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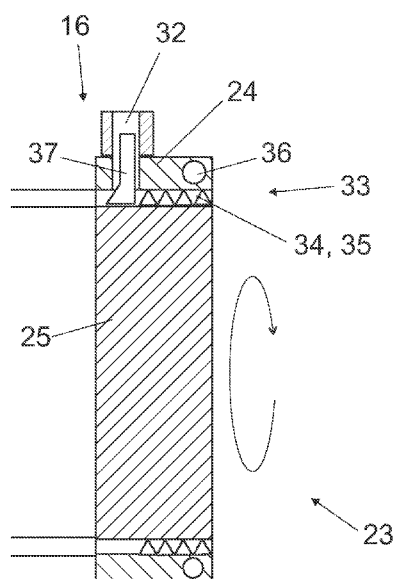


Fig. 4

(57) Abstract: A single-screw extruder (100) and method. The extruder comprises a cylindrical rotor member, the rotor member (1) arranged in a barrel (2), and a drive system (4) for the rotation of the rotor member (1) in the barrel (2). The extruder further comprises an outlet (16) of the extruder is provided with a die (23), comprising an outer ring (24) arranged to the barrel (2), an inner die part (25), the die (23) establishing a flow channel (26) that is continuously circular in all its cross-sections.



A SINGLE-SCREW EXTRUDER AND A METHOD FOR EXTRUSION

BACKGROUND

The invention relates to a single-screw extruder, comprising a cylindrical rotor member having diameter and length and comprising a feeding zone, the rotor member arranged in a barrel.

The invention further relates to a method for extrusion.

The demand for processing recycled materials is continuously growing. This type of materials are in their density, physical state, particle size and shape etc. extremely heterogeneous materials. A problem arising with these materials is that heterogeneous materials are extremely difficult to be processed in commonly known extruders and compounding devices.

BRIEF DESCRIPTION

Viewed from a first aspect, there can be provided a single-screw extruder, comprising

- a cylindrical rotor member having diameter and length and comprising a feeding zone,
- the rotor member arranged in a barrel,
- the cylindrical surface of the rotor member carrying cavity/cavities and/or projection(s) arranged in helically extending rows,
- the helically extending row(s) of the rotor member having a pitch and depth in the feeding zone of the rotor member, and the extruder further comprising
- a drive system for the rotation of the rotor member (1) in the barrel, wherein
- the relation of the depth to the diameter of the rotor member, i.e. $d:D$, is not more than 1:20, and
- the relation of the pitch of the rotor member to the diameter (of the rotor member, i.e. $P:D$, is not more than

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1:4, wherein an outlet of the extruder is provided with a die, comprising

- an outer ring arranged to the barrel,
- an inner die part arranged to the cylindrical rotor member and rotate therewith,
- the die establishing a flow channel that is continuously circular in all its cross-sections.

Thereby an extruder for processing heterogeneous materials may be achieved.

Viewed from a second aspect, there can be provided a single-screw extruder, comprising

- a cylindrical rotor member having diameter and length and comprising a feeding zone,
- the rotor member arranged in a barrel,
- the cylindrical surface of the rotor member carrying cavity/cavities and/or projection(s) arranged in helically extending rows,
- the helically extending row(s) of the rotor member having a pitch and depth in the feeding zone of the rotor member, and the extruder further comprising
 - a drive system for the rotation of the rotor member in the barrel, wherein
 - the relation of the depth to the diameter of the rotor member, i.e. $d:D$, is not more than 1:20, and
 - the relation of the pitch of the rotor member to the diameter of the rotor member, i.e. $P:D$, is not more than 1:4, wherein
- the rotor member comprises a cylindrical channel, the diameter of which is at least 75%, preferably 80 to 85 %, of the diameter of the rotor member, that
 - an outlet of the extruder is provided with a die, the die comprising an outer ring and an inner die part creating a flow channel that is continuously circular in all its cross-sections, that

- the outer ring is attached to the barrel, and that
 - the inner die part is supported to a support structure that is arranged inside said cylindrical channel,
 - the rotor member being arranged rotatable in respect to
- 5 the inner die part.

Thereby an extruder for converting heterogeneous material flows into raw material for further processing may be achieved.

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Viewed from a third aspect, there can be provided a method for extrusion, the method comprising steps of:

A) feeding the material in a single-screw extruder, the extruder comprising

- 15 - a cylindrical rotor member having diameter and length and comprising a feeding zone,

- the rotor member arranged in a barrel,
- the cylindrical surface of the rotor member carrying cavity/cavities and/or projection(s) arranged in helically

20 extending rows,

- the helically extending row(s) of the rotor member having a pitch and depth in the feeding zone of the rotor member, and the extruder further comprising

- 25 - a drive system for the rotation of the rotor member in the barrel, wherein

- the relation of the depth to the diameter of the rotor member, i.e. $d:D$, is not more than 1:20, and

- the relation of the pitch of the rotor member to the diameter of the rotor member, i.e. $P:D$, is not more than

30 1:4,

B) heating the material in said single-screw extruder to a flowable state, and

C) feeding the material in outlet of the extruder, the outlet being provided with a die, comprising

- 35 - an outer ring arranged to the barrel,

- an inner die part arranged to the cylindrical rotor member and rotate therewith,
 - the die establishing a flow channel that is continuously circular in all its cross-sections, and
- 5 D) allowing the material to exit between the outer ring and the rotating inner die part.

Thereby a method for converting heterogeneous material flows into raw material for further processing may be
10 achieved.

Viewed from a fourth aspect, there can be provided a method for extrusion, the method comprising steps of:

- 15 A) feeding the material in a single-screw extruder, the extruder comprising
- a cylindrical rotor member having diameter and length and comprising a feeding zone,
 - the rotor member arranged in a barrel,
 - the cylindrical surface of the rotor member carrying
- 20 cavity/cavities and/or projection(s) arranged in helically extending rows,
- the helically extending row(s) of the rotor member having a pitch and depth in the feeding zone of the rotor member, and the extruder further comprising
- 25 - a drive system for the rotation of the rotor member in the barrel, wherein
- the relation of the depth to the diameter of the rotor member, i.e. $d:D$, is not more than 1:20, and
 - the relation of the pitch of the rotor member to the di-
- 30 ameter of the rotor member, i.e. $P:D$, is not more than 1:4,
- B) heating the material in said single-screw extruder to a flowable state, and
- C) feeding the material in outlet of the extruder, the
35 outlet being provided with a die, comprising an outer ring

and an inner die part creating a flow channel that is continuously circular in all its cross-sections, wherein

- the outer ring is arranged to the barrel, and
 - the inner die part is supported to a support structure
- that is arranged inside said cylindrical channel,
- the rotor member being arranged rotatable in respect to the inner die part, and

D) allowing the material to exit between the outer ring and the unrotating inner die part.

Thereby a method for converting heterogeneous material flows into raw material for further processing may be achieved.

The arrangements and the methods are characterised by what is stated in the independent claims. Some other embodiments are characterised by what is stated in the other claims. Inventive embodiments are also disclosed in the specification and drawings of this patent application. The inventive content of the patent application may also be defined in other ways than defined in the following claims. The inventive content may also be formed of several separate inventions, especially if the invention is examined in the light of expressed or implicit sub-tasks or in view of obtained benefits or benefit groups. Some of the definitions contained in the following claims may then be unnecessary in view of the separate inventive ideas. Features of the different embodiments of the invention may, within the scope of the basic inventive idea, be applied to other embodiments.

BRIEF DESCRIPTION OF FIGURES

Some embodiments illustrating the present disclosure are described in more detail in the attached drawings, in which

Figure 1a is a schematic side view of an extruder in partial cross-section,

Figure 1b is a schematic view of a detail of the extruder
5 shown in Figure 1a in partial cross-section,

Figure 1c is a schematic view of a detail of the extruder shown in Figure 1a in partial cross-section,

10 Figure 1d is a schematic view of a detail of the extruder shown in Figure 1a in partial cross-section,

Figure 2 is a schematic view of a piece of an extruder barrel,
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Figure 3a is side view of another extruder in partial cross-section,

Figure 3b is a schematic view of a detail of the extruder
20 shown in Figure 3a in partial cross-section,

Figure 4 is side view of an extruder die in partial cross-section, and

25 Figure 5 is side view of another extruder die in partial cross-section.

In the figures, some embodiments are shown simplified for the sake of clarity. Similar parts are marked with the
30 same reference numbers in the figures.

DETAILED DESCRIPTION

Figure 1a is a schematic side view of a screw extruder in partial cross-section, Figure 1b is a schematic view of a detail of the extruder shown in Figure 1a in partial
35 cross-section, Figure 1c is a schematic view of a detail of the extruder shown in Figure 1a in partial cross-

section, and Figure 1d is a schematic view of a detail of the extruder shown in Figure 1a in partial cross-section.

The term "screw extruder" or "extruder" means here not only extruders for plastic extrusion but also compounding extruders, and extruders for other materials that may be in flowable form at least partly or that may be rendered, at least partly, in flowable form, such as recycled materials originating e.g. from industrial activities or households.

According to an aspect, the extruder 100 may be used for converting waste or recycled materials into raw material for use in subsequent processes. One aspect of the invention is that raw material can be used or stored essentially easier and/or in more compact physical state and/or more cleanly, etc. than the material fed in the extruder. The subsequent process may be another extrusion process, molding process etc.

According to another aspect, the extruder 100 may be used for compounding process, e.g. in manufacturing polymer-fibre compositions.

The extruder 100 is a single-screw extruder comprising a cylindrical rotor member 1, a barrel 2, a feed opening 3, and a drive system 4 for the rotation of the rotor member 1 in the barrel 2.

The rotor member 1 has diameter D and length L. In an embodiment, the relation of the length to the diameter, i.e. L:D, is in range of 2:1 to 4:1.

The cylindrical outer surface of the rotor member 1 comprises projections 5 that realizes a screw thread compris-

ing at least one screw flight 6 and at least one screw channel 7 between the at least one screw flight 6.

5 The screw thread constitutes a structure that transfers the material to be processed in the barrel from the feed opening 3 towards the outlet 9 while the rotor member 1 is rotating in the barrel 2. In an embodiment, the profile of the screw thread is invariable. In another embodiment, the profile of the screw thread is variable such that the vol-
10 ume of the screw channel decreases towards the outlet 16 of the extruder. In an embodiment, the depth d of the cavity/cavities and/or projection(s) 5 arranged on the surface of rotor is arranged to decrease after feed zone (10).

15 The decreasing of the screw channel volume causes a compression ratio which is typically 1:2 to 1:4. The profile may change step by step, or it may comprise at least one section where the profile changes rapidly from one profile
20 to another profile.

The screw flight 6 has pitch P and the screw channel 7 has depth d in the feeding zone 14 of the rotor member 1. The "feeding zone" means that part of the rotor member 1 that
25 is directly under the feed opening 3 and one to five lap(s) of the flight 6 following the feed opening.

According to an aspect, the relation of the depth d to the diameter D , i.e. $d:D$, is not more than 1:20, and the rela-
30 tion of the pitch P to the diameter D , i.e. $P:D$, is not more than 1:4. An advantage is that the volume of the screw channel 7 is very low compared to the screw diameter D . Thus it is possible to provide the extruder 100 with a very large feed opening 3 compared to the volume of the
35 screw channel 7. Following this, light density and/or heterogeneous materials, such as materials comprising fibres,

waste/recycled plastic, can be fed in the extruder 100 in amounts sufficient to fill optimally the screw channel 7. Another advantage is that the low volume compared to the screw diameter D decreases power requirement of the extruder.

In an embodiment, $d:D$ is in range of 1:300 to 1:20 (in the feeding zone 14 of the rotor member 1). An advantage is that the temperature of the material to be processed in the screw channel 7 may be controlled very precisely due to large surface area of the screw channel compared to volume of the material, and thus e.g. materials or processes highly sensitive to temperature may be processed by the extruder.

In an embodiment, $P:D$ is in range of 1:60 to 1:4. An advantage is that the material to be processed may be transferred towards the outlet 7 by low power usage.

In an embodiment, the rotor member 1 realizes equation

$$CL \cdot d \leq RD \cdot 0.01, \text{ wherein}$$

CL = CL = channel length measured in direction of length (L) of the rotor member 1,

d = channel depth measured in radial direction of the rotor member 1, and

RD = cross-sectional area of the rotor member, including also the cross-sectional area of the channel 8.

An advantage is that the volume of the screw channel 7 is very low compared to the screw diameter D, and thus easily filled with the material to be processed due to a large feed opening 3. For instance, the diameter of the rotor member 1 may be 350 mm whereas the length following the feed opening is 400 mm.

In an embodiment, the feed opening 3 or the feeding zone 14 comprises shearing or cutting means for reducing the particle size of the material being fed in the extruder 100. This means may comprise e.g. cutting teeth arranged on the rotor member 1 and counterpart(s) arranged in the barrel 2.

According to an aspect, the rotor member 1 is hollow. In an embodiment, the rotor member comprises a cylindrical channel 8, such as circular cylinder, the diameter of which is at least 75%, preferably 80 to 85 %, of the diameter D of the rotor member. This means that the diameter D of the rotor member may be increased compared to the known rotor members without increasing the weight and expenses thereof.

In an embodiment, the rotor member comprises one screw flight. In another embodiment, the rotor member comprises two, or even more, screw flights.

Thanks to the large diameter of the rotor member 1, the drive system 4 may be construed to transmit high torques in the rotor member 1. Also the structure of the rotor member 1 may stand high torques without risk for damages. The extruder 100 may be realized many alternative ways. For instance, in an embodiment the rotor member 1 comprises helically extending rows of plurality of separate cavities, instead of the screw thread. Said cavities constitute a structure that transfers the material to be processed in the barrel from the feed opening 3 towards the outlet 9.

The shape of the cavities may be e.g. dome, hemispheric, a section or calotte of tear-drop, oval or combinations thereof.

According to an aspect, the relation of the depth d to the diameter D in the feeding zone 14 of the rotor member 1, i.e. $d:D$, is not more than 1:20, and the relation of the pitch P to the diameter D , i.e. $P:D$, is not more than 1:4. An advantage is that the volume of the cavities is very low compared to the screw diameter D , and thus light density and/or heterogeneous materials, such as materials comprising fibres, waste/recycled plastic, can be fed in the extruder 100 in amounts sufficient to fill optimally the volume between the rotor member 1 and the barrel 2.

In an embodiment, $d:D$ is in range of 1:300 to 1:20.

In an embodiment, $P:D$ is in range of 1:60 to 1:4.

In another embodiment, the rotor member 1 comprises projections that realize helically extending rows of plurality of discrete projections, the row comprising pitch P .

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According to an aspect, the relation of the depth d , or height of the projections, to the diameter D , i.e. $d:D$, is not more than 1:20, and the relation of the pitch P to the diameter D , i.e. $P:D$, is not more than 1:4.

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In an embodiment, $d:D$ is in range of 1:300 to 1:20.

In an embodiment, $P:D$ is in range of 1:60 to 1:4.

According to an aspect, the cylindrical inner surface of the barrel 2 may comprise barrel cavity/cavities and/or projection(s). In an embodiment, said barrel cavity/cavities and/or projection(s) are arranged in helically extending rows. In another embodiment, the barrel cavity/cavities and/or projection(s) are arranged parallel with longitudinal axis of the rotor member 1. In still an-

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other embodiment, the barrel cavity/cavities and/or projection(s) are arranged perpendicular with the longitudinal axis of the rotor member 1.

- 5 In an embodiment, the barrel 2 comprises a barrel screw thread comprising at least one barrel flight 10 and at least one barrel channel 11 between the at least one flight, the barrel flight having a barrel pitch BP and the barrel channel having a barrel depth BD.

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An advantage is that transfer of the material to be processed towards the outlet 9 may be enhanced.

- 15 In another embodiment, the cavities arranged in the barrel 2 realize helically extending rows of plurality of separate cavities.

An advantage is that the mixing and blending properties of the extruder may be enhanced.

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The cavities arranged in the barrel 2 may be invariable in their shape and size in all the length of the barrel they exist. In another embodiment, the barrel 2 may comprise variable sized and/or shaped cavities.

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In an embodiment, the barrel cavity/cavities and/or projection(s) 5 are not continuous, such that there are several cavities or grooves side by side.

- 30 The outlet 16 of the extruder is provided with a die 23. The die 23 comprises an outer ring 24 that is attached to the barrel 2, and an inner die part 25 attached to the cylindrical rotor member 1. The inner die part 25 thus rotates with the rotor member 1.

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The die 23 establishes a flow channel 26 that is continuously circular in all its cross-sections, as can be seen best in Figure 1c.

- 5 In an embodiment, the outer ring 24 is removably attached to the extruder 100 by e.g. bolts. In another embodiment, the outer ring 24 is attached permanently to the barrel e.g. by welding.
- 10 In an embodiment, the inner die part 25 is removably attached to the extruder 100, more precisely to the rotor member 1. In another embodiment, the inner die part 25 is attached permanently to the rotor member 1.
- 15 In an embodiment, both the outer ring 24 and the inner die part 25 are fixedly attached to the extruder 100. In another embodiment, both the outer ring 24 and the inner die part 25 are removably attached to the extruder 100.
- 20 The outer ring 24 and the inner die part 25 has a flow surfaces 27 that define the flow channel 26. In an embodiment, the flow surface 27 of the outer ring 24 is essentially smooth. In another embodiment, the flow surface 27 of the outer ring 24 comprises corrugations that differ
- 25 from surface structure the inner surface of the barrel 2.

- In an embodiment, the flow surface 27 of the inner die part 25 is essentially smooth. In another embodiment, the flow surface 27 of the inner die part 25 comprises corrugations that differ from surface structure arranged on the
- 30 rotor member 1.

- In an embodiment, deepness of said corrugations in the flow surface 27 mentioned above are in range of 1:300 to
- 35 1:20, preferably 1:160 to 1:300, compared to the diameter of the corresponding flow surface 27.

In an embodiment, the cross-sectional area of the flow channel 26 of the die is constant all the length of the die 23. An advantage is that the geometry is easy to manufacture. The pressure before the die is easy to control by the die section length. Additionally, when the channel is constant, it is easy to connect one or more die sections sequentially.

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In another embodiment, said cross-sectional area is reducing towards the exit of the die 23. An advantage is that the die can be used to increase the pressure of outcoming material flow and thus improve the mixing process.

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In still another embodiment, said cross-sectional area is expanding towards the exit of the die 23. An advantage is that the die is self-cleaning, any material which access the die can come out. In the case of cooled die even poorly flowing material can exit the die.

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Figure 2 is a schematic view of a piece of an extruder barrel. According to an aspect, the barrel 2 is construed from two or more barrel modules 12 that are separately manufactured and then connected consecutively.

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An advantage is that the barrel cavity/cavities and/or projection(s), such as barrel screw thread comprising at least one barrel flight 10 and at least one barrel channel 11, may be manufactured in short pieces of the barrel more easily into short and large in diameter barrel module 12 than they would be manufactured in one monolithic barrel having equal length. It is to be noted, however, that the barrel 2 may also be manufactured in one piece. In the latter case, the barrel cavity/cavities and/or projec-

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tion(s) can still be manufactured extremely easily due to high D:L relationship of the extruder.

Figure 3a is side view of another extruder in partial cross-section, and **Figure 3b** is a schematic view of a detail of the extruder shown in Figure 3a in partial cross-section.

The feed opening 3 is substantially big comparing to the capacity of the extruder and the depth of the rotor cavities. In an embodiment, the projected area of the feed opening is about 50 square centimeters per kilowatt.

In an embodiment, the feed opening 3 is cut to the halfway of the diameter of the barrel 2, i.e. approximately $D/2$. Thus the feed opening 3 potentially weakens the structure of the barrel 2 such an extent, that the barrel 2 is not able to carry the load caused during an extrusion process. Especially when the diameter of the barrel is large and the barrel is short, the axial forces tend to bend the barrel at the feeding zone 14.

In an embodiment, the barrel 2 is supported by a support structure 15 that lies outside of the barrel 2. The support structure 15 comprises a first support part 17 that is attached to a section of the barrel 2 between the feed opening 3 and the discharge end 16 of the barrel, a second support part 18 attached to the drive system side 19 of the extruder, and a load transmit structure 20 connecting the first support part 17 to the second support part 18. In the embodiment shown in Figure 4, the second support part 18 has been fixed to a bearing housing 22 that covers the drive system 4. The load transmit structure 20 may be composed of one or more beam(s), plate structure or trussed construction, for instance.

The support structure 15 bears a part of the loads and stresses caused in an extrusion process and prevents the structure of the extruder from bending.

- 5 In an embodiment, there is an axial slot 21 arranged between the feeding zone 14 of the barrel and the bearing housing 22 of the extruder for receiving material (if any) flowing from the feeding zone backwards. Thus the axial slot 21 is to prevent the material to enter in the bearing
- 10 housing 22. Instead, the material will drop through the slot in a room where it does not cause any problems to the extruder or the extrusion process.

- In an embodiment, the barrel 2 is totally separated from
- 15 the bearing housing 22, i.e. the axial slot 21 extends 360° around longitudinal axle of the extruder. In another embodiment, there are plurality of axial slots 21 that are separated by short sections of material.

- 20 In the embodiment shown in Figures 3a and 3b, the outlet 16 is provided with a die 23, the outer ring 24 of which is attached to the barrel 2, and the inner die part 25 is supported to a support structure 28 that is arranged inside of the cylindrical channel 8. Thus the rotor member 1
- 25 rotates in respect to the inner die part 25, or in other words, the inner part does not rotate.

- In the embodiment shown in Figures 3a and 3b, the inner surface of a section of the cylindrical channel 8 lying in
- 30 proximity of the die 23 comprises a counter thread 29, best shown in Figure 3b. The pitch of the counter thread 29 is arranged in the same direction as the pitch of the cavity/cavities and/or projection(s) 5 arranged in the helically extending rows. The counter thread 29 establishes a counter screw channel 30 with an outer surface of the
- 35 support structure 28. The counter thread 29 and the coun-

ter screw channel 30 create a counteracting means that prevents or essentially inhibits the processed material to penetrate in the channel 8.

5 In another embodiment, counter thread 29 is arranged on outer surface of the support structure 28. In this embodiment, the pitch of the counter thread 29 is arranged in opposite direction as the pitch of the cavity/cavities and/or projection(s) 5 arranged in the helically extending
10 rows.

In still another embodiment, the extruder comprises both counter threads 29 mentioned above, i.e. in on outer surface of the support structure 28 and the inner surface of the cylindrical channel 8.

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Figure 4 is side view of an extruder die in partial cross-section.

In the embodiments discussed above, the exit of the die 23
20 is coaxial with the longitudinal axis of the rotor member 1. In another embodiments, the outer ring 24 is provided with at least one radial opening 32 as a material output port. There is also a blocking means 33 arranged to block the end of the flow channel 26 after the radial opening 32
25 such that the processed material may exit only through the at least one radial opening 32.

In the embodiment shown in Figure 4, the inner die part 25 rotates with the rotor member 1. The blocking means 33
30 comprises a reverse thread 34 arranged in the inner die part, the pitch of which is arranged in opposite direction as the pitch of the cavity/cavities and/or projection(s) 5 arranged in the helically extending rows. The reverse thread 34 establishes a reverse screw channel 35 with an
35 inner surface or flow surface 27 of the outer ring 24.

In another embodiment, the reverse thread 34 is arranged in the outer ring 24. In this embodiment, the pitch is in same direction with the pitch of the cavity/cavities and/or projection(s) 5.

5

In a third embodiment, both the inner die part 25 and the outer ring 24 comprises the reverse thread 34 mentioned above.

10 The reverse thread(s) 34 direct(s) material to flow towards the radial opening 32.

Additionally, the blocking means 33 may comprise a cooling arrangement 36 arranged to cool the outer ring 24. Cooling
15 of the die 23 rises the viscosity of the processed material, and thus reduces its ability to intrude into gaps and joints in the die. The cooling arrangement 36 may comprise e.g. channels in which cooling liquid may flow.

20 Embodiments comprising at least one radial opening 32 may have a scraper arrangement 37 that is arranged to remove raw material on a rotating inner die part 25 (as shown) or on a rotating rotor member 1. This may help exit of the material out of the extruder.

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Figure 5 is side view of another extruder die in partial cross-section. In the embodiment shown in Figure 5, the inner die part 25 does not rotate with the rotor member 1. The outer ring 24 is provided with at least one radial
30 opening 32 as a material output port, and a blocking means 33 for blocking the end of the flow channel 26 after the radial opening 32 being arranged in the die 23.

The blocking means 33 comprises here a simple plate or
35 similar element that closes the flow channel 26. The plate

may be fixed removable or permanently to the outer ring 24 and the inner die part 25.

Also this embodiment of the blocking means 33 may comprise
5 a cooling arrangement 36.

The invention is not limited solely to the embodiments described above, but instead many variations are possible within the scope of the inventive concept defined by the
10 claims below. Within the scope of the inventive concept the attributes of different embodiments and applications can be used in conjunction with or replace the attributes of another embodiment or application.

15 The drawings and the related description are only intended to illustrate the idea of the invention. The invention may vary in detail within the scope of the inventive idea defined in the following claims.

REFERENCE SYMBOLS

	1	rotor member
	2	barrel
5	3	feed opening
	4	drive system
	5	projection or cavity
	6	screw flight
	7	screw channel
10	8	channel
	9	outlet
	10	barrel flight
	11	barrel channel
	12	barrel module
15	13	hollow bar
	14	feeding zone
	15	barrel support structure
	16	extruder outlet end
	17	first support part
20	18	second support part
	19	drive system side
	20	load transmit structure
	21	axial slot
	22	bearing housing
25	23	die
	24	outer ring
	25	inner die part
	26	flow channel
	27	flow surface
30	28	support structure
	29	counter thread
	30	counter screw channel
	31	attaching means
	32	radial opening
35	33	blocking means
	34	reverse thread

	35	reverse screw channel
	36	cooling arrangement
	37	scraper arrangement
5	100	extruder
	BD	barrel depth
	BP	barrel pitch
	C	counter flow
10	CL	channel length
	D	diameter of the rotor member
	d	depth
	L	length of the rotor member
	P	pitch
15	RD	cross-sectional area of the rotor member
	V	leakage

CLAIMS

1. A single-screw extruder (100), comprising
- a cylindrical rotor member (1) having diameter (D) and length (L) and comprising a feeding zone (14),
 - 5 - the rotor member (1) arranged in a barrel (2),
 - the cylindrical surface of the rotor member (1) carrying cavity/cavities and/or projection(s) (5) arranged in helically extending rows,
 - the helically extending row(s) of the rotor member (1)
 - 10 having a pitch (P) and depth (d) in the feeding zone (14) of the rotor member, and the extruder (100) further comprising
 - a drive system (4) for the rotation of the rotor member (1) in the barrel (2), wherein
 - 15 - the relation of the depth (d) to the diameter (D) of the rotor member, i.e. $d:D$, is not more than 1:20, and
 - the relation of the pitch (P) of the rotor member to the diameter (D) of the rotor member, i.e. $P:D$, is not more than 1:4, characterized in that
 - 20 - an outlet (16) of the extruder is provided with a die (23), comprising
 - an outer ring (24) arranged to the barrel (2),
 - an inner die part (25) arranged to the cylindrical rotor member (1) and rotate therewith,
 - 25 - the die (23) establishing a flow channel (26) that is continuously circular in all its cross-sections.
2. The extruder as claimed in claim 1, wherein at least one of the outer ring (24) and the inner die part (25) is
- 30 removably attached to the extruder (100).
3. The extruder as claimed in claim 1, wherein at least one of the outer ring (24) and the inner die part (25) is fixedly attached to the extruder (100).

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4. The extruder as claimed in any of the preceding claims, wherein a flow surface (27) of the outer ring (24) is essentially smooth.
- 5 5. The extruder as claimed in any of claims 1 - 3, wherein the flow surface (27) of the outer ring (24) comprises corrugations that differ from the inner surface of the barrel (2).
- 10 6. The extruder as claimed in any of the preceding claims, wherein a flow surface (27) of the inner die part (25) is essentially smooth.
- 15 7. The extruder as claimed in any of claims 1 - 5, wherein the flow surface (27) of the inner die part (25) comprises corrugations the shape and/or dimensions differing from cavity/cavities and/or projection(s) (5) arranged on the rotor member (1).
- 20 8. The extruder as claimed in any of the preceding claims, wherein cross-sectional area of the flow channel (26) of the die is constant all the length of the die (23).
- 25 9. The extruder as claimed in any of the preceding claims, wherein the outer ring (24) is provided with at least one radial opening (32) as a material output port, and a blocking means (33) for blocking the end of the flow channel (26) after the radial opening (32) being arranged in the die (23).
- 30 10. The extruder as claimed in claim 9, wherein the blocking means (33) comprises a reverse thread (34), the pitch of which is arranged in opposite direction as the pitch of the cavity/cavities and/or projection(s) (5) arranged in the helically extending rows, and wherein
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the reverse thread (34) establishes a reverse screw channel (35) with an outer surface of the outer ring (24).

11. The extruder as claimed in claim 9 or 10, wherein the
5 blocking means (33) comprises a cooling arrangement (36) arranged to cool the outer ring (24).

12. A single-screw extruder (100), comprising
- a cylindrical rotor member (1) having diameter (D) and
10 length (L) and comprising a feeding zone (14),
- the rotor member (1) arranged in a barrel (2),
- the cylindrical surface of the rotor member (1) carrying cavity/cavities and/or projection(s) (5) arranged in heli-
cally extending rows,
15 - the helically extending row(s) of the rotor member (1) having a pitch (P) and depth (d) in the feeding zone (14) of the rotor member, and the extruder (100) further comprising
- a drive system (4) for the rotation of the rotor member
20 (1) in the barrel (2), wherein
- the relation of the depth (d) to the diameter (D) of the rotor member, i.e. $d:D$, is not more than 1:20, and
- the relation of the pitch (P) of the rotor member to the diameter (D) of the rotor member, i.e. $P:D$, is not more
25 than 1:4, characterized in that
- the rotor member (1) comprises a cylindrical channel (8), the diameter of which is at least 75%, preferably 80 to 85 %, of the diameter (D) of the rotor member (1), that
- an outlet (16) of the extruder is provided with a die
30 (23), the die comprising an outer ring (24) and an inner die part (25) creating a flow channel (26) that is continuously circular in all its cross-sections, that
- the outer ring (24) is attached to the barrel (2), and
that

- the inner die part (25) is supported to a support structure (28) that is arranged inside said cylindrical channel (8),
 - the rotor member (1) being arranged rotatable in respect
- 5 to the inner die part (25).

13. The extruder as claimed in claim 12, wherein the inner surface of a section of the cylindrical channel (8) lying in proximity of the die (23) comprises a counter thread

10 (29), the pitch of which is arranged in the same direction as the pitch of the cavity/cavities and/or projection(s) (5) arranged in the helically extending rows, and wherein the counter thread (29) establishes a counter screw channel (30) with an outer surface of the support structure

15 (28).

14. The extruder as claimed in claim 12 or 13, wherein the outer ring (24) is provided with at least one radial opening (32) as a material output port, and

20 a blocking means (33) for blocking the end of the flow channel (26) after the radial opening (32) being arranged in the die (23).

15. The extruder as claimed in claim 14, wherein the

25 blocking means (33) comprises a reverse thread (34), the pitch of which is arranged in opposite direction as the pitch of the cavity/cavities and/or projection(s) (5) arranged in the helically extending rows, and wherein the reverse thread (34) establishes a reverse screw channel (35) with an inner surface of the outer ring (24).

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16. The extruder as claimed in claim 14 or 15, wherein the blocking means (33) comprises a cooling arrangement (36) arranged to cool the outer ring (24).

17. A method for extrusion, the method comprising steps of:

A) feeding the material in a single-screw extruder (100), the extruder comprising

- 5 - a cylindrical rotor member (1) having diameter (D) and length (L) and comprising a feeding zone (14),
- the rotor member (1) arranged in a barrel (2),
- the cylindrical surface of the rotor member (1) carrying cavity/cavities and/or projection(s) (5) arranged in heli-
- 10 cally extending rows,
- the helically extending row(s) of the rotor member (1) having a pitch (P) and depth (d) in the feeding zone (14) of the rotor member, and the extruder (100) further comprising
- 15 - a drive system (4) for the rotation of the rotor member (1) in the barrel (2), wherein
- the relation of the depth (d) to the diameter (D) of the rotor member, i.e. $d:D$, is not more than 1:20, and
- the relation of the pitch (P) of the rotor member to the
- 20 diameter (D) of the rotor member, i.e. $P:D$, is not more than 1:4,

B) heating the material in said single-screw extruder (100) to a flowable state, and

- C) feeding the material in outlet (16) of the extruder,
- 25 the outlet being provided with a die (23), comprising
 - an outer ring (24) arranged to the barrel (2),
 - an inner die part (25) arranged to the cylindrical rotor member (1) and rotate therewith,
 - the die (23) establishing a flow channel (26) that is
 - 30 continuously circular in all its cross-sections, and
- D) allowing the material to exit between the outer ring (24) and the rotating inner die part (25).

18. A method for extrusion, the method comprising steps of:

A) feeding the material in a single-screw extruder (100), the extruder comprising

- 5 - a cylindrical rotor member (1) having diameter (D) and length (L) and comprising a feeding zone (14),
- the rotor member (1) arranged in a barrel (2),
- the cylindrical surface of the rotor member (1) carrying cavity/cavities and/or projection(s) (5) arranged in heli-
- 10 cally extending rows,
- the helically extending row(s) of the rotor member (1) having a pitch (P) and depth (d) in the feeding zone (14) of the rotor member, and the extruder (100) further comprising
- 15 - a drive system (4) for the rotation of the rotor member (1) in the barrel (2), wherein
- the relation of the depth (d) to the diameter (D) of the rotor member, i.e. $d:D$, is not more than 1:20, and
- the relation of the pitch (P) of the rotor member to the
- 20 diameter (D) of the rotor member, i.e. $P:D$, is not more than 1:4,

B) heating the material in said single-screw extruder (100) to a flowable state, and

- C) feeding the material in outlet (16) of the extruder,
- 25 the outlet being provided with a die (23), comprising an outer ring (24) and an inner die part (25) creating a flow channel (26) that is continuously circular in all its cross-sections, wherein
 - the outer ring (24) is arranged to the barrel (2), and
 - 30 - the inner die part (25) is supported to a support structure (28) that is arranged inside said cylindrical channel (8),
 - the rotor member (1) being arranged rotatable in respect to the inner die part (25), and
 - 35 D) allowing the material to exit between the outer ring (24) and the unrotating inner die part (25).

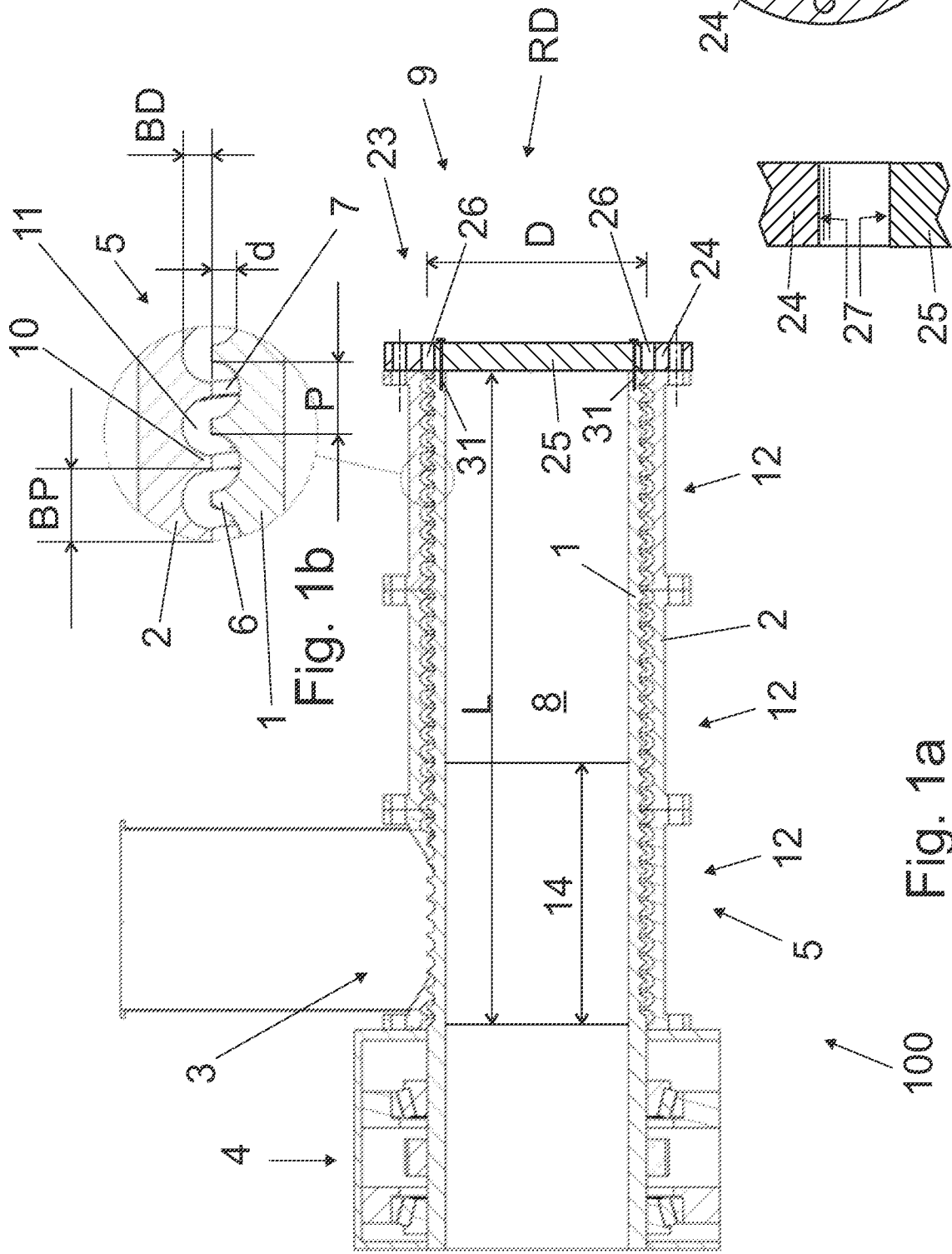


Fig. 1c

Fig. 1d

Fig. 1a

Fig. 1b

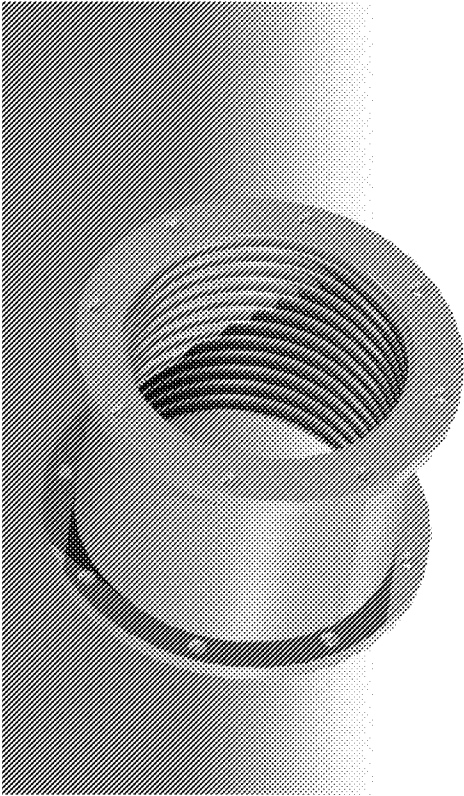


Fig. 2

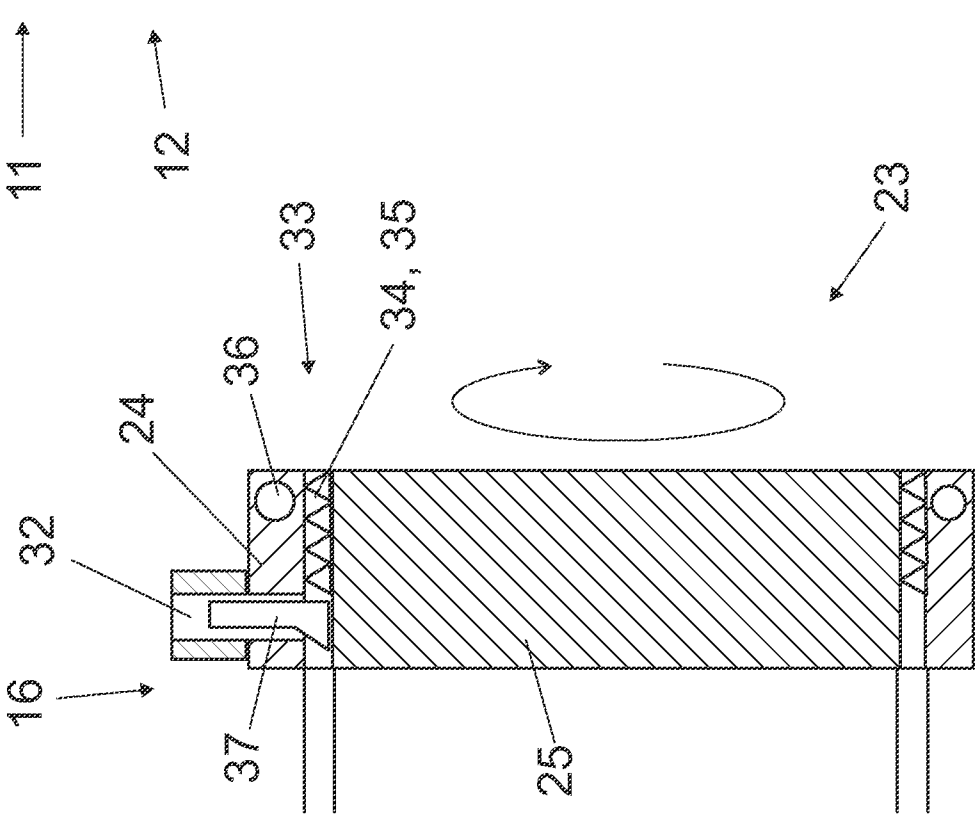


Fig. 4

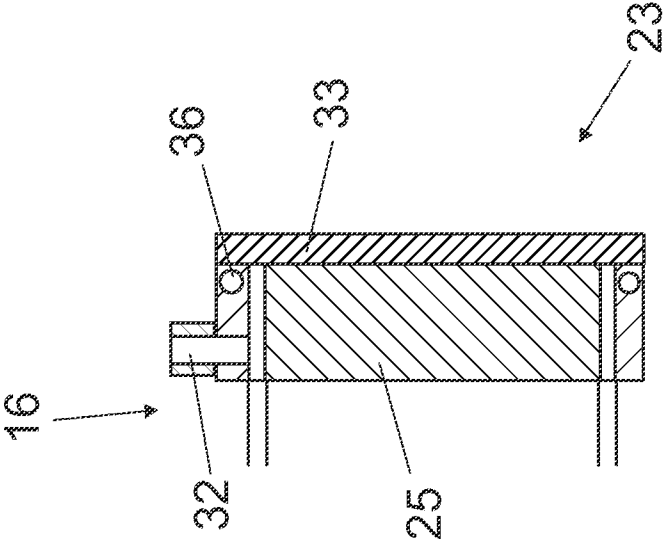
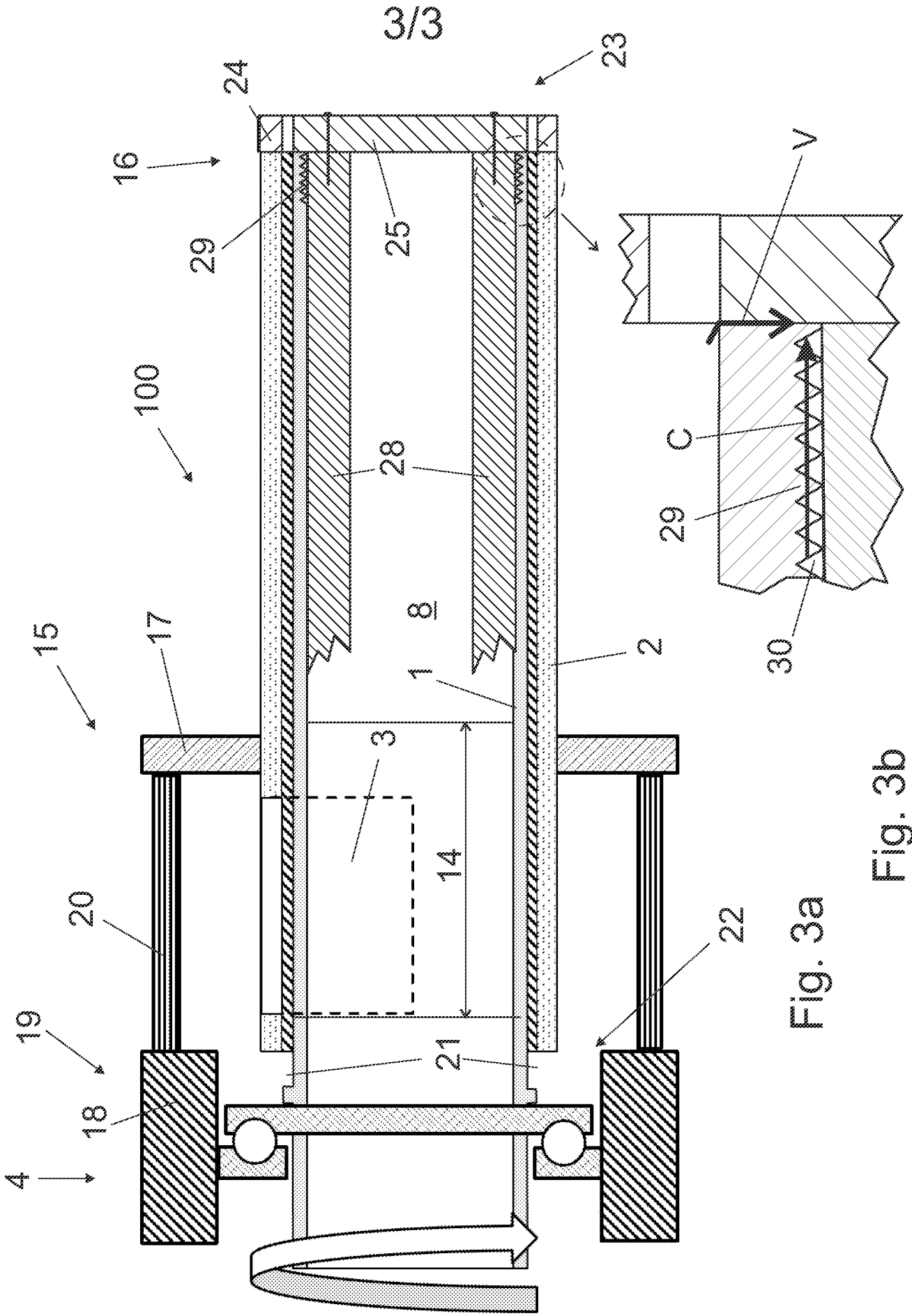


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No

PCT/FI2020/050017

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29C48/09 B29C48/33 B29C48/395 B29C48/68 B29C48/505
ADD.

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)
B29C

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2018/037164 A1 (TEKNOLOGIAN TUTKIMUSKESKUS VTT OY [FI]) 1 March 2018 (2018-03-01) abstract page 5, lines 23-26 claim 1 figures 1a,1b -----	1-4,6, 12,13, 17,18 5,7-11, 14-16
Y A	EP 0 489 534 A1 (MITSUI TOATSU CHEMICALS [JP]) 10 June 1992 (1992-06-10) abstract figures 1-3 -----	1-4,6,17 5,7-16, 18
Y A	EP 0 999 030 A2 (WIRSB0 BRUKS AB [SE]) 10 May 2000 (2000-05-10) abstract paragraph [0025] figures 1,2 -----	12,13,18 1-11, 14-17



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

24 April 2020

Date of mailing of the international search report

06/05/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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