



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
16.09.2020 Bulletin 2020/38

(51) Int Cl.:
D21J 7/00 (2006.01)

(21) Application number: **19173703.0**

(22) Date of filing: **10.05.2019**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **Saxena, Prateek**
302015 Jaipur Rajasthan (IN)
• **Bissacco, Giuliano**
25354 Mörap (SE)

(74) Representative: **Guardian**
IP Consulting I/S
Diplomvej, Building 381
2800 Kgs. Lyngby (DK)

(30) Priority: **14.03.2019 IN 201911010049**

(71) Applicant: **Danmarks Tekniske Universitet**
2800 Kgs. Lyngby (DK)

(54) **METHOD OF MANUFACTURING A MOULDED PULP PRODUCT AND PULP MOULDING APPARATUS**

(57) The method includes the following steps: activating the vacuum source (10), injecting an amount of pulp into the internal mould chamber (3) through the mould opening (7), thereby forming a pulp preform on the internal mould surface (8), injecting a dewatering and heating fluid through the mould opening at gradually increasing pressure until a maximum pressure, thereby performing a dewatering and drying step whereby the pulp preform on the internal mould surface is dewatered

and dried, deactivating the injection of dewatering and heating fluid, deactivating the vacuum source, and extracting the moulded pulp product. Further included is a step of initiating rotation of the mould (2) about the central axis (4) of the mould and increasing rotational speed gradually, maintaining a maximum rotational speed of the mould at least during a substantial part of the dewatering and drying step, decreasing rotational speed gradually until standstill of the mould.

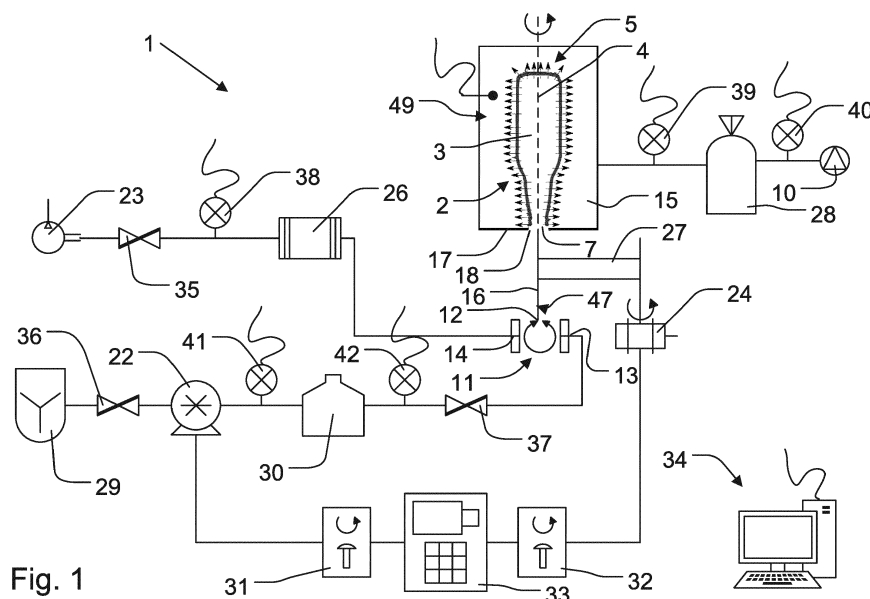


Fig. 1

Description

[0001] The present invention relates to a method of manufacturing a moulded pulp product by means of a pulp moulding apparatus including a mould with an internal mould chamber generally having rotational symmetry about a central axis of the mould and having a closed end and an open end forming a mould opening, the internal mould chamber having an internal mould surface generally provided with a number of evacuation openings connected to a vacuum source, the method including the following steps:

- activating the vacuum source,
- injecting an amount of pulp into the internal mould chamber through the mould opening, thereby forming a pulp preform on the internal mould surface,
- injecting a dewatering and heating fluid through the mould opening at gradually increasing pressure until a maximum pressure, thereby performing a dewatering and drying step whereby the pulp preform on the internal mould surface is dewatered and dried,
- deactivating the injection of dewatering and heating fluid,
- deactivating the vacuum source,
- extracting the moulded pulp product.

[0002] EP 1 104 822 A2 discloses a method of producing a pulp moulded article comprising a papermaking step in which a pulp slurry is fed to the papermaking net surface of a papermaking mould having suction paths, and water contained in the pulp slurry is sucked through the suction paths whereby the pulp is deposited on the surface to form a wet preform, and a dewatering step in which the wet preform is dewatered, wherein the temperature of the fed pulp slurry is raised while the pulp is being deposited on the surface. The dewatering step may be performed by injection of a dewatering fluid into the cavity of the papermaking mould, and an inflatable hollow pressing member may optionally be inserted into and inflated inside the cavity while evacuating the cavity by suction.

[0003] EP 1 288 369 A1 discloses a similar method of producing a pulp moulded article wherein said undried moulded article formed on the inner side of said papermaking screen is dewatered by feeding pressurizing air into the cavity.

[0004] WO 2016/055073 A1 discloses a system for producing a moulded article, in particular a bottle-shaped article, from pulp, said system comprising a pressure device for applying a pressure to the pulp, a first compressor, and a split mould having a central first cavity, said first cavity having an opening for supplying said pulp to said first cavity, one or more further cavities together surrounding said first cavity, and a wall separating said first cavity from said one or more further cavities, said wall having a structure allowing for fluid to flow between said first cavity and said one or more further cavities, said wall

having a first surface facing the interior of said first cavity and being for a layer of said pulp deposited thereon. An expandable pressing tool in the form of a balloon having a hollow inside may be inserted into the first cavity and a heating device may be configured for heating said expandable pressing tool. In an alternative embodiment, there is no balloon, but instead the layer of deposited pulp is pressed against the interior surface of the mould by use of superheated steam.

[0005] GB191418339 discloses an apparatus for making bottles and other receptacles from paper pulp of the type having a mould and a distributing tube for the pulp inserted therein. The distributing tube has openings varying in size proportionally to the size of that portion of the mould opposite thereto. Centrifugal packing-means are provided for packing the pulp in the mould in that, when ejecting the fluid pulp through slots of the distributing tube against the interior face of the rapidly rotating mould, the pressure from a piston will force the pulp against said mould and the centrifugal force due to rotation of said mould will further tend to pack the pulp against the walls of the mould while said rotation will also tend to distribute the pulp equally circumferentially. Said mould being of net or otherwise perforated the fluid in which the pulp is suspended will be forced outwardly there through. However, this known apparatus is mostly suitable as a manual method of making paper bottles having a rough uneven surface and is not in any way suitable to meet today's demand for packaging.

[0006] WO 2018/033209 A1 discloses a method for manufacturing a moulded article from pulp in the form of a detergent packaging which is not rotation symmetric. Pulp is distributed in the mould by rotation about one or more axes and the pulp may be kept in place on the mould by means of vacuum. The mould may be heated by means of a heating element which can comprise at least one duct through which a heating medium such as a heating fluid, in particular a heating liquid can flow so that the mould and, thus, the pulp contained in the mould can be heated by said heating medium. However, the method of distributing the pulp material by rotation of a mould about several axes seems not fast enough and not suitable for mass production of paper bottles of the like.

[0007] WO 2016/132328 A1 discloses a moulding process and a moulding apparatus for the moulding of articles by using paper and/or wood and, more precisely, pulp of paper and/or wood, recycled and milled paper and/or paper powder. The moulding process comprises the phases of loading milled paper or pulp of paper and/or wood into the mould, adding water or water vapour by means of an injection device to the milled paper or to the pulp of paper and/or wood into the mould, rotating the mould on itself with respect to at least two axes so as to have the milled paper or the pulp of paper and/or wood arranged on the mould walls. Due to the centrifugal force, the mixture of paper and/or wood is arranged on the walls of the mould ontaking the same shape of the mould. A

lattice is arranged around an injection device to act as a drainage filter so as to drain the excess water in the shell and ensure the release of the water vapour from the shell itself when the milled paper or the pulp of paper and/or wood is heated for its solidification. However, the method of distributing the pulp material by rotation of a mould about several axes seems not fast enough and not suitable for mass production of paper bottles of the like.

[0008] In the known methods of manufacturing moulded pulp products, however, production speed and accuracy of the final pulp products may be a challenge. In order to obtain efficient drying of the pulp preform and to still obtain a final product having a smooth surface, most known methods in reality make use of a first dewatering mould having an internal mould surface formed by a net allowing water to drain and a second drying mould made of porous material allowing vapour to escape and incorporating heating channels.

[0009] The reason for the above known setup is as follows. The first dewatering mould having an internal mould surface formed by a net allows substantially draining of the wet preform which would not be possible using a porous mould. However, this first dewatering mould does not allow for a substantial internal pressure to be applied on the wet preform, because the net would deform, and this first dewatering mould cannot be heated itself by heating channels or the like. Furthermore, the net of the first dewatering mould tends to leave a visible pattern on the moulded product if excess pressure is applied to the preform. On the other hand, the second drying mould made of porous material allows incorporation of heating channels and allows for a substantial internal pressure to be applied on the wet preform. The second drying mould even leaves the final moulded product with a surface of desired texture, such as a smooth surface. As a further known measure, an inflatable balloon may be used in the first or both moulds in order to apply a pressure on the wet preform. As it will be understood, the use of a first dewatering mould and a second drying mould involves moving the wet preform from the first mould to the second mould, thereby increasing production time considerably. Additionally inflating and deflating a balloon in one or both moulds adds even further to production time.

[0010] According to the known solutions, as mentioned above, the second drying mould is typically made of porous material which allows vapour to escape through the wall of the mould. The micro-structure of the porous material gives rise to inter-connected channels inside the mould. These channels can be utilized as evacuation pathways for flushing out water-steam during the pulp moulding process. However, the pulp fibres may be very small and tend to enter the tool material. This results in clogging of the tool. With a limited fraction of area available for water-steam transport, a water evacuation capability from the tool is hard to achieve. Cleaning of the tool is in reality not possible due to the labyrinth of closed pathways in the porous material. Clogging over long du-

rations of time reduce the fatigue life of tool, due to development of internal cracks in the tool. None of the known methods has succeeded in both obtaining a commercially profitable production rate and a suitable final product having a desired smooth surface quality. There is therefore a need for an improved method of manufacturing a moulded pulp product.

[0011] The object of the present invention is to provide a simplified method of manufacturing a moulded pulp product whereby production speed may be increased.

[0012] In view of this object, the method is characterised by

- initiating rotation of the mould about the central axis of the mould and increasing rotational speed gradually,
- maintaining a maximum rotational speed of the mould at least during a substantial part of the dewatering and drying step,
- decreasing rotational speed gradually until standstill of the mould.

[0013] Thereby, by gradually initiating rotation of the mould and maintaining a maximum rotational speed of the mould at least during a substantial part of the dewatering and drying step, a synergistic effect between rotation of the mould and gradual injection of dewatering and heating fluid into the mould is obtained in the following way. The synergistic effect facilitates the evacuation of the water absorbed by the pulp fibres which is defined as bound water. When heating the bound water by means of the dewatering and heating fluid, the water is desorbed and acts as free water which is defined as the water that is not absorbed by the pulp fibres. When the free water is subjected to the centrifugal force, the evacuation of the water from the mould is accelerated, because the free water is now free to move away from the pulp. This synergism between rotation and heating, when subjected to vacuum, results in much faster drying of the pulp than according to the prior art methods and will also mean a reduction in energy costs.

[0014] In a structurally particularly advantageous embodiment, the apparatus includes a rotary union having a rotatable fluid port connected to the mould opening, a stationary pulp port and a stationary dewatering and heating fluid port, pulp is injected into the internal mould chamber through the stationary pulp port, and the dewatering and heating fluid is injected into the internal mould chamber through the stationary dewatering and heating fluid port.

[0015] In an embodiment, the mould is arranged inside a vacuum chamber connected to the vacuum source, and the rotatable fluid port of the rotary union is connected to the mould opening through a tube extending through a wall of the vacuum chamber by means of a rotary shaft seal.

[0016] In an embodiment, the relative injection pressure of the dewatering and heating fluid through the

mould opening is increased gradually from approximately 0 to minimum 500 kPa, preferably from approximately 0 to minimum 700 kPa and most preferred from approximately 0 to minimum 1 MPa. By increasing the relative injection pressure of the dewatering and heating fluid gradually, it is avoided that the wet pulp preform is negatively affected by the injection. Otherwise, the already formed pulp preform could deform during the injection.

[0017] In an embodiment, the relative injection pressure (p) of the dewatering and heating fluid through the mould opening is increased gradually with a pressure rate of $dp/dt = 1$ to 20 kPa/s in the range $p = 0$ to 200 kPa and with a pressure rate of $dp/dt = 1$ to 50 kPa/s in the range $p = 200$ to 400 kPa. By increasing the relative injection pressure of the dewatering and heating fluid gradually, it is avoided that the wet pulp preform is negatively affected by the injection.

[0018] In an embodiment, the rotational speed of the mould is increased gradually from 0 rpm to at least 5.000 rpm, preferably from 0 rpm to at least 7.000 rpm, and most preferred from 0 rpm to about 10.000 rpm. By increasing the rotational speed of the mould gradually, it is avoided that the wet pulp preform is negatively affected by the rotation. Otherwise, the already formed pulp preform could deform during the rotation.

[0019] In an embodiment, the rotational speed (r) of the mould is increased gradually with a rotation rate of $dr/dt = 10$ to 1000 rpm/s until a maximum rotational speed. By increasing the rotational speed of the mould gradually, it is avoided that the wet pulp preform is negatively affected by the rotation.

[0020] In an embodiment, simultaneous injection of dewatering and heating fluid and mould rotation is maintained for at least 10 seconds, preferably at least 20 seconds, more preferred at least 40 seconds and most preferred for about 1 minute.

[0021] In an embodiment, fluid is evacuated to an outer surface of the mould through inner evacuation openings on the internal mould surface, and each inner evacuation opening is connected to an outer evacuation opening on the outer surface of the mould by means of an evacuation channel having a gradually increasing cross-sectional area in the direction from the internal mould surface to the outer surface of the mould. Thereby, a mould with a considerable wall thickness and resulting strength may be obtained without increasing the risk that an evacuation opening gets clogged. In fact, the risk of clogging is reduced considerably, because a pulp particle being able to enter the inner evacuation opening may also pass through the evacuation channel which has a gradually increasing cross-sectional area. Moreover, if any pulp would nevertheless be trapped in an evacuation channel, it may quite simply be blown out by means of compressed air from the inside of the mould chamber. Therefore, the mould is more or less self-cleaning and in any event much easier to clean than known solutions. Because of the strength of such a mould, it is possible to both form and dry the produced pulp product in one single mould as

opposed to known methods as described above. Thereby, a substantial increase in production speed may be possible.

[0022] The present invention further relates to a moulding apparatus for manufacturing of moulded pulp products including a mould with an internal mould chamber generally having rotational symmetry about a central axis of the mould and having a closed end and an open end forming a mould opening, the internal mould chamber having an internal mould surface generally provided with a number of evacuation openings, a vacuum source connected to said evacuation openings, a pressurised pulp source arranged to inject pressurised pulp into the internal mould chamber through the mould opening, a dewatering and heating fluid source arranged to inject dewatering and heating fluid through the mould opening at gradually increasing pressure in order to perform dewatering and drying of a pulp preform on the internal mould surface.

[0023] The moulding apparatus is characterised in that the apparatus includes a rotary union having a rotatable fluid port connected to the mould opening, a stationary pulp port and a stationary dewatering and heating fluid port, in that the pressurised pulp source is connected to the stationary pulp port, in that the dewatering and heating fluid source is connected to the stationary dewatering and heating fluid port, and in that a motor is arranged to rotate the mould about the central axis of the mould. Thereby, the above mentioned features may be obtained.

[0024] In an embodiment, the mould is arranged inside a vacuum chamber connected to the vacuum source, and the rotatable fluid port of the rotary union is connected to the mould opening through a tube extending through a wall of the vacuum chamber by means of a rotary shaft seal. Thereby, the above mentioned features may be obtained.

[0025] In an embodiment, the pulp moulding apparatus is adapted to initiate rotation of the mould about the central axis of the mould and increase rotational speed gradually, maintain a maximum rotational speed of the mould at least during a substantial part of the dewatering and drying step, and decrease rotational speed gradually until standstill of the mould. Thereby, the above mentioned features may be obtained.

[0026] In an embodiment, the mould has inner evacuation openings through which fluid may be evacuated to an outer surface of a mould wall, and each inner evacuation opening is connected to an outer evacuation opening on the outer surface of the mould by means of an evacuation channel having a gradually increasing cross-sectional area in the direction from the internal mould surface to the outer surface of the mould. Thereby, the above mentioned features may be obtained.

[0027] The invention will now be explained in more detail below by means of examples of embodiments with reference to the very schematic drawing, in which

Fig. 1 is a diagram of a pulp moulding apparatus

according to the present invention;

Fig. 2 is a perspective view of a mould half of the moulding apparatus of Fig. 1;

Fig. 3 is a perspective view of a complete mould formed by two mould halves of which one is shown in Fig. 2;

Fig. 4 is a bottom view of the mould illustrated in Fig. 3;

Fig. 5 is a perspective view of a section illustrating, on a larger scale, the bottom of the mould half shown in Fig. 2;

Fig. 6 is a side view of the section of Fig. 5;

Fig. 7 is a perspective view of a section illustrating, on a larger scale, a middle part of the mould half shown in Fig. 2;

Fig. 8 is a side view of the section of Fig. 7, seen from outside the mould;

Fig. 9 is a cross-section taken along the line IX - IX of Fig. 8; and

Fig. 10 is a perspective view of a rotary mould clamp including a mould half as shown in Fig. 2.

[0028] Fig. 1 shows a pulp moulding apparatus 1 for manufacturing of moulded pulp products in the form of a bottle-shaped article suitable for beverage or the like. However, the moulded pulp products may have different shape and purpose and does not necessary have a bottleneck as the illustrated product. For instance, the method is also suitable for manufacturing of beakers.

[0029] The pulp moulding apparatus 1 includes a mould 2 with an internal mould chamber 3 generally having rotational symmetry about a central axis 4 of the mould 2 and having a closed end 5 and an open end 6 forming a mould opening 7 as seen in Figs. 2 and 3. The internal mould chamber 3 has an internal mould surface 8 generally provided with a number of evacuation openings 9 through which fluid may be evacuated to an outer surface 19 of a mould wall 25 as described in further detail below. A vacuum source 10 is connected to said evacuation openings 9 in that the mould 2 is arranged in a vacuum chamber 15 and , a pressurised pulp source 22 is arranged to inject pressurised pulp into the internal mould chamber 3 through the mould opening 7, and a dewatering and heating fluid source 23 is arranged to inject dewatering and heating fluid in the form of hot air through the mould opening 7 at gradually increasing pressure in order to perform dewatering and drying of a pulp preform on the internal mould surface 8.

[0030] Furthermore, the apparatus 1 includes a rotary

union 11 having a rotatable fluid port 12 connected to the mould opening 7, a stationary pulp port 13 and a stationary dewatering and heating fluid port 14. The pressurised pulp source 22 is connected to the stationary pulp port 13, the dewatering and heating fluid source 23 is connected to the stationary dewatering and heating fluid port 14, and a motor 24 is arranged to rotate the mould 2 about the central axis 4 of the mould 2. The vacuum chamber 15 is connected to the vacuum source 10, and the rotatable fluid port 12 of the rotary union 11 is connected to the mould opening 7 through a tube 16 extending through a wall 17 of the vacuum chamber 15 by means of a rotary shaft seal 18. The pulp moulding apparatus 1 is adapted to initiate rotation of the mould 2 about the central axis 4 of the mould 2 and increase rotational speed gradually, maintain a maximum rotational speed of the mould 2 at least during a substantial part of the dewatering and drying step, and decrease rotational speed gradually until standstill of the mould 2. In order to rotate the mould 2, the motor 24 is via a belt 27 rotatably coupled to a main rotating shaft 47 including the tube 16.

[0031] As further seen in Fig. 1, the apparatus 1 includes a control panel 33 adapted to control by means of a first frequency drive 31 the speed of a pump forming the pressurised pulp source 22. The pump receives pulp from a pulp tank 29 provided with a stirrer and the pulp is pumped to the mould 2 via a pressure vessel 30 or expansion vessel in order to maintain a suitable pressure during pumping. The raw materials in this case are wood fibres. With an existing manufacturing process, wood obtained from trees is chipped and converted to paper fibres. They can easily be obtained from any commercial pulp supplier. Once the fibres are obtained, the next step is to make a slurry. The paper fibres, which are primarily made-up of cellulose, are mixed with water to form a viscous and thick slurry. The water content in the slurry is important, because it is the water molecule which facilitates the binding of cellulosic material with the help of hydrogen bonding. The pulp suspension is stirred continuously in the tank 29 to avoid settling down of fibres and to have a uniform distribution of the fibres inside the suspension. The control panel 33 is further adapted to control by means of a second frequency drive 32 the speed of the motor 24 for rotation of the mould. Furthermore, the control panel 33 is adapted to control the dewatering and heating fluid source 23 which has the form of an air compressor, a heater 26 for the dewatering and heating fluid, the vacuum source 10 in the form of a vacuum pump connected to the vacuum chamber 15 via a waste tank 28, and flow controllers 35, 36, 37. A data logger 34 is provided for data collection and is connected to pressure sensors 38-42. As the skilled person will understand, the flow controllers 35, 36, 37 in cooperation with the pressure sensors 38-42 form respective pressure regulators adapted to regulate the pressure of the dewatering and drying fluid, the vacuum provided and the pressure of the pulp supplied.

[0032] As seen in Figs. 2 and 3, the mould 2 has a wall

25 forming the internal mould chamber 3 with the mould opening 7 through which pulp may be injected. The internal mould surface 8 of the internal mould chamber 3 is generally provided with a number of inner evacuation openings 9 through which fluid may be evacuated to the outer surface 19 of the mould wall 25. As illustrated in Fig. 9, each inner evacuation opening 9 is connected to an outer evacuation opening 20 on the outer surface 19 of the mould 2 by means of an evacuation channel 21 having a gradually increasing cross-sectional area in the direction from the internal mould surface 8 to the outer surface 19 of the mould 2.

[0033] The mould wall 25 has a considerable wall thickness of at least 2 millimetres, preferably at least 4 millimetres, more preferred at least 5 millimetres, and most preferred at least 6 millimetres. Thereby, a strong mould 2 may be obtained without increasing the risk that an evacuation opening gets clogged. In fact, the risk of clogging is reduced considerably, because a pulp particle being able to enter an inner evacuation opening 9 may also pass through the corresponding evacuation channel 21 which has a gradually increasing cross-sectional area and out through the corresponding outer evacuation opening 20. Moreover, if any pulp would nevertheless be trapped in an evacuation channel 21, it is easy to blow it out by means of compressed air from the inside of the mould chamber 3. Therefore, the mould 2 is more or less self-cleaning and in any event much easier to clean than known solutions. Because of the strength of such a mould 2, it is possible to both form and dry the produced pulp product in one single mould as opposed to known methods as described above. Thereby, a substantial increase in production speed may be possible.

[0034] As seen in Fig. 2, over at least the main part of the internal mould surface 8, the inner evacuation openings 9 are distributed, preferably substantially evenly, with at least 500.000 holes pr. square metre, preferably at least 800.000 holes pr. square metre, and most preferred at least 900.000 holes pr. square metre.

[0035] The inner evacuation openings 9 have a smallest cross-sectional dimension of less than 600 micrometres, preferably less than 400 micrometres, more preferred less than 300 micrometres and most preferred less than 250 micrometres. Thereby, depending of the general size of the pulp fibres used for the moulding process, it may be avoided that the evacuation openings of the internal mould surface 8 replicate on the surface of the moulded pulp product. Thereby a smooth finish of the surface of the final product may be ensured. The pulp may be formed by fibres generally having a length of approximately 1 to 2 millimetres and generally having a cross-sectional dimension of approximately 20 to 40 micrometres. For instance, if the pulp fibres generally have a length of approximately 1.2 to 1.9 millimetres and generally have a cross-sectional dimension of approximately 25 to 35 micrometres, and the inner evacuation openings 9 have a circular cross-section with a diameter of less than 250 micrometres, and preferably about 200 mi-

crometres, then a very smooth finish of the moulded product without any visible replications of the evacuation openings may be obtained.

[0036] The inner evacuation openings 9 have a smallest cross-sectional dimension of more than 50 micrometres, preferably more than 70 micrometres, more preferred more than 80 micrometres and most preferred more than 90 micrometres. In this way, an efficient draining of the wet pulp preform may be ensured.

[0037] Each evacuation channel 21 is conical with a draft angle D of at least 1 degree, preferably at least 1,5 degrees and most preferred about 2 degrees. Thereby, the risk of clogging is even better reduced.

[0038] The total volume of all evacuation channels 21 is at least 40 per cent, preferably at least 45 per cent, more preferred at least 50 per cent and most preferred at least 55 per cent of the total volume of the material of the mould 2. In this way, an efficient draining of the wet pulp preform may be ensured.

[0039] Referring in particular to Figs. 8 and 9, it is seen that each evacuation channel 21 has a circular cross-section from the internal mould surface 8 to the outer surface 19 of the mould 2, and all evacuation channels 21 are arranged so that the respective outer evacuation openings 20 are separated from each other by having a minimum material thickness between each other at the outer surface 19 of the mould 2. Thereby, a strong mould may be obtained which is useful for forming as well as drying of a pulp preform.

[0040] In the illustrated embodiment, the mould 2 is a split-mould composed of two moulds halves 43, 44, as illustrated in Figs. 2, 3 and 10. The illustrated mould 2 which is intended for production of paper bottles is further designed in a CAD system in sections which are, however, integrated in the final mould 2. The sections of each mould half 43, 44 are as follows: neck section 51, shoulder section 52, middle section 53, and bottom section 54. The illustrated mould halves 43, 44 each has four middle sections 53.

[0041] Comparing Figs. 7 and 8, illustrating a middle section 53 seen in perspective from the inside and from the outside, respectively, it is seen in Fig. 8 that the outer evacuation openings 20 are arranged closely packed in a so-called round straight configuration. However, in Fig. 7, it is seen that the inner evacuation openings 9 of the internal mould surface 8 are arranged closer to each other in the peripheral direction of the internal mould surface 8 than in the longitudinal direction of the internal mould surface 8. This is an advantageous arrangement of the evacuation channels 21, because the internal mould surface 8 forms a circle about the central axis 4 of mould 2. In this way, the tapering channels may be arranged very close to each other. The same principle has been applied when designing the bottom section 54 as illustrated in Figs. 5 and 6. Here, the outer evacuation openings 20, in the upper part of the bottom section 54, are arranged closely packed in a so-called round straight configuration. In this upper part of the bottom section 54, the inner evac-

uation openings 9 of the internal mould surface 8 are arranged closer to each other in the longitudinal direction of the internal mould surface 8 than in the peripheral direction of the internal mould surface 8. This is advantageous, because in this case, the internal mould surface 8 has a smaller radius of curvature about a horizontal axis than about a vertical axis. As seen in Fig. 4, in the centre of the bottom section 54, the outer evacuation openings 20 are arranged closely packed in straight configuration, whereas the inner evacuation openings 9 are arranged directly over outer evacuation openings 20 so that a central axis of the evacuation channels are arranged at right angles to the mould wall 25. This arrangement is advantageous, because the centre of the bottom section 54 has a flat configuration. However, according to the present invention, the illustrated configuration of the inner and outer evacuation openings 9, 20 and the evacuation channels 21 may be varied in many different ways.

[0042] The mould 2 is produced by designing a 3D model of the mould 2 in a CAD system, and the mould 2 is produced by means of a metal 3D printing technique, such as additive manufacturing (AM), preferably Powder bed fusion (PBF). However, the mould could also be produced in plastic material using a 3D printing technique. The CAD model of the part in the form of the mould is given as an input to the manufacturing system. A base on which the intended part is to be produced, is kept inside the machine. The metal powder is then added. With a piston system, the base is slowly lowered down, layer by layer in the vertical direction. Each time when the base is lowered, a scraper distributes a fresh layer of powder. The laser beam scans the layer, following a path determined by the intended geometry of the part. The path on which laser moves is consolidated due to power melting and the rest of the powder is left loose. The loose powder is known as powder cake and can be reused again in the next production cycle. Once the process is finished, the part with support structure is taken out and the structure is dismantled. The parts and tools produced by this method are very fast compared to the conventional manufacturing methods. The method is capable of producing micro-features even below 300 microns, which is very challenging to produce by any other means in shorter time durations. The method is very economical to be commercialized for production of moulds for paper bottles and the like. The mould 2 is preferably fabricated using aluminium powder.

[0043] As seen in Figs. 2 and 3, each mould half 43, 44 is provided with mounting flanges 50 for mounting the mould in the mould setup 49. The mould setup 49 is illustrated in Fig. 10. The mounting flanges 50 of the mould halves 43, 44 are mounted between two rotating frame parts 45, 46 so that the mould halves 43, 44 are pressed against each other and form the complete mould 2. The two rotating frame parts 45, 46 are arranged on a pivoting shaft 48 so that they may be pivoted between a closed position in which the mould halves 43, 44 are fixed in

place and an open position in which the mould halves 43, 44 may be mounted or exchanged. The two rotating frame parts 45, 46 are further arranged on the vertical, main rotating shaft 47 for rotation of the mould 2 during the dewatering and drying step.

[0044] The method according to the invention of manufacturing a moulded pulp product by means of the pulp moulding apparatus 1 includes the following steps: activating the vacuum source 10, injecting an amount of pulp into the internal mould chamber 3 through the mould opening 7, thereby forming a pulp preform on the internal mould surface 8, injecting a dewatering and heating fluid through the mould opening 7 at gradually increasing pressure until a maximum pressure, thereby performing a dewatering and drying step whereby the pulp preform on the internal mould surface 8 is dewatered and dried, deactivating the injection of dewatering and heating fluid, deactivating the vacuum source 10, extracting the moulded pulp product. These steps are not necessarily performed exactly in the mentioned sequence and additional steps may be performed. When the injection of pulp into the internal mould chamber 3 is finished, excess pulp may optionally be pumped out of the mould 2 by means of the pump of the pressurised pulp source 22. However, in the illustrated setup, the mould opening 7 points downwards, and excess pulp may therefore simply leave back to the pressure vessel 30 as a result of gravity. In order to efficiently dewater and dry the pulp preform during the dewatering and drying step, rotation of the mould 2 about the central axis 4 of the mould is initiated and rotational speed is increased gradually, a maximum rotational speed of the mould 2 is maintained at least during a substantial part of the dewatering and drying step, and the rotational speed is decreased gradually until standstill of the mould 2. Rotation of the mould 2 may possibly be initiated before the dewatering and drying step. The pulp is injected into the internal mould chamber 3 through the stationary pulp port 13, and the dewatering and heating fluid is injected into the internal mould chamber 3 through the stationary dewatering and heating fluid port 14.

[0045] Preferably, the relative injection pressure of the dewatering and heating fluid through the mould opening 7 is increased gradually from approximately 0 to minimum 500 kPa, preferably from approximately 0 to minimum 700 kPa and most preferred from approximately 0 to minimum 1 MPa. Preferably, the relative injection pressure p of the dewatering and heating fluid through the mould opening 7 is increased gradually with a pressure rate of $dp/dt = 1$ to 20 kPa/s in the range $p = 0$ to 200 kPa and with a pressure rate of $dp/dt = 1$ to 50 kPa/s in the range $p = 200$ to 400 kPa.

[0046] Preferably, the rotational speed r of the mould 2 is increased gradually from 0 rpm to at least 5.000 rpm, preferably from 0 rpm to at least 7.000 rpm, and most preferred from 0 rpm to about 10.000 rpm. Preferably, the rotational speed r of the mould 2 is increased gradually with a rotation rate of $dr/dt = 10$ to 1000 rpm/s until a maximum rotational speed.

[0047] Preferably, simultaneous injection of dewatering and heating fluid and mould rotation is maintained for at least 10 second, preferably at least 20 seconds, even more preferred at least 40 seconds and most preferred for about 1 minute.

[0048] Purely as an example, suitable process parameters may be as follows:

- Pulp is preheated to about 70 °C in the heater 26.
- Before first moulding operation, mould may be preheated to about 150 °C, for instance by means of blowing preheated dewatering and drying fluid in the form of hot air through the mould.
- Suction pressure is about - 30 kPa (relative pressure).
- Pulp is pumped to the mould 2 at a pressure of about 200 to 300 kPa (relative pressure).
- Pulp injection time about 10 seconds.
- Temperature of dewatering and drying fluid in the form of hot air is about 150-250°C.
- Pressure of dewatering and drying fluid in the form of hot air: from about 0 kPa and gradually increased to about 1 MPa (relative pressure).
- Pressure rate of dewatering and drying fluid in the form of hot air: $dp/dt = 1$ to 20 kPa/s in the range $p = 0$ to 200 kPa and with a pressure rate of $dp/dt = 1$ to 50 kPa/s in the range $p = 200$ to 400 kPa.
- Rotational speed range of mould 2: about 0-10.000 rpm starting from 0 rpm.
- Time of dewatering and drying step with rotation of mould 2: about 0-60 seconds.

[0049] List of reference numbers

D	draft angle	35
1	pulp moulding apparatus	
2	mould	
3	internal mould chamber	
4	central axis of mould	
5	closed end of mould	40
6	open end of mould	
7	mould opening	
8	internal mould surface	
9	inner evacuation openings of internal mould surface	45
10	vacuum source	
11	rotary union	
12	rotatable fluid port of rotary union	
13	stationary pulp port of rotary union	
14	stationary dewatering and heating fluid port of rotary union	50
15	vacuum chamber	
16	tube	
17	wall of vacuum chamber	
18	rotary shaft seal	55
19	outer surface of mould	
20	outer evacuation opening	
21	evacuation channel	

22	pressurised pulp source
23	dewatering and heating fluid source
24	motor
25	mould wall
5 26	heater
27	belt
28	waste tank
29	pulp tank and stirrer
30	pressure vessel
10 31	frequency drive for pulp source
32	frequency drive for motor
33	control panel
34	data logger
35, 36, 37	flow controllers
15 38-42	pressure sensors
43, 44	moulds halves
45, 46	rotating frame parts
47	main rotating shaft
48	pivoting shaft
20 49	mould setup
50	mould flanges
51	neck section of mould half
52	shoulder section of mould half
53	middle section of mould half
25 54	bottom section of mould half

Claims

1. A method of manufacturing a moulded pulp product by means of a pulp moulding apparatus (1) including a mould (2) with an internal mould chamber (3) generally having rotational symmetry about a central axis (4) of the mould (2) and having a closed end (5) and an open end (6) forming a mould opening (7), the internal mould chamber (3) having an internal mould surface (8) generally provided with a number of evacuation openings (9) connected to a vacuum source (10), the method including the following steps:

- activating the vacuum source (10),
- injecting an amount of pulp into the internal mould chamber (3) through the mould opening (7), thereby forming a pulp preform on the internal mould surface (8),
- injecting a dewatering and heating fluid through the mould opening (7) at gradually increasing pressure until a maximum pressure, thereby performing a dewatering and drying step whereby the pulp preform on the internal mould surface (8) is dewatered and dried,
- deactivating the injection of dewatering and heating fluid,
- deactivating the vacuum source (10),
- extracting the moulded pulp product,

characterised by

- initiating rotation of the mould (2) about the

- central axis (4) of the mould and increasing rotational speed gradually,
- maintaining a maximum rotational speed of the mould (2) at least during a substantial part of the dewatering and drying step,
 - decreasing rotational speed gradually until standstill of the mould (2).
2. A method of manufacturing a moulded pulp product according to claim 1, wherein the apparatus (1) includes a rotary union (11) having a rotatable fluid port (12) connected to the mould opening, a stationary pulp port (13) and a stationary dewatering and heating fluid port (14), wherein pulp is injected into the internal mould chamber (3) through the stationary pulp port (13), and wherein the dewatering and heating fluid is injected into the internal mould chamber (3) through the stationary dewatering and heating fluid port (14).
 3. A method of manufacturing a moulded pulp product according to claim 1, wherein the mould (2) is arranged inside a vacuum chamber (15) connected to the vacuum source (10), and wherein the rotatable fluid port (12) of the rotary union (11) is connected to the mould opening (7) through a tube (16) extending through a wall (17) of the vacuum chamber (15) by means of a rotary shaft seal (18).
 4. A method of manufacturing a moulded pulp product according to any one of the preceding claims, wherein the relative injection pressure of the dewatering and heating fluid through the mould opening (7) is increased gradually from approximately 0 to minimum 500 kPa, preferably from approximately 0 to minimum 700 kPa and most preferred from approximately 0 to minimum 1 MPa.
 5. A method of manufacturing a moulded pulp product according to any one of the preceding claims, wherein the relative injection pressure (p) of the dewatering and heating fluid through the mould opening (7) is increased gradually with a pressure rate of $dp/dt = 1$ to 20 kPa/s in the range $p = 0$ to 200 kPa and with a pressure rate of $dp/dt = 1$ to 50 kPa/s in the range $p = 200$ to 400 kPa.
 6. A method of manufacturing a moulded pulp product according to any one of the preceding claims, wherein the rotational speed (r) of the mould (2) is increased gradually from 0 rpm to at least 5.000 rpm, preferably from 0 rpm to at least 7.000 rpm, and most preferred from 0 rpm to about 10.000 rpm.
 7. A method of manufacturing a moulded pulp product according to any one of the preceding claims, wherein the rotational speed (r) of the mould (2) is increased gradually with a rotation rate of $dr/dt = 10$ to 1000 rpm/s until a maximum rotational speed.
 8. A method of manufacturing a moulded pulp product according to any one of the preceding claims, wherein simultaneous injection of dewatering and heating fluid and mould rotation is maintained for at least 10 seconds, preferably at least 20 seconds, even more preferred at least 40 seconds and most preferred for about 1 minute.
 9. A method of manufacturing a moulded pulp product according to any one of the preceding claims, wherein fluid is evacuated to an outer surface (19) of the mould (2) through inner evacuation openings (9) on the internal mould surface (8), and wherein each inner evacuation opening (9) is connected to an outer evacuation opening (20) on the outer surface (19) of the mould (2) by means of an evacuation channel (21) having a gradually increasing cross-sectional area in the direction from the internal mould surface (8) to the outer surface (19) of the mould (2).
 10. A pulp moulding apparatus (1) for manufacturing of moulded pulp products including a mould (2) with an internal mould chamber (3) generally having rotational symmetry about a central axis (4) of the mould (2) and having a closed end (5) and an open end (6) forming a mould opening (7), the internal mould chamber (3) having an internal mould surface (8) generally provided with a number of evacuation openings (9), a vacuum source (10) connected to said evacuation openings (9), a pressurised pulp source (22) arranged to inject pressurised pulp into the internal mould chamber (3) through the mould opening (7), a dewatering and heating fluid source (23) arranged to inject dewatering and heating fluid through the mould opening (7) at gradually increasing pressure in order to perform dewatering and drying of a pulp preform on the internal mould surface (8), **characterised in that** the apparatus (1) includes a rotary union (11) having a rotatable fluid port (12) connected to the mould opening (7), a stationary pulp port (13) and a stationary dewatering and heating fluid port (14), **in that** the pressurised pulp source (22) is connected to the stationary pulp port (13), **in that** the dewatering and heating fluid source (23) is connected to the stationary dewatering and heating fluid port (14), and **in that** a motor (24) is arranged to rotate the mould (2) about the central axis (4) of the mould (2).
 11. A pulp moulding apparatus according to claim 10, wherein the mould (2) is arranged inside a vacuum chamber (15) connected to the vacuum source (10), and wherein the rotatable fluid port (12) of the rotary union (11) is connected to the mould opening (7) through a tube (16) extending through a wall (17) of the vacuum chamber (15) by means of a rotary shaft

seal (18).

12. A pulp moulding apparatus according to claim 10 or 11, wherein the pulp moulding apparatus (1) is adapted to initiate rotation of the mould (2) about the central axis (4) of the mould (2) and increase rotational speed gradually, maintain a maximum rotational speed of the mould (2) at least during a substantial part of the dewatering and drying step, and decrease rotational speed gradually until standstill of the mould (2).
13. A pulp moulding apparatus according to claim 10 or 12, wherein the mould (2) has inner evacuation openings (9) through which fluid may be evacuated to an outer surface (19) of a mould wall (25), and wherein each inner evacuation opening (9) is connected to an outer evacuation opening (20) on the outer surface (19) of the mould (2) by means of an evacuation channel (21) having a gradually increasing cross-sectional area in the direction from the internal mould surface (8) to the outer surface (19) of the mould (2).

25

30

35

40

45

50

55

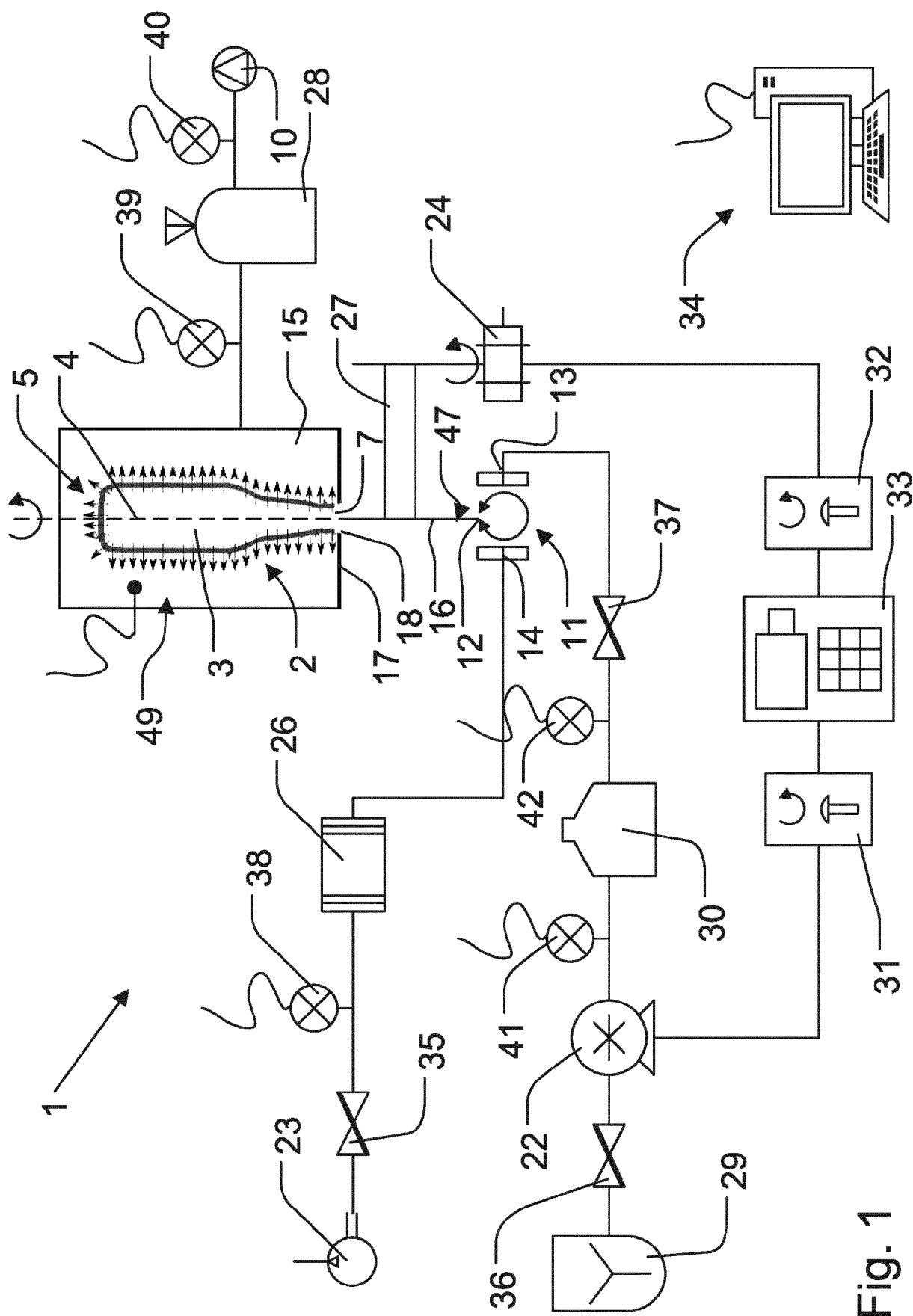


Fig. 1

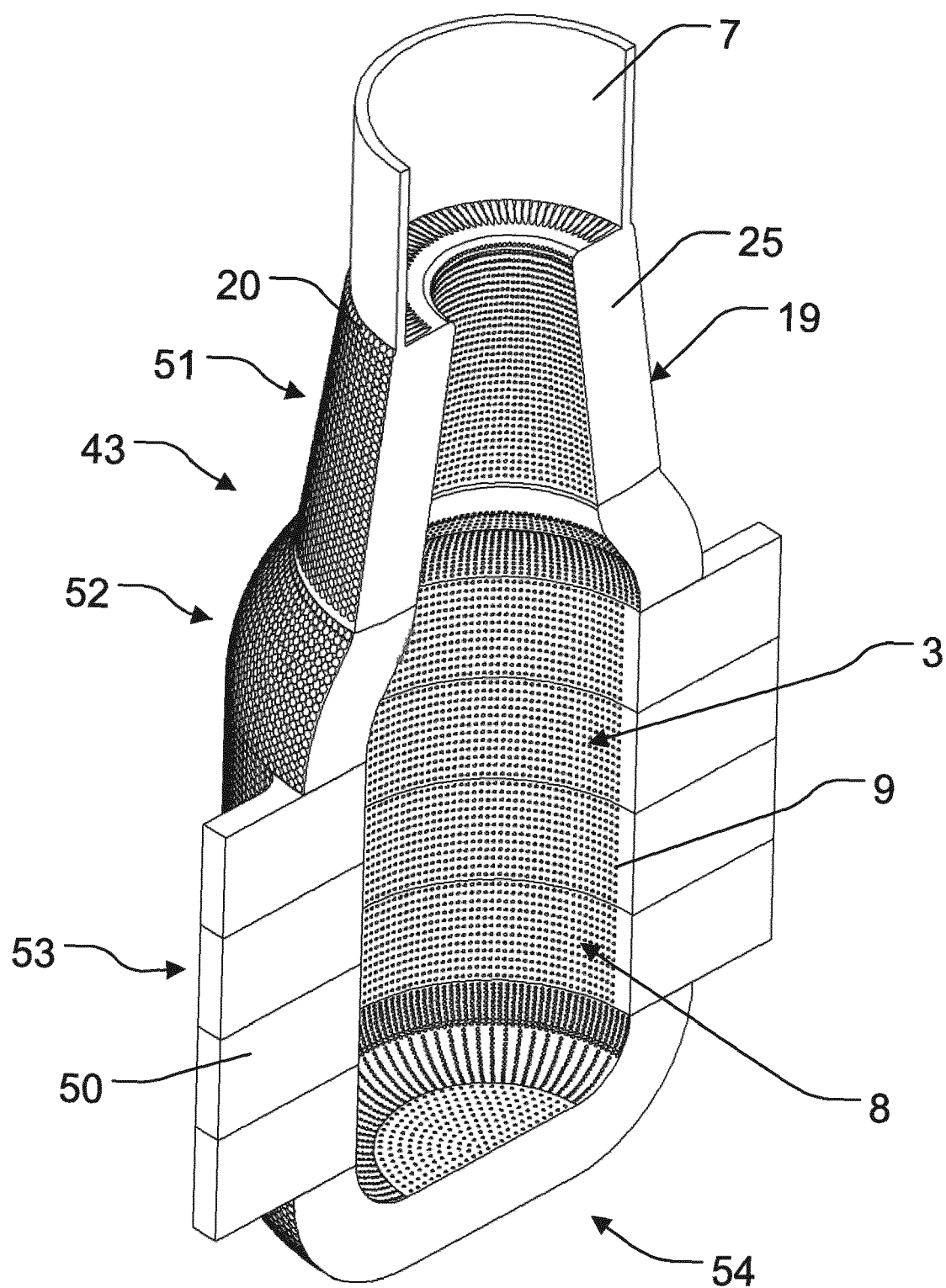


Fig. 2

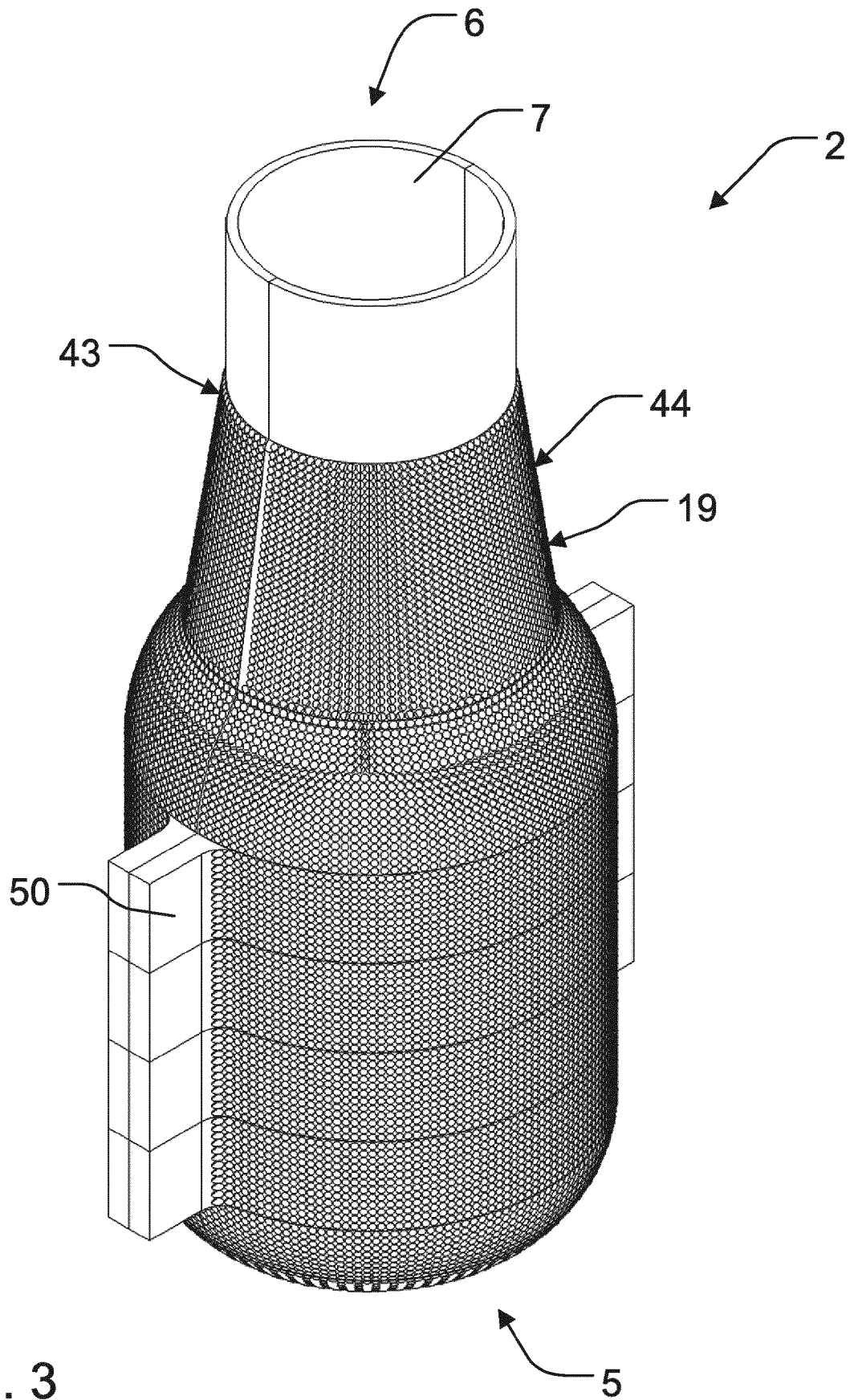


Fig. 3

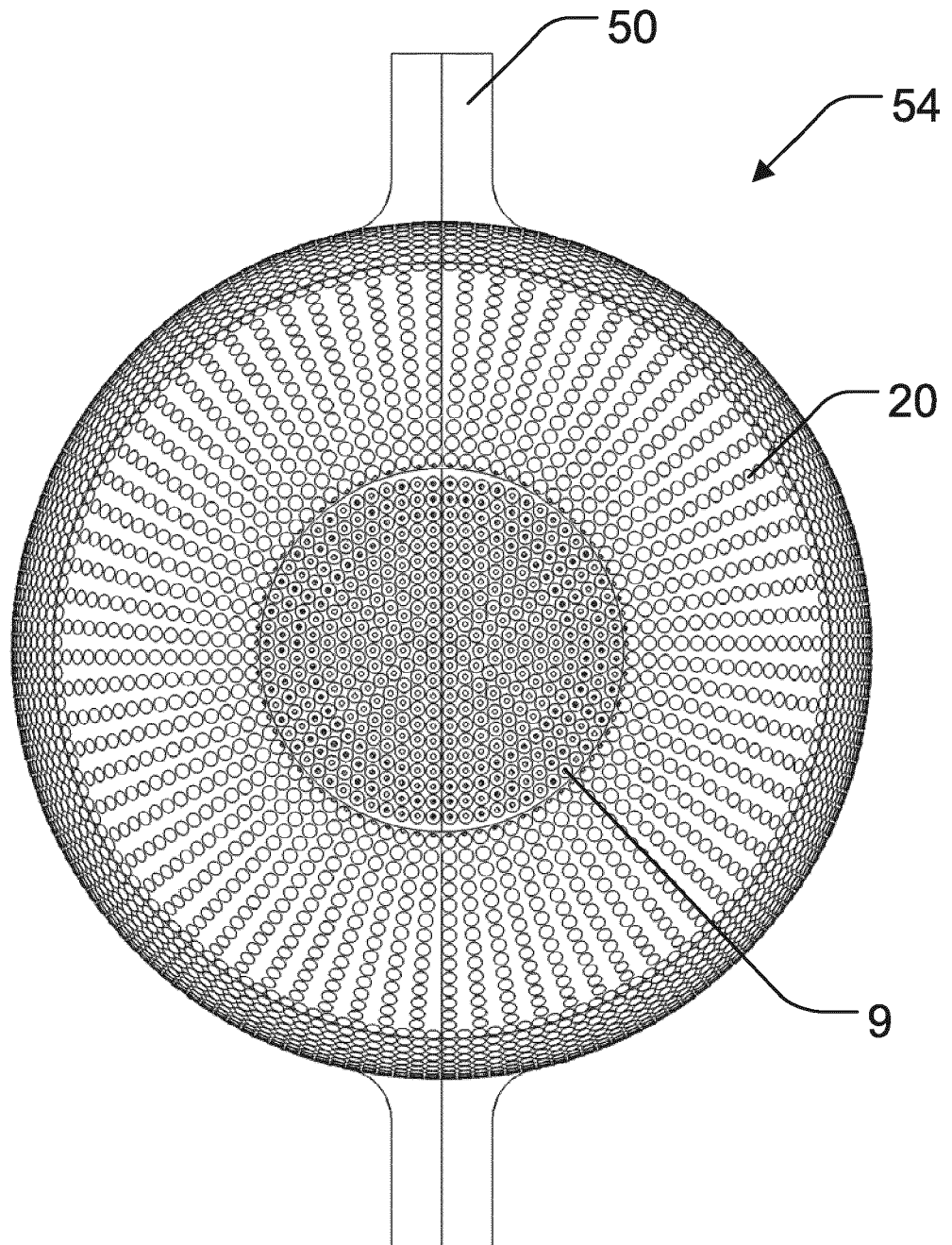


Fig. 4

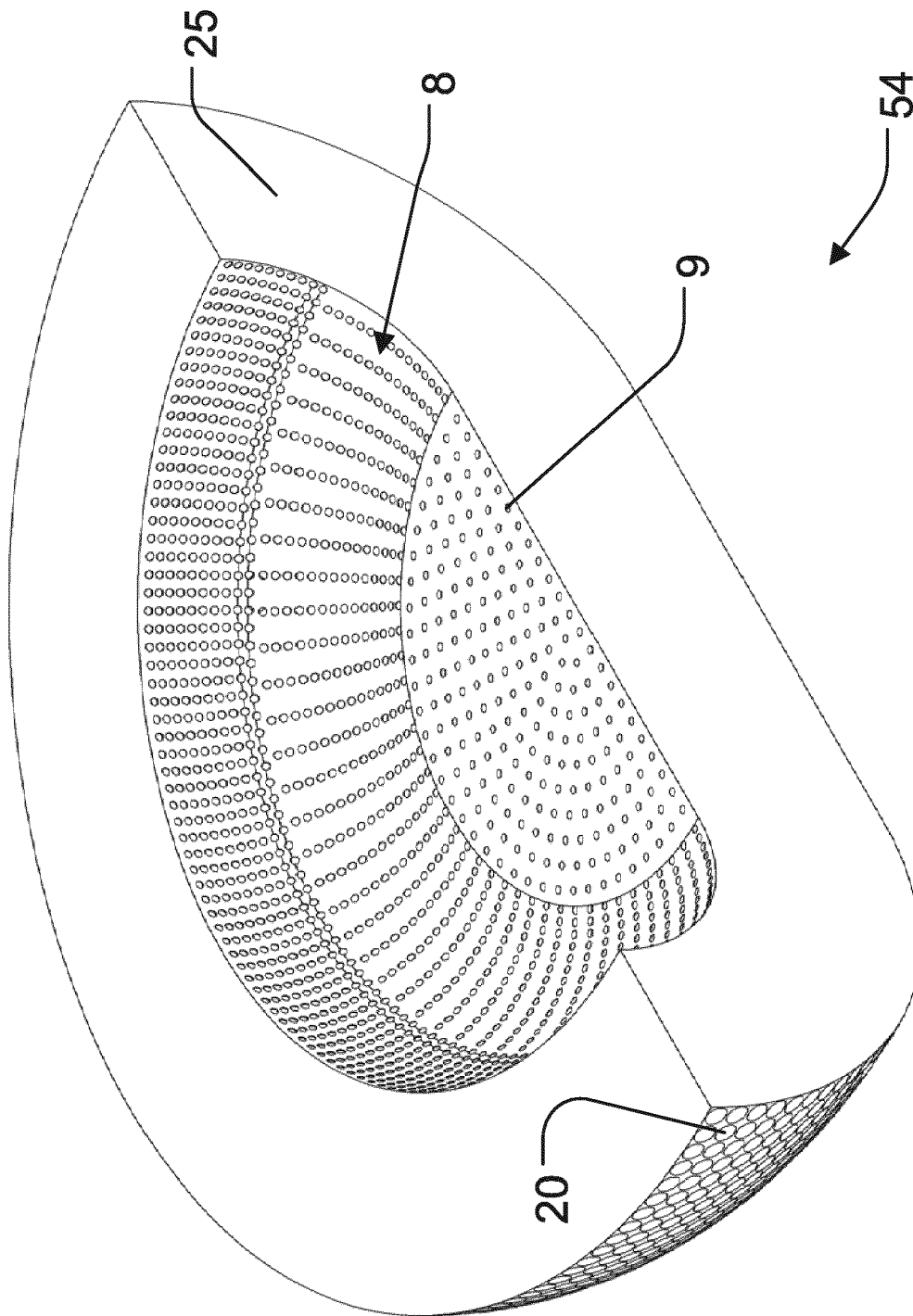


Fig. 5

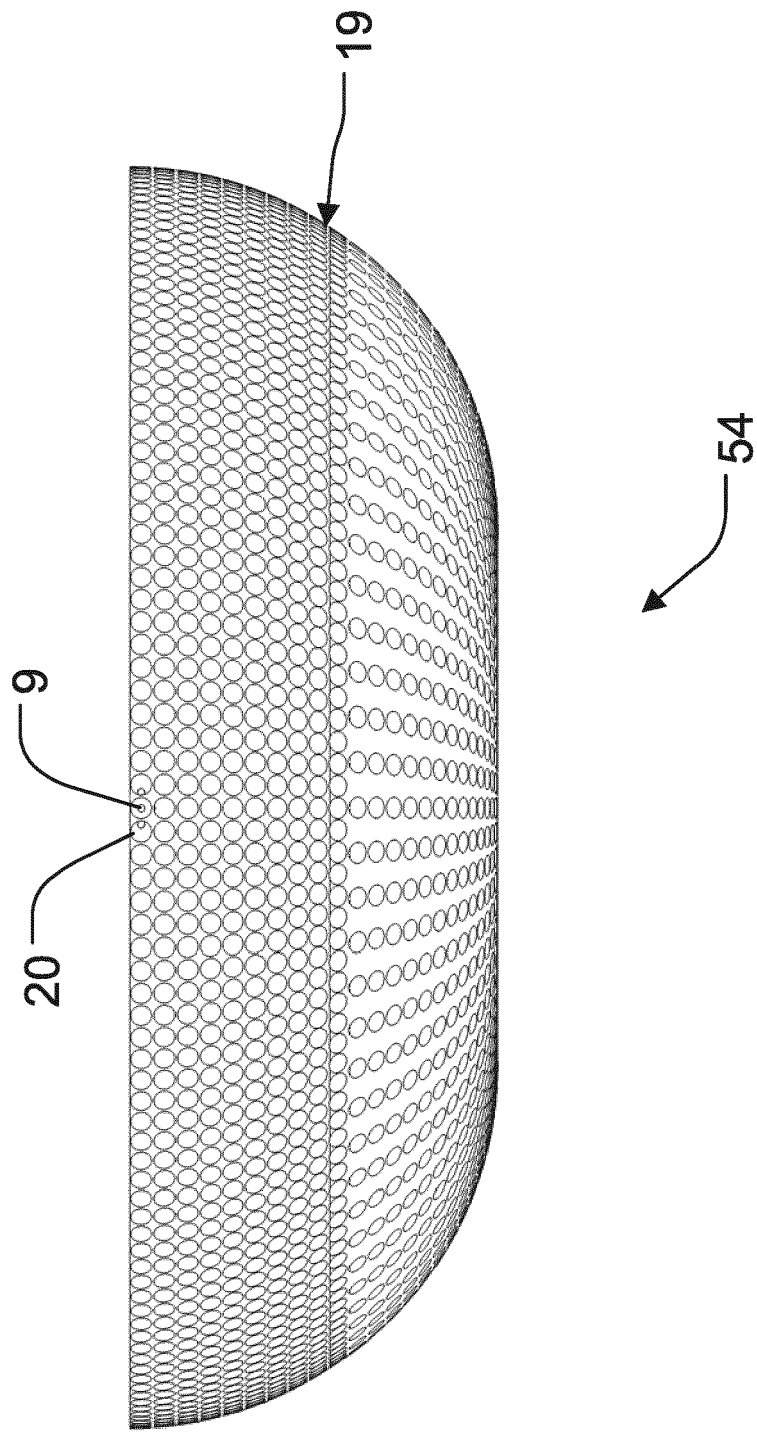


Fig. 6

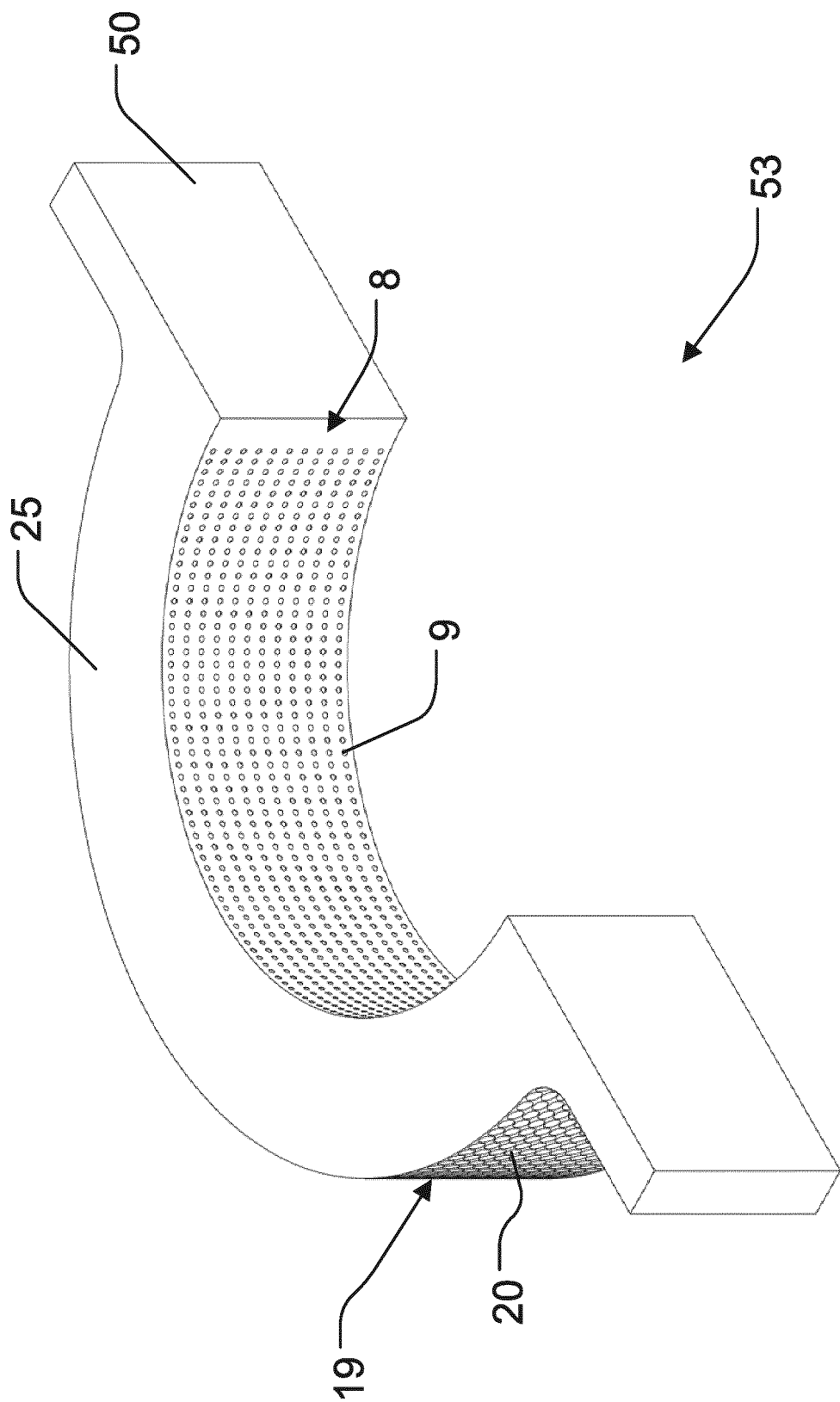


Fig. 7

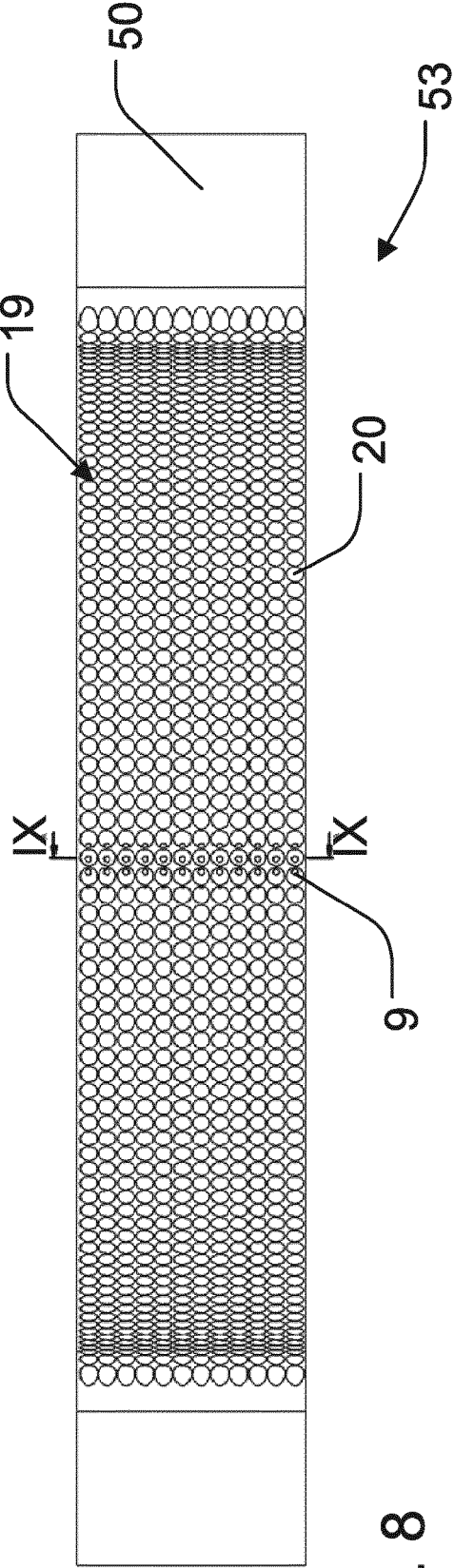


Fig. 8

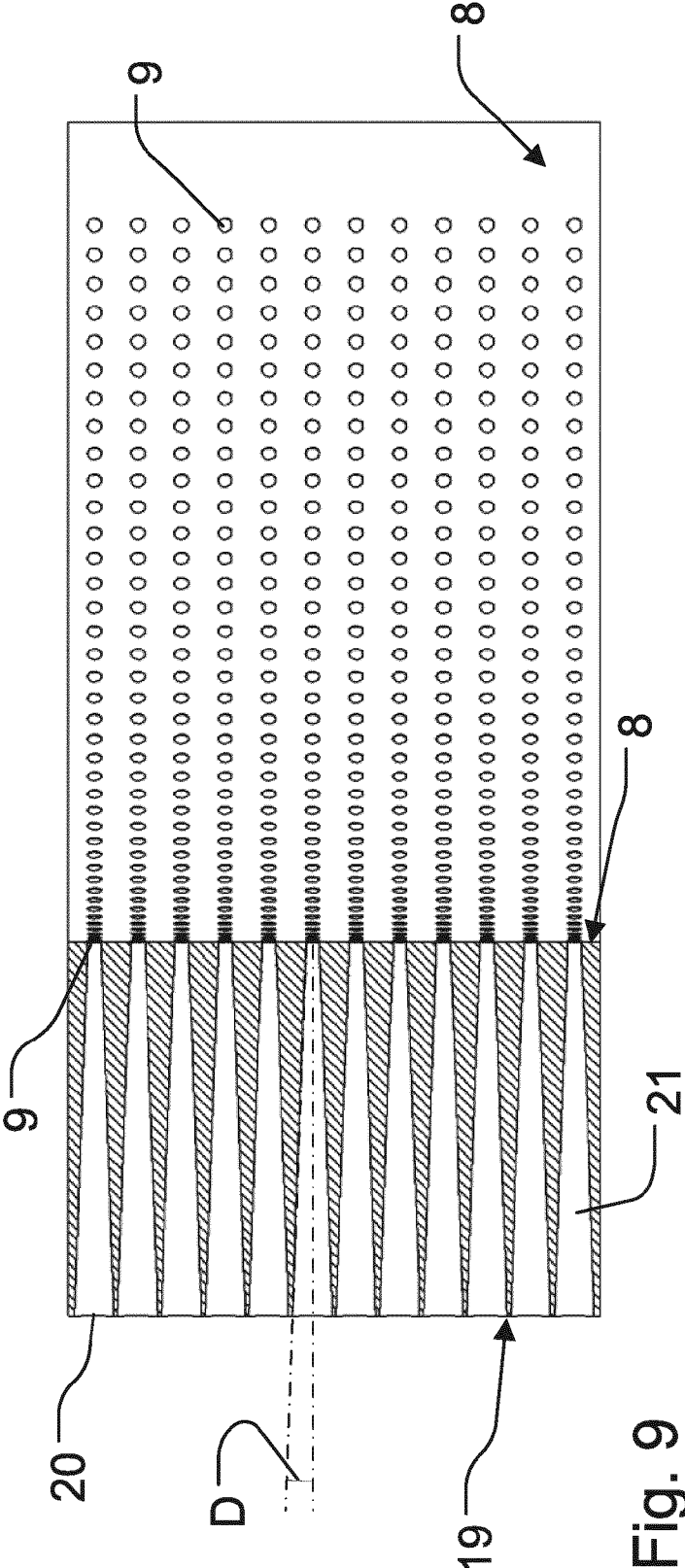


Fig. 9

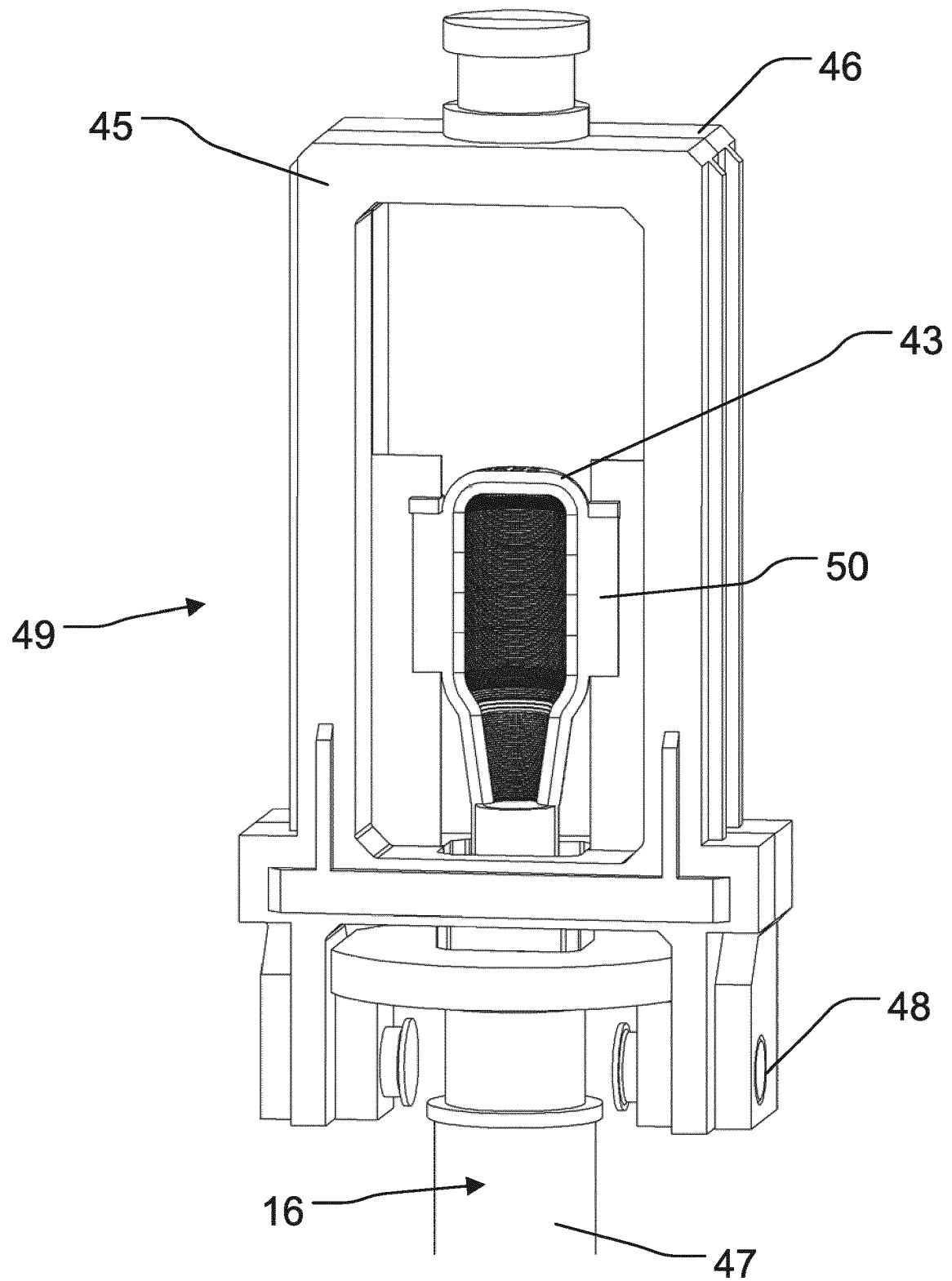


Fig. 10



EUROPEAN SEARCH REPORT

Application Number
EP 19 17 3703

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	EP 1 104 822 A2 (KAO CORP [JP]) 6 June 2001 (2001-06-06) * paragraphs [0049] - [0068]; figure 3 *	1-13	INV. D21J7/00
A	DE 10 2004 059268 A1 (FRORMANN LARS [DE]) 29 June 2006 (2006-06-29) * the whole document *	1-13	
			TECHNICAL FIELDS SEARCHED (IPC)
			D21J
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 December 2019	Examiner Maisonnier, Claire
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

 1
EPO FORM 1503 03/02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 19 17 3703

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

02-12-2019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1104822 A2	06-06-2001	CN 1297086 A	30-05-2001
		CN 1515742 A	28-07-2004
		DE 60033358 T2	31-10-2007
		EP 1104822 A2	06-06-2001
		KR 20010051765 A	25-06-2001
		US 6605187 B1	12-08-2003

DE 102004059268 A1	29-06-2006	NONE	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 1104822 A2 [0002]
- EP 1288369 A1 [0003]
- WO 2016055073 A1 [0004]
- GB 191418339 A [0005]
- WO 2018033209 A1 [0006]
- WO 2016132328 A1 [0007]