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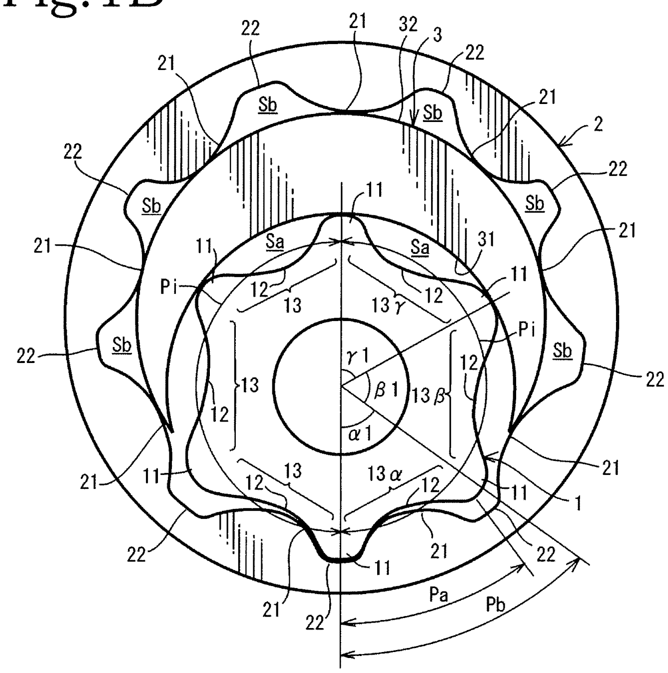
(54) **Internal gear pump with non-equal teeth pitch spacings**

(57) An internal gear pump which has a crescent (3) disposed between an outer rotor (2) and an inner rotor (1) having a trochoidal tooth profile, and which reduces vibrations caused by pulsations generated when the fluid is discharged. The internal gear pump has an outer rotor (2) having internal teeth (21) formed therein, an inner rotor (1) disposed on the inner peripheral side of the outer rotor and having formed therein external teeth (11) that mesh with the internal teeth (21), and a crescent (3) disposed in a clearance between the outer rotor and the inner rotor. Pitch spacings of the external teeth (11) of the inner rotor (1) are formed as non-equal spacings, and pitch spacings of the internal teeth of the outer rotor correspond to the pitch spacings of the external teeth of the inner rotor.

Fig.1B



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Description

[0001] The present invention relates to an internal gear pump which comprises a crescent disposed between an outer rotor and an inner rotor and which is provided with the inner rotor with a trochoidal tooth profile, the internal gear pump making it possible to reduce vibrations caused by pulsations generated during fluid discharge.

[0002] Internal gear pumps comprising a crescent have been used for a long time because they can increase the discharge pressure above that in the internal gear pumps having no crescent. In recent years, the use or rotors with a trochoidal tooth profile in the internal gear pumps having a crescent has been studied as means for further increasing the efficiency and raising the discharge pressure. These developments can improve efficiency and discharge performance, but the problem associated therewith is that the peak value of discharge pulsations increases accordingly, the vibrations of the pump body increase, and an adverse effect is produced on the peripheral equipment.

[0003] Accordingly, in order to raise further the discharge pressure in the crescent-type internal gear pumps using rotors with a trochoidal tooth profile, such pumps have to be studied more thoroughly. Japanese Patent Application Laid-open No. 7-253083 discloses a technique for reducing the peak value of discharge pulsations.

[0004] With the invention disclosed in Japanese Patent Application Laid-open No. 7-253083, it is possible that the peak value of discharge pulsations will not be sufficiently or effectively reduced by merely creating a difference in pitches between the teeth, without specifying the tooth profile and the like. Further, the invention disclosed in Japanese Patent Application Laid-open No. 7-253083 is concerned only with the reduction of audible noise level, and technical issues relating to other effects or improvement of discharge performance remain unresolved. Moreover, no description concerning a specific method for reducing discharge pulsations is provided, and a specific method for reducing discharge pulsations remains unclear. It is an object of the present invention to prevent the discharge amount of liquid from assuming a constant value, reduce the peak of pulsations generated when the fluid is discharged, and decrease the vibrations and noise of the pump.

[0005] The inventors have conductive a comprehensive study to attain the above-described object. The results obtained demonstrate that the aforementioned problems are resolved by the invention of claim 1 that provides an internal gear pump, comprising an outer rotor having internal teeth formed therein, an inner rotor disposed on the inner peripheral side of the outer rotor and having formed therein external teeth that mesh with the internal teeth, and a crescent disposed in a clearance between the outer rotor and the inner rotor, wherein pitch spacings of the external teeth of the inner rotor are formed as non-equal spacings, and pitch spacings of the internal teeth of the outer rotor correspond to the pitch spacings of the external teeth of the inner rotor.

[0006] The aforementioned problems are resolved by the invention of claim 2 that provides the internal gear pump of the above-described configuration, wherein a row of teeth with the number of teeth equal to the common divisor of the number of external teeth of the inner rotor and the number of internal teeth of the outer rotor is taken as a non-equal spacing pitch row, and identical non-equal spacing pitch rows are formed repeatedly. The aforementioned problems are resolved by the invention of claim 3 that provides the internal gear pump of the above-described configuration, wherein the number of the non-equal spacing pitch rows is 3 or more. The aforementioned problems are resolved by the invention of claim 4 that provides the internal gear pump of the above-described configuration, wherein the number of teeth of the inner rotor is 6 or more, and the number of teeth of the outer rotor is 9 or more. The aforementioned problems are resolved by the invention of claim 5 that provides the internal gear pump of the above-described configuration, wherein the tooth thicknesses of the external teeth and internal teeth in the non-equal spacing pitch rows are set to differ. The aforementioned problems are resolved by the invention of claim 6 that provides the internal gear pump of the above-described configuration, wherein the tooth profile of the inner rotor is a trochoidal tooth profile.

[0007] The aforementioned problems are resolved by the invention of claim 7 that provides an internal gear pump comprising an outer rotor having internal teeth formed therein, an inner rotor disposed on the inner peripheral side of the outer rotor and having formed therein external teeth that mesh with the internal teeth, and a crescent disposed in a clearance between the outer rotor and the inner rotor, wherein tooth thickness dimensions of the external teeth of the inner rotor are formed to be non-uniform, and the tooth thicknesses of the internal teeth of the outer rotor correspond to the tooth thickness dimensions of the inner rotor.

[0008] The aforementioned problems are resolved by the invention of claim 8 that provides the internal gear pump of the above-described configuration, wherein the number of external teeth of the inner rotor and the number of internal teeth of the outer rotor are multiples of a common divisor of the number of external teeth and the number of internal teeth, a plurality of unit external tooth rows having the number of teeth at least equal to the greatest common divisor and also having different tooth thicknesses are provided in the external teeth of the inner rotor, and a plurality of unit internal tooth rows in which the internal teeth corresponding to the unit external tooth row of the inner rotor are arranged consecutively are provided in the outer rotor.

[0009] The aforementioned problems are resolved by the invention of claim 9 that provides the internal gear pump of the above-described configuration, wherein the number of unit external tooth rows of the inner rotor is 3 or more. The aforementioned problems are resolved by the invention of claim 10 that provides the internal gear pump of the above-described configuration, wherein the number of teeth of the inner rotor is 6 or more, and the number of teeth of the outer rotor is 9 or more. The aforementioned problems are resolved by the invention of claim 11 that provides the internal gear pump of the above-described configuration, wherein the tooth profile of the inner rotor is a trochoidal tooth profile.

[0010] The aforementioned problems are resolved by the invention of claim 12 that provides the internal gear pump of the above-described configuration, wherein a pitch angle of the external teeth of the inner rotor is formed to be non-uniform, and a pitch angle of the internal teeth of the outer rotor corresponds to the pitch angle of the external teeth. The aforementioned problems are resolved by the invention of claim 13 that provides the internal gear pump of the above-described configuration, wherein a pitch angle of the external teeth of the unit external tooth row of the inner rotor is formed to be non-uniform, and a pitch angle of the internal teeth of the unit internal tooth row of the outer row corresponds to the pitch angle of the external teeth of the unit external tooth row.

[0011] With the invention of claim 1, in an internal gear pump comprising a crescent in a void between an outer rotor and an inner rotor, the pitch spacings of the external teeth of the inner rotor are made different from each other. As a result, the size of cells that are formed by the inner rotor and outer rotor at the time of discharge differ from each other, the amount of discharge from the cells is irregular, and the peak value of discharge pulsations is reduced, whereby the audible noise level and vibrations can be decreased.

[0012] With the invention of claim 2, a row of teeth with the number of teeth equal to the common divisor of the number of external teeth of the inner rotor and the number of internal teeth of the outer rotor is taken as a non-equal spacing pitch row, and identical non-equal spacing pitch rows are formed repeatedly. As a result, the irregular discharge state produced by non-equal (uneven) discharge amount is generated periodically and consecutively, and the peak value of discharge pulsations can be reduced even more significantly. With the invention of claim 3, the period of pitch spacings is 3 or more. As a result, three or more different pitch spacings can be created consecutively, the period of pitch spacings can be made even more complex, and the irregularity of discharge pulsations can be further increased.

[0013] With the invention of claim 4, the number of teeth of the inner rotor is 6 or more, and the number of teeth of the outer rotor is 9 or more. As a result, the common divisor of the numbers of teeth of the inner rotor and outer rotor can be made equal to or more than 3, and three or more different irregular discharge states can be realized. With the invention of claim 5, the tooth thicknesses of the external teeth and internal teeth in the non-equal spacing pitch rows are set to differ. As a result, irregular pulsations are produced due to non-equally spaced pitches and also irregular pulsations are produced from cells of different size due to a sequential difference in tooth thickness. With the invention of claim 6, the tooth profile of the inner rotor is a trochoidal tooth profile. As a result, the discharge performance can be improved, while reducing the peak of pulsations.

[0014] With the invention of claim 7, tooth thickness dimensions of the external teeth of the inner rotor are formed to be non-uniform, and the tooth thicknesses of the internal teeth of the outer rotor correspond to the tooth thickness dimensions of the inner rotor. As a result, the tooth thickness dimensions of the external teeth of the inner rotor differ from each other, and the volume (capacity) of spaces bounded by the adjacent external teeth and the crescent differ from each other. In the outer rotor, the tooth thickness dimensions of the internal teeth also differ from each other, and the volume (capacity) of spaces bounded by the adjacent internal teeth and the crescent differ from each other. Therefore, the size of cells that are formed by the inner rotor and outer rotor at the time of discharge differ from each other, the amount of discharge from the cells is irregular, and the peak value of discharge pulsations is reduced, whereby the audible noise level and vibrations can be decreased.

[0015] With the invention of claim 8, the number of external teeth of the inner rotor and the number of internal teeth of the outer rotor are multiples of a common divisor of the number of external teeth and the number of internal teeth, a plurality of unit external tooth rows having the number of teeth at least equal to the greatest common divisor and also having different tooth thicknesses are provided in the external teeth of the inner rotor, and a plurality of unit internal tooth rows in which the internal teeth corresponding to the unit external tooth row of the inner rotor are arranged consecutively are provided in the outer rotor. As a result, by using a configuration comprising unit external tooth rows and unit internal tooth rows, it is possible to generate consecutively and periodically the irregular discharge states with different discharge amounts, thereby further reducing the peak value of discharge pulsations.

[0016] With the invention of claim 9, the number of unit external tooth rows of the inner rotor is 3 or more. As a result, three or more external teeth with different tooth thickness dimensions can be arranged sequentially, the configuration of the unit external tooth row can be further complicated, and the irregularity of the discharge pulsations can be further increased. With the invention of claim 10, the number of teeth of the inner rotor is 6 or more, and the number of teeth of the outer rotor is 9 or more. As a result, the common divisor of the numbers of teeth of the inner rotor and outer rotor can be made equal to or more than 3, and three or more irregular different discharge states can be realized. With the invention of claim 11, the tooth profile of the inner rotor is a trochoidal tooth profile. As a result, the discharge performance can be improved, while reducing the peak of pulsations.

[0017] With the invention of claim 12, a pitch angle of the external teeth of the inner rotor is formed to be non-uniform, and a pitch angle of the internal teeth of the outer rotor corresponds to the pitch angle of the external teeth. As a result, a more complex configuration of the unit external tooth row and unit internal tooth row can be obtained and the peak value of discharge pulsations can be further reduced. With the invention of claim 13, a pitch angle of the external teeth of the unit external tooth row of the inner rotor is formed to be non-uniform, and a pitch angle of the internal teeth of the unit internal tooth row of the outer row corresponds to the pitch angle of the external teeth of the unit external tooth row. As a result, a more complex configuration of the unit external tooth row and unit internal tooth row can be obtained and the peak value of discharge pulsations can be further reduced.

FIG. 1A is a plan view illustrating the configuration in accordance with the present invention, and FIG. 1B is a plan view illustrating the assembly of the inner rotor and crescent with the outer rotor;
FIG. 2A is a plan view of the inner rotor, FIG. 2B is a plan view of the outer rotor, and FIG. 2C is a plan view of the crescent;
FIG. 3A is a process diagram showing the position of a random external tooth in which the inner rotor starts rotating, and
FIG. 3B is a process diagram illustrating the state in which the random external tooth has moved by one tooth;
FIG. 4A is a process diagram illustrating the state in which the random external tooth has reached the crescent, and FIG. 4B is a process diagram illustrating the state in which the random external tooth has reached the crescent center;
FIG. 5A is a process diagram illustrating the state in which the random external tooth has reached the end side of the crescent, and FIG. 5B is a process diagram illustrating the state in which the random external tooth has separated from the crescent;
FIG. 6A is a rotor assembly configuration of the second embodiment of the present invention, and FIG. 6B is a plan view of the outer rotor of the second embodiment;
FIG. 7A is a graph illustrating the discharge pulsations in accordance with the present invention, and FIG. 7B is a graph illustrating the discharge pulsations of the conventional type;
FIG. 8A is a plan view illustrating the configuration of the second embodiment of the present invention, and FIG. 8B is a plan view illustrating the assembly of the inner rotor and crescent with the outer rotor;
FIG. 9A is a plan view of the inner rotor, FIG. 9B is a plan view of the outer rotor, and FIG. 9C is a plan view of the crescent;
FIG. 10A is a process diagram showing the position of a random external tooth in which the inner rotor of the second embodiment of the present invention starts rotating, and FIG. 10B is a process diagram illustrating the state in which the random external tooth has moved by one tooth;
FIG. 11A is a process diagram illustrating the state in which the random external tooth of the second embodiment of the present invention has reached the crescent, and FIG. 11B is a process diagram illustrating the state in which the random external tooth has reached the crescent center;
FIG. 12A is a process diagram illustrating the state in which the random external tooth of the second embodiment of the present invention has reached the end side of the crescent, and
FIG. 12B is a process diagram illustrating the state in which the random external tooth has separated from the crescent;
FIG. 13A is a plan view of the inner rotor of the third embodiment of the present invention, FIG. 13B is a plan view of the outer rotor, and FIG. 13C is a plan view of the crescent;
FIG. 14A is a process diagram showing the position of a random external tooth in which the inner rotor of the third embodiment of the present invention starts rotating, and FIG. 14B is a process diagram illustrating the state in which the random external tooth has moved by one tooth;
FIG. 15A is a process diagram illustrating the state in which the random external tooth of the third embodiment of the present invention has reached the crescent, and FIG. 15B is a process diagram illustrating the state in which the random external tooth has reached the crescent center; and
FIG. 16A is a process diagram illustrating the state in which the random external tooth of the third embodiment of the present invention has reached the end side of the crescent, and
FIG. 16B is a process diagram illustrating the state in which the random external tooth has separated from the crescent.

[0018] The embodiments of the present invention will be described below with reference to the appended drawings. The configuration of the first embodiment of the present invention, as shown in FIG. 1A, mainly comprises an inner rotor 1, an outer rotor 2, a crescent 3, and a pump casing 4. The pump casing 4 has formed therein a rotor chamber 41, a suction port 42, and a discharge port 43. The suction port 42 and discharge port 43 are formed as flow channels communicating with the outside of the pump casing 4. Further, the pump casing 4 can be used together with a casing cover (this configuration is not shown in the figure).

[0019] As shown in FIG. 2A, the inner rotor 1 has a plurality of external teeth 11, 11, ... formed on the outer periphery thereof. The external teeth 11 can be also formed with trochoidal tooth profiles (including tooth profiles of an almost trochoidal shape). A tooth bottom portion 12 is formed between the external teeth 11, 11. Different spacings, that is, pitch spacings Pa, are set between the adjacent external teeth 11, 11, and these different pitch spacings Pa will be described below.

[0020] As shown in FIG. 2B, the outer rotor 2 has a plurality of internal teeth 21, 21, ... formed on the inner periphery thereof, and tooth bottom portions 22 are formed between the internal teeth 21, 21, ... The inner rotor 1 is disposed on he inner peripheral side of the outer rotor 2, and the external teeth 11, 11, ... of the inner rotor 1 mesh with the internal teeth 21, 21, ... of the outer rotor 2. Likewise, pitch spacings Pb of the internal teeth 21, 21, ... of the outer rotor 2 are formed correspondingly to the pitch spacings Pa of the external teeth 11, 11, ... of the inner rotor 1 so as to enable effective meshing with the external teeth 11, 11, ... of the inner rotor 1. Further, when the external teeth 11 of the inner rotor 1 have a trochoidal tooth profile (including a tooth profile of an almost trochoidal shape), the internal teeth 21 of the outer rotor 2 have a tooth profile enabling effective meshing with the external teeth 11 of the inner rotor 1. Thus, by forming the external teeth 11 of the inner rotor 1 to have a trochoidal tooth profile (including a tooth profile of an almost trochoidal shape), it is possible to increase a discharge performance, while reducing the peak of pulsations.

[0021] As shown in FIG. 1, the crescent 3 is inserted and disposed in a gap formed between the outer rotor 2 and inner rotor 1. This gap is called an almost crescent-like space formed between the inner peripheral side of the outer rotor 2 and the outer periphery of the inner rotor 1. As shown in FIG. 2C, the crescent 3 has an almost crescent-like or arcuate shape and is composed of an arcuate concave surface side 31 and an arcuate convex surface side 32.

[0022] Interior cells Sa are formed between the arcuate concave surface side 31 of the crescent 3 and the external teeth 11, 11, ... of the inner rotor 1 (see FIG. 1B). Likewise, exterior cells Sb are formed between the arcuate convex surface side 32 of the crescent 3 and the internal teeth 21, 21, ... of the outer rotor 2 (see FIG. 1B). The interior cells Sa are voids formed in a portion bounded by the external teeth 11, 11 of the inner rotor 1 and the arcuate concave surface side 31 of the crescent 3, and the exterior cells Sb are voids formed in a portion bounded by the internal teeth 21, 21, ... and the arcuate convex surface side 32 of the crescent 3.

[0023] The configuration of the external teeth 11, 11, ... of the inner rotor 1 and the internal teeth 21, 21, ... of the outer rotor 2 is determined by the following relationship. First, in a plurality of the external teeth 11, 11, ... of the inner rotor 1, the pitch spacings Pa, Pa, ... between he adjacent external teeth 11, 11 are formed to differ from each other. The pitch spacings Pb between the internal teeth 21, 21, ... of the outer rotor 2 are formed correspondingly to the pitch spacings Pa between the external teeth 11, 11, ... of the inner rotor 1, so as to ensure the meshing of the external teeth 11, 11, ... and internal teeth 21, 21, ..., and these pitch spacings Pb, Pb, ... are also different from each other.

[0024] The size of the pitch spacing Pa is determined by the pitch angle of the adjacent external teeth 11, 11, and the size of the range of the tooth bottom portion 12 between the adjacent external teeth 11, 11 is determined thereby. Regions 13 between the teeth that configure the interior cells Sa are set between the adjacent external teeth 11, 11 to center on the tooth bottom portions 12 positioned between the adjacent external teeth 11, 11 (see FIG. 1B and FIG. 2A). The regions 13 between the teeth are equal to the corresponding pitch spacings Pa. More specifically, as shown in FIG. 2A, where the pitch angles of three appropriate external teeth 11, 11, ... in the inner rotor 1 are denoted by $\alpha 1$, $\gamma 1$, $\beta 1$, the relationship between the pitch spacings Pa will be $\alpha 1 < \gamma 1 < \beta 1$. The regions 13 between the teeth match the size of the pitch angles $\alpha 1$, $\gamma 1$, $\beta 1$, and are denoted by 13α, 13γ, and 13β (see FIG. 2A).

[0025] Accordingly, the size of these regions satisfies the conditions $13\alpha < 13\gamma < 13\beta$. Thus, the size of regions changes in the following order in the rotation direction of the inner rotor 1: small (13α), large (13γ), and intermediate (13β). The volumes of interior cells Sa, Sa, ... formed between the inner rotor 1 and the crescent 3 also differ from each other, and there are small and large volumes. Therefore, the amount of liquid transferred by the plurality of interior cells Sa varies among the interior cells Sa.

[0026] The pitch spacings Pb of the internal teeth 21, 21, ... of the outer rotor 2 are made to correspond to the pitch spacings Pa of the external teeth 11, 11, ... of the inner rotor 1 so as to ensure the meshing of the teeth. With such a configuration, the volumes of the interior cell Sa and exterior cell Sb formed by he crescent 3 in the inner rotor 1 and outer rotor 2 differ from each other, the discharged amount varies among the cells (interior cell Sa, exterior cell Sb), the peak value of discharge pulsations is reduced, and vibrations and noise level that can be heard are reduced.

[0027] The pitch spacings of the external teeth 11, 11, ... of the inner rotor 1 and the internal teeth 21, 21, ... of the outer rotor 2 are defined as follows. First, a tooth row with a number of teeth equal to a numerical value N that is a common divisor of the number Za of the external teeth 11, 11, ... of the inner rotor 1 and the number Zb of the internal teeth 21, 21, ... of the outer rotor 2 is taken as a non-equal spacing pitch row Pi in the inner rotor 1, and the identical non-equal spacing pitch rows Pi are formed repeatedly (see FIG. 2A). Thus, a plurality of non-equal spacing pitch rows Pi are included in one inner rotor 1.

[0028] However, when the greatest common divisor N of the number of teeth Za of the inner rotor 1 and the number of teeth Zb of the outer rotor 2 is equal to the number of teeth Za of the inner rotor 1, only one non-equal spacing pitch row Pi is present in the inner rotor 1. An actual embodiment of this case is shown in FIG. 6 wherein the number of teeth Za of the inner rotor 1 is 6 and the number of teeth Zb of the outer rotor 2 is 12. In this case, 6 that is the number of teeth Za of the inner rotor 1 is the greatest common divisor, and one non-equal spacing pitch row Pi is present in the inner rotor 1. In such a case, all the pitch spacings Pa of the external teeth 11, 11, ... of the inner rotor 1 differ from each other.

[0029] In the non-equal spacing pitch row Pi, the teeth with different pitch spacing Pa are formed as a unit (group) by the N (common divisor) external teeth 11, 11, ... Thus, in the non-equal spacing pitch row Pi, the pitch spacings Pa vary depending on whether the pitch angle (α, β, γ) is large, medium, or small, and the regions 13 between the teeth in the non-equal spacing pitch row Pi also vary. Further, it is preferred that the arrangement order of the size of a plurality regions 13, 13, ... between the teeth in the non-equal spacing pitch row Pi be non-regular (random). However, the order of sizes of regions 13 between the teeth in a plurality of non-equal spacing pitch rows Pi in one inner rotor 1 is such that they all are formed with the same pattern. In the outer rotor 2, there is present a non-equal spacing pitch row Po in which N (common divisor) internal teeth 21, 21, ... are configured with different pitch spacings Pb, in the same manner as in the non-equal spacing pitch row Pi.

[0030] The number of teeth Za, number of teeth Zb, and numerical value N, which is a common divisor, will be explained below as specific integer values. The number of teeth Za of the inner rotor 1 is taken as 6, and the number of teeth Zb of the outer rotor 2 is taken as 9. The common divisor (numerical value N) of the number of teeth Za and number of teeth Zb is "3". This value is not necessarily the greatest common divisor of the number of teeth Za and number of teeth Zb. The non-equal spacing pitch row Pi is composed of three external teeth 11, 11, ... with a different pitch spacing Pa. The three regions 13, 13, ... between the teeth that are set by the three external teeth 11, 11, ... are composed of three different pitch angles and, as described above, denoted by α1, β1, γ1. Where the size relationship thereof is assumed to be $\alpha 1 < \gamma 1 < \beta 1$, as described hereinabove, the size relationship of the regions 13 between the teeth will be $13\alpha < 13\gamma < 13\beta$ (see FIG. 2A).

[0031] Further, the non-equal spacing pitch row Po of the outer rotor 2 is composed of three internal teeth 21, 21, ... with a different pitch spacing Pb. The regions 23, 23, ... between the teeth that are formed by the three internal teeth 21, 21, ... are composed of three pitch angles and, as described above, denoted by α2, β2, γ2. The order of sizes of a plurality of regions 23, 23, ... between the teeth in the non-equal spacing pitch row Po has a pattern identical to the order of sizes of the regions 13, 13, ... between the teeth in the non-equal spacing pitch row Pi of the inner rotor 1. Two non-equal spacing pitch rows Pi are present in the inner rotor 1, and three non-equal spacing pitch rows Po are present in the outer rotor 2 (see FIG. 2B).

[0032] The non-equal spacing pitch row Pi and non-equal spacing pitch row Po have three (common divisor) external teeth 11, 11, ... and internal teeth 21, 21, ..., respectively. The arrangement of the order of sizes of the regions 13 between the teeth and regions 23 between the teeth can be an appropriate irregular arrangement. For example, the order of sizes of the pitch angles (α, β, γ) of the regions 13, 13, ... between the teeth in the rotation direction of the rotor can be small, medium, large, or large, medium, small. However, the order of sizes of the regions 23, 23, ... in the non-equal spacing pitch row Po of the outer rotor 2 is identical to that of the non-equal spacing pitch row Pi.

[0033] With such a configuration, the period of the size of volume of the interior cells Sa (exterior cells Sb) formed by regions 13 (23) between the teeth of different size varies non-monotonically rather than monotonically when the external teeth 11 (internal teeth 21) move with different pitch spacings Pa (Pb). As a result, the discharge pulsations with a larger irregularity (randomness) can be realized. The non-monotonous changes as referred to herein mean that the regions 13 (23) between the teeth of different size move through a predetermined position with irregular periods because of the irregular pitch spacing Pa (Pb).

[0034] FIG. 3 to FIG. 5 show the operation states in which the interior cells Sa and exterior cells Sb that differ in volume due to the difference in pitch angle between the regions 13α, 13β, 13γ between the teeth or regions 23α, 23β, 23γ between the teeth are discharged successively into the discharge port 43 as the inner rotor 1 makes one revolution. One of the external teeth 11 of the inner rotor 1 is marked with a black dot, and the external tooth 11 with a dot makes one revolution as shown in FIG. 3 to FIG. 5.

[0035] The size of the shape, that is, a tooth thickness dimension Wa, differs between the external teeth 11, 11, ... arranged with the irregular pitch spacing Pa in the non-equal spacing pitch row Pi. Because there is a difference in size between the external teeth 11, 11, ..., as described above, the volume of interior cells Sa also varies (see FIG. 2A). Likewise, the size of the shape, that is, a tooth thickness dimension Wb, differs between the internal teeth 21, 21, ... of the outer rotor 2 that are arranged in the irregular pitch spacing Pb in the non-equal spacing pitch row Po, and because there is a difference in size between the internal teeth 21, 21, ..., as described above, the volume of exterior cells Sb also varies.

[0036] FIG. 6 illustrates a configuration in which the number of teeth Za of the inner rotor 1 is 6 and the number of teeth Zb of the outer rotor 2 is 12. The value of the common divisor of the number of teeth Za and number of teeth Zb is 6, and the number of non-equal spacing pitch rows Po of the outer rotor 2 formed thereby is 2. Thus, the value of the common divisor is equal to the number of teeth Za of the inner rotor 1. FIG. 7A is a graph illustrating the discharge pulsations in accordance with the present invention. FIG. 7B is a graph illustrating the discharge pulsations of the conventional configuration. The comparison of the two graphs shows that in accordance with the present invention the pulsations are dispersed, whereby the peak of discharge pulsations is reduced (see FIG. 7A).

[0037] The second embodiment of the present invention will be described below with reference to FIG. 8 to FIG. 12. In the second embodiment, in the internal gear pump having the configuration similar to that of the first embodiment of the present invention, as shown in FIG. 9A, the tooth thickness dimension Wa of the tooth thickness of the external teeth 11, 11, ... of the inner rotor 1 is not uniform. The pitch angles θa, θa, ... of the adjacent external teeth 11, 11 in a plurality of external teeth 11, 11, ... of the inner rotor 1 are all formed as equal angles (see FIG. 8B, FIG. 9A). Thus, the pitch spacing Pa of the external teeth 11, 11, ... is uniform. The tooth thickness dimension Wb of the internal teeth 21, 21, ... of the outer rotor 2 corresponds to the tooth thickness Wa of the inner rotor 1 and is not uniform. The term "corresponds" as used herein means that the internal teeth 21, 21, ... of the outer rotor 2 can mesh with the external teeth 11, 11, ... of the inner rotor 1 in the internal gear pump and the inner rotor 1 and outer rotor 2 can rotate effectively (see FIG. 10 to FIG. 12).

[0038] The tooth thickness dimension Wa of the external tooth 11 of the inner rotor 1 is a dimension of the portion that crosses a reference pitch circle Ca (see FIG. 9A). The reference pitch circle Ca is a virtual circle that passes through the intermediate position between the tooth tip and tooth bottom of the external tooth 11, this circle having the center of the diameter of the inner rotor 1 as a center. The shape of the tooth bottom portion 12 between the adjacent external teeth 11, 11 differs depending on the tooth thickness dimension Wa of the external teeth 11. The volumes of the interior cells Sa, Sa, ... formed between the adjacent external teeth 11, 11 of the inner rotor 1 and the crescent 3 differ accordingly, and there are large volumes and small volumes. Therefore, the amount of liquid transferred by a plurality of the interior cells Sa varies from one interior cell Sa to another. The outer rotor 2 also has a reference pitch circle Cb (see FIG. 9B).

[0039] In the external teeth 11, 11, ... of the inner rotor 1, which have different tooth thickness dimensions Wa, the number Za of external teeth 11, 11, ... of the inner rotor 1 and the number Zb of internal teeth 21, 21, ... of the outer rotor 2 are multiples of the common divisor of Za and Zb. In the external teeth 11 of the inner rotor 1, a tooth row is composed of the number of teeth at least equal to the greatest common divisor, and the external teeth 11 in this tooth row have different tooth thickness dimensions Wa. This tooth row is called a unit external tooth row Li (see FIG. 9A). As described above, the unit external tooth row Li is composed of N external teeth 11, where the numerical value N is the (greatest) common divisor, and the unit external tooth rows Li are formed repeatedly. Thus, one inner rotor 1 comprises a plurality of unit external tooth rows Li.

[0040] Where the numerical value N, which is the greatest common divisor of the number of teeth Za of the inner rotor 1 and the number of teeth Zb of the outer rotor 2, is equal to the number of teeth Za of the inner rotor 1, only one unit external tooth row Li is contained in the inner rotor 1. For example, such is the case with the number of teeth Za of the inner rotor 1 equal to 6 and the number of teeth Zb of the outer rotor 2 equal to 12. In this case, the number 6, which is the number of teeth Za of the inner rotor 1, is the greatest common divisor, and the inner rotor 1 is composed only of one unit external tooth row Li. In this case, the tooth thickness dimensions Wa of the external teeth 11, 11, ... are all different from each other.

[0041] The arrangement order of sizes of tooth thickness dimensions Wa, Wa, ... of a plurality of external teeth 11, 11, ... contained in the unit external tooth row Li is preferably irregular (random). However, the arrangement orders of sizes of the tooth thickness dimensions Wa in a plurality of unit external tooth rows Li in one inner rotor 1 are all formed according to the same pattern. In the outer rotor 2, a unit internal tooth row Lo composed of a total of N (common divisor) internal teeth 21, 21, ... with different tooth thickness dimensions Wb is provided similarly to the above-described unit external tooth row Li (see FIG. 9B). Thus, where the inner rotor 1 and outer rotor 2 mesh and rotate normally, the unit external tooth rows Li of the inner rotor 1 and the unit internal tooth rows Lo of the outer rotor 2 mesh periodically (see FIG. 8A, FIG. 9 to FIG. 12).

[0042] Specific integer values of the numerical value N, which is the common divisor, will be explained below for the number of teeth Za of the inner rotor 1 and the number of teeth Zb of the outer rotor 2. The number of teeth Za of the inner rotor 1 is taken as 6, and the number of teeth Zb of the outer rotor 2 is taken as 9 (see FIGS. 9A, 9B). The common divisor (numerical value N) of the number of teeth Za and the number of teeth Zb is "3". Depending on the numerical values of the number of teeth Za and the number of teeth Zb, this numerical value "3" is not necessarily the greatest common divisor. The unit external tooth row Li is composed of three external teeth 11, 11, ... having mutually different tooth thickness dimensions Wa. Here, the tooth thickness dimension Wa1, tooth thickness dimension Wa2, and tooth thickness dimension Wa3 are used to indicate that the three external teeth 11, 11, ... of the unit external tooth row Li have different tooth thickness dimensions Wa. The size relationship of the tooth thickness dimensions is such that the tooth thickness dimension Wa1 is the maximum dimension and the tooth thickness dimension Wa3 is the minimum dimension. Thus, the size relationship of the tooth thickness dimensions is Wa1 > Wa2 > Wa3 (see FIG. 9A).

[0043] Further, the unit internal tooth row Lo of the outer rotor 2 is composed of three internal teeth 21, 21, ... having mutually different tooth thickness dimensions Wb. The tooth thickness dimension Wb1, tooth thickness dimension Wb2, and tooth thickness dimension Wb3 are used to indicate that the internal teeth 21, 21, ... contained in the unit internal tooth row Lo also have different tooth thickness dimensions Wb. Thus, the inner rotor 1 has two unit external tooth rows Li, Li, and the outer rotor 2 has three unit internal tooth rows Lo, Lo, ... (see FIGS. 9A, 9B).

[0044] The external tooth 11 with the tooth thickness dimension Wa1 meshes with the tooth bottom portion 22 located between the internal tooth 21 with the tooth thickness dimension Wb3 and the internal tooth 21 with the tooth thickness dimension Wb1, the external tooth 11 with the tooth thickness dimension Wa2 engages with tooth bottom portion 22 located between the internal tooth 21 with the tooth thickness dimension Wb1 and the internal tooth 21 with the tooth thickness dimension Wb2, the external tooth 11 with the tooth thickness dimension Wa3 meshes with the tooth bottom portion 22 located between the internal tooth 21 with the tooth thickness dimension Wb2 and the internal tooth 21 with the tooth thickness dimension Wb3, and such engagement state of the inner rotor 1 and outer rotor 2 is repeated (see FIG. 10 to FIG. 12).

[0045] With such a configuration, the period of the size of volume of the interior cells Sa formed by the external teeth 11, 11, ... having mutually different tooth thickness dimensions Wa (Wa1, Wa2, Wa3) that are contained in the unit external tooth row Li of the inner rotor 1 and the crescent 3 varies non-monotonically rather than monotonically. As a result, the discharge pulsations with a larger irregularity (randomness) can be realized. Likewise, the period of the size of volume of the interior cells Sb formed by the internal teeth 21, 21, ... having mutually different tooth thickness dimensions Wb (Wb1, Wb2, Wb3) that are contained in the unit internal tooth row Lo of the outer rotor 2 and the crescent 3 also varies non-monotonically rather than monotonically. As a result, the discharge pulsations with a larger irregularity (randomness) can be realized, and the peak of discharge pulsations can be reduced.

[0046] FIG. 10 to FIG. 12 show how the volume of interior cells Sa, Sa, ... successively configured by the external teeth 11, 11, ... having mutually different tooth thickness dimensions (Wa1, Wa2, Wa3) of the unit external tooth row Li and the crescent 3 varies as the inner rotor 1 makes one revolution. The figures also show the variation of the volume of exterior cells Sb, Sb, ... successively configured by the crescent 3 and the internal teeth 21, 21, ... having mutually different tooth thickness dimensions (Wb1, Wb2, Wb3) of the unit internal tooth row Lo of the outer rotor 2 that rotates together with the inner rotor 1.

[0047] The third embodiment of the present invention will be described below with reference to FIG. 13 to FIG. 16. In the third embodiment, in the internal gear pump having the configuration similar to that of the second embodiment of the present invention, the pitch angles θa of the external teeth 11, 11, ... of the inner rotor 1 differ from each other. Thus, in the inner rotor 1, the tooth thickness dimensions Wa and pitch angles θa of the external teeth 11, 11, ... are not uniform and differ from each other. The tooth thickness dimensions Wb of the external teeth 21, 21, ... of the outer rotor 2 correspond to the tooth thickness dimensions Wa of the external teeth 11 of the inner rotor 1.

[0048] The term "corresponds" as used herein means that the external teeth 11, 11, ... of the inner rotor 1 and the internal teeth 21, 21, ... of the outer rotor 2 mesh effectively in the internal gear pump in the same manner as in the first and second embodiments. The definition of the tooth thickness dimension Wa of the external tooth 11 of the inner rotor 1 is identical to that given in the second embodiment. As a result, the volumes of interior cells Sa, Sa, ... formed between the adjacent external teeth 11, 11 of the inner rotor 1 and the crescent 3 differ from each other and there are small and large volumes. Likewise, the volumes of exterior cells Sb, Sb, ... formed between the adjacent internal teeth 21, 21 of the outer rotor 2 and the crescent 3 also differ from each other. Therefore, the amount of liquid transferred by the plurality of interior cells Sa and exterior cells Sb varies among the interior cells Sa and exterior cells Sb.

[0049] Also in the third embodiment, the inner rotor 1 has unit external teeth rows Li and the outer rotor 2 has unit internal tooth rows Lo, and the unit external tooth rows Li and unit internal tooth rows Lo are configured similarly to the unit external tooth rows Li and unit internal tooth rows Lo in the second embodiment described above. The arrangement order of sizes of tooth thickness dimensions Wa, Wa, ... of a plurality of external teeth 11, 11, ... contained in the unit external tooth row Li is preferably irregular (random).

[0050] Further, similarly to the second embodiment, the arrangement orders of sizes of the tooth thickness dimensions Wa in a plurality of unit external tooth rows Li in one inner rotor 1 are all formed according to the same pattern. In the outer rotor 2, a unit internal tooth row Lo composed a total of N (common divisor) of internal teeth 21, 21, ... with different tooth thickness dimensions Wb is provided similarly to the above-described unit external tooth row Li. Where the inner rotor 1 and outer rotor 2 mesh and rotate normally, the unit external tooth rows Li of the inner rotor 1 and the unit internal tooth rows Lo of the outer rotor 2 mesh periodically.

[0051] Further, similarly to the second embodiment, the following specific integer values are taken for the number of teeth Za of the inner rotor 1 and the number of teeth Zb of the outer rotor 2. Thus, the number of teeth Za of the inner rotor 1 is taken as 6 and the number of teeth Zb of the outer rotor 2 is taken as 9 (see FIGS. 13A, 13B). The tooth thickness dimension Wa1, tooth thickness dimension Wa2, and tooth thickness dimension Wa3 are used to indicate that the three external teeth 11, 11, ... contained in the unit external tooth row Li have different tooth thickness dimensions Wa. The size relationship of the tooth thickness dimensions is Wa1 > Wa2 > Wa3 (see FIG. 13A).

[0052] Furthermore, the pitch angles θa of the external teeth 11, 11, ... contained in the unit external tooth row Li are assumed to differ from each other. More specifically, the pitch angle of the external teeth 11, 11 with the tooth thickness dimension Wa1 and tooth thickness dimension Wa2 is taken as θa1, the pitch angle of the external teeth 11, 11 with the tooth thickness dimension Wa2 and tooth thickness dimension Wa3 is taken as θa2, and the pitch angle of the external teeth 11, 11 with the tooth thickness dimension Wa3 and tooth thickness dimension Wa1 is taken as θa3. Here, the pitch angle of the external teeth 11, 11 with the tooth thickness dimension Wa3 and tooth thickness dimension Wa1 is a pitch angle of the pitch angle of the external tooth 11 with the tooth thickness dimension Wa3 and the pitch angle of the external tooth 11 with the tooth thickness dimension Wa1 of the adjacent unit external rows Li, Li.

[0053] Further, similarly to the configuration of the second embodiment, the unit internal tooth row Lo of the outer rotor 2 is also composed of three internal teeth 21, 21, ... having mutually different tooth thickness dimensions Wb, and the internal teeth 21, 21, ... contained in the unit internal tooth row Lo also have respectively different tooth thickness dimensions Wb1, Wb2, Wb3. The inner rotor 1 has two unit external tooth rows Li, Li, and the outer rotor 2 has three unit internal tooth rows Lo, Lo, ... (see FIGS. 13A, 13B). The pitch angles θb of the internal teeth 21, 21, ... in the unit internal tooth row Lo of the outer rotor 2 also differ from each other correspondingly to the external teeth 11, 11, ... of the inner rotor 1. More specifically, as shown in FIG. 13B, the pitch angle θb1, pitch angle θb2, and pitch angle θb3 differ from each other.

[0054] With such a configuration, the teeth contained in the unit external tooth row Li of the inner rotor 1 have mutually different tooth thickness dimensions Wa (Wa1, Wa2, Wa3) and the pitch angles θa (θa1, θa2, θa3) of the external teeth 11, 11, ... also differ from each other. As a result, the period of the size of volume of the interior cells Sa configured by the external teeth 11, 11, ... and crescent 3 varies non-monotonically rather than monotonically. Therefore, discharge pulsations with a larger irregularity (randomness) can be realized. Likewise, the period of the size of volume of the exterior cells Sb configured by the crescent 3 and the internal teeth 21, 21, ... having mutually different tooth thickness dimensions Wb (Wb1, Wb2, Wb3) and contained in the unit internal tooth row Lo of the outer rotor 2 also varies non-monotonically rather than monotonically. Therefore, discharge pulsations with a larger irregularity (randomness) can be realized.

[0055] FIG. 14 to FIG. 16 show how the volume of interior cells Sa, Sa, ... successively configured by the external teeth 11, 11, ... having mutually different tooth thickness dimensions (Wa1, Wa2, Wa3) of the unit external tooth row Li and the crescent 3 varies as the inner rotor 1 makes one revolution in the third embodiment. The figures also show the variation of the volume of exterior cells Sb, Sb, ... successively configured by the crescent 3 and the internal teeth 21, 21, ... having mutually different tooth thickness dimensions (Wb1, Wb2, Wb3) of the unit internal tooth row Lo of the outer rotor 2 that rotates together with the inner rotor 1.

Claims

1. An internal gear pump, comprising: an outer rotor having internal teeth formed therein; an inner rotor disposed on the inner peripheral side of the outer rotor and having formed therein external teeth that mesh with the internal teeth; and a crescent disposed in a clearance between the outer rotor and the inner rotor, wherein
pitch spacings of the external teeth of the inner rotor are formed as non-equal spacings, and pitch spacings of the internal teeth of the outer rotor correspond to the pitch spacings of the external teeth of the inner rotor.

2. The internal gear pump according to claim 1, wherein a row of teeth with the number of teeth equal to the common divisor of the number of external teeth of the inner rotor and the number of internal teeth of the outer rotor is taken as a non-equal spacing pitch row, and identical non-equal spacing pitch rows are formed repeatedly.

3. The internal gear pump according to claim 2, wherein the number of the non-equal spacing pitch rows is 3 or more.

4. The internal gear pump according to claim 1, 2, or 3, wherein the number of teeth of the inner rotor is 6 or more, and the number of teeth of the outer rotor is 9 or more.

5. The internal gear pump according to any of claims 1 to 4, wherein the tooth thicknesses of the external teeth and internal teeth in the non-equal spacing pitch rows are set to differ.

6. The internal gear pump according to any of claims 1 to 5, wherein the tooth profile of the inner rotor is a trochoidal tooth profile.

7. An internal gear pump, comprising: an outer rotor having internal teeth formed therein; an inner rotor disposed on the inner peripheral side of the outer rotor and having formed therein external teeth that mesh with the internal teeth; and a crescent disposed in a clearance between the outer rotor and the inner rotor, wherein
tooth thickness dimensions of the external teeth of the inner rotor are formed to be non-uniform, and the tooth thicknesses of the internal teeth of the outer rotor correspond to the tooth thickness dimensions

of the inner rotor.

8. The internal gear pump according to claim 7, wherein the number of external teeth of the inner rotor and the number of internal teeth of the outer rotor are multiples of a common divisor of the number of external teeth and the number of internal teeth, a plurality of unit external tooth rows having the number of teeth at least equal to the greatest common divisor and also having different tooth thicknesses are provided in the external teeth of the inner rotor, and a plurality of unit internal tooth rows in which the internal teeth corresponding to the unit external tooth row of the inner rotor are arranged consecutively are provided in the outer rotor.

9. The internal gear pump according to claim 8, wherein the number of unit external tooth rows of the inner rotor is 3 or more.

10. The internal gear pump according to claim 7, 8, or 9, wherein the number of teeth of the inner rotor is 6 or more, and the number of teeth of the outer rotor is 9 or more.

11. The internal gear pump according to claim 7, 8, 9, or 10, wherein the tooth profile of the inner rotor is a trochoidal tooth profile.

12. The internal gear pump according to claim 7, 8, 9, 10, or 11, wherein a pitch angle of the external teeth of the inner rotor is formed to be non-uniform, and a pitch angle of the internal teeth of the outer rotor corresponds to the pitch angle of the external teeth.

13. The internal gear pump according to claim 8, 9, 10, 11, or 12, wherein a pitch angle of the external teeth of the unit external tooth row of the inner rotor is formed to be non-uniform, and a pitch angle of the internal teeth of the unit internal tooth row of the outer row corresponds to the pitch angle of the external teeth of the unit external tooth row.

Fig. 1A

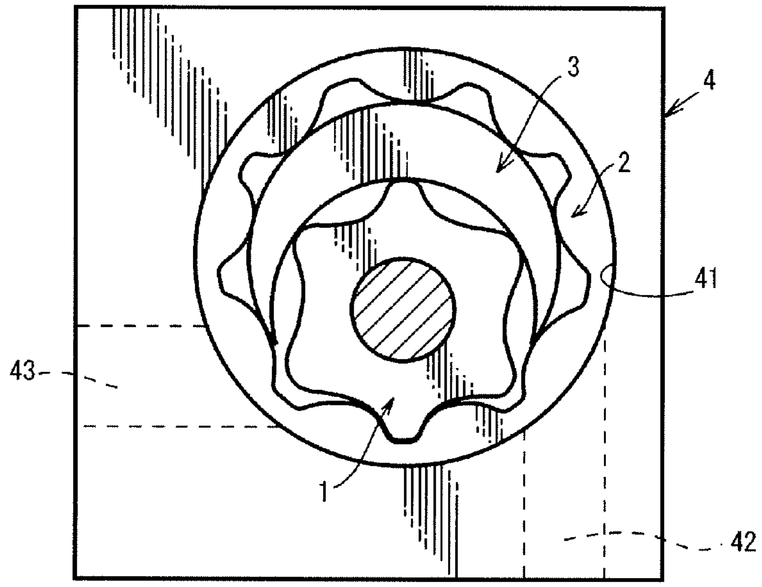
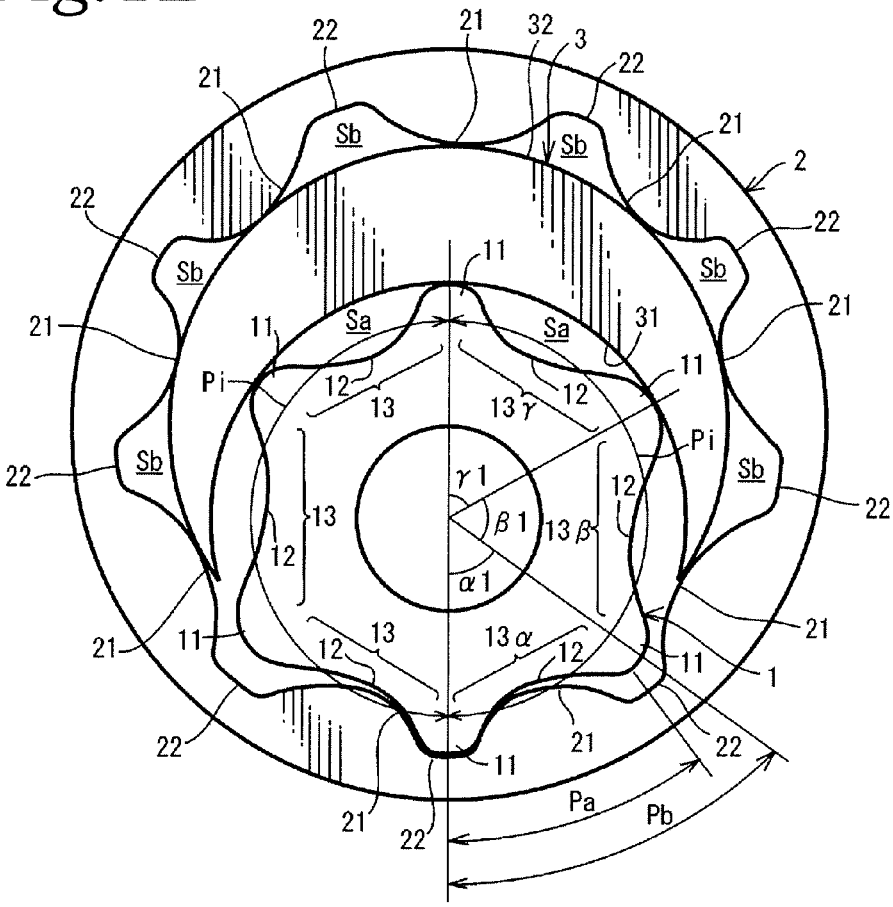

3
4
2
41
43
1
42

Fig. 1B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13γ
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Pi
Sb
Sb
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γ1
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22
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β1
13β
12
α1
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22
Pa
Pb

Fig.2A

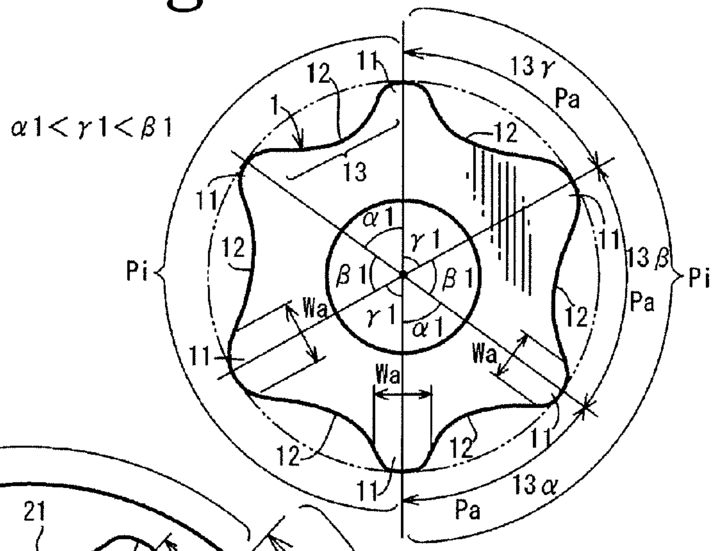


Fig.2B

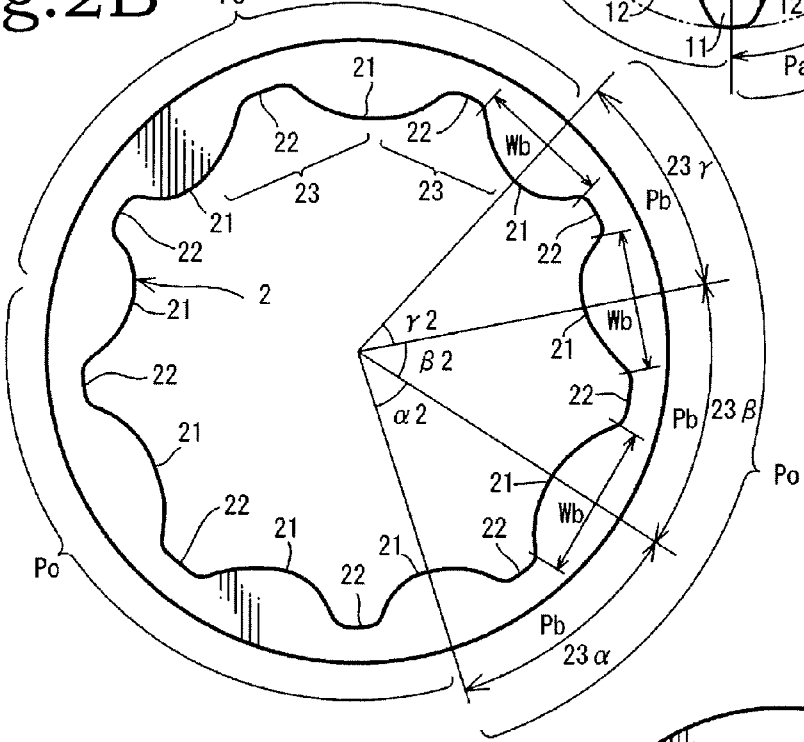


Fig.2C

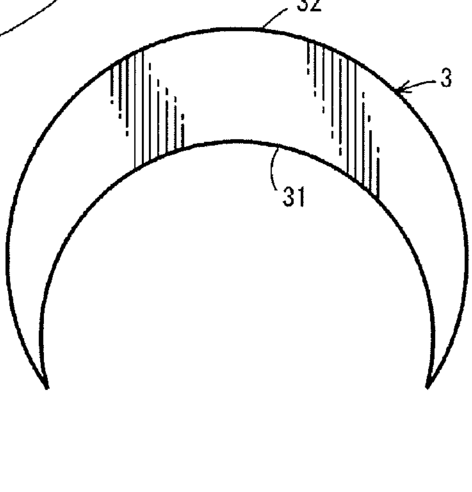
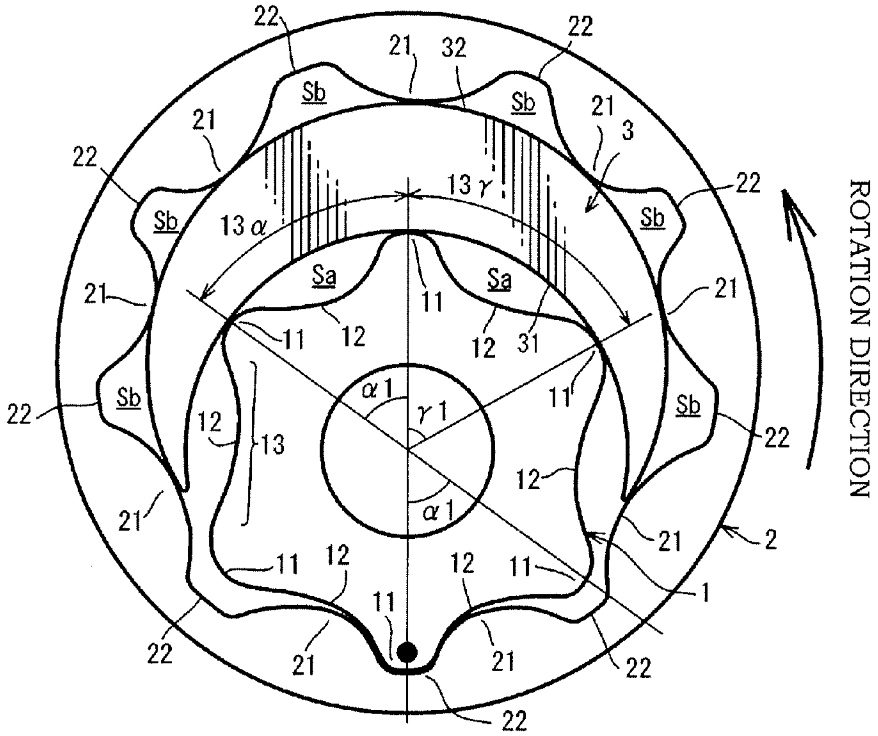


Fig.3A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13 γ
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13 α
Sa
Sa
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12
12
31
α 1
11
22
Sb
γ 1
Sb
22
12
13
12
α 1
21
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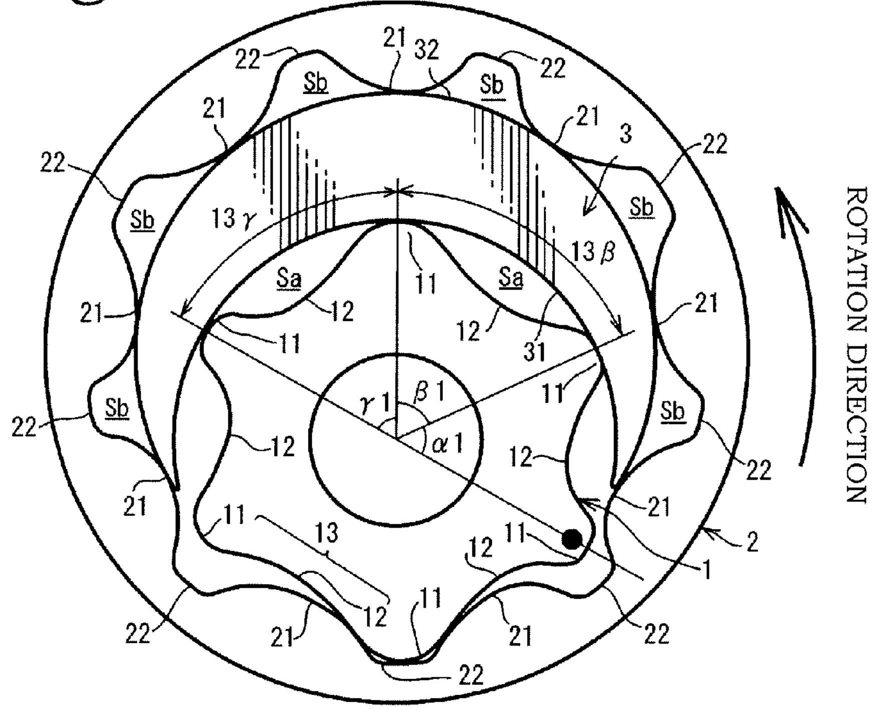
12
12
11
1
11
22
21
21
22
22
ROTATION DIRECTION

Fig.3B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13 β
Sa
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12
11
31
11
γ 1
β 1
22
Sb
Sb
α 1
12
12
22
21
21
11
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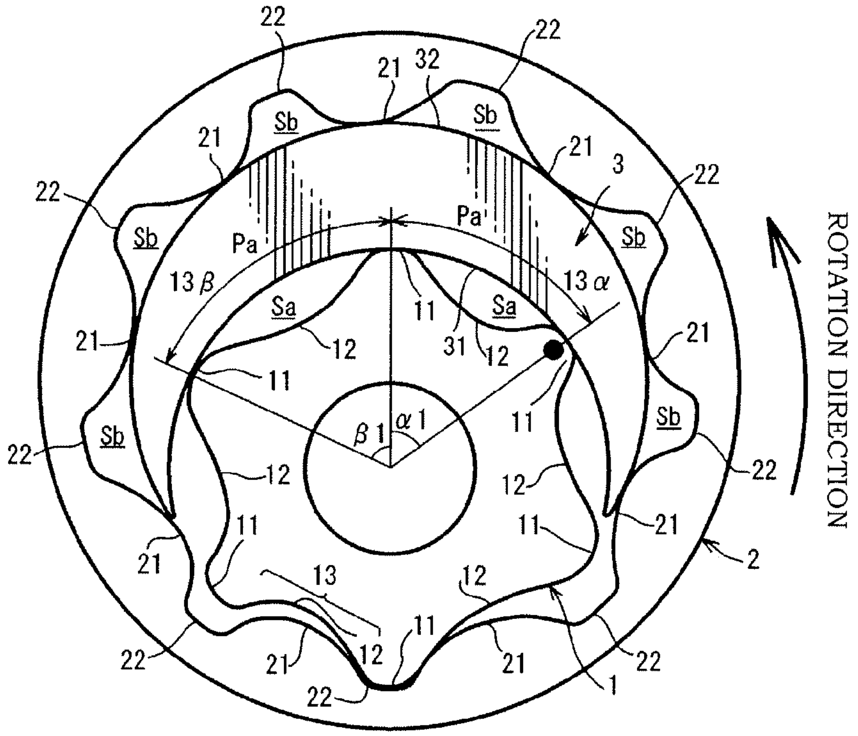
11
2
12
1
12
11
22
21
21
22
22
ROTATION DIRECTION

Fig.4A


ROTATION DIRECTION
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Sa
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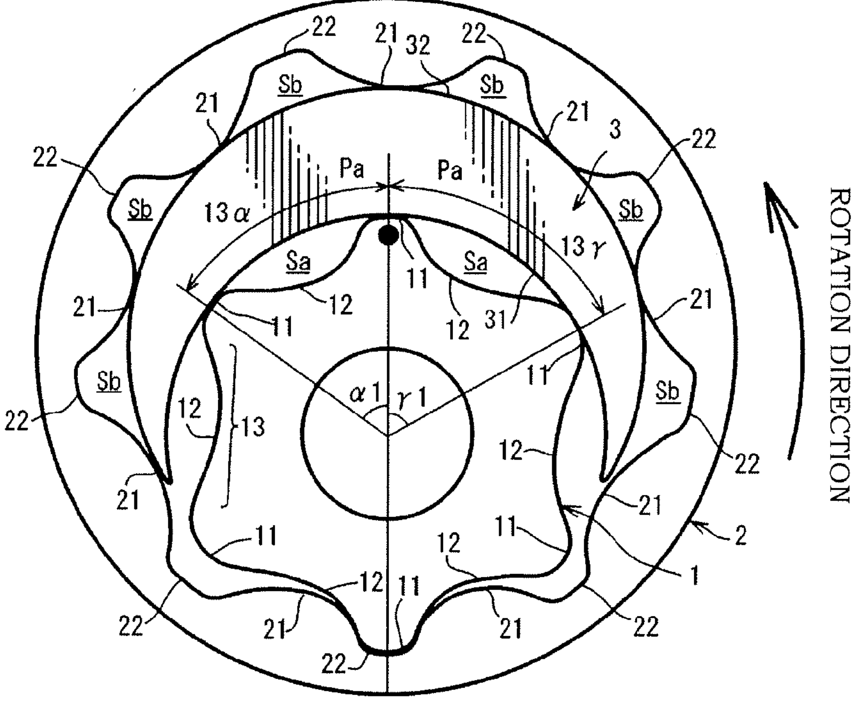
α1
β1
22
21
32
31
11
12
13
3
2
1

Fig.4B


ROTATION DIRECTION
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Sa
Pa
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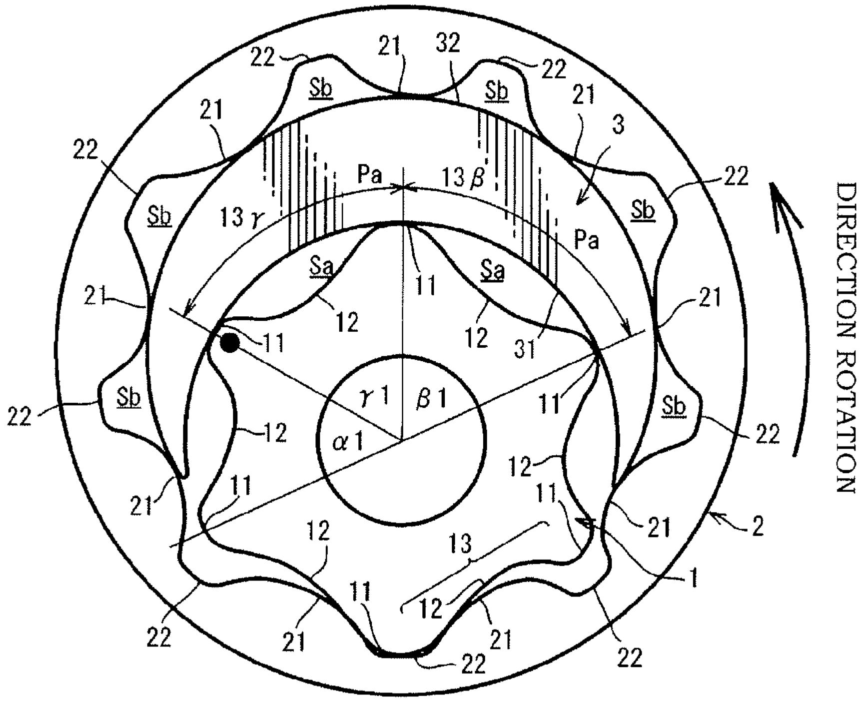
13γ
α1
γ1
22
21
32
31
11
12
13
3
2
1

Fig.5A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13γ
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Pa
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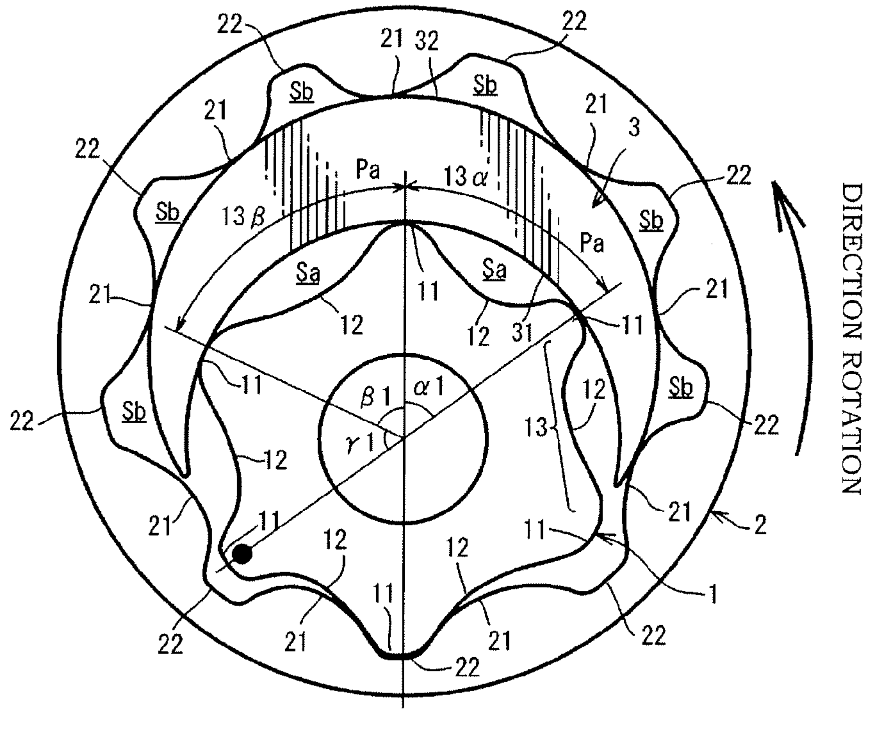
12
31
21
11
γ1
β1
11
22
Sb
Sb
22
12
α1
12
21
11
11
21
2
13
12
1
11
12
22
21
21
22
22
DIRECTION ROTATION

Fig.5B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Sa
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12
12
31
11
11
β1
α1
Sb
22
Sb
12
22
13
γ1
12
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11
11
2
12
12
1
11
22
21
21
22
22
DIRECTION ROTATION

Fig.6A

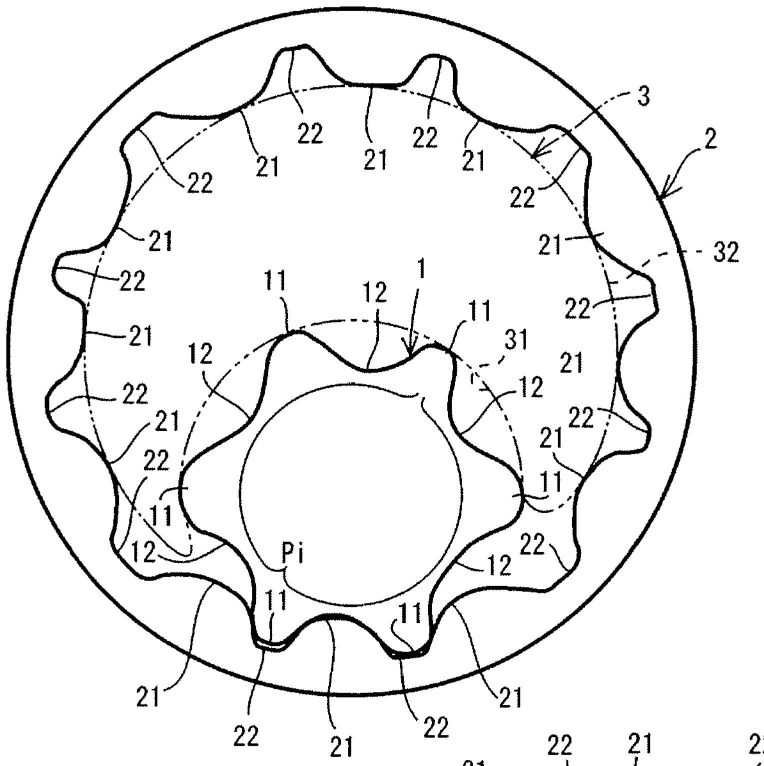


Fig.6B

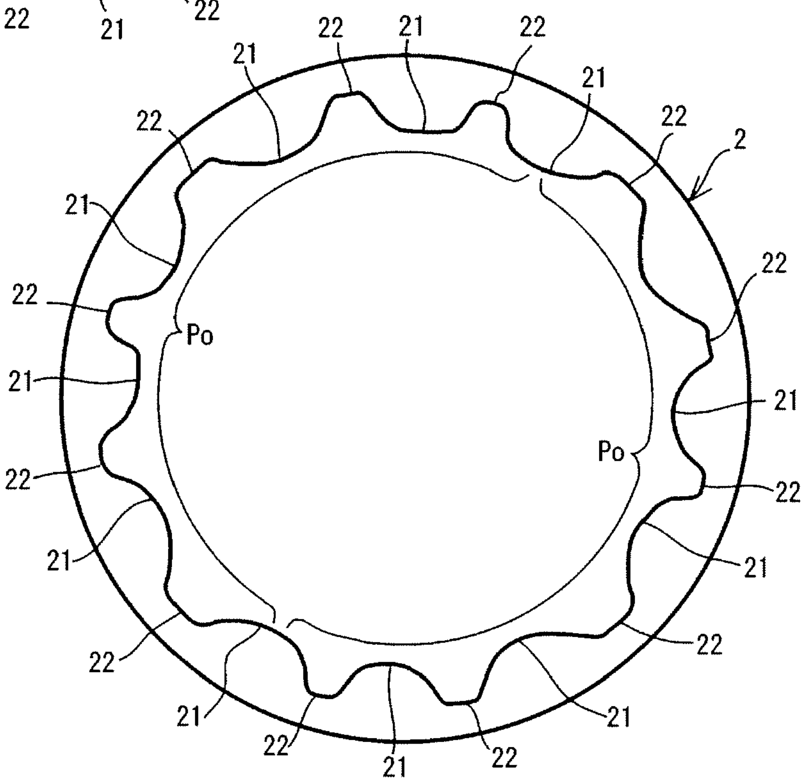


Fig.7A

TOOTH PROFILE IN ACCORDANCE WITH THE PRESENT INVENTION

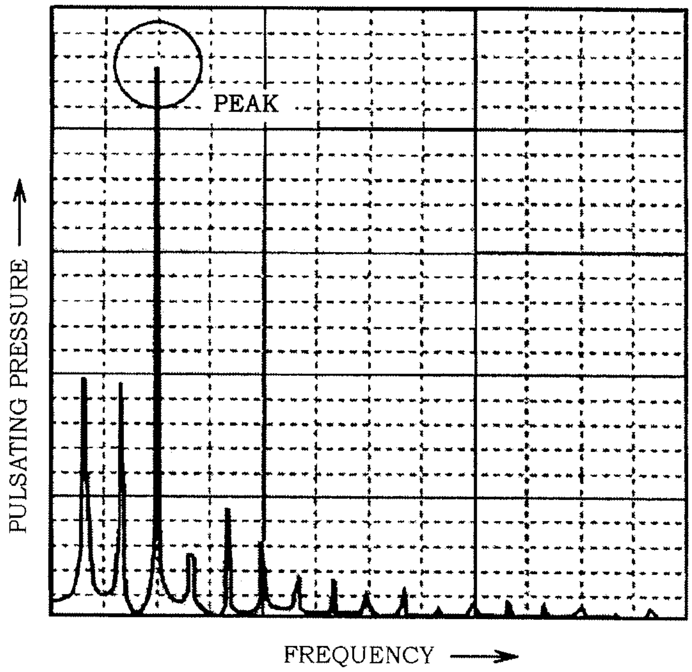


Fig.7B

CONVENTIONAL TOOTH PROFILE

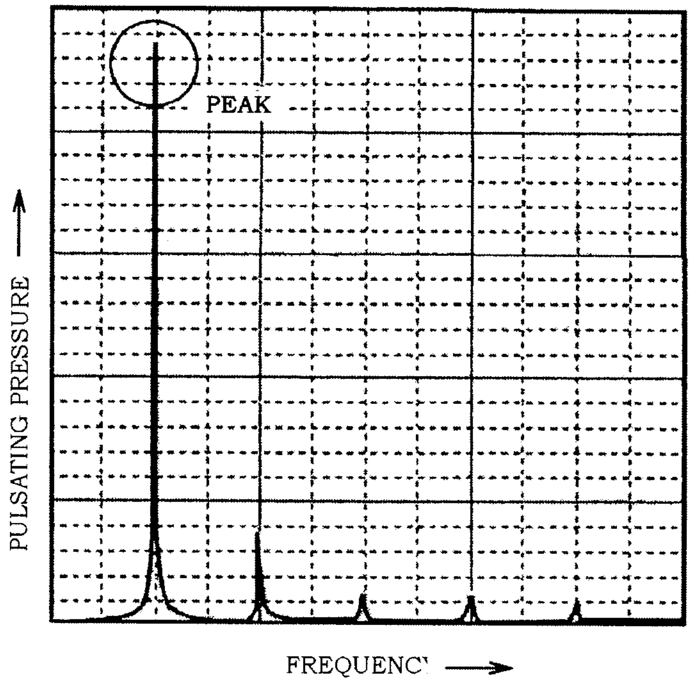
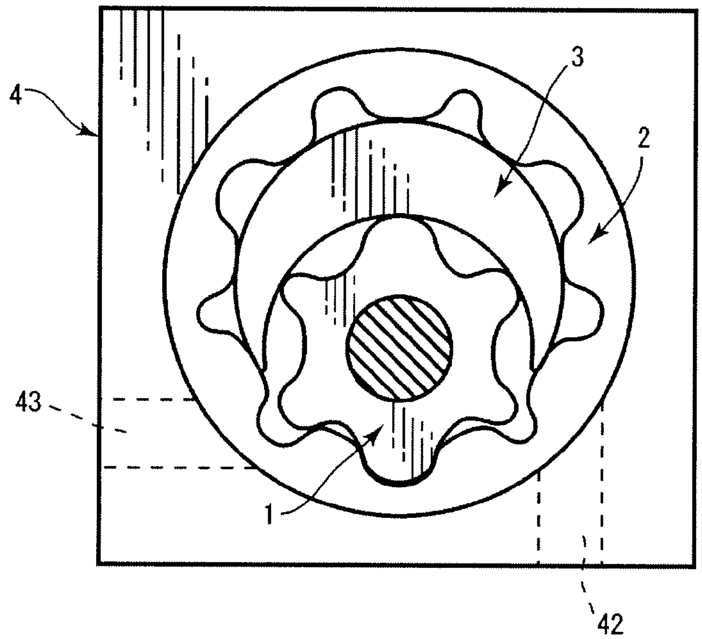


Fig.8A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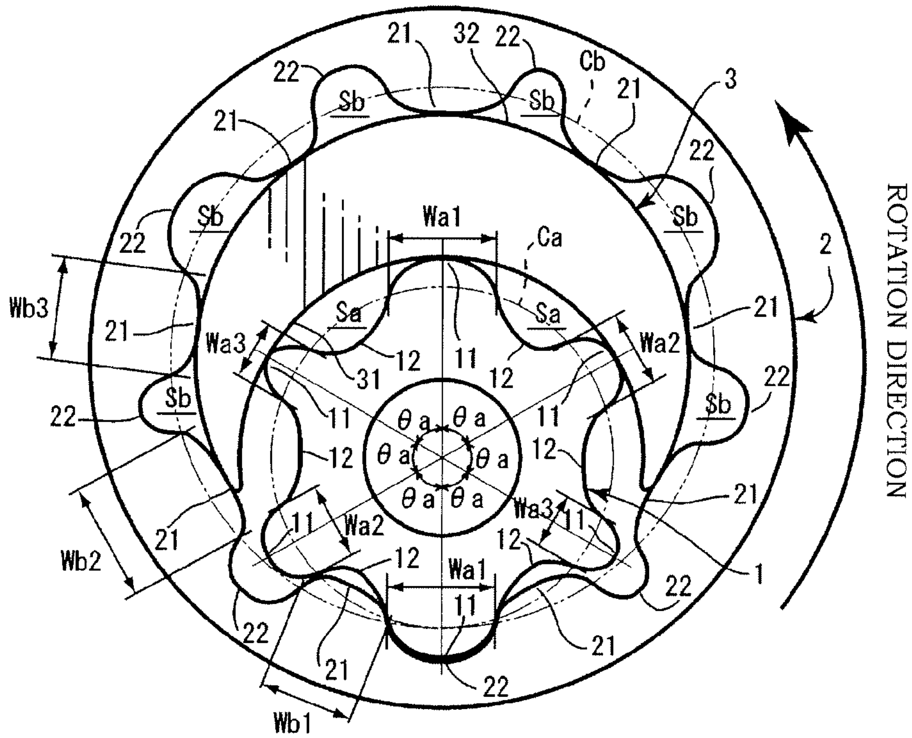
3
2
43
1
42

Fig.8B


21
32
22
Cb
21
3
22
Sb
Sb
21
22
Sb
Sb
22
Wa1
Ca
2
ROTATION DIRECTION
Wb3
21
Sa
Sa
21
Wa3
12
11
12
Wa2
31
22
Sb
22
11
θa
θa
11
22
12
θa
θa
12
21
θa
θa
Wa3
11
21
11
Wa2
12
Wb2
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12
22
1
Wa1
11
22
21
21
22
Wb1

Fig.9A

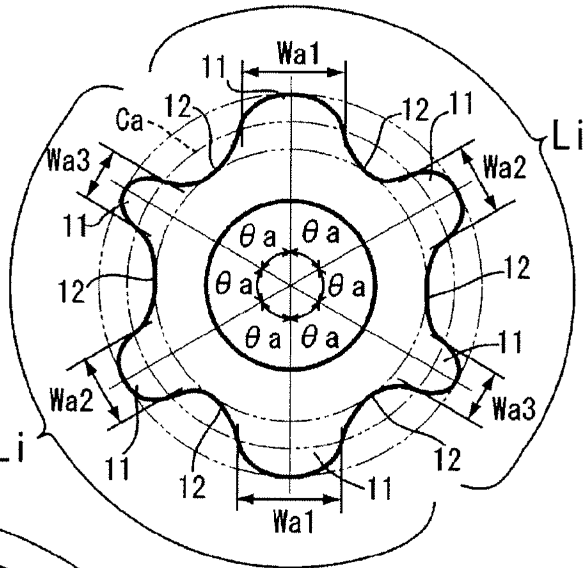


Fig.9B

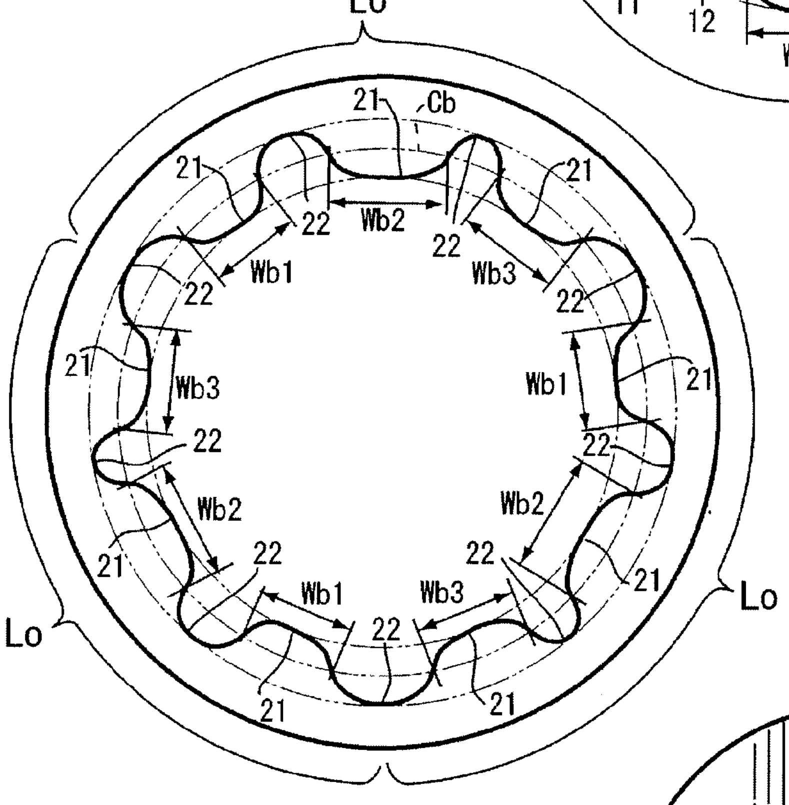


Fig.9C

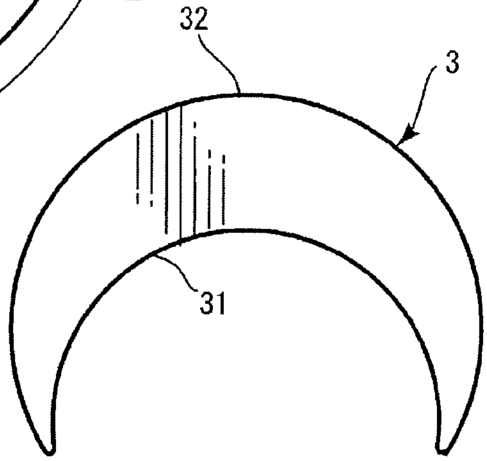


Fig. 10A

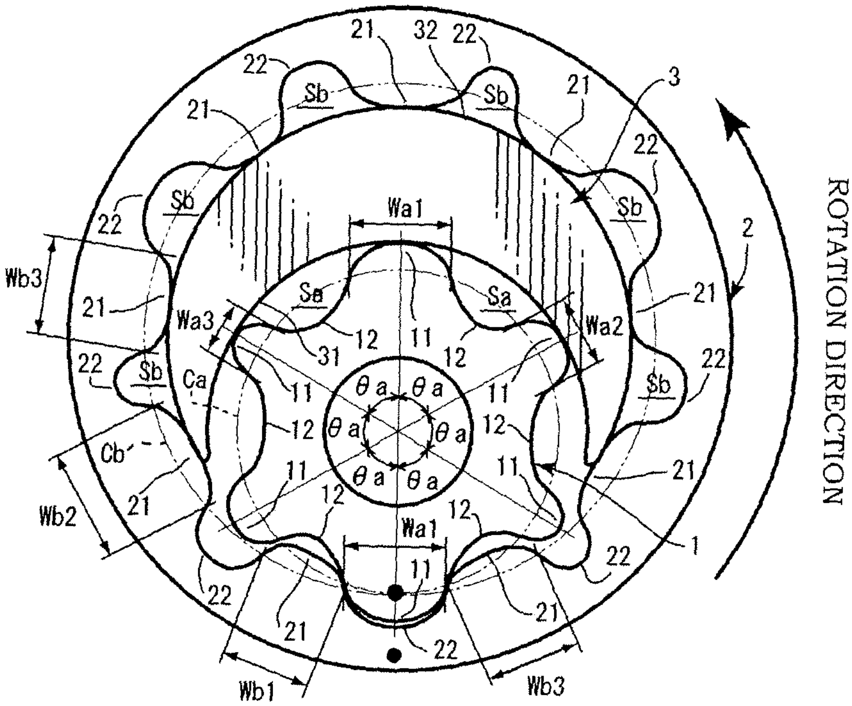


Fig. 10B

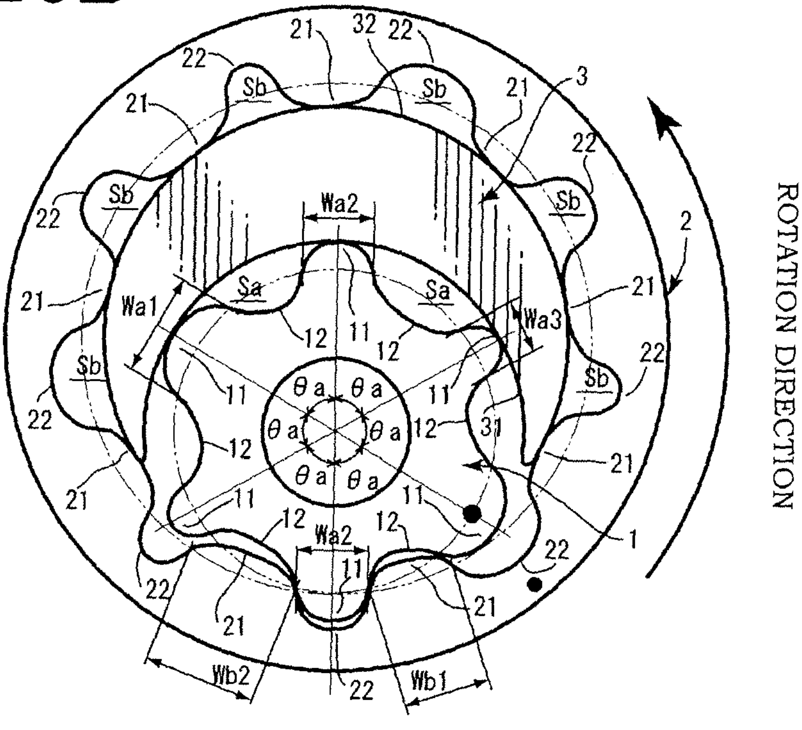


Fig. 11A

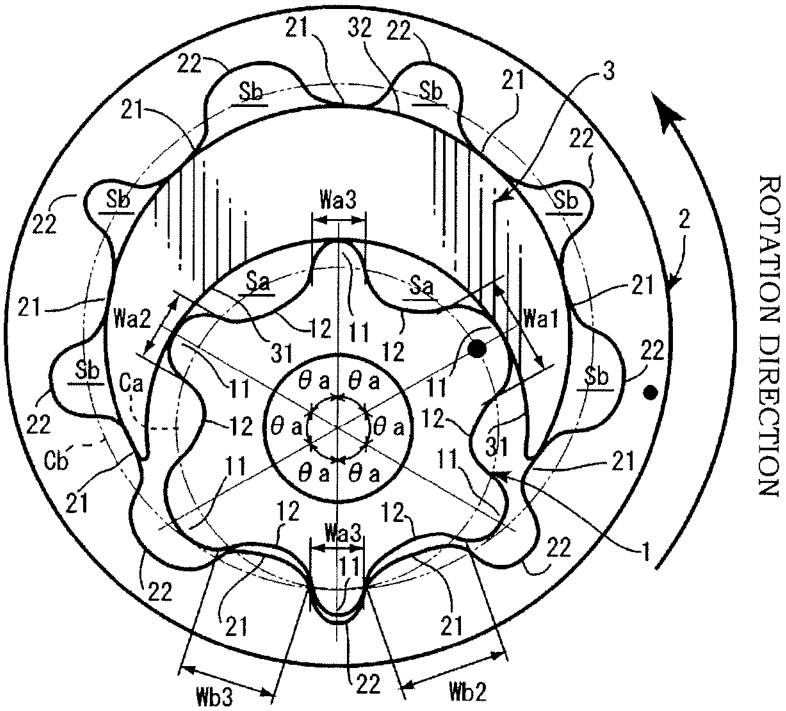


Fig. 11B

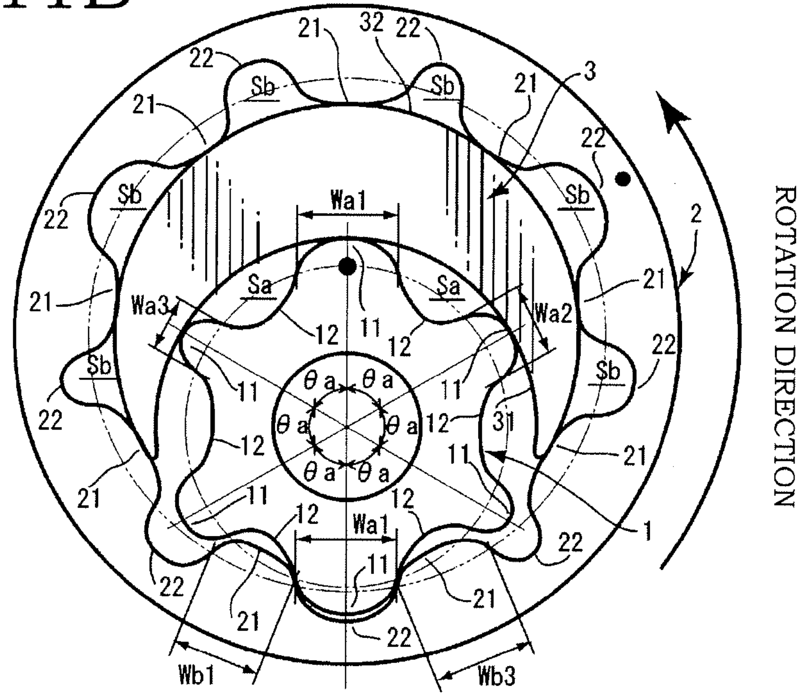


Fig.12A

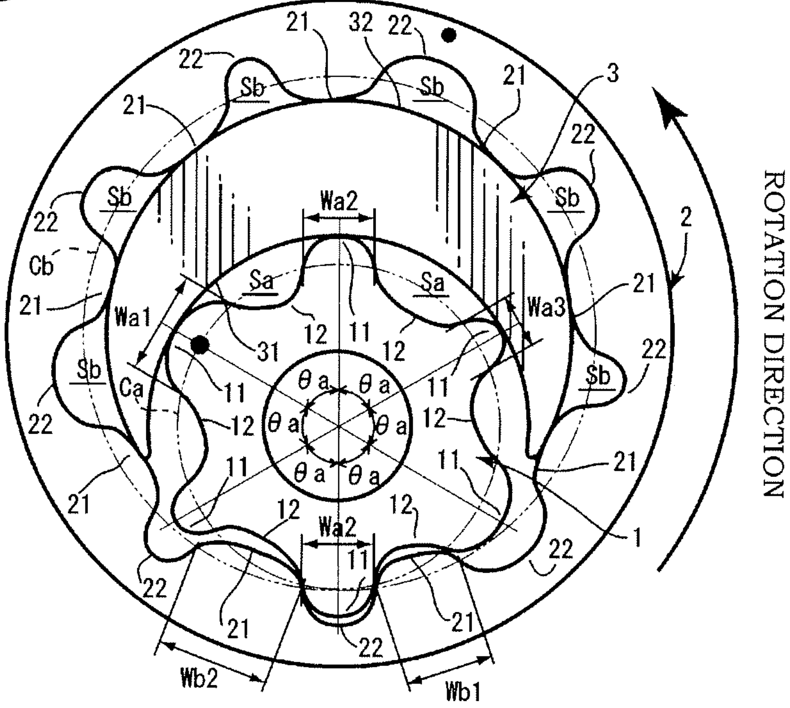


Fig.12B

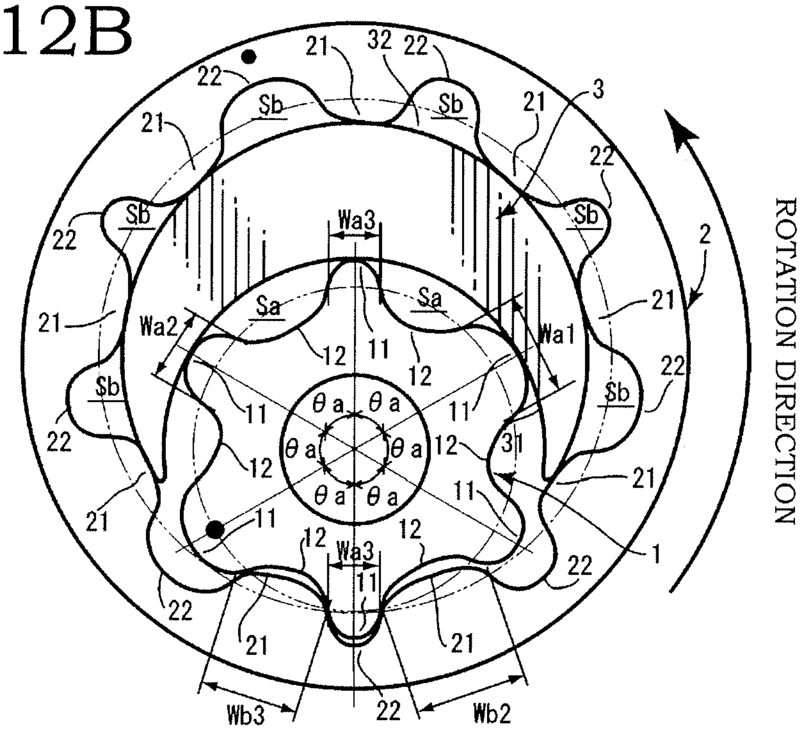


Fig. 13A

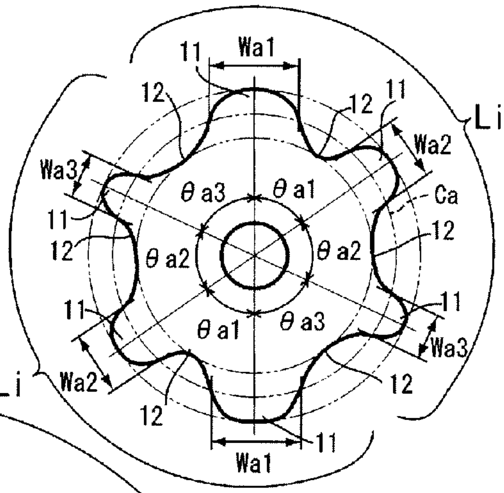


Fig. 13B

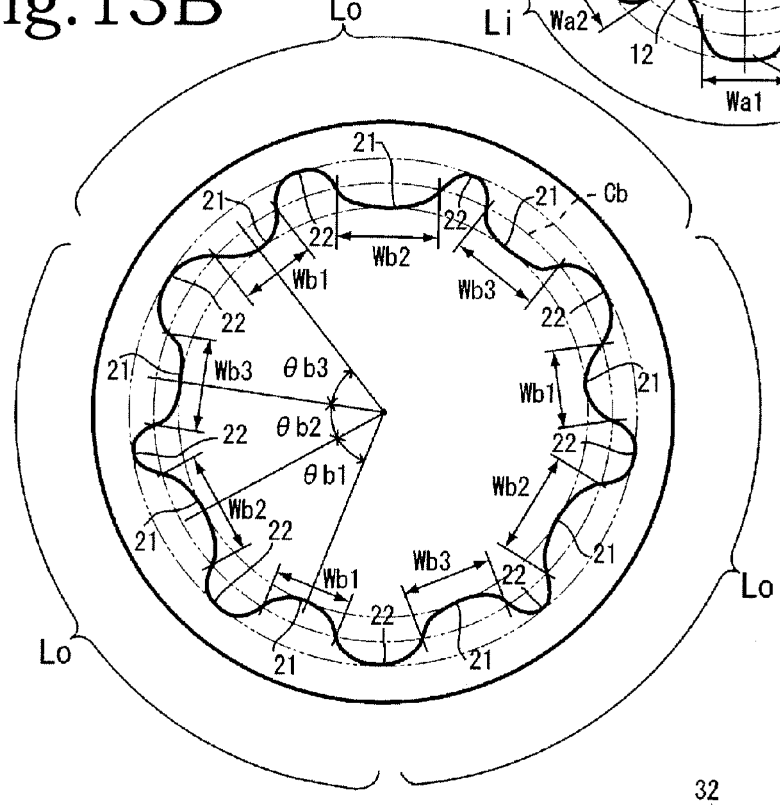


Fig. 13C

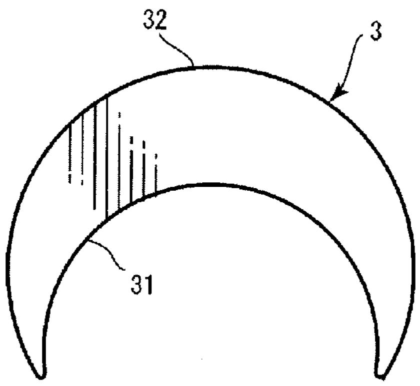


Fig. 14A

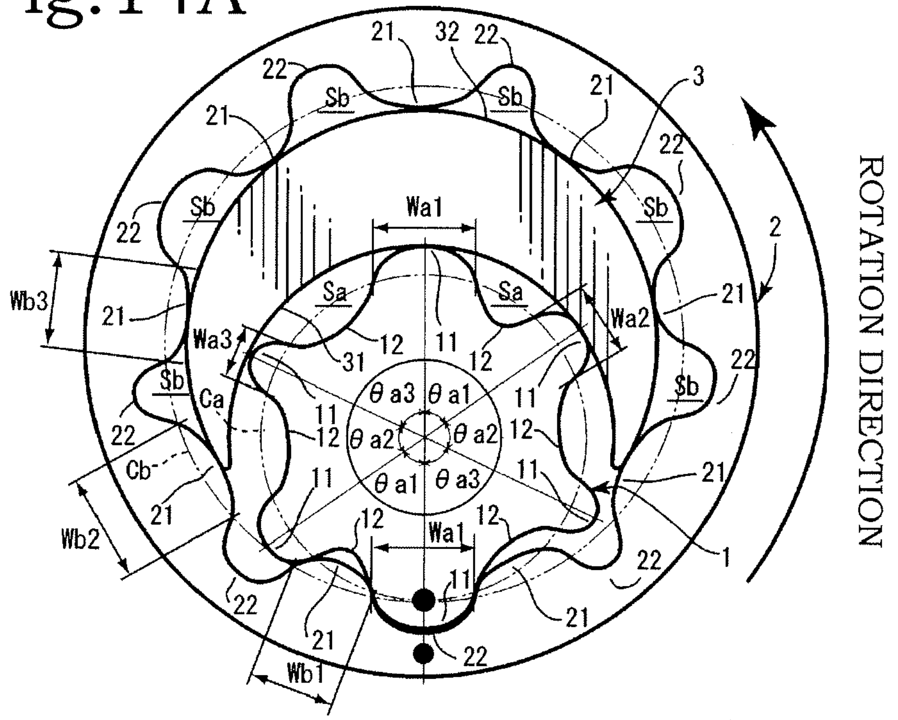


Fig. 14B

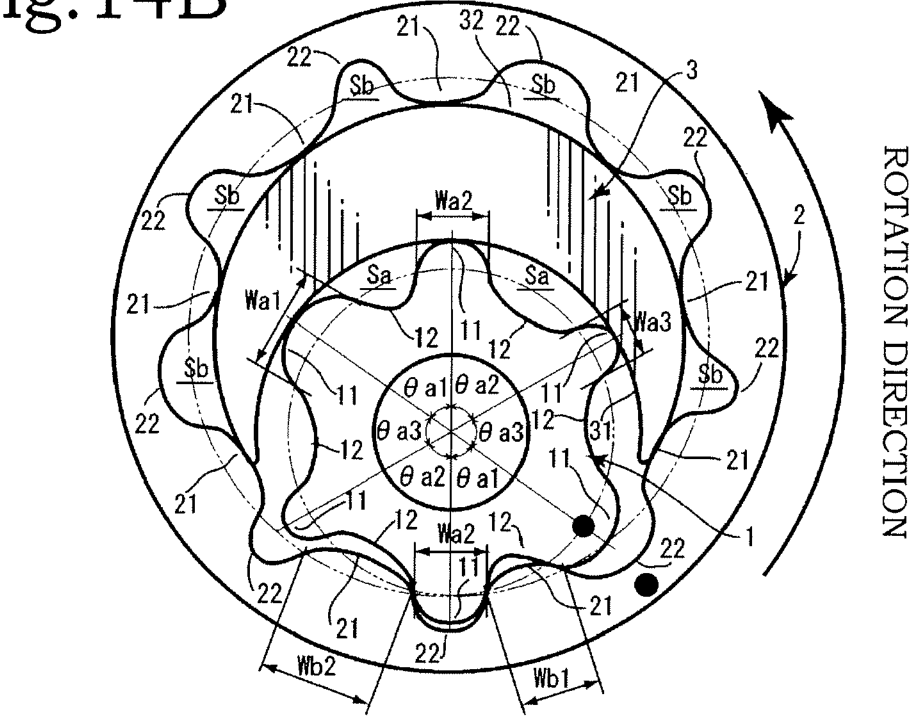


Fig. 15A

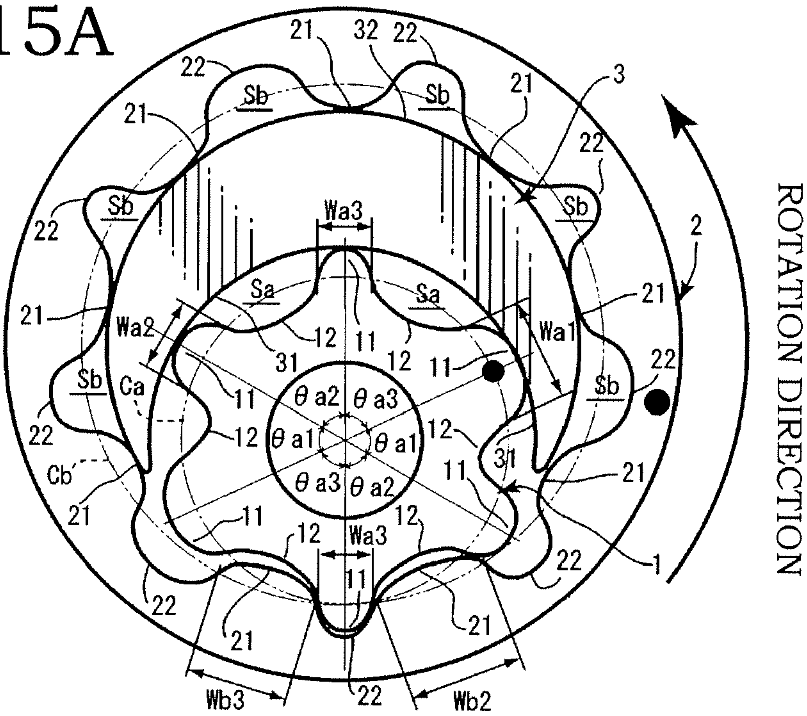


Fig. 15B

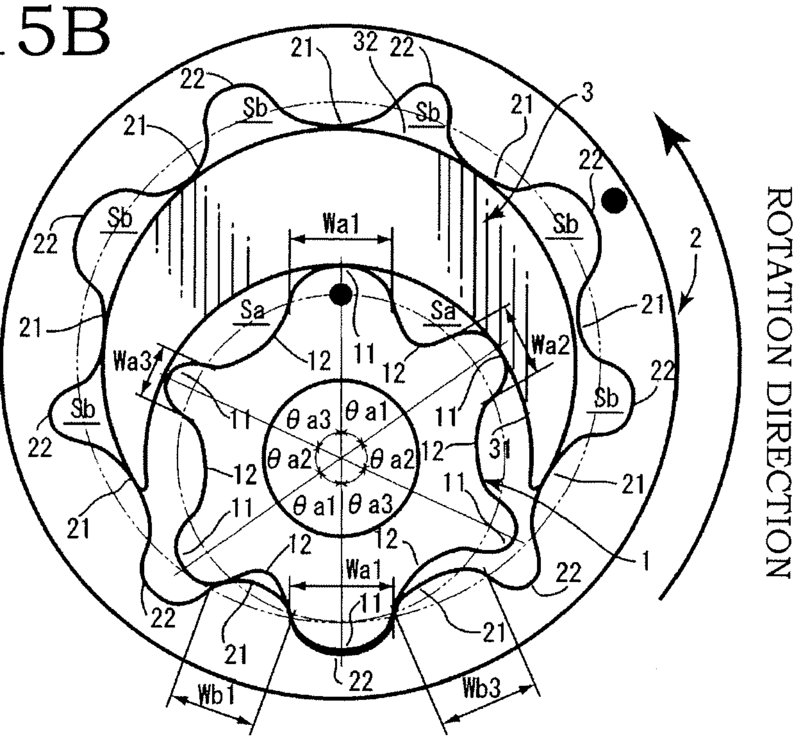


Fig. 16A

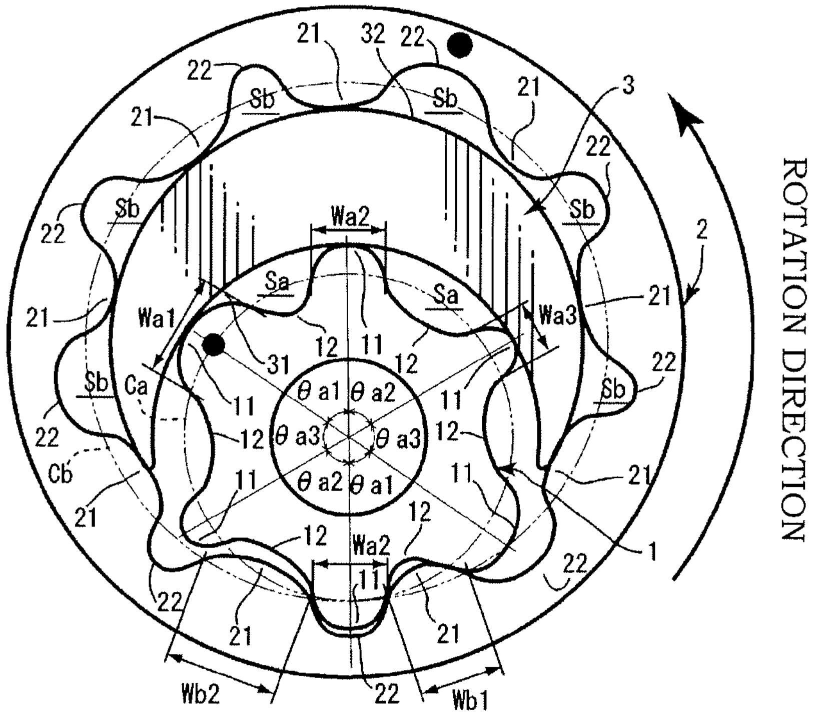
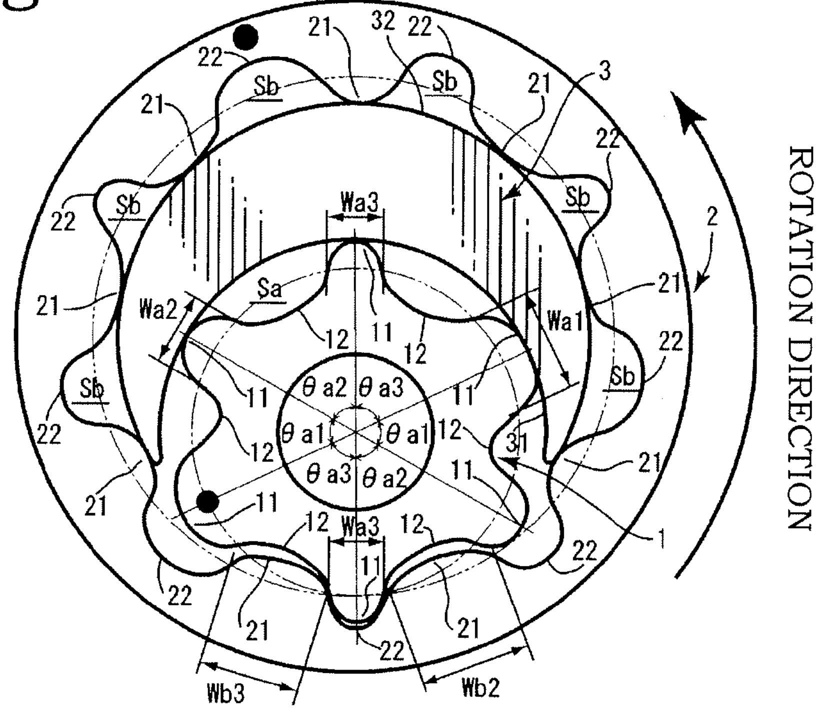


Fig. 16B



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Application Number
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Place of search	Date of completion of the search	Examiner
The Hague	29 October 2008	Sbresny, Heiko

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