry, or for other clienteles. When thin-walled plastic products of low mass and low material volume are manufactured, the plastic mass in the mould cavity cools down very rapidly because the outer surface area of the product, i.e. that resting against the cooling mould surface, is large in relation to the material volume and mass of the product. Since the cooling is rapid and uniform, these dependent on the cooling of the material in the feed system; in other words, the process is longer than what the manufacturing of the actual product would require.

[0009] To some extent the cooling of the material in the feed system can be speeded up by reducing the cross-section of the flow conduit, but the increased shear forces thereby caused raise the temperature of the fluid material significantly. Too high temperatures destroy molecule chains in the material and may cause degradation of additives, such as pigments, used in the plastic mass. The reduction of the cross-section therefore provides only a very limited means for restricting the cooling time.

[0010] Another known solution for speeding up the cooling of the material left in the system is to enhance the cooling of the mould within the feed system area. It is, however, extremely difficult to maintain permanent temperature differences or zones in the fairly compact mould.

[0011] In some cases cycle time in the injection moulding of thermoplastics can be reduced by what is known as a hot runner tip technique. This is a method in which the material left in the feed system is not hardened but kept in a molten form until the next injection. During injection the pressure in the material increases to a significantly high level and the material is subjected to very strong shear forces. This naturally restricts the application of the method significantly. In addition, hot runner tip systems have a relatively limited life cycle and therefore the technique is fairly expensive to utilize.

[0012] It is an object of the present invention to provide an injection moulding method, an injection mould and an injection-moulding machine nozzle in which the above shortcomings are avoided and which provide improved cost-efficiency.

[0013] The injection moulding method of the invention is characterized by arranging the ratio of the cross-sectional area of the flow conduits to their outer surface area taking into account the capacity and shape of the mould cavity (7) such that the injected moulding material left in the flow conduits hardens at the latest simultaneously with the moulding material that fills the mould cavity (7).

[0014] The injection mould of the invention is characterized in that the ratio of the cross-sectional area of a flow conduit of the feed system to its outer surface area is arranged in relation to the capacity and shape of the mould cavity such that the injected moulding material left in the conduits hardens at the latest substantially simultaneously with the moulding material that fills the mould cavity.

[0015] Further, the injection-moulding machine nozzle of the invention is characterized in that the ratio of the cross-sectional area of the output end of the flow conduit of the nozzle to the outer surface area of the nozzle is arranged in relation to the capacity and shape of the mould cavity such that injected moulding material left in the output end of the flow conduit hardens at the latest simultaneously with the moulding material that fills the mould cavity.

[0016] An underlying idea of the method of the invention is that the moulding material is supplied from the injection unit to the mould cavity in flow conduits in which the ratio of their cross-sectional area to their outer surface area is arranged such that injected plastic material left in the channels becomes sufficiently hard for removal from the mould earlier than the plastic material that fills the mould cavity or at least substantially simultaneously with it.

[0017] An underlying idea of a mould of the invention is that the ratio of the cross-sectional area of a flow conduit in the feed system to the outer surface area of the corresponding conduits is arranged such that injected plastic material left in the conduits becomes sufficiently hard for removal from the mould earlier than the plastic material that fills the mould cavity or at the latest substantially simultaneously with it. Further, a preferred embodiment is based on the idea that said ratio of the surface area of the conduits in the feed system to their capacity is maximized within the preconditions set by the flow properties of the moulding material. Still further, a second preferred embodiment is based on the idea that the cross-section of the conduits is substantially rectangular. Still further, a third preferred embodiment is based on the idea that the cross-section of the conduits is elliptic. Still further, a fourth preferred embodiment is based on the idea that the cross-section of the conduits is a cross section of a polyhedron.

[0018] An underlying idea of the injection-moulding machine nozzle of the invention is that the cross-section of the output end of its flow conduit is shaped to engage with the sprues in a flow-technically advantageous manner, the sprues being shaped such that injected plastic material left in the sprues becomes sufficiently hard for removal from the mould earlier than the plastic material that fills the mould cavity or at the latest substantially simultaneously with it.

[0019] An advantage of the invention is that the cooling time of the plastic material left in the feed system and in the nozzle is substantially closer to the cooling time of the plastic material that is in the mould cavity, which allows the cycle time of the injection moulding process to be reduced and the related unit costs to be cut to a fraction of those in the prior art.

[0020] The invention will be described in greater detail with reference to the following drawings, in which

Figure 1a is a schematic, partly sectional side view of an embodiment of an injection moulding method, mould and an injection moulding machine nozzle of the invention in connection with an injection-moulding machine;

Figure 1b is a sectional view of the injection mould of Figure 1a, seen from the mould to the direction of an injection unit;

Figure 1c is a sectional view of the injection-moulding machine nozzle of Figure 1a seen from the direction of the injection-moulding machine;

Figure 1d is a sectional view of a runner of the injection mould of Figure 1a;

Figure 2 is a schematic, perspective view of a moulding removed from the mould of Figure 1;

Figure 3a is a schematic, sectional view of a second flow conduit of the feed system of the invention; and

Figure 3b is a schematic, sectional view of a third flow conduit of the feed system of the invention.

[0021] Figure 1a is a schematic, partly sectional side view of an embodiment of an injection moulding method, mould and an injection-moulding machine nozzle of the invention. The mould 4 is closed, i.e. mould halves 5 and 6 are closed against each other and there is a parting surface 14 between them. The mould 4 is closed with a closing unit known per se to a person skilled in the art and therefore not shown, for the sake of clarity. A nozzle 3 of the injection-moulding machine is fixed to an injection unit 2, which is thereby pressed against the first mould half 5.

[0022] The injection unit 2 is usually a screw-type unit which plastifies the moulding material, or, when thermosetting plastics are concerned, softens the material into an extrudable form. The injection unit 2 can naturally be for example a piston-type unit or any other type known per se.

When thermoplastics are injection-moulded, the injection unit 2 is heated either with an outer heat source or with heat produced by the friction of the material. Correspondingly, the mould 4 is cooled by means of a liquid medium flowing in the cooling channels or by other means known per se. When thermosetting plastics are injection-moulded, the situation is contrary: the injection unit 2 is cooled to prevent the material that is to be injected from stiffening, and the mould 4 is heated.

[0023] The mould 4 comprises a mould cavity 7 that produces the desired three-dimensional shape for the material to be injected. In addition, the mould 4 comprises a feed system through which the moulding material flows from the injection unit 2 to the mould cavity 7. As already stated, the feed system usually comprises a sprue 8 and a runner 9. In a single-cavity mould 4 the sprue 8 usually continues, without a clear transition point, as a runner 9. In a multi-cavity mould 4, such as the one shown in Figures 1a-1d, the runner 9 begins at the point where the feed system branches to form conduits ending in separate mould cavities 7.

[0024] A person skilled in the art will find it apparent that the mould 7 typically comprises also other parts and members, such as ejection pins and plates, which push the hardened material out of the mould 4; measurement sensors for temperature measurement, for example; cores for producing inner shapes; and the like.

[0025] The injection unit 2 injects the moulding material through the nozzle 3 into the conduits of the closed mould 4 and further to the mould cavity 7. Only some of the injected material arrives at the mould cavity 7, while the rest is left in the conduits 8, 9 and the nozzle 3.

[0026] The material in the mould cavity 7, which forms the actual product, cools down at a specific rate determined not only by the properties of the moulding material but also by the temperature of the mould 4 and the ratio of the product's material volume to the surface area of the product resting against the cooling mould surface. In the embodiment of the invention shown in Figures 1a-1d, the cross-section of a flow conduit in the conduit system 8, 9 is machined to be substantially rectangular. The outer surface area of the rectangular flow conduit, through which heat is conducted from the material that is in the conduit, is maximized in proportion to the capacity of the conduits, taking into account the dimensioning of the mould cavity 7, the filling rate of the mould cavities 7, and the cooling rate of the moulding material that is injected into the mould cavity 7. The conduits may be dimensioned either experimentally or computationally using flow-determining software.

[0027] The conduits are built in a module 10 which is detachably fastened to the first mould half 5. The detachable module 10 is easy to detach from the mould 4 for the purpose of changing the shaping of the conduits, in case their operation is detected to be deficient. Also modules 10 containing different kinds of conduits can be rapidly changed, the costs being significantly lower compared with those of changing the entire first mould half 5. The mould 4 may also comprise other module parts, such as mould cavities, but these are characteristics known to a person skilled in the art and therefore they are not discussed in greater detail in this context. Since the product to be manufactured has thin walls, the material injected into the mould cavity 7 cools down extremely rapidly and evenly and thus no holding-pressure or holding-pressure time is needed for packing the mould cavity 7. The material left in the conduits 8, 9 is thus allowed to harden immediately when the mould cavity 7 has been filled with the moulding material. The length of the cooling phase is thus determined by the hardening of the material that is in the mould cavity 7. The material is allowed to cool in the closed mould 7 until it is hard enough for the mould 7 to be opened and the product and the moulding formed of the material left in the conduits 8, 9 can be removed. It is to be noted that in the context of the present application, the term 'hardened' refers to a degree of stiffening of the material which allows the moulding to be removed from the mould 4 –the mould cavity 7 and the conduits 8, 9 – without undesired deformations being produced in the material. Since it is not necessary to wait that the material in the feed system 8, 9 hardens, the mould 4 can be opened and the hardened material that is in the mould cavity 7 and the feed system can be removed immediately after the material that forms the actual product is hardened. The planning and implementation of the conduits 8, 9 and the mould cavity 7 are integrated such that the cross-section of a flow conduit of the feed system, more particularly the ratio of the outer surface area of the conduit to its cross-sectional area, is dimensioned on the basis of the mould cavity 7 and the product to be manufactured such that the hardening time is determined by the hardening of the plastic mass that is in the mould cavities.

[0028] The flow conduits of the injection-moulding machine 1, i.e. the flow conduit 11 of the nozzle and the conduits 8, 9 of the mould, are dimensioned and shaped according to the requirements set by the mould cavities 7. In practice this means, on one hand, that the shape of the flow conduits minimizes the temperature rise in the plastic mass to be injected and, on the other hand, that the injected plastic material left in the flow conduits hardens at the latest simultaneously with the material in the mould cavities 7 that forms the actual product.

[0029] Figure 1b shows a cross-sectional view of the injection mould of Figure 1a, seen in the direction of the injection unit 2. The Figure shows the cross-section of the sprue 8, which is substantially rectangular. The corners of the sprue 8 having a rectangular basic form are rounded to ensure that the flow rate of the moulding material would be relatively uniform in the entire cross-section. There is usually a clearance angle in the sprue 8, which facilitates the loosening of the hardened mass from the opened mould. The sprue 8 is connected through runners 9 to the mould cavities 7, the multi-cavity mould 4 of the Figure including two cavities. A mould may also comprise more mould cavities 7 that are, nevertheless, filled rapidly and in a balanced manner. Naturally the invention may also be applied to a single-cavity mould.

[0030] Figure 1c shows a cross-section of the injection-moulding machine nozzle 3 of Figure 1a seen from the direction of the injection-moulding machine. The nozzle 3 is what is known as an open nozzle, i.e. it does not contain means for closing the flow conduit 11. The invention can naturally be also applied in a shut-off nozzle in which the flow conduit 11 can be closed to thereby prevent the material from flowing out of the injection unit when it is detached from the mould. The output end 12 of the flow conduit, seen in the direction of flow of the moulding material, is substantially rectangular and it is arranged to the shape of the sprue 8 of the mould 4 such that the interface between the conduits 8 and 12 is substantially continuous, whereby the material flow is not subjected to significant disturbances at the interface which would slow down the flow of the moulding material, add to counter pressure, to the heating up of the material, or the like.

[0031] The input end 13 of the flow conduit of the nozzle is conically shaped and it connects the injection unit 2 and the output end 12 of the flow conduit together in a rheologically advantageous manner. The shape of the cross-section of the flow conduit 11 may also substantially correspond to that of the cross-section of the output end 12 of the flow conduit along the entire length of the nozzle 3.

[0032] Figure 1d shows a cross-section of the runner of the injection mould of Figure 1a. The entire runner 9 is machined to the parting surface 14 of the module 10. The surface of the runner 9 on the second mould half 6 is uniform with the parting surface 14 of the mould half 6. The runner 9 may also be located in the second mould half 6, or it may be divided between both mould halves.

[0033] The cooling surface of the runner 9 is large in proportion to its capacity, the thermal energy from the moulding material being thus rapidly conducted from the material to the mould, which is colder. The moulding material hardens rapidly and substantially simultaneously with the portion of the moulding material that has flowed into the mould.

[0034] Figure 2 is a schematic perspective view of a moulding removed from the mould of Figure 1a. The actual injection-moulded products 17 are attached to mouldings 19 produced in the runners 9 and further to a moulding 18 formed in the sprue 8. In the next production phase the products 17 are detached from the mouldings 18 and 19, which can usually be reused as raw material either in the same or in another process for manufacturing plastic products.

[0035] Figure 3a is a schematic view of another cross-section 20 of a flow conduit of the feed system 8, 9 and the nozzle 3 of the invention. In this embodiment the cross-section 20 is substantially elliptic, which is a most preferred shape from the point of view of the moulding material flow and which provides a large cooling surface in proportion to capacity.

[0036] Figure 3b is a schematic view of a third cross-section 21 of the feed system 8, 9 and the nozzle 3 of the invention. The shape of the cross-section 21 is that of the cross-section of a polyhedron, and it is formed in accordance with the invention, i.e. taking into account the hardening rate of the moulding material in the moulding cavity 7 of the mould 4 such that the moulding material hardens substantially simultaneously in the mould cavity 7 and in the conduits 8, 9. The flow conduit can be applied as a sprue 8 in some multi-cavity moulds to pre-guide the flow of the moulding material to the runners 9. A flow conduit in the form of a cross-section of a polyhedron constitutes a preferred embodiment also for some runners 9, because the shape can be used for guiding the flow of the moulding material into the mould cavity. The flow conduit may naturally also be shaped differently than in Figure 3b.

[0037] The drawings and the related specification are only intended to illustrate the idea of the invention. The details of the invention may vary within the scope of the claims. The basic form of the cross-section of the flow conduit may thus differ at different points of the feed system 8, 9, but at every point of the feed system 8, 9 the dimensions of the conduit are determined taking into account the hardening rate of the material injected into the mould cavity 7.

CLAIMS

1. A method for reducing cycle time in injection moulding, the method comprising
- arranging moulding material into an injection unit (2);
- injecting the moulding material through flow conduits into a mould cavity (7) of an injection mould (4);
- hardening the moulding material that is in the mould cavity (7) and the moulding material that is left in the flow conduits;
- removing the hardened moulding material from the mould (4),
characterized by
- arranging the ratio of the cross-sectional area of the flow conduits to their outer surface area taking into account the capacity and shape of the mould cavity (7) such that the injected moulding material left in the flow conduits hardens at the latest simultaneously with the moulding material that fills the mould cavity (7).

2. A method according to claim 1, **characterized** by minimizing the ratio of the cross-sectional area of the flow conduits to their outer surface area.

3. A method according to claim 1 or 2, **characterized** in that the mould (4) is cooled and the moulding material hardens while cooling down.

4. An injection mould according to claim 1 or 2, **characterized** in that the mould (4) is heated and the material to moulded hardens while heating up.

5. An injection mould, particularly an injection mould (4) for manufacturing thin-walled injection-moulded products, the mould comprising a mould cavity (7) and a feed system (8, 9) for supplying the moulding material from an injection unit (2) to the mould cavity (7), **characterized** in that the ratio of the cross-sectional area of a flow conduit of the feed system (8, 9) to its outer surface area is arranged in relation to the capacity and shape of the mould cavity (7) such that the injected moulding material left in the conduits (8, 9) hardens at the latest simultaneously with the moulding material that fills the mould cavity (7).

6. An injection mould according to claim 5, **characterized** in that said ratio of the cross-sectional area to the outer surface area is minimized.

7. An injection mould according to claim 5 or 6, **characterized** in that the basic form of the cross-section is rectangular.

8. An injection mould according to claim 5 or 6, **characterized** in that the basic form of the cross-section of the sprues is elliptic.

9. An injection mould according to claim 5 or 6, **characterized** in that the basic form of the cross-section of the sprues is a cross-section of a polyhedron.

10. An injection mould according to any one of the preceding claims, **characterized** in that there are at least two mould cavities (7).

11. An injection mould according to any one of the preceding claims, **characterized** in that the mould (4) is cooled and the moulding material hardens while cooling down.

12. An injection mould according to any one of the preceding claims 5 to 10, **characterized** in that the mould (4) is heated and the moulding material hardens while heating up.

13. A nozzle of an injection-moulding machine, the nozzle comprising a flow conduit (11, 12, 13) arranged to guide moulding material from an injection unit (2) to a sprue (8) of an injection mould, **characterized** in that the ratio of the surface area of the cross-section of the output end (12) of the flow conduit of the nozzle (3) to its outer surface area is arranged in relation to the capacity and shape of the mould cavity (7) such that injected moulding material left in the output end (12) of the flow conduit hardens at the latest simultaneously with the moulding material that fills the mould cavity (7).

14. A nozzle according to claim 13, **characterized** in that it is an open nozzle (3).

15. A nozzle according to claim 13, **characterized** in that it is a shut-off nozzle (3).

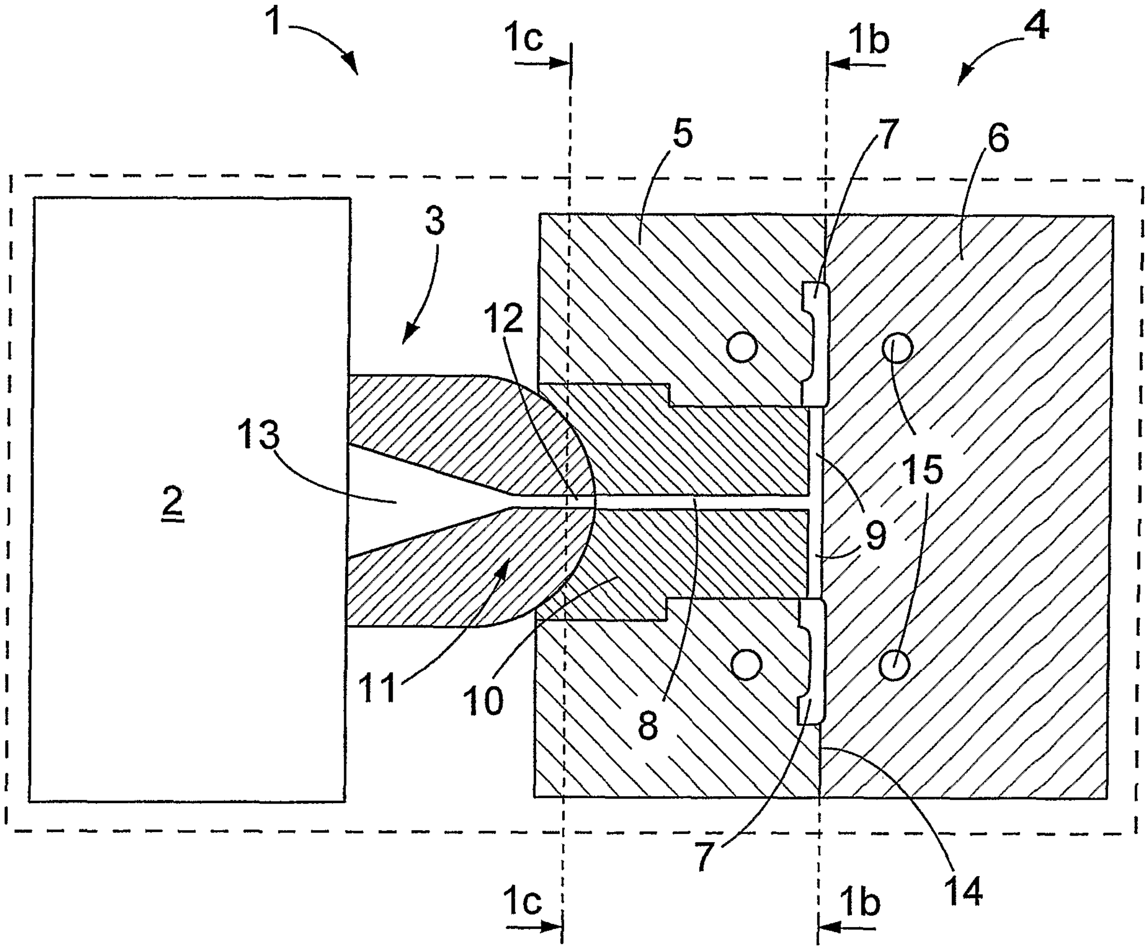

FIG. 1a

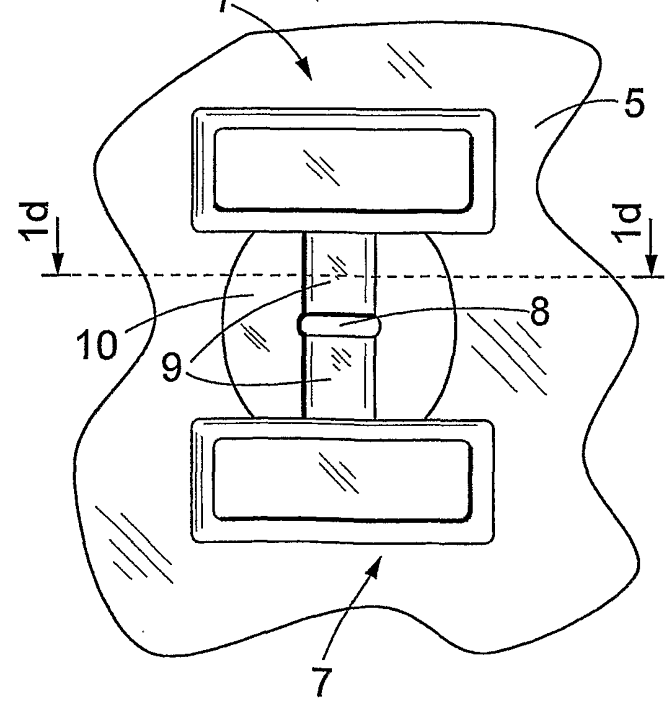

FIG. 1b

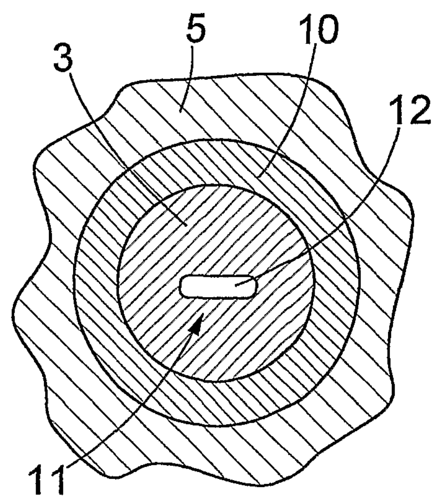

FIG. 1c

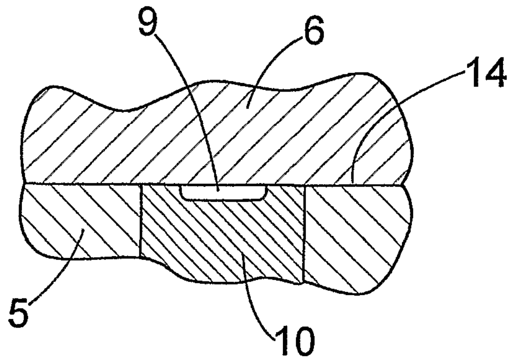

FIG. 1d

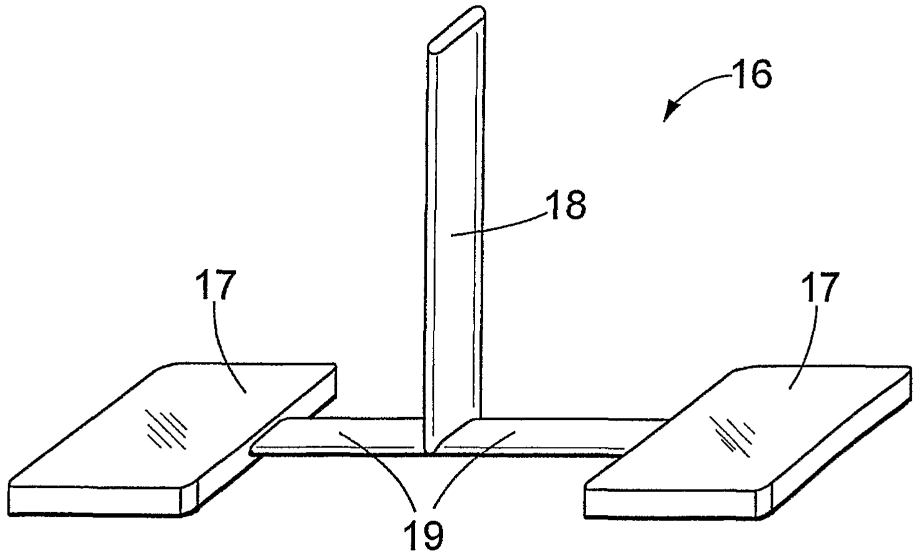

FIG. 2

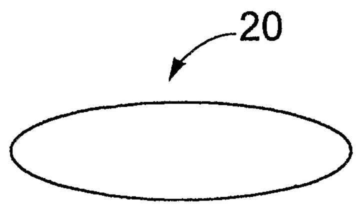

FIG. 3a

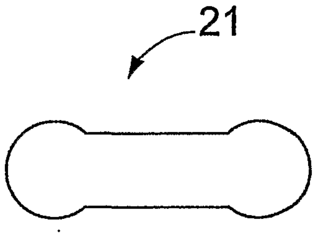

FIG. 3b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 01/00756

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B29C 45/27
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 9052260 A (DAICEL CHEM IND LTD) 1997-02-25 (abstract) World Patents Index (online). London, U.K.: Derwent Publications, Ltd. (retrieved on 2001-12-10). Retrieved from: EPO WPI Database. DW199718; Accession No 1997-196697 --	1-15
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A	US 4451224 A (JAMES H. HARDING), 29 May 1984 (29.05.84), abstract --	1-15

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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10 December 2001	11 -12- 2001
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Mattias Arvidsson/MP Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

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