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- **Furuhashi, Satoshi**
Kariya-shi, Aichi-ken 448-8671 (JP)
- **Saito, Shinya**
Kariya-shi, Aichi-ken 448-8671 (JP)
- **Takahashi, Naoki**
Kariya-shi, Aichi-ken 448-8671 (JP)

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(71) Applicant: **Kabushiki Kaisha Toyota Jidoshokki**
Seisakusho
Aichi-ken 448-8671 (JP)

(74) Representative: **Karrais, Martin**
Hoeger, Stellrecht & Partner
Uhlandstrasse 14 c
70182 Stuttgart (DE)

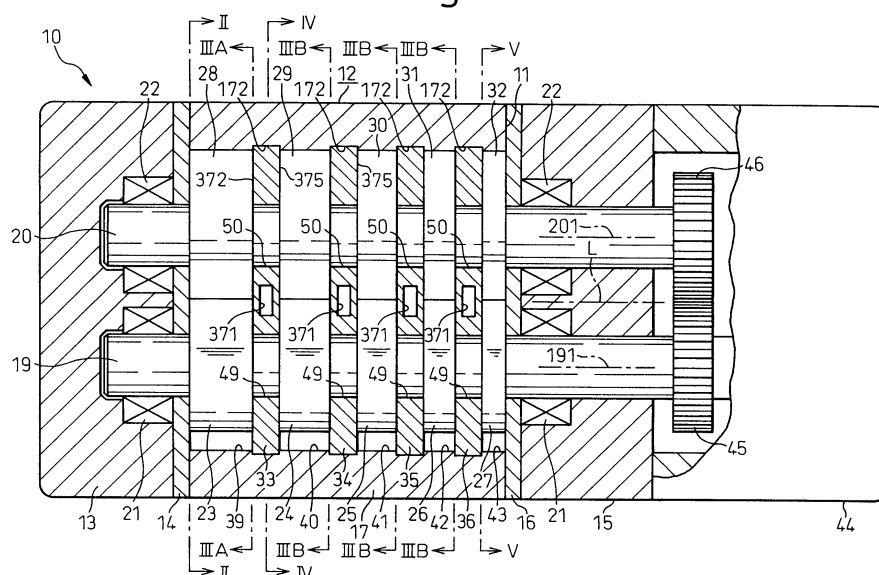
(72) Inventors:
 • **Goto, Kunifumi**
Kariya-shi, Aichi-ken 448-8671 (JP)

(54) **Multi-stage Roots pump and method of producing the housing**

(57) The multi-stage Roots pump has a rotor housing having a plurality of axially spaced pump chambers (39-43). A set of rotors (23-32) are arranged on respective shafts (19,20) in mesh with each other and accommodated in each of the pump chambers. The rotor housing includes a cylinder block (11) and a plurality of partition walls (33-36) formed separately from and coupled

to the cylinder block to divide the cylinder block into the pump chambers. The cylinder block includes a plurality of block elements (17,18) parted along lines (L) extending parallel to the axes of the shafts and joined together so as to form inner circumferential surfaces of the pump chambers. The block elements and the partition walls form, in combination, the rotor housing.

Fig. 1



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a multi-stage Roots pump in which a plurality of rotatable shafts are arranged in parallel, rotors are arranged on said rotatable shafts with rotors on the neighboring rotary shafts brought in mesh with each other, and axially spaced pump chambers accommodating respective sets of rotors in mesh with each other are formed in a rotor housing. The present invention also relates to a method of producing a rotor housing therefor.

2. Description of the Related Art

[0002] In a multi-stage Roots pump disclosed in Japanese Unexamined Patent Publication (Kokai) No. 8-14172, a rotor housing forming a plurality of pump chambers arranged in the axial direction of the pair of rotary shafts, is formed by joining a pair of outer shells. Each outer shell has a plurality of partitioning walls formed as a unitary structure. One outer shell and the other outer shell are joined together with their partitioning walls being opposed to each other. The partitioning walls joined together being opposed to each other, sectionalize a plurality of pump chambers in the axial direction of the rotary shafts.

[0003] Rotors accommodated in the pump chambers rotate in the pump chambers to deliver the fluid under pressure. In order to efficiently pump the fluid with pressure, however, it is important to highly precisely maintain a very small clearance between the rotors that are rotating and any part on the wall surfaces of the pump chambers. The inner peripheral surfaces of the outer shells forming the partitioning walls integrally together must be machined for each of the pair of outer shells. Circumferential surfaces are formed on some of the inner peripheral surfaces of the pump chambers accommodating the rotors, and the pair of outer shells are joined together at portions of the circumferential surfaces. When the inner peripheral surfaces of the outer shells are separately machined, therefore, it becomes difficult to maintain highly precisely machined circumferential surfaces after the pair of outer shells are joined together to constitute the rotor housing. Further, the end surfaces of the partitioning walls forming the wall surfaces of the pump chambers are machined by using a side cutter requiring a difficult machining operation for accomplishing a high degree of flatness. It is further necessary to machine the wall surfaces of the plurality of pump chambers one by one, requiring a further extended operation time for machining.

SUMMARY OF THE INVENTION

[0004] It is therefore a first object of the present invention to highly precisely form the wall surfaces of pump chambers in the multi-stage Roots pump. A second object of the present invention is to produce the rotor housing in a decreased period of time.

[0005] The present invention provides a multi-stage Roots pump comprising: a rotor housing having a plurality of axially spaced pump chambers formed therein; a plurality of shafts parallelly and rotatably arranged in said rotor housing, said shafts having respective axes; a plurality of sets of rotors arranged on said shafts, each set of rotors being arranged on adjacent shafts in mesh with each other and accommodated in each of said pump chambers; and said rotor housing comprising a cylinder block including a plurality of block elements parted along at least one plane extending parallel to the axes of said shafts and joined together so as to form inner circumferential surfaces of said pump chambers, and a plurality of partition walls formed separately from and coupled to said cylinder block to divide said cylinder block into said pump chambers, whereby said block elements and said partition walls form, in combination, said rotor housing.

[0006] The constitution in which the cylinder block constituted by a plurality of block pieces is separate from the partitioning walls, makes it possible to highly precisely machine the wall surfaces in the pump chambers and to produce the rotor housing in a decreased period of time.

[0007] Preferably, the axes of said shafts lie in a first plane, and said cylinder block comprises a pair of block elements having parting surfaces joined together in a second plane passing through a line located at a middle position between said axes of said shafts and lying in said first plane.

[0008] The cylinder block is parted into two and comprises a pair of block pieces that are joined together in the second plane. The constitution in which the cylinder block is parted into two is the simplest from the standpoint of production.

[0009] Preferably, the second plane is the same as said first plane.

[0010] The constitution in which the second plane is the same as the first plane makes it easy to set the shape of the pump chambers for enhancing the pumping efficiency. However, the second plane can be perpendicular to the first plane.

[0011] Preferably, the cylinder block comprises a pair of block elements having inner circumferential surfaces identical to each other.

[0012] The pair of such block pieces are effective in enhancing the efficiency for producing the block pieces.

[0013] Preferably, each of said partition walls comprises a pair of wall elements having parting surfaces joined together in said second plane passing through said line.

[0014] The partitioning wall has a two-part constitution comprising a pair of wall pieces that are joined on the second plane. The partitioning walls of the two-part constitution are the simplest even from the standpoint of production.

[0015] Preferably, a plurality of positioning grooves are formed in parallel in the inner surfaces of said plurality of block pieces, and said partitioning walls are fitted into said positioning grooves.

[0016] The constitution in which the partitioning walls are fitted into the positioning grooves makes it possible to highly precisely guarantee a very small clearance between the rotors and the wall surfaces of the pump chambers formed by the partitioning walls.

[0017] Preferably, the partitioning walls are forcibly introduced into said positioning grooves.

[0018] The constitution in which the partitioning walls are forcibly introduced into the positioning grooves is most desired for easily assembling the cylinder block and the partitioning walls.

[0019] The present invention also provides a method of producing a rotor housing of a multi-stage Roots pump which includes said rotor housing having a plurality of axially spaced pump chambers formed therein, a plurality of shafts parallelly and rotatably arranged in said rotor housing, said shafts having respective axes, and a plurality of sets of rotors arranged on said shafts, each set of rotors being arranged on adjacent shafts in mesh with each other and accommodated in each of said pump chambers. The method comprising the steps of: preparing rough block elements constituting a plurality of block elements for forming a cylinder block having an inner surface forming inner circumferential surfaces of said pump chambers; provisionally joining said rough block elements together; grinding the inner circumferential surfaces of said rough block elements while maintaining said provisional joining; releasing said provisional joining; and joining together said block elements constituted by said rough block elements.

[0020] In a state in which rough block pieces of the plurality of block pieces are joined together, the wall surfaces of a partly circular shape of the pump chambers can be highly precisely machined at one time.

[0021] Preferably, the method further comprises the step of forming positioning grooves in the block elements in which partition walls dividing the inner space in the cylinder block into said pump chambers are to be fitted, prior to or after the step of grinding the inner circumferential surfaces.

[0022] Preferably, the method further comprises the step of press fitting wall elements constituting said partition walls in the positioning grooves in said block elements, after the step of grinding the inner circumferential surfaces and after the step of forming said positioning grooves.

[0023] The rotors are incorporated in the assembly of the block pieces and the wall pieces after the wall pieces have been press fitted into the positioning grooves of

the block pieces. The working procedure according to which the rotors are incorporated in the assembly of the block pieces and the wall pieces after the wall pieces have been forcibly introduced into the positioning grooves of the block pieces, helps enhance the operation efficiency for assembling the rotor housing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The present invention will become more apparent from the following description of the preferred embodiments, with reference to the accompanying drawings, in which:

Fig. 1 is a cross-sectional plan view illustrating a multi-stage Roots pump according to the first embodiment of the present invention;

Fig. 2 is a cross-sectional view of the pump of Fig. 1, taken along the line II-II in Fig. 1;

Fig. 3A is a cross-sectional view of the pump of Fig. 1, taken along the line IIIA-IIIA in Fig. 1;

Fig. 3B is a cross-sectional view of the pump of Fig. 1, taken along the line IIIB-IIIB in Fig. 1;

Fig. 4 is a cross-sectional view of the pump of Fig. 1, taken along the line IV-IV in Fig. 1;

Fig. 5 is a cross-sectional view of the pump of Fig. 1, taken along the line V-V in Fig. 1;

Fig. 6 is a perspective view of a pair of rough block pieces joined together;

Fig. 7 is a perspective view of the block piece and the wall piece before the wall piece is fitted in the block piece;

Fig. 8 is a perspective view of another block piece and the corresponding wall piece before the wall piece is fitted in the block piece;

Fig. 9 is a perspective view of the block pieces and the wall pieces after the wall pieces are fitted in the block pieces;

Fig. 10 is a perspective view of the block pieces and the wall pieces according to the second embodiment after the wall pieces are fitted in the block pieces;

Fig. 11 is a vertical cross-sectional view of the pump according to the third embodiment; and

Fig. 12 is another vertical cross-sectional view of the pump of Fig. 11.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Embodiments of the present invention will now be described with reference to Figs. 1 to 9.

[0026] Referring to Fig. 1, a multi-stage Roots pump 10 has a rotor housing 12, a front housing 13 joined to the front end of the rotor housing 12 via a compartment plate 14, and a rear housing 15 joined to the rear end of the rotor housing 12 via a compartment plate 16. The rotor housing 12 comprises a cylinder block 11 and a

plurality of partitioning walls 33, 34, 35 and 36. Referring to Fig. 4, the cylinder block 11 comprises a pair of block pieces 17 and 18, and each of partitioning walls 33, 34, 35 and 36 comprises a pair of wall pieces 37 and 38. Inner space in the cylinder block 11 is divided such that a first pump chamber 39 is formed between the compartment plate 14 and the partitioning wall 33, a second pump chamber 40 is formed between the partitioning walls 33 and 34, a third pump chamber 41 is formed between the partitioning walls 34 and 35 and a fourth pump chamber 42 is formed between the partitioning walls 35 and 36. A fifth pump chamber 43 is formed between the partitioning wall 36 and the compartment plate 16.

[0027] A pair of rotary shafts 19 and 20 are rotatably supported by the front housing 13 and the rear housing 15 via bearings 21 and 22. The two rotary shafts 19 and 20 are arranged in parallel with each other. The rotary shaft 19 is inserted in an insertion holes 49 formed by hole-forming walls 376 and 386 of the wall pieces 37 and 38, and the rotary shaft 20 is inserted in insertion holes 50 formed by hole-forming walls 377 and 387 of the wall pieces 37 and 38.

[0028] A plurality of rotors 23, 24, 25, 26 and 27 are integrally formed on the rotary shaft 19, and the same number of rotors 28, 29, 30, 31 and 32 are integrally formed on the rotary shaft 20. The rotors 23 to 32 have the same shape and the same size, as viewed in the direction of axes 191 and 201 of the rotary shafts 19, 20. The rotors 23, 24, 25, 26 and 27 have thicknesses decreasing in this order, and the rotors 28, 29, 30, 31 and 32 have thicknesses decreasing in this order. The rotors 23 and 28 have the same thickness, the rotors 24 and 29 have the same thickness, the rotors 25 and 30 have the same thickness, and the rotors 26 and 31 have the same thickness. The rotors 27 and 32 have the same thickness. The rotors 23 and 28 are accommodated in the first pump chamber 39 in mesh with each other, and the rotors 24 and 29 are accommodated in the second pump chamber 40 in mesh with each other. The rotors 25 and 30 are accommodated in the third pump chamber 41 in mesh with each other, and the rotors 26 and 31 are accommodated in the fourth pump chamber 42 in mesh with each other. The rotors 27 and 32 are accommodated in the fifth pump chamber 43 in mesh with each other.

[0029] A drive unit 44 is incorporated in the rear housing 15. The rotary shafts 19 and 20 protrude into the drive unit 44 penetrating through the rear housing 15. Gears 45 and 46 are fixed to the protruded ends of the rotary shafts 19 and 20 in mesh with each other. The rotary shaft 19 is rotated by a motor (not shown) in the drive unit 44 in the direction of an arrow R1 in Figs. 2 to 5. The rotation of the rotary shaft 19 is transmitted to the rotary shaft 20 through the gears 45 and 46, and the rotary shaft 20 is rotated in the direction opposite to the rotary shaft 19 as indicated by an arrow R2 in Figs. 2 to 5.

[0030] Referring to Figs. 1 and 7, a passage 371 is

formed in the wall piece 37, and an inlet 373 of the passage 371 is formed in the end surface 372 of the wall piece 37. Pair of partly circular circumferential surfaces 174 and 175 are formed in the inner surface of the block piece 17. A plurality of positioning grooves 172 are formed in parallel in the inner surface of the block piece 17, and the wall pieces 37 are press-fitted in the positioning grooves 172. Referring to Figs. 2 and 8, a passage 381 is formed in the wall piece 38, and an outlet 383 of the passage 381 is formed in the end surface 382 of the wall piece 38. Pair of partly circular circumferential surfaces 184 and 185 are formed in the inner surface of the block piece 18. A plurality of positioning grooves 182 are formed in parallel in the inner surface of the block piece 18, and the wall pieces 38 are press-fitted in the positioning grooves 182. The rotors 23 to 27 rotate with a very small clearance relative to the circular circumferential surfaces 174 and 184, and the rotors 28 to 32 rotate with a very small clearance relative to the circular circumferential surfaces 175 and 185.

[0031] Referring to Figs. 2 to 5, the block pieces 17 and 18 have the same shape, and have the circular circumferential wall surfaces 174, 175, 184 and 185 of the same shape. The parting surfaces 171 and 181 of the block pieces 17 and 18 are joined in a plane S1, and the parting surfaces 374 and 384 of the wall pieces 37 and 38 are joined in the plane S1. The passages 371 and 381 of the wall pieces 37 and 38 joined to each other, are continuous to one another.

[0032] Referring to Figs. 2 and 8, a fluid introduction port 183 is formed in the block piece 18 in communication with the first pump chamber 39. Referring to Figs. 5 and 7, a fluid exhaust port 173 is formed in the block piece 17 in communication with the fifth pump chamber 43. The fluid introduced into the first pump chamber 39 through the fluid introduction port 183 is delivered under pressure into the second pump chamber 40 due to the rotation of the rotors 23 and 28, passing through the inlet 373 of the partitioning wall 33, passages 371 and 381, and the outlet 383. The fluid introduced into the second pump chamber 40 is delivered under pressure to the third pump chamber 41 due to the rotation of the rotors 24 and 29, passing through the inlet 373 of the partitioning wall 34, passages 371 and 381 and the outlet 383. Similarly, the fluid delivered under pressure from the third pump chamber 41 to the fourth pump chamber 42, and from the fourth pump chamber 42 to the fifth pump chamber 43, i.e., pumped in order of decreasing volumes of the pump chambers through the passages 371, 381 in the partitioning walls 35 and 36. The fluid pumped into the fifth pump chamber 43 is discharged to the external side through the fluid discharge port 173.

[0033] The rotor housing 12 is produced in the manner as described below. First, rough block pieces 47 and 48 shown in Fig. 6, that are bases of the block pieces 17 and 18, are molded. In the inner surfaces of the rough block pieces 47 and 48 have been formed, in advance, rough, circular circumferential surfaces 471, 472, 481

and 482 and rough positioning grooves 374 and 483. The molded rough block pieces 47 and 48 are provisionally joined, as indicated by solid lines in Fig. 6. In this state of being joined together, the rough, circular circumferential surfaces 471, 472, 481 and 482 and the rough positioning grooves 473 and 483 are finished by grinding. Upon executing the finishing, the circular circumferential surfaces 174, 175, 184 and 185 and the positioning grooves 172 and 182 are formed, as shown in Figs. 7 and 8.

[0034] Next, the wall pieces 37 and 38, which are formed separately from the block pieces 17 and 18, are press fitted into the positioning grooves 172 and 182, after the provisional joining is released, as shown in Fig. 9. The wall pieces 37 are incorporated in the block pieces 17 and the wall pieces 38 are incorporated in the block piece 18. Thereafter, the parting surfaces 171 and 181 of the block pieces 17 and 18 as well as the parting surfaces 374 and 384 of the wall pieces 37 and 38 are finished by grinding. The fluid introduction port 183 and the fluid discharge port 173 are formed thereafter.

[0035] The first embodiment exhibits the following effects.

(1-1) A strictly precise clearance must be ensured between the circular circumferential surfaces 174 and 184 of the cylinder block 11 and the rotors 23 to 37 that rotate, and between the circular circumferential surfaces 175 and 185 and the rotors 28 to 32 that rotate. In the step of finishing the circular circumferential surfaces 174 and 184 and the circular circumferential surfaces 175 and 185 by machining the rough circumferential surfaces 471 and 481 and the rough circumferential surfaces 472 and 482 in the state where the pair of rough block pieces 47 and 48 are joined together, the circular circumferential surfaces 174 and 184 are continuously finished, and the circular circumferential wall surfaces 175 and 185 are continuously finished. Further, the thickness of the rough block pieces 47 and 48 in the state of being joined and held together is made uniform, and the distortion during the grinding is made uniform in any circumferential direction of the inner peripheral walls. Therefore, the circular circumferential surfaces 174 and 184 and the circular circumferential surfaces 175 and 185 maintain the shape of a high precision, and a very small clearance is maintained with a high precision at any portion in the circumferential direction of the circular circumferential surfaces 174 and 184 and of the circular circumferential surfaces 175 and 185.

(1-2) A strictly precise clearance must be ensured between the rotors 23 to 32 and the partitioning walls 33 to 37. For this purpose, the end surfaces of the partitioning walls 33 to 37 opposed to the end surfaces of the rotors 23 to 32 must have a high degree of flatness and a high degree of parallelism. It is easy to enhance the degree of flatness and the

degree of parallelism of the end surfaces 372, 375, 382 and 385 of the wall pieces 37 and 38 constituting the partitioning walls 33 and 34 separate from the block pieces 17 and 18, and flatness and parallelism of high degrees are maintained on the end surfaces of the partitioning walls 33 to 37.

(1-3) The circular circumferential surfaces 174, 184, 175 and 185 of the pump chambers 39 to 43 are machined at one time. Therefore, the circular circumferential surfaces of the pump chambers 39 to 43 are machined requiring a decreased number of steps and a shortened period of time. This makes it possible to decrease the cost of the multi-stage Roots pump 10.

(1-4) The cylinder block 11 has a two-part constitution comprising a pair of block pieces 17 and 18 joined in the plane S1. The cylinder block 11 having the two-part constitution is the simplest from the standpoint of producing the cylinder block 11 having a plurality of pump chambers 39 to 43.

(1-5) The pumping efficiency in the pumping chambers 39 to 43 increase with an increase in the angular range $\theta 1$ of the circular circumferential surfaces 174 and 184 having the axis 191 of the rotatable shaft 19 as a center and with an increase in the angular range $\theta 2$ of the circular circumferential surfaces 175 and 185 having the axis 201 of the rotatable shaft 20 as a center. The rotors 23 to 32 are incorporated in the pump chambers 39 to 43 after the block pieces 17 and 18 and the wall pieces 37 and 38 are assembled as shown in Fig. 9. The constitution in which the parting surfaces 171 and 181 of the block pieces 17 and 18 are joined in the plane S1 facilitates the incorporation of the rotors 23 and 32 in the pump chambers 39 to 43, and makes it possible to maximize the degree of freedom for setting the shapes of the pump chambers 39 to 43. This large degree of freedom for setting the shapes of the pump chambers 39 to 43 makes it possible to set the shapes of the pump chambers 39 to 43 having increased angular ranges $\theta 1$ and $\theta 2$. Therefore, the constitution in which the parting surfaces 171 and 181 of the block pieces 17 and 18 are joined in the plane S1 facilitates the setting of shapes of the pump chambers 39 to 43 for accomplishing a high pumping efficiency.

(1-6) A straight line L is located at a middle position equidistant from the axes 191 and 201 in the plane S1 that passes through the axes 191 and 201 of the parallel rotatable shafts 19 and 20, and is in parallel with the axes 191 and 201. The shapes of the pair of block pieces 17 and 18 are symmetrical relative to the straight line L except the fluid discharge port 173 and the fluid introduction port 183, i.e., symmetrical as they are turned by 180° with the straight line L as a center. The rough block pieces 47 and 48 which are the bases of the block pieces 17 and 18 of the main shape except the fluid discharge port

173 and the fluid introduction port 183, can be molded by using the same metal mold. Therefore, the symmetry in the main shape of the block pieces 17 and 18 enhances the efficiency for producing the block pieces.

(1-7) The partitioning walls 33 to 37 have the two-part constitution comprising a pair of wall pieces 37 and 38 joined in the plane S1. The partitioning walls 33 to 37 of the two-part constitution is the simplest from the standpoint of producing the rotor housing 12 having a plurality of pump chambers 39 to 43.

(1-8) The constitution in which the parting surfaces 374 and 384 of the wall pieces 37 and 38 are joined in the plane S1, facilitates the incorporation of the rotatable shafts 191 and 201 in the insertion holes 49 and 50.

(1-9) The pair of wall pieces 37 and 38 have the same shape, and are symmetrical relative to the straight line L except the passages 371 and 381, i. e., symmetrical as they are turned by 180° with the straight line L as a center. The wall pieces 37 and 38 having such a shape can be molded by using the same metal mold maintaining an enhanced efficiency.

(1-10) The positioning grooves 172 and 182 formed in the inner peripheral surfaces of the block pieces 17 and 18, form annular grooves circulating one turn along the inner peripheral wall surface of the cylinder block 11. It is easy to increase the degree of parallelism of the plurality of positioning grooves 172 and 182 and, hence, the annular grooves comprising the positioning grooves 172 and 182 feature a high degree of parallelism. The constitution in which the wall pieces 37 and 38 are fitted into the plurality of highly parallel positioning grooves 172 and 182, helps increase the degree of parallelism between the end surfaces 382, 382 and the end surfaces 375, 385 that serve as wall surfaces for forming a pump chamber. It therefore becomes possible to maintain a very small clearance with high precision between the rotors 23 to 32 and the end surfaces 372, 382, 375 and 385 of the wall pieces 37 and 38 serving as wall surfaces for forming the pump chambers 39 to 43. (1-11) The constitution in which the wall pieces 37 and 38 constituting the partitioning walls 33 to 36 are press fitted into the positioning grooves 172 and 182, is best suited for facilitating the assembling of the block pieces 17, 18 constituting the cylinder block 11 together with the wall pieces 37 and 38 constituting the partitioning walls 33 to 36.

(1-12) The rotors 23 to 32 are most efficiently incorporated in the cylinder block 11 while joining the assembly of the block piece 17 and the wall pieces 37 to the assembly of the block piece 18 and the wall pieces 38. The operation for assembling the rotor housing 12 is improved owing to the assembly of the block piece 17 and the wall pieces 37 after the

wall pieces 37 and 38 have been forcibly introduced into the positioning grooves 172, 182 of the block pieces 17 and 18, and owing to the procedure for incorporating the rotors 23 to 32 in the assembly of the block piece 18 and the wall pieces 38.

[0036] The second embodiment of the present invention will now be described with reference to Fig. 10. The same constituent portions as those of the first embodiment are denoted by the same reference numerals.

[0037] In this embodiment, pins 51 are press fitted into the boundaries between the parting surfaces 171 and 181 of the block pieces 17, 18 and the parting surfaces 374 and 384 of the wall pieces 37 and 38 fitted in the positioning grooves 172, 182. The wall pieces 37 and 38 fitted in the positioning grooves 172 and 182 are secured to the positioning grooves 172 and 182 as the pins 51 are press fitted therein. The wall pieces 37 and 38 are easily secured to the block pieces 17 and 18 by forcibly introducing the pins 51.

[0038] Next, the third embodiment of the present invention will be described with reference to Figs. 11 and 12. The same constituent portions as those of the first embodiment are denoted by the same reference numerals.

[0039] In this embodiment, the cylinder block 53 forming the rotor housing 52 is constituted by a pair of block pieces 54 and 55 that are joined in a second plane S2 that intersects the first plane S1 at right angles and passes through the straight line L. The wall pieces 37 and 38 constitute partitioning walls as the recessed portions 378 and 389 thereof and the protruded portions 388 and 379 thereof are press fitted to each other. The wall pieces 37 and 38 are fitted to the positioning grooves 541 and 551 in a state where the wall pieces 37 and 38 are coupled together permitting the rotary shafts 19 and 20 to pass through.

[0040] This embodiment too, exhibits the same effects as those mentioned in (1-1) to (1-4), (1-6), (1-7) and (1-9) to (1-11) of the first embodiment.

[0041] The following embodiments can also be realized according to the present invention.

(1) The cylinder block is constituted by joining three or more block pieces about the axes of the rotatable shafts.

(2) In the first embodiment, the circular circumferential surfaces 471, 481, 472 and 482 of the rough blocks 47 and 48 without positioning grooves 473 and 483, are ground to finish the circular circumferential surfaces 174 and 184 and, then, the positioning grooves 172 and 182 are formed by grinding.

(3) Insertion holes 49 and 50 for inserting the rotatable shafts 19 and 20 are formed after the rotor housing 12 has been assembled.

(4) In the second embodiment, the wall pieces 37 and 38 are secured to the block pieces 17 and 18 without forming the positioning grooves 172 and

182 but using the pins 51 only.

(5) The invention is applied to a multi-stage Roots pump having rotors mounted on three or more rotary shafts.

[0042] According to the present invention as described above in detail, the cylinder block forming the circumferential surfaces of the pump chambers is formed separately from a plurality of partitioning walls that sectionalize the neighboring pump chambers, the cylinder block being constituted by joining a plurality of block pieces in a direction to surround the axes of the rotatable shafts, and the rotor housing being constituted by combining the plurality of block pieces and the plurality of partitioning walls together. Therefore, the wall surfaces of the pump chambers of the multi-stage Roots pump are formed highly precisely, and the rotor housing is produced in a decreased period of time.

Claims

1. A multi-stage Roots pump comprising:

a rotor housing having a plurality of axially spaced pump chambers formed therein;
a plurality of shafts parallelly and rotatably arranged in said rotor housing, said shafts having respective axes;
a plurality of sets of rotors arranged on said shafts, each set of rotors being arranged on adjacent shafts in mesh with each other and accommodated in each of said pump chambers; and
said rotor housing comprising a cylinder block including a plurality of block elements parted along at least one plane extending parallel to the axes of said shafts and joined together so as to form inner circumferential surfaces of said pump chambers, and a plurality of partition walls formed separately from and coupled to said cylinder block to divide said cylinder block into said pump chambers, whereby said block elements and said partition walls form in combination said rotor housing.

2. A multi-stage Roots pump according to claim 1, wherein said axes of said shafts lie in a first plane, and said cylinder block comprises a pair of block elements having parting surfaces joined together in a second plane passing through a line located at a middle position between said axes of said shafts and lying in said first plane.

3. A multi-stage Roots pump according to claim 2, wherein said second plane coincides with said first plane.

4. A multi-stage Roots pump according to claim 2, wherein said second plane is perpendicular to said first plane.

5. A multi-stage Roots pump according to claim 1, wherein said cylinder block comprises a pair of block elements having inner circumferential surfaces identical to each other.

6. A multi-stage Roots pump according to claim 5, wherein each of said partition walls comprises a pair of wall elements having parting surfaces joined together in said second plane passing through said line.

7. A multi-stage Roots pump according to claim 1, wherein each of said block elements has an inner surface, said inner surface having parallel positioning grooves in which said partition walls are fitted.

8. A multi-stage Roots pump according to claim 1, wherein said partition walls are press fitted in said positioning grooves.

9. A method of producing a rotor housing of a multi-stage Roots pump which includes said rotor housing having a plurality of axially spaced pump chambers formed therein, a plurality of shafts parallelly and rotatably arranged in said rotor housing, said shafts having respective axes, and a plurality of sets of rotors arranged on said shafts, each set of rotors being arranged on adjacent shafts in mesh with each other and accommodated in each of said pump chambers, said method comprising the steps of:

preparing rough block elements constituting a plurality of block elements for forming a cylinder block having an inner surface forming inner circumferential surfaces of said pump chambers; provisionally joining said rough block elements together;
grinding the inner circumferential surfaces of said rough block elements while maintaining said provisional joining;
releasing said provisional joining; and
joining together said block elements constituted by said rough block elements.

10. A method of producing a rotor housing of a multi-stage Roots pump according to claim 9, further comprising the step of forming positioning grooves in the block elements in which partition walls dividing the inner space in the cylinder block into said pump chambers are to be fitted, prior to or after the step of grinding the inner circumferential surfaces.

11. A method of producing a rotor housing of a multi-

stage Roots pump according to claim 10, further comprising the step of press fitting wall elements constituting said partition walls in the positioning grooves in said block elements, after the step of grinding the inner circumferential surfaces and after the step of forming said positioning grooves.

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Fig. 1

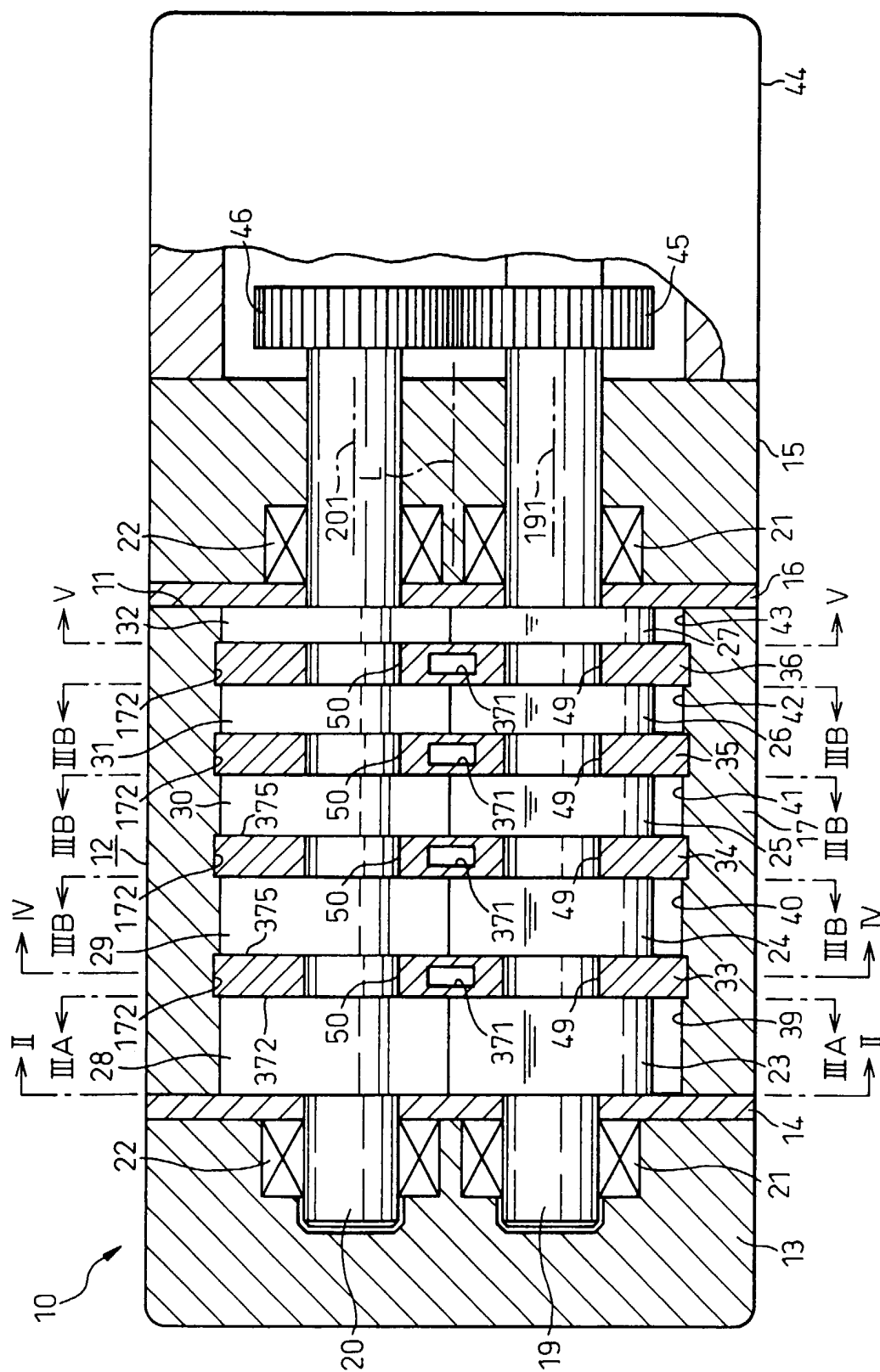


Fig. 2

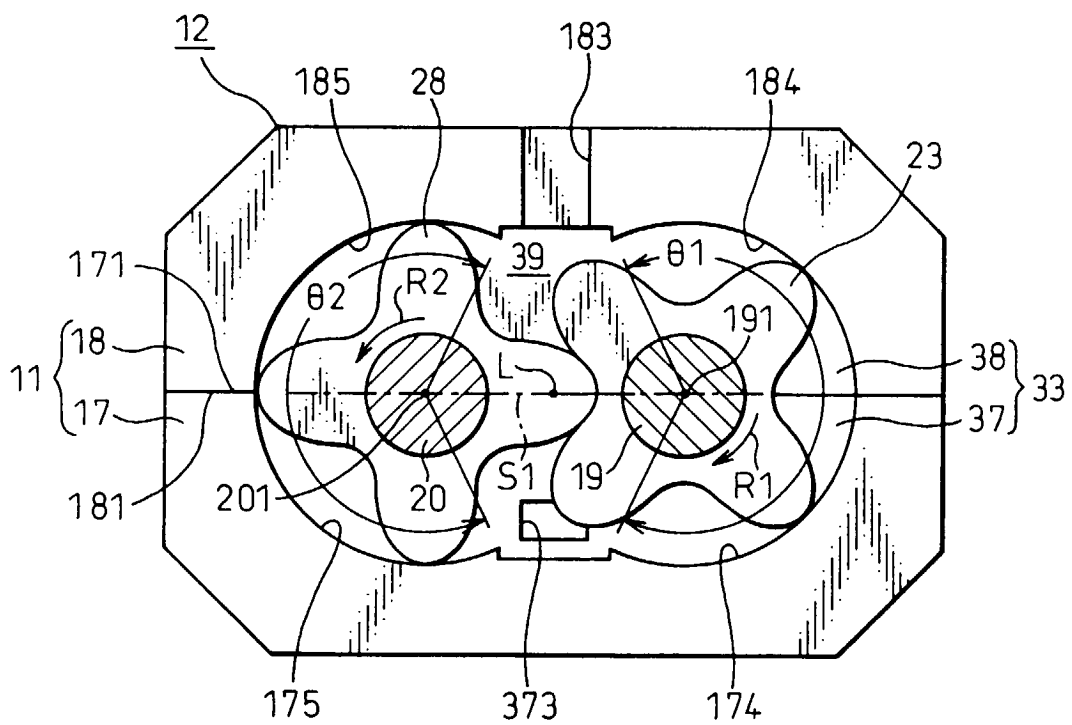


Fig. 3A

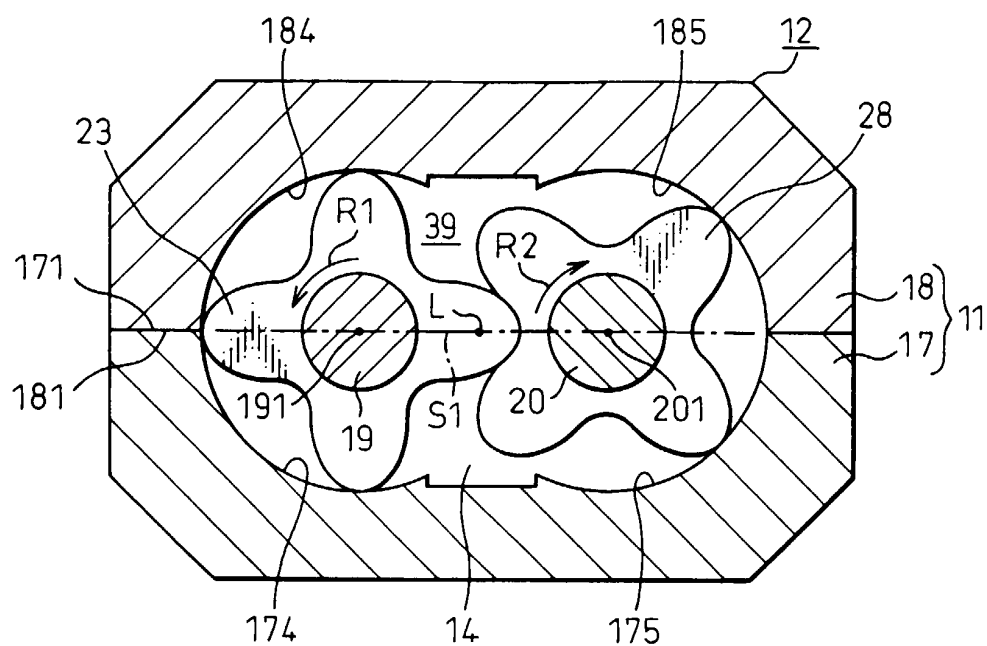


Fig. 3B

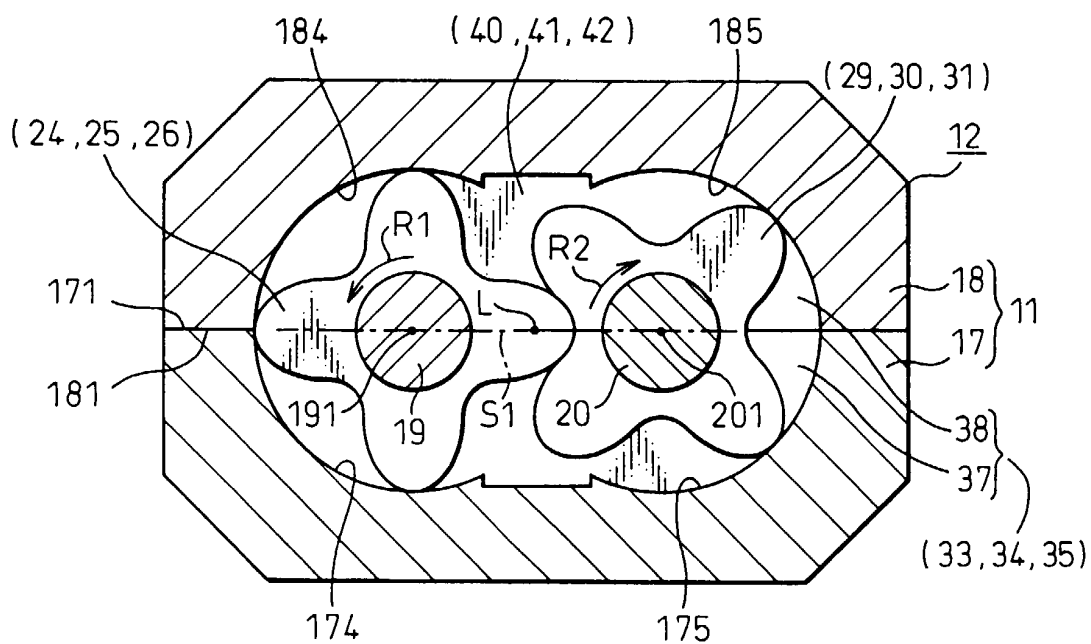


Fig. 4

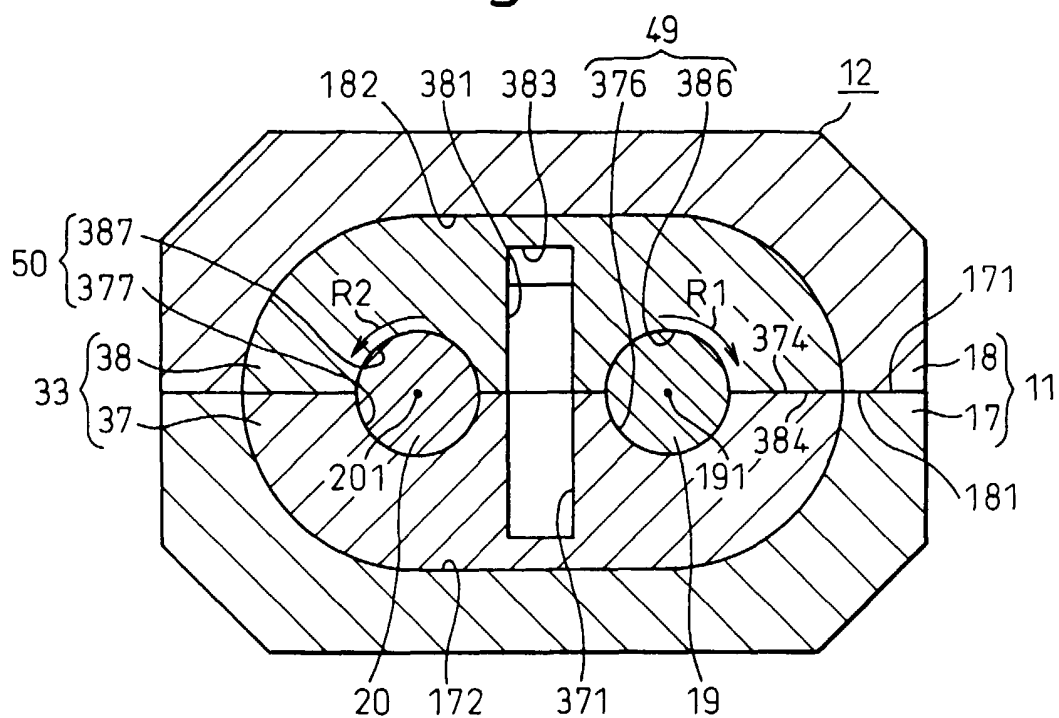


Fig. 5

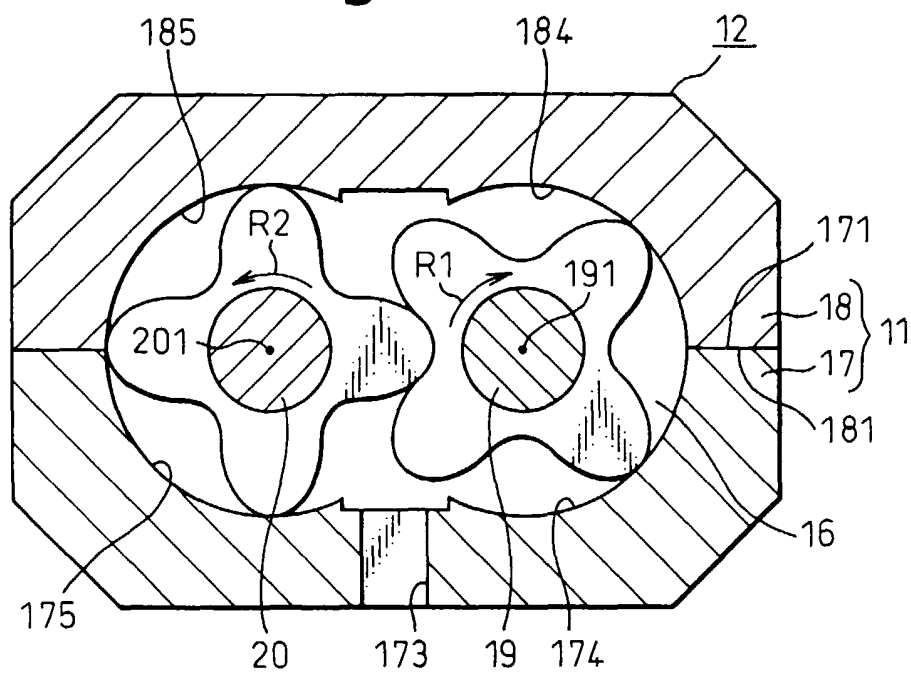


Fig. 6

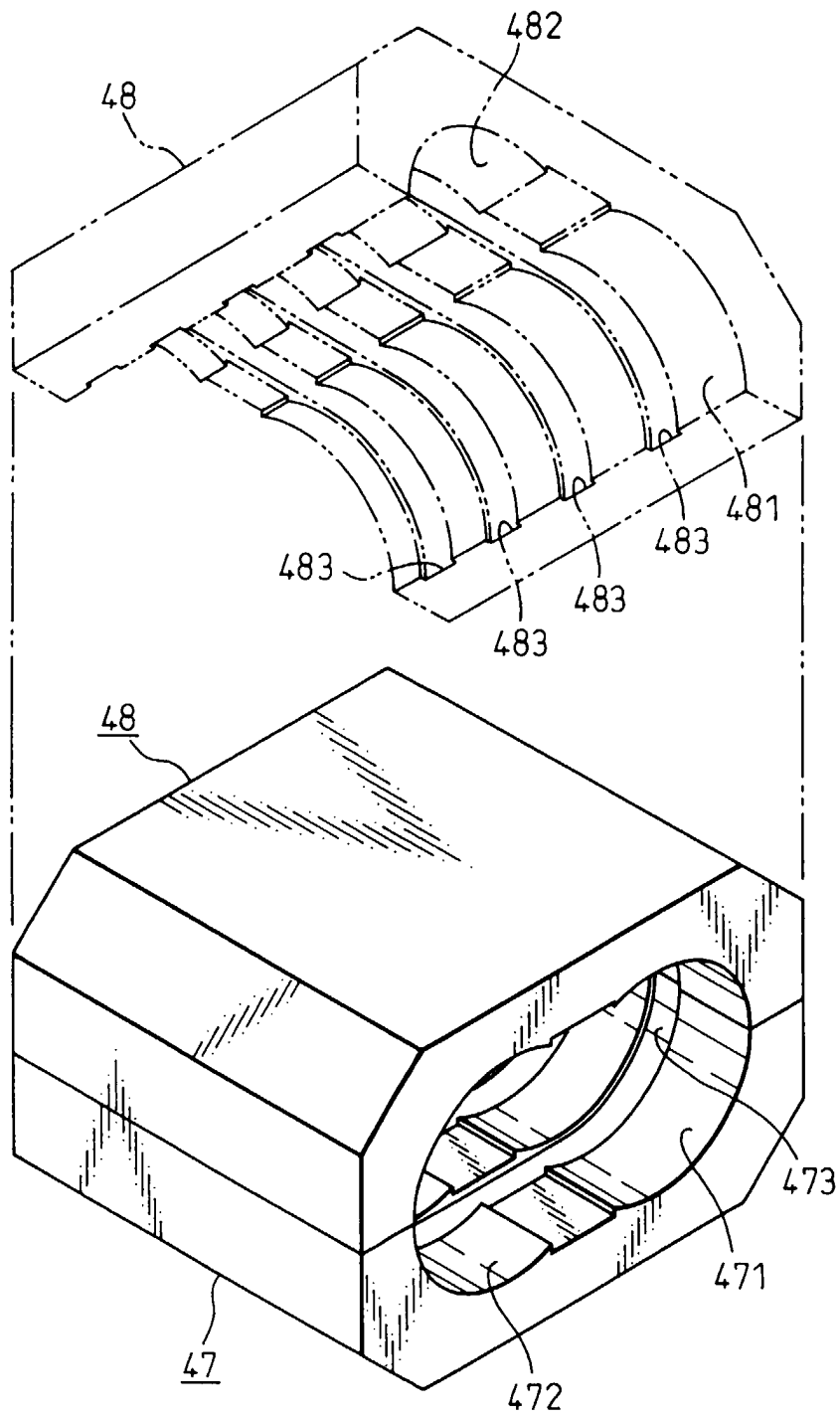


Fig. 7

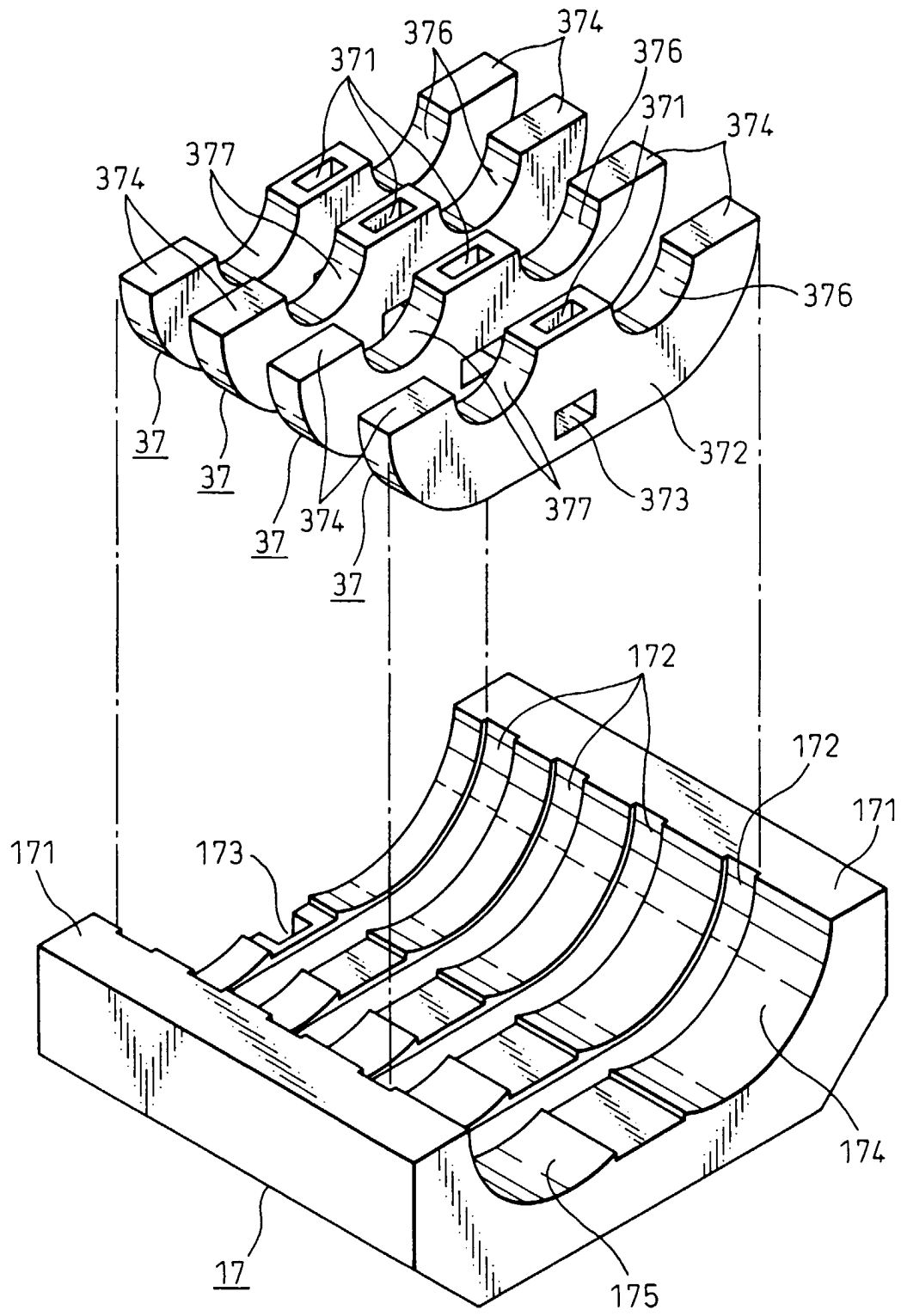


Fig. 8

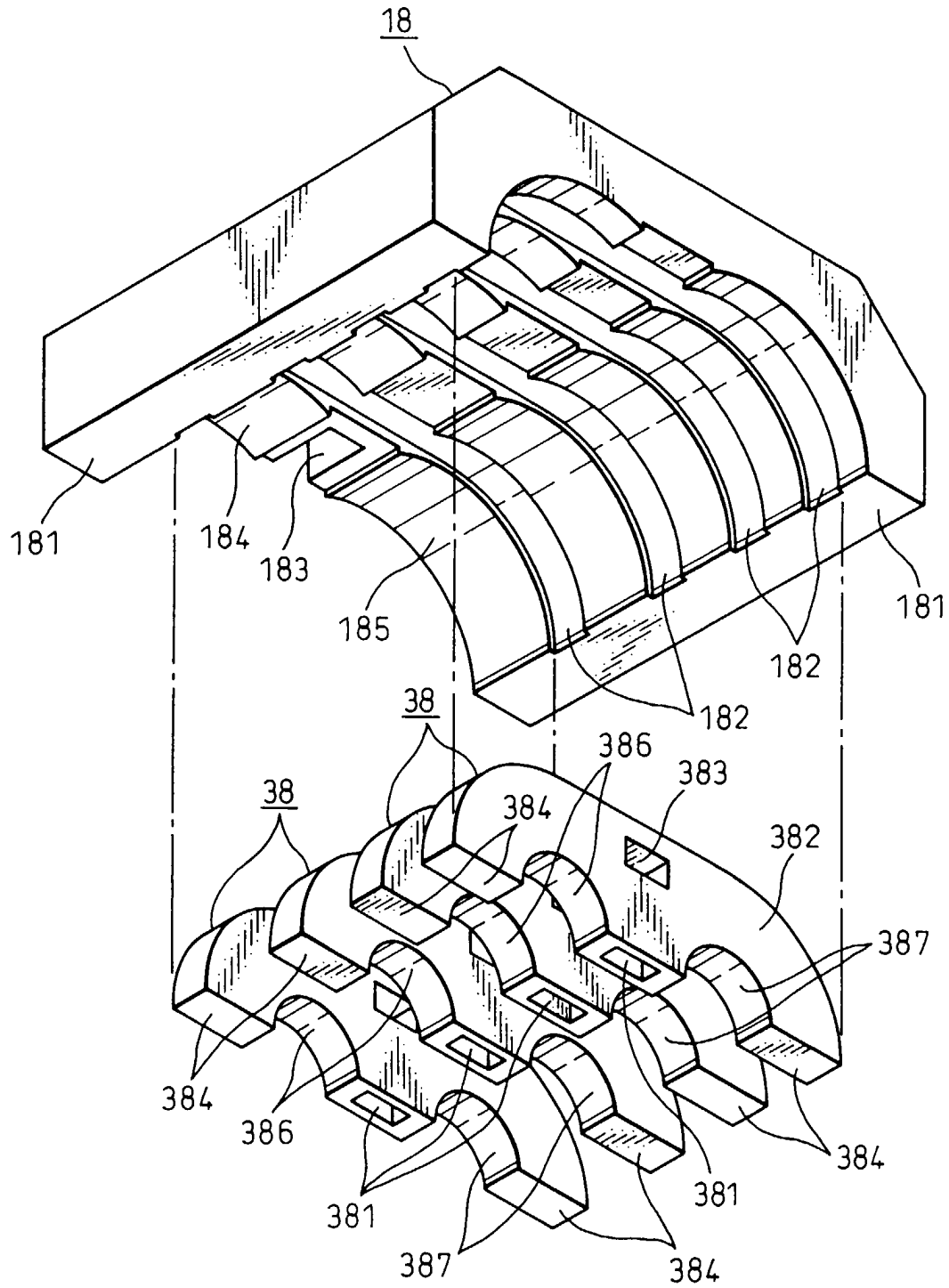


Fig. 9

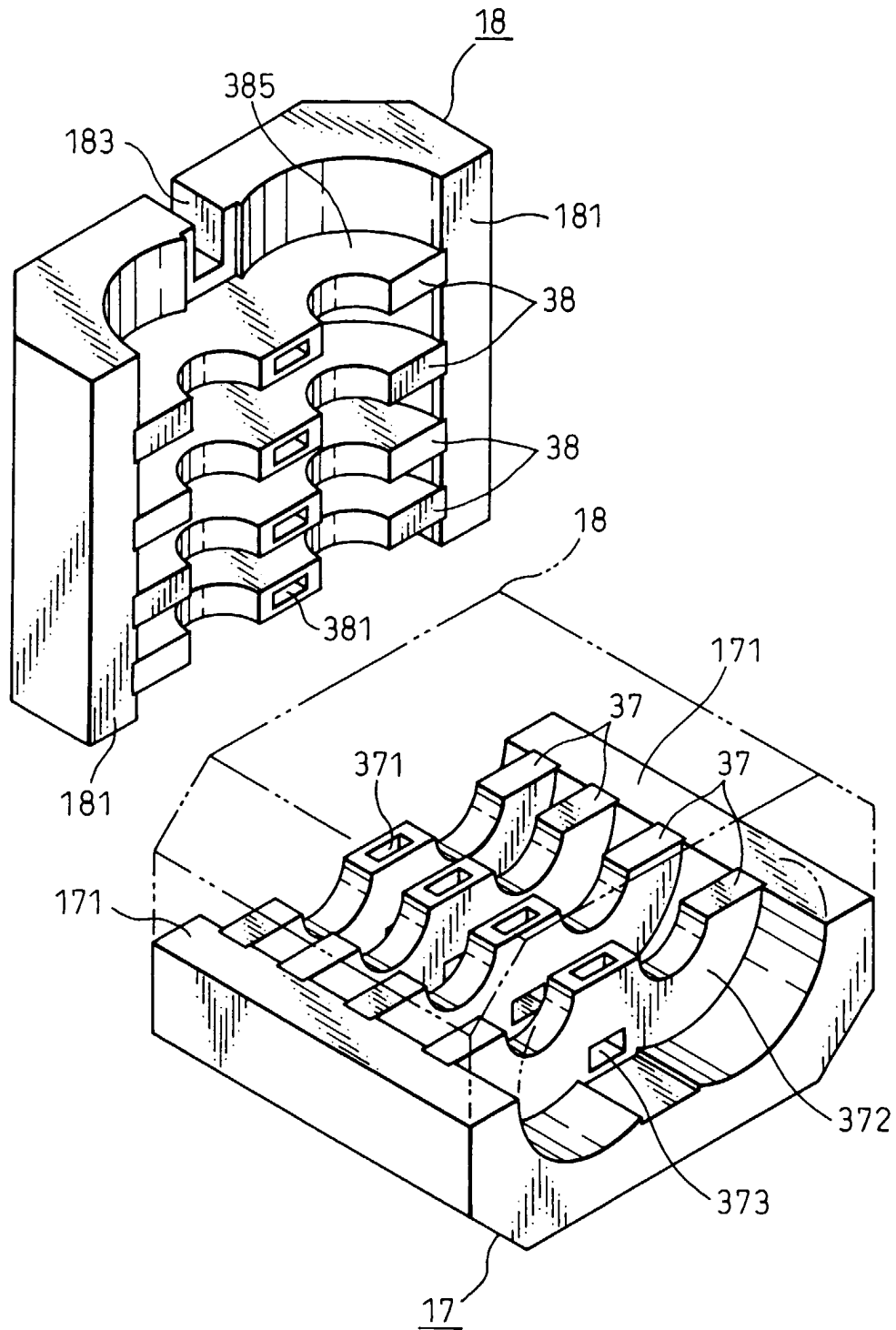


Fig. 10

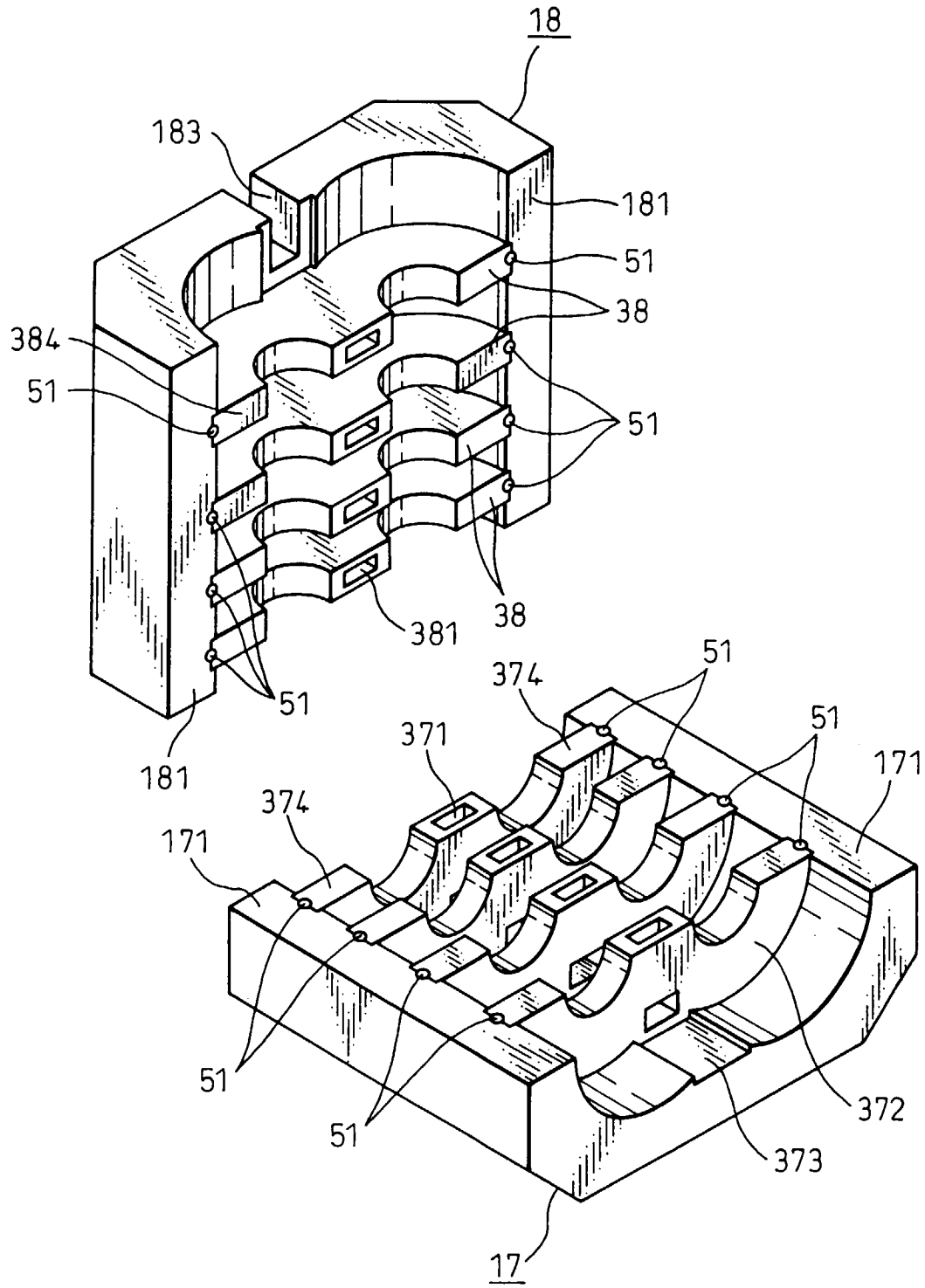


Fig.11

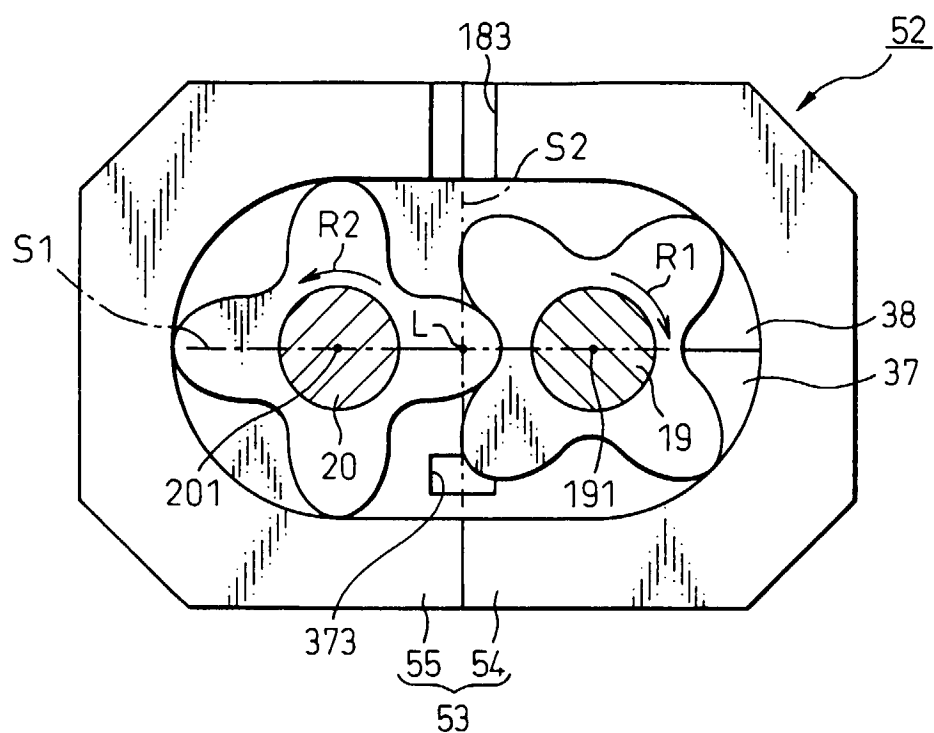
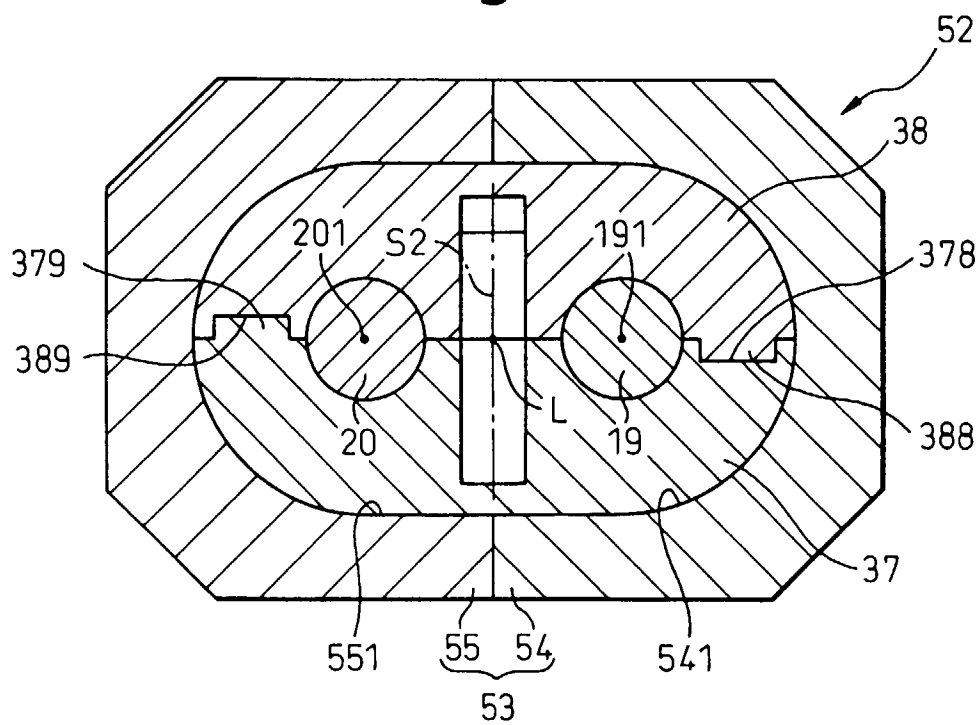


Fig.12





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 12 4197

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X	EP 0 480 629 A (BOC GROUP) 15 April 1992 (1992-04-15)	1	F04C11/00
Y	* column 3, line 10 - line 27 * * column 4, line 19 - column 5, line 11; figures 1-5 *	2,3,5,6	
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			F04C F01C
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 30 March 2000	Examiner Kapoulas, T
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			

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