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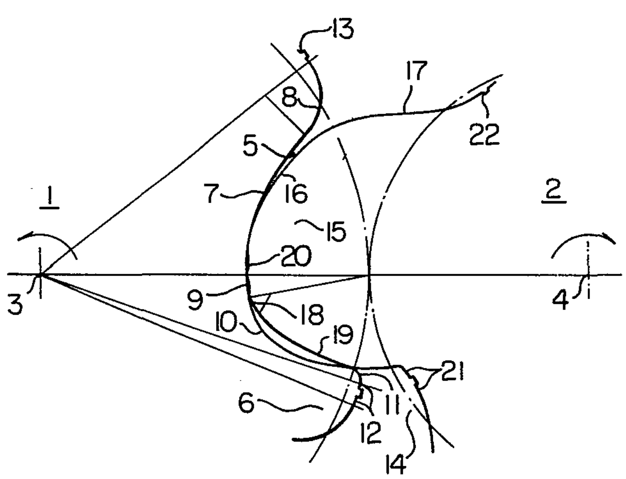
(54) **Screw rotor.**

(57) A pair of screw rotors in the form of a female rotor and a male rotor, wherein, by taking deformation of the rotor due to thermal expansion during operation into consideration, the female rotor has a rotor tooth form including a flank of a surface of advance constituted by an arc (7) and a second order curve, and a flank of a surface of retrocession (10) constituted by a curve generated by an arc (18) of a forward end portion of a robe on the male rotor and an arc, and the male rotor has a rotor tooth form essentially formed by generating loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof.

In addition to the influences exerted by the thermal expansion, the backlash of synchronizing means may be taken into consideration in deciding the rotor tooth forms.

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# SCREW ROTOR

## BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

This invention relates to screw rotors of screw compressors, and more particularly it deals with a pair of screw rotors suitable for use with a dry type screw compressor, blower, expander, etc., in which the rotors rotate while in meshing engagement with each other by using synchronizing means without being brought into contact with each other.

Generally, in oilless type screw compressors for use in applications where mingling of oil in the gas discharged from a screw compressor is not desirable, transmission of rotation between screw rotors forming a pair is effected through synchronizing means mounted at shaft portions outside the working chambers of the rotors, and at this time the rotors rotate while meshing with each other without coming into contact with each other. The screw rotors of this type of screw compressors have a greater chance of the gas leaking from between the rotors and the casing and between the rotors and from the blowholes than the screw rotors of screw compressors of the oil-cooled type in which the oil is injected into the working chambers in which the rotors mesh with each other to effect lubrication and cooling of the rotors and provide a seal to the rotors.

As a result, the size of the clearance and the blowholes exert great influences on the efficiency of the compressors. In view of this fact, there has been a demand for a high degree of accuracy and precision with which the rotors are shaped and for a rotor tooth form of small blowholes.

In the screw rotors of this type of screw compressors, the teeth of the rotors have their temperatures raised to a high level during operation and are consequently greatly deformed during operation as compared with the rotor teeth in normal temperature during an inoperative period. Thus, in designing the shape of the two rotors of a screw compressor, it is necessary not only to take into consideration the dimensions of the rotors to provide clearances between the rotors and between the rotors and the casing in such a manner that the rotors are not brought into contact with each other during operation and yet the clearance is minimized, but also to provide means for avoiding the occurrence of seizure between the rotors and the casing.

Heretofore, it has been usual practice to decide, in designing screw rotors, a clearance between the two rotors and a clearance between the rotors and the casing based on a casual idea, and consequently the clearances formed have had no theoretical basis. This has given rise to a number of problems with regard to the operation efficiency of the screw compressors that have remained unsolved.

More specifically, as a process for imparting a clearance between the two rotors, proposals have been made to use a male rotor as a reference for providing a basic tooth form of the rotors and a clearance of a predetermined size is provided in the direction normal to the female rotor tooth form by taking into consideration deformation and other factors that might possibly be caused to occur by thermal expansion during operation. The screw rotors produced by this process have already been put to practical use.

In view of the fact, however, that deformation of the tooth form on account of thermal expansion may vary depending on the shape of the tooth form, the value of the clearance decided by the process described hereinabove would not be considered an optimum value that is obtained by careful analysis of the condition of the rotors expanded by heat and of the condition of the clearance during operation.

In another process for imparting a clearance to the two rotors of a screw compressor that is also known in the art, a small clearance is provided to a region in which the relative sliding movement between the two rotor teeth meshing with each other is small and a sufficiently large clearance is provided to other regions of the rotor teeth. This process is disclosed in U.S. Patent Specification No. 3,414,189, for example.

This process could not, however, be considered to take the thermal deformation of the two rotors into consideration quantitatively in providing a clearance to between the rotor.

SUMMARY OF THE INVENTION

OBJECT OF THE INVENTION

An object of this invention is to provide a pair of screw rotors wherein a minimum clearance can be provided through the entire region of the teeth of the female rotor and the male rotor in meshing engagement with each other during operation to thereby greatly improve performance.

Another object is to provide a pair of screw rotors wherein the female rotor and the male rotor are constructed by taking into consideration the backlash of the synchronizing gears to avoid seizing on account of contact of the two rotors during operation, to thereby improve the reliability of the screw compressor.

Still another object is to provide a pair of screw rotors capable of greatly improving performance by taking into consideration the axial temperature distribution inside and outside the rotors when they are constructed.

A further object is to provide a pair of screw rotors capable of greatly prolonging the service life of the tools used for producing the screw rotor and having a reduced area of blowholes.

To accomplish the aforesaid objects, the invention provides the following outstanding characteristics. One of them is that novel tooth forms are imparted to a female rotor and a male rotor rotating about two axes parallel to each other and forming a pair of screw rotors as follows: the flank of the surface of advance of the female rotor is constituted by a first flank of the surface of advance formed by a second order curve, and a second flank of the surface of advance formed by an arc of an imaginary circle of a radius $R_1$ having its center in the pitch circle of the female rotor in normal temperature condition. The flank of the surface of retrocession of the female rotor is constituted by a first flank of the surface of retrocession generated by a forward end portion of a robe of the male rotor formed by an arc of an imaginary circle of a radius $R_4$ having its center on a line drawn from the pitch point which is inclined through an angle $\phi$ with respect to a straight line connecting the two axes together, and a second flank of the surface of retrocession formed by an arc of an imaginary circle of a radius $R_3$ of an imaginary circle having its center in the pitch circle of the female rotor. The male rotor is essentially formed by generating loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof, to thereby provide basic tooth forms of the female rotor and the male rotor. One of the basic tooth forms of the female and male rotors is used as one rotor tooth form, and a rotor tooth form is obtained from the one basic tooth form by deformation caused by thermal expansion during operation of the rotors. Another rotor tooth form is generated based on the thermally deformed tooth form and, and a normal temperature version of the generated thermally deformed tooth form is produced and used as the other rotor tooth form.

Another outstanding characteristic is that novel tooth forms are imparted to a female rotor and a male rotor rotating about two axes parallel to each other and forming a pair of screw rotors as follows: the flank of the surface of advance of the female rotor is constituted by a first flank of the surface of advance formed by a second order curve, and a second flank of the surface of advance formed by an arc of an imaginary circle of a radius $R_1$ having its center in the pitch circle of the female rotor in normal temperature condition. The flank of the surface of retrocession of the female rotor is constituted by a first flank of the surface of retrocession generated by a forward end portion of a robe of the male rotor formed by an arc of an imaginary circle of a radius $R_4$ having its center on a line drawn from the pitch point which is inclined through an angle $\phi$ with respect to a straight line connecting the two axes together, and a second flank of the surface of retrocession formed by an arc of an imaginary circle of a radius $R_3$ of an imaginary circle having its center in the pitch circle of the female rotor. The male rotor is essentially formed by generating loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof, to thereby provide basic tooth forms of the female rotor and the male rotor. One of the basic forms of the female and male rotors is used as one rotor tooth form, and a rotor tooth form of the one basic tooth form that is deformed by thermal expansion during operation of the rotors is obtained. Then another rotor tooth form is generated based on the thermally deformed tooth form, and a rotor tooth form is obtained by reducing an amount corresponding to the backlash of synchronizing means from the another tooth form. A normal temperature version of this rotor tooth form is used as the other tooth form.

Still another outstanding characteristic is that novel tooth forms are imparted to a female rotor and a male rotor rotating about two axes parallel to each other and forming a pair of rotor screws as follows: the flank of the surface of advance of the female rotor is constituted by a first flank of the surface of advance formed by a second order curve, and a second flank of the surface of advance formed by an arc of an imaginary circle of a radius $R_1$ having its center in the pitch circle of the female rotor in normal temperature condition. The flank of the surface of retrocession of the female rotor is constituted by a first flank of the surface of retrocession generated by a forward end portion of a robe of the male rotor formed by an arc of an imaginary circle of a radius $R_4$ having its center on a line drawn from the pitch point which is inclined through an angle $\phi$ with respect to a straight line connecting the two axes together, and a second flank of the surface of retrocession formed by an arc of an imaginary circle of a radius $R_3$ of an imaginary circle having its center in the pitch circle of the female rotor. The male rotor is essentially formed by generating loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof, to thereby provide basic tooth forms of the female and male rotors. One of the basic tooth forms of the female and male rotors is used as one rotor tooth form, and a rotor tooth form is obtained by adding to the one rotor tooth form an amount corresponding to the thermal expansion of the rotor and the backlash of the synchronizing means occurring during operation of the rotor. The rotor tooth form thus produced is used for generating the other tooth form from which a normal temperature version of the other rotor tooth form is obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view perpendicular to the axis of the basic tooth forms of the screw rotors comprising a first embodiment of the invention;

Fig. 2 is a view similar to Fig. 1 but shown on an enlarged scale;

Fig. 3 is a view of the details of the tip of the tooth top of the male rotor;

Fig. 4 is a sectional view perpendicular to the axis of the basic tooth forms of the screw rotors comprising a second embodiment;

Fig. 5 is a view in explanation of the basic tooth forms of the screw rotors according to the invention;

Figs. 6-9 are views showing the first embodiment of the screw rotors in conformity with the invention in which thermal expansion is taken into consideration, in explanation of the process for obtaining the tooth forms for the screw rotors;

Figs. 10 ana 11 are views showing the second embodiment of the screw rotors in conformity with the invention in which thermal expansion is taken into consideration, in explanation of the process for obtaining the tooth forms for the screw rotors;

Figs. 12 and 13 are views showing the third embodiment of the screw rotors in conformity with the invention in which thermal expansion is taken into consideration, in explanation of the process for obtaining the tooth forms for the screw rotors; and

Fig. 14 is a side view of a screw rotor representing a modification of the embodiments of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One embodiment of the basic tooth forms of the screw rotors according to the invencion will be described. Referring to Fig. 1, a female rotor 1 and a male rotor 2 are in meshing engagement with each other. The two rotors 1 and 2 have their centers of rotation at 3 and 4 respectively for rotation in a casing, not shown, in the directions of arrows, so as to function as a compressor. The two rotors 1 and 2 have synchronizing means, not shown, mounted at their respective shafts outside working chambers, to enable the rotors 1 and 2 to rotate while a small clearance is being maintained therebetween without coming into contact with each other.

In normal temperature condition, the female rotor 1 is formed with a plurality of grooves 5 and robes 6. The surface of advance of each groove 5 is constituted by a first flank 7 and a second flank 8, while the surface of retrocession of each groove 5 is constituted by a tooth root flank 9, a first flank 10 and a second flank 11. The tooth top of each robes 6 is constituted by an outer peripheral flank 12 and a tooth top tip 13. Meanwhile the male rotor 2 is formed with a plurality of grooves 14 and robes 15. The surface of advance of each robe 15 is constituted by a first flank 16 and a second flank 17, and the surface of retrocession thereof is constituted by a first flank 18 and a second flank 19. The forward end of each robe

15 is constituted by a tooth top tip 20, and the tooth root of each groove 14 is constituted by a tooth root flank 21 and a recess 22.

Fig. 2 shows the rotors 1 and 2 on an enlarged scale. In the surface of advance of the female rotor 1, a section 25-26 of the first flank 7 is formed by a parabola, one kind of a second order curve, focused on a point 28 on a straight line connecting the centers 3 and 4 of the two rotors 1 and 2 together. A section 26-29 of the second flank 8 is formed by an arc of an imaginary circle of a radius $R_1$ centered at a point 30 inside a pitch circle 23. In the surface of retrocession of the female rotor 1, a section 25-31 of the tooth root flank 9 is formed by an arc of an imaginary circle of a radius $R_2$ centered at a pitch point 32, and a section 31-35 of the first flank 10 is formed as a locus generated by the first flank 18 of the surface of retrocession of the male rotor 2 formed by an arc of an imaginary circle of a radius $R_4$ centered at a point 34 on a line 33 inclined through an angle $\phi$ with respect to a straight line connecting the centers 3 and 4 of the two rotors 1 and 2 together. A section 35-36 of the second flank 11 of the surface of retrocession of the female rotor 1 is formed by an arc of an imaginary circle of a radius $R_3$ smaller than the radius $R_1$ of the imaginary circle forming the second flank 8 of the surface of advance and centered at a point 37 inside the pitch circle 23.

By forming the second flank 8 of the surface of advance of the female rotor 1 by the arc of the imaginary circle of the radius $R_1$ which is greater than the radius $R_3$ of the imaginary circle of the arc forming the second flank 11 of the surface of retrocession of the female rotor 1, it is possible to greatly prolong the service life of the cutting blade of a hob for working on the rotors and to use an inexpensive material for producing the cutting blade of the hob with precision finishes. Thus it is possible to produce the rotors by using a hob with a cutting blade of high precision finishes, so that the precision with which the rotors can be produced is increased and the performance of the compressor can be greatly improved. Since the radius $R_3$ of the imaginary circle of the arc for forming the second flank 11 of the surface of retrocession is small, the blowholes have a small area and leaks of gas are reduced, to thereby improve the performance of the compressor.

By forming the first flank 7 of the surface of advance by a secondary curve of parabola, it is possible to lower the rate of slipping occurring when the female rotor 1 is driven by the male rotor 2. This is conductive to a reduction in wear caused on the two rotors 1 and 2 and a mechanical loss suffered as by bearings of the rotors.

Referring to Fig. 2 again, a section 36-29 of the outer peripheral flank 12 of each robe 6 of the female rotor 1 is formed by an arc of an imaginary circle having its center at the aforesaid center 3 except for an elevated portion of the tooth top tip 13.

Meanwhile in the surface of advance of the male rotor 2, a section 38-39 of the first flank 16 is of a shape generated by the first flank 7 of the surface of advance of the female rotor 1, and a section 39-40 of the second flank 17 is of a shape generated by the second flank 8 of the surface of advance of the female rotor 1. A section 41-42 of the first flank 18 of the surface of retrocession is formed by the aforesaid arc of the imaginary circle of the radius $R_4$ centered at the point 34, and a section 42-43 of the second flank 19 is generated by the second flank 11 of the surface of retrocession of the female rotor 1. A forward end of each robe 15 is formed by the tooth top tip 20, and a section 40-43 of the tooth root flank 21 is formed by an arc of an imaginary circle having its center at the center point 4 of the male rotor 2 except for the recess 22 which is formed as a groove of a size large enough to receive the tooth top tip 13 of the female rotor 1.

Fig. 3 shows in detail the tooth top tip 20 of the male rotor 2. The tooth top tip 20 of the male rotor 2 is formed with a section indicated by a solid line 41-44-45-38, and the shape of the tooth top tip 20 is a tip form that can be generated when the male rotor 2 is produced by hobbing.

 

By forming at the forward end of the robe on the female rotor 1 and the male rotor 2 tooth top tips 13 and 20 of a shape that can best be produced by hobbing, it is possible to produce screw rotors by relying on hobbing alone for forming all the shapes of the rotors. This is conductive to improved productivity. The provision of the tooth top tips enables seizure between the rotors and the casing to be avoided, thereby improving the reliability of compressor.

Fig. 4 shows another embodiment of the invention in which the first flank of the surface of advance of the female rotor of the screw rotors shown in Figs. 1-3 is modified. In the figure, parts similar to those shown in Figs. 1-3 are designed by like reference characters.

The numeral 46 designates a first flank of the surface of advance of the female rotor formed by an arc of a second order curve which extends from a point 26 to a point 47. The section 26-47 is formed by an arc of an imaginary circle of a radius $R_5$ having its center 48 outside the pitch circle 23 of the female rotor 1. A section 25-47 is formed by an arc of an imaginary circle having its center at a point of intersection between the pitch circles 23 and 24.

By forming the first flank of the surface of advance by an arc, it is possible to increase the pressure angle of the cutting blade of a hob, thereby facilitating hobbing.

A first embodiment of the screw rotors in conformity with the invention in which thermal expansion is taken into consideration will now be described by referring to the drawings.

In Fig. 5, parts similar to those shown in Figs. 1-4 are designated by like reference characters. In the figure, the numerals 49 and 50 designate basic tooth forms of the female rotor 1 and the male rotor 2 respectively. The rotor tooth forms 49 and 50 are such that they are in meshing engagement with each other without any clearance therebetween in normal temperature condition (at about 20° at which the rotors are produced).

Figs. 6-8 show the process for working the invention. In the embodiment shown and described hereinabove, the male rotor 2 is used as a reference and imparting of the basic tooth form 50 to the male rotor 2 will be described.

In Figs. 6 and 7, the numeral 51 designates a rotor tooth form obtained by thermal deformation of the basic tooth form of the male rotor during operation of the rotors 1 and 2. The rotor tooth form 51 obtained by deformation caused by thermal expansion can be obtained by calculation by a process of finite elements or the like based on a temperature distribution obtained by measuring the temperature in the rotor. The numeral 52 designates a rotor tooth form of the female rotor 1 generated by the rotor tooth form 51 of the male rotor 2 that can be obtained from the rotor tooth form 51 that is deformed by thermal expansion.

By returning the rotor tooth form 52 to a normal temperature condition, a rotor tooth form 53 of the female rotor 1 in normal temperature condition can be obtained. At this time, one has only to obtain the rotor tooth form 53 by the process of finite elements or the like based on a temperature distribution in the female rotor 1 as described hereinabove.

A concrete example of the aforesaid process will be described in a most simple form.

Assume that a temperature in a cross section of the two rotors perpendicular to the axis under operation is constant, and that thermal expansion of the rotors due to a rise in temperature occurs such that the rotors expand in a radial direction corresponding to the distance from the center of each rotor to an arbitrarily selected point on the rotor tooth form.

In Fig. 8, a normal to an arbitrarily selected point 54 on the basic tooth form 50 of the male rotor 2 is 54-55. The point 54 shifts to a point 56 as a result of expansion in the radial direction due to a rise in temperature. At this time, a normal 56-57 to the point 56 moves parallel to the line 54-55, so that the point 56 exists on the rotor tooth form 51 obtained by thermal deformation of the basic tooth form 50 of the male rotor 2.

Calculation is done in like manner on thermal deformation at various points on the basic tooth form 50 to obtain the rotor tooth form 51.

Then the rotor tooth form 52 of the female rotor 1 generated by the rotor tooth form 51 of the male rotor 2 obtained by deformation of the basic tooth form 50 is obtained as follows. As shown in Fig. 9, when the point 57 is located on an intersection of the pitch circles a point 58 on a rotor tooth form generated by the rotor tooth form at the point 56 can be obtained. The point 58 exists on the rotor tooth form 52.

To change the rotor tooth form 52 back to the rotor tooth form 53, one has only to follow, in reverse, the steps of the process described hereinabove by referring to conversion of the rotor tooth form 50 to the rotor tooth form 51.

In the present invention, one rotor tooth form produced by taking thermal expansion into consideration is used for generating the other tooth form, so that it is possible to maintain a minimum clearance through the entire region of the tooth forms of the female and male rotors 1 and 2 during operation. This is conductive to a marked improvement in the performance of the screw rotors of the dry type screw compressors in operation.

Fig. 10 shows a second embodiment of the process which is distinct from the first embodiment described hereinabove. In Fig. 10, transmission of rotation between the female and male rotors 1 and 2 is effected through synchronizing means, such as synchronizing gears, not shown, located outside the working chambers of the rotors 1 and 2. Like the example shown in Fig. 9, this example shown in Fig. 10 also uses the male rotor 2 as a reference and imparts the basic tooth form to the male rotor 2.

The numeral 59 designates a rotor tooth form obtained from the rotor tooth form 52 of the female rotor 1 by reducing the backlash of the synchronizing gears and the minimum clearance necessary for avoiding contacting between the rotors 1 and 2 while they are meshing with each other. The numeral 60 designates a rotor tooth form obtained by returning the rotor tooth form 59 to a normal temperature condition that can be obtained as by the process of finite elements based on a temperature distribution in the female rotor 1 as described hereinabove.

The process for obtaining the rotor tooth form 59 will be described by referring to Fig. 11. In Fig. 11, let the sum of the backlash of the synchronizing gear on the pitch circle 23 of the female rotor 1 and the necessary minimum clearance between the rotors 1 and 2, a length 3-61 of the radius vector at an arbitrarily selected point 61 of the rotor tooth form 52 deformed by thermal expansion, the angle formed by the radius vector and the normal to the tooth form at the point 61 and the radius from the center point 3 to the pitch circle 23 be denoted by $C_o$, R, $\alpha$ and $R_p$

respectively. Thus when backlash is taken into consideration, the point 61 arbitrarily selected on the rotor tooth form 52 shifts to a point 62. The distance C between the two points 61 and 62 can be expressed by the following equation:

$$C = \frac{R}{R_p} \cdot C_o \cdot \sin \alpha.$$

By this equation, the rotor tooth form 59 taking the backlash into consideration can be obtained from the rotor tooth form 52 deformed by thermal expansion.

The rotor tooth form 59 can be converted to the rotor tooth form 60 by following, in reverse, the steps of the process described hereinabove with reference to conversion of the rotor tooth form 50 to the rotor tooth form 51.

The reason why the backlash is taken into consideration is because greater effects can be achieved by taking into consideration the backlash of the synchronizing gears in obtaining optimum meshing of the rotors during operation, when such gears are used as synchronizing means.

In the invention, the backlash of the synchronizing gears is taken into consideration when the female and male rotors are deformed by thermal expansion during operation, so that it is possible to keep the two rotors from coming into contact with each other during operation. This is conductive to improved reliability of the screw compressor. It is possible, of course, to improve the performance of the screw compressor by imparting to the rotors a minimum amount of backlash in an allowable range of values.

Figs. 12 and 13 show a third embodiment which is distinct from the first and second embodiments. In Figs. 12 and 13, parts similar to those shown in Figs. 1-11 are designated by like reference characters.

The numeral 63 designates a rotor tooth form that takes the backlash into consideration. The rotor tooth form 63 represents the rotor tooth form 51 obtained by deformation due to thermal expansion of the basic tooth form 50 plus the backlash of the synchronizing gears and the necessary minimum clearance between the rotors for avoiding contacting of the rotors while rotating in meshing engagement. The numeral 64 designates a rotor tooth form of the female rotor 1 generated by the rotor tooth form 63 that is defined in consideration of the thermal expansion of the male rotor 2 and the backlash of the synchronizing gears, and the numeral 65 designates a rotor tooth form of the female rotor 1 obtained by returning the rotor tooth form 64 to a normal temperature condition.

By forming the female rotor 1 and the male rotor 2 as described hereinabove, various advantages can be offered because the clearance between the two rotors is minimized due to their being free from the backlash of the synchronizing gears and to a minimum clearance being maintained between them to avoid direct contact therebetween. It is thus possible, to minimize leaks of the gas, thereby enabling the efficiency of the screw compressor to be greatly improved.

The clearance between the rotors and the casing can be effectively reduced because of the fact that thermal deformation of the rotors can be determined accurately.

In the first, second and third embodiments of the invention described hereinabove, the temperature distribution in the axial direction of the rotors under operation is considered constant. However, in actual operating conditions, a temperature gradient of a substantial degree may exist in the axial direction of the rotors depending on the operating conditions including the conditions of the working fluid, pressure, etc. When the temperature distribution on the suction side of low temperature and the temperature distribution on the discharge side of high temperature are taken into consideration, the rotor tooth form is given with a shape which tapers or its outer periphery converges in going from the suction side (indicated by A) at one end of the rotor toward the discharge side (indicated by B) at the other end thereof, as shown in Fig. 14.

The female rotor 1 or the male rotor 2 or both of them may be tapered as shown in Fig. 14.

The second and third embodiments of the

invention have been described as being applied to rotors of a dry type screw compressors. It is to be understood, however, that they may have application in an oil-cooled type screw compressors as well.

From the foregoing description, it will be appreciated that in the screw rotors comprising a female rotor and a male rotor according to the invention, the tooth form of the female rotor includes a flank of the surface of advance constituted by an arc and a second order curve, and a flank of the surface of retrocession constituted by a curve generated by an arc located at a forward end portion of a robe of the male rotor and an arc, and the tooth form of the male rotor is essentially produced by generating the loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof. This enables a minimum clearance to be maintained through the entire region between the tooth forms of the female and male rotors meshing with each other, thereby greatly improving the performance and reliability of the screw compressors.

Additional advantages are that the service life of the tools can be prolonged and the area of the blowholes can be minimized.

WHAT IS CLAIMED IS:

1. A pair of screw rotors comprising a female rotor and a male rotor rotating about two axes parallel to each other, said female screw rotor having a rotor tooth form produced in normal temperature condition including a flank of a surface of advance comprising a first flank of the surface of advance formed by a second order curve, and a second flank of the surface of advance formed by an arc of an imaginary circle of a radius $R_1$ having its center in the pitch circle of the female rotor, and a flank of a surface of retrocession comprising a first flank of the surface of retrocession generated by a forward end portion of a robe on the male rotor formed by an arc of an imaginary circle of a radius $R_4$ having its center on a line drawn from the pitch point which is inclined through an angle $\phi$ with respect to a straight line connecting the two axes together, and a second flank of the surface of retrocession formed by an arc of an imaginary circle of a radius $R_3$ having its center in the pitch circle of the female rotor, the male rotor being essentially formed by generating loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof, wherein basic tooth forms are provided to the female rotor and the male rotor and one of the basic tooth forms of the female rotor and the male rotor is used as one rotor tooth form; a rotor tooth form is obtained from said one basic tooth form

by deformation caused by thermal expansion during operation of the rotors; another rotor tooth form is generated based on the thermally deformed tooth form; and a normal temperature version of the generated thermally deformed tooth form is produced and used as the other rotor tooth form.

2. A pair of screw rotors as claimed in Claim 1, wherein said second order curve forming said first flank of the surface of advance of said female rotor comprises a parabola focused inside the pitch circle of said female rotor.

3. A pair of screw rotors as claimed in Claim 2, wherein the arc of the imaginary circle of the radius $R_3$ constituting the second flank of the surface of retrocession of said female rotor is smaller than the arc of the imaginary circle of the radius $R_1$ constituting the second flank of the surface of advance of said female rotor.

4. A pair of screw rotors as claimed in Claim 2, wherein said male and female rotors are formed at their outer peripheral portions with elevated portions serving as tooth top tips.

5. A pair of screw rotors as claimed in Claim 1, wherein said second order curve constituting the first flank of the surface of advance of said female rotor comprises an arc of an imaginary circle having its center outside the pitch circle of said female rotor.

6. A pair of screw rotors as claimed in Claim 5,

wherein the arc of the imaginary circle of the radius $R_3$ constituting the second flank of the surface of retrocession of said female rotor is smaller than the arc of the imaginary circle of the radius $R_1$ constituting the second flank of the surface of advance of said female rotor.

7. A pair of screw rotors as claimed in Claim 5, wherein said male and female rotors are formed at their outer peripheral portions with elevated portions serving as tooth top tips.

8. A pair of screw rotors comprising a female rotor and a male rotor rotating about two axes parallel to each other, said female rotor having a rotor tooth form produced in normal temperature condition including a flank of a surface of advance comprising a first flank of the surface of advance formed by a second order curve, and a second flank of the surface of advance formed by an arc of an imaginary circle of a radius $R_1$ having its center in the pitch circle of the female rotor, and a flank of a surface of retrocession comprising a first flank of the surface of retrocession generated by a forward end portion of a robe on the male rotor formed by a arc of an imaginary circle of a redius $R_4$ having its center on a line drawn from the pitch point which is inclined through an angle $\phi$ with respect to a straight line connecting the two axes together, and a second flank of the surface of retrocession formed by an arc of an imaginary circle of a

radius $R_3$ having its center in the pitch circle of the female rotor, the male rotor being essentially formed by generating loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof, wherein basic tooth forms are provided to the female rotor and the male rotor and one of the basic tooth forms of the female rotor and the male rotor is used as one rotor tooth form; a rotor tooth form is obtained from said one basic tooth form by deformation caused by thermal expansion during operation of the rotors; another rotor tooth form is generated based on the thermally deformed tooth form; another rotor tooth form is obtained from said another rotor tooth form by reducing an amount corresponding to the backlash of synchronizing means; and a normal temperature version of the last mentioned another rotor tooth form is produced and used as the other tooth form.

9. A pair of screw rotors as claimed in Claim 8, wherein said second order curve forming said first flank of the surface of advance of said female rotor comprises a parabola focused inside the pitch circle of said female rotor.

10. A pair of screw rotors as claimed in Claim 9, wherein the arc of the imaginary circle of the radius $R_3$ constituting the second flank of the surface of retrocession of said female rotor is smaller than the arc of the imaginary circle of the radius $R_1$ constituting the second flank of the surface of advance of said

female rotor.

11. A pair of screw rotors as claimed in Claim 9, wherein said male and female rotors are formed at their outer peripheral portions with elevated portions serving as tooth top tips.

12. A pair of screw rotors as claimed in Claim 8, wherein said second order curve constituting the first flank of the surface of advance of said female rotor comprises an arc of an imaginary circle having its center outside the pitch circle of said female rotor.

13. A screw rotor as claimed in Claim 12, wherein the arc of the imaginary circle of the radius $R_3$ constituting the second flank of the surface of retrocession of said female rotor is smaller than the arc of the imaginary circle of the radius $R_1$ constituting the second flank of the surface of advance of said female rotor.

14. A pair of screw rotors as claimed in Claim 12, wherein said male and female rotors are formed at their outer peripheral portions with elevated portions serving as tooth top tips.

15. A pair of screw rotors comprising a female rotor and a male rotor rotating about two axes parallel to each other, said female rotor having a rotor tooth form produced in normal temperature condition including a flank of a surface of advance comprising a first flank of the surface of advance formed by a second order curve, and a second flank of the surface of

advance formed by an arc of an imaginary circle of a radius $R_1$ having its center in the pitch circle of the female rotor, and a flank of a surface of retrocession comprising a first flank of the surface of retrocession generated by a forward end portion of a robe on the male rotor formed by an arc of an imaginary circle of a radius $R_4$ having its center on a line drawn from the pitch point which is inclined through an angle $\phi$ with respect to a straight line connecting the two axes together, and a second flank of the surface of retrocession formed by an arc of an imaginary circle of a radius $R_3$ having its center in the pitch circle of the female rotor, the male rotor being essentially formed by generating loci of the flank of the surface of advance of the female rotor and the flank of the surface of retrocession thereof, wherein basic tooth forms are provided to the female rotor and the male rotor and one of the basic tooth forms of the female rotor and the male rotor is used as one rotor tooth form; a rotor tooth form is obtained from said one basic tooth form by adding thereto an amount corresponding to the thermal expansion of the rotor and the backlash of synchronizing means occurring during operation of the rotor; another rotor tooth form is generated based on the thermally deformed tooth form; and a normal temperature version of the generated thermally deformed tooth form is produced and used as the other rotor tooth form.

16. A pair of screw rotors as claimed in Claim 15, wherein said second order curve forming said first flank of the surface of advance of said female rotor comprises a parabola focused inside the pitch circle of said female rotor.

17. A pair of screw rotors as claimed in Claim 15, wherein the arc of the imaginary circle of the radius $R_3$ constituting the second flank of the surface of retrocession of said female rotor is smaller than the arc of the imaginary circle of the radius $R_1$ constituting the second flank of the surface of advance of said female rotor.

18. A pair of screw rotors as claimed in Claim 16, wherein said male and female rotors are formed at their outer peripheral portions with elevated portions serving as tooth top tips.

19. A pair of screw rotors as claimed in Claim 15, wherein said second order curve constituting the first flank of the surface of advance of said female rotor comprises an arc of an imaginary circle having its center outside the pitch circle of said female rotor.

20. A pair of screw rotors as claimed in Claim 19, wherein the arc of the imaginary circle of the radius $R_3$ constituting the second flank of the surface of retrocession of said female rotor is smaller than the arc of the imaginary circle of the radius $R_1$ constituting the second flank of the surface of advance of said female rotor.

21. A pair of screw rotors as claimed in Claim 19, wherein said male and female rotors are formed at their outer peripheral portions with elevated portions serving as tooth top tips.

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FIG. 1

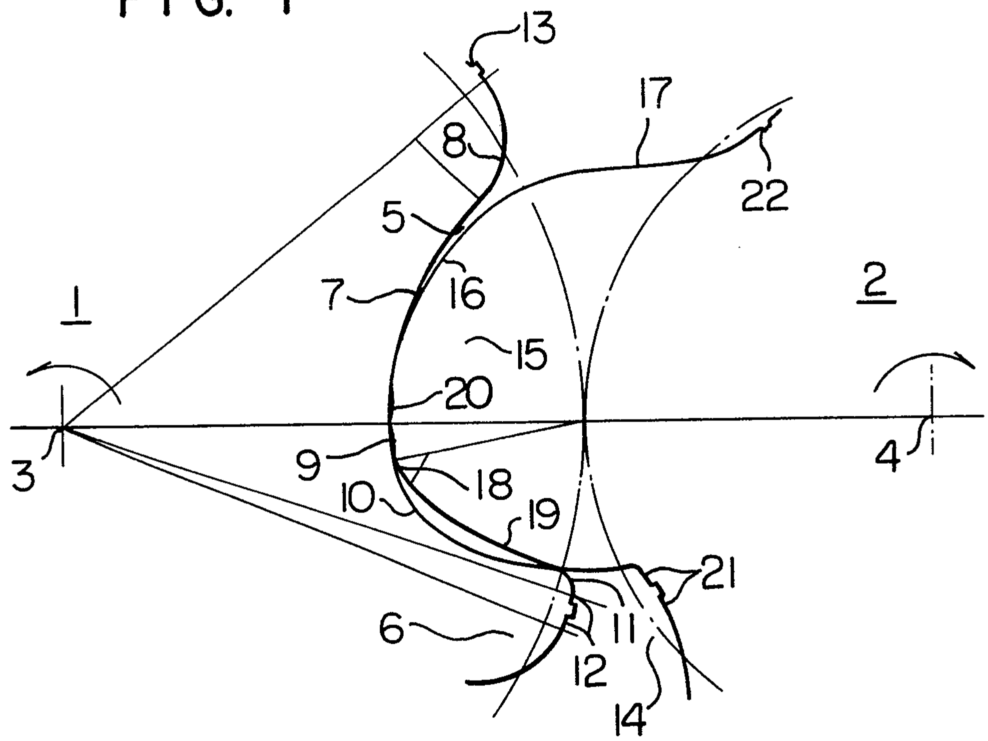



FIG. 3

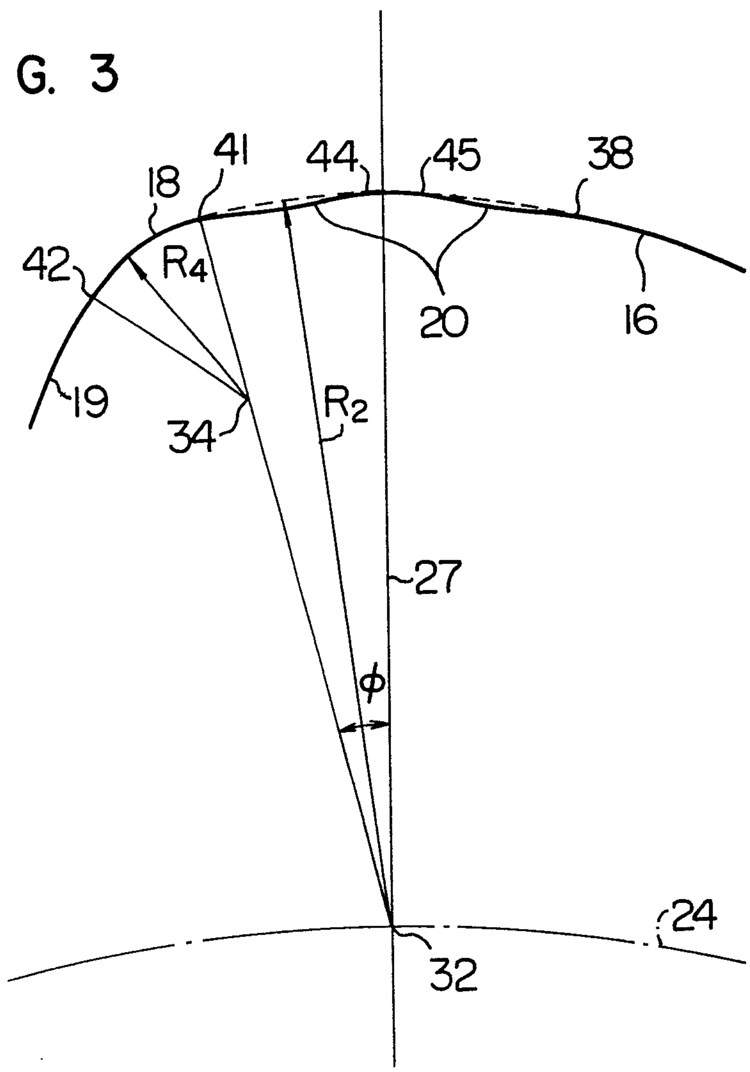
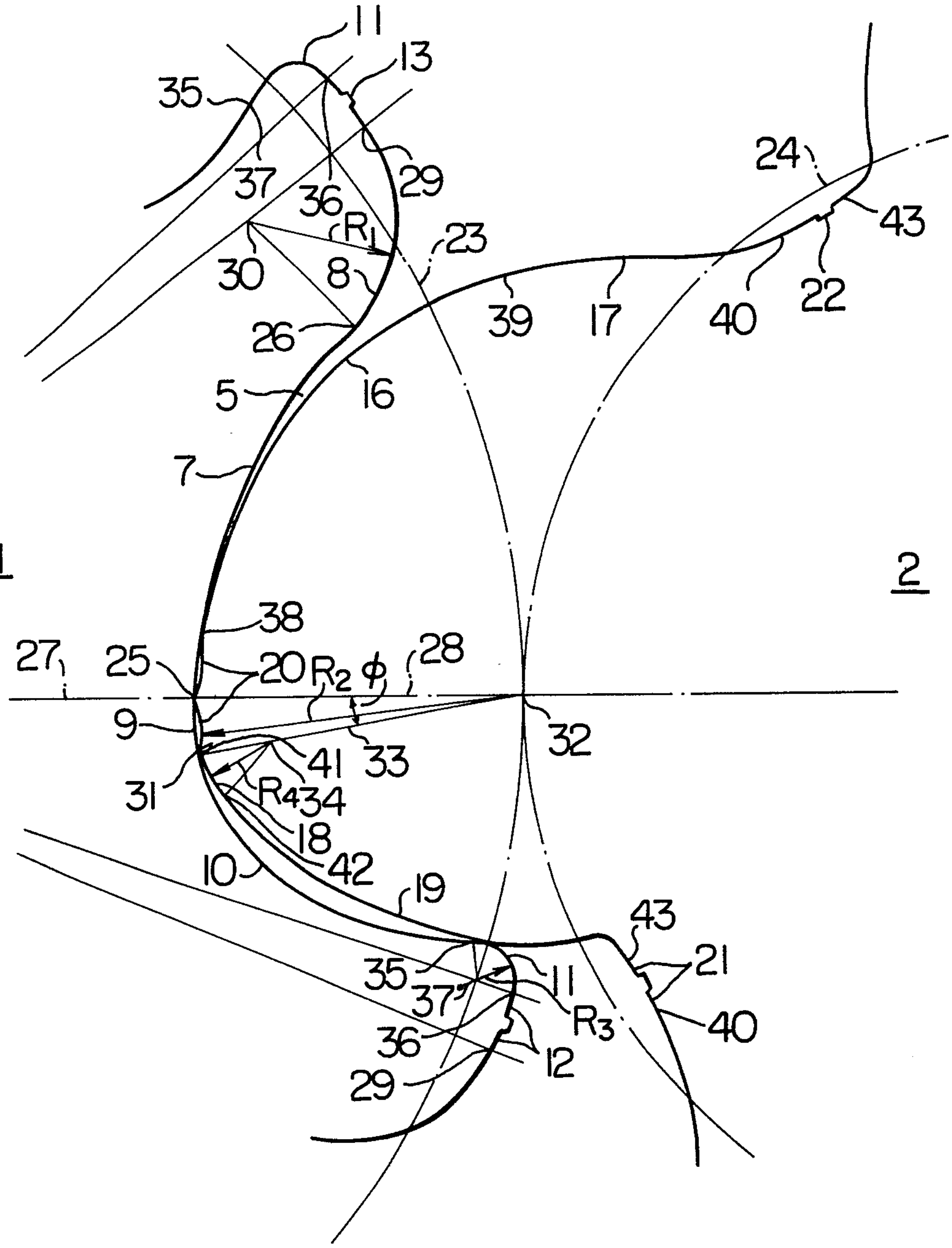


FIG. 2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2
38
27
25
20
R2
φ
28
9
41
33
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R3
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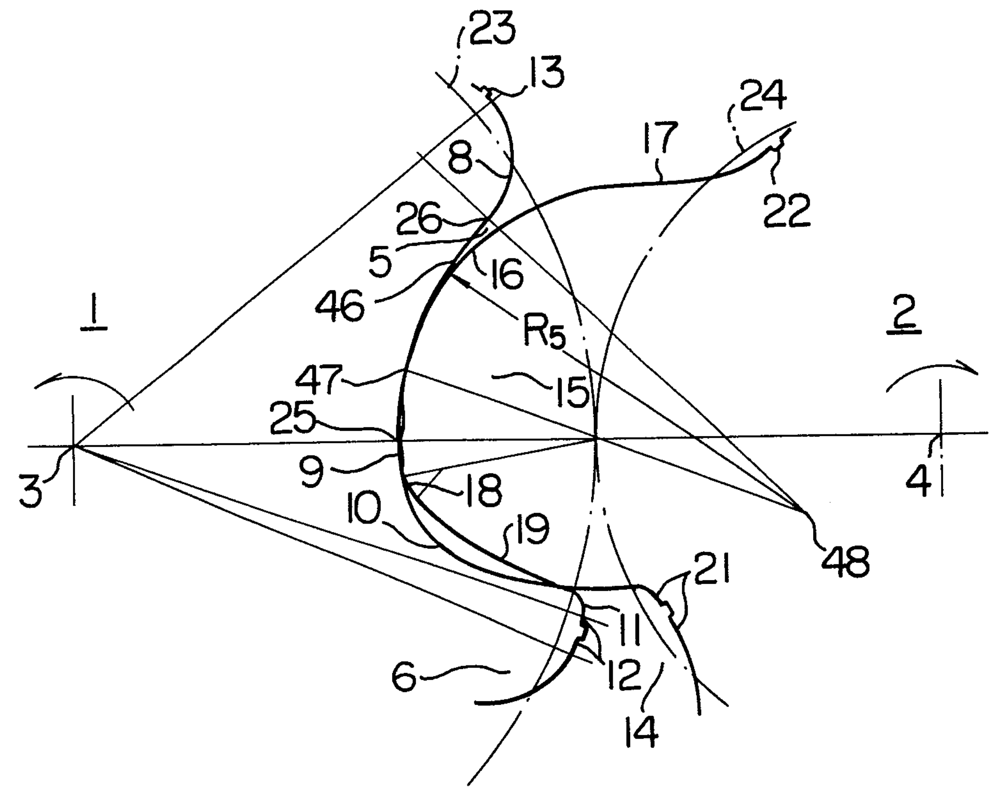
FIG. 4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R5
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14

FIG. 5

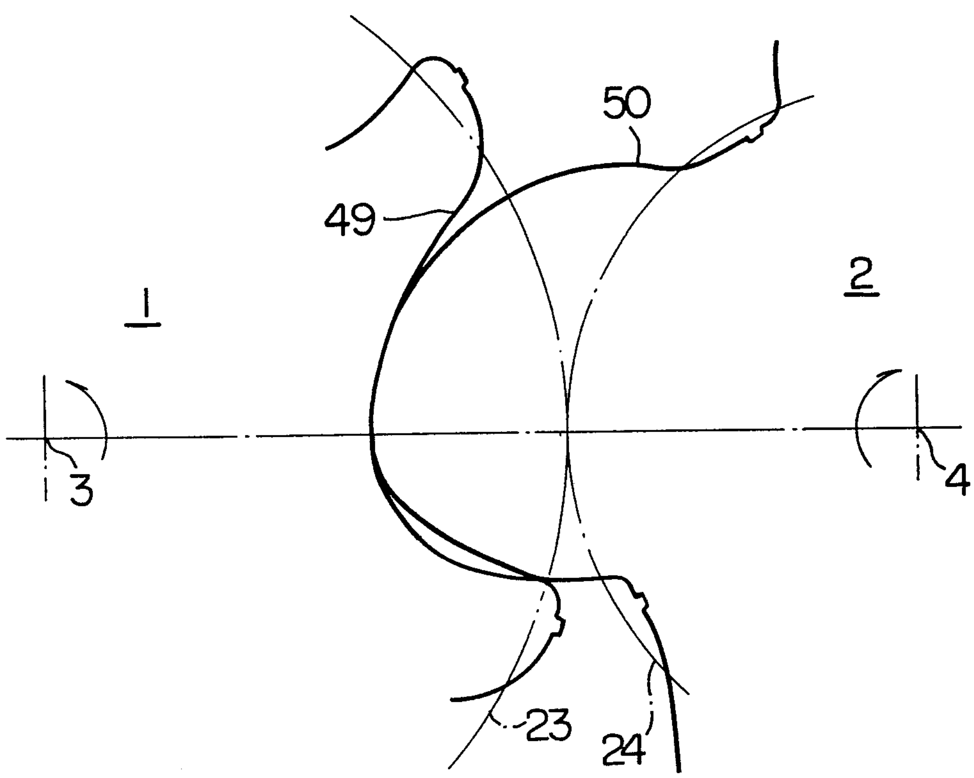
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FIG. 6

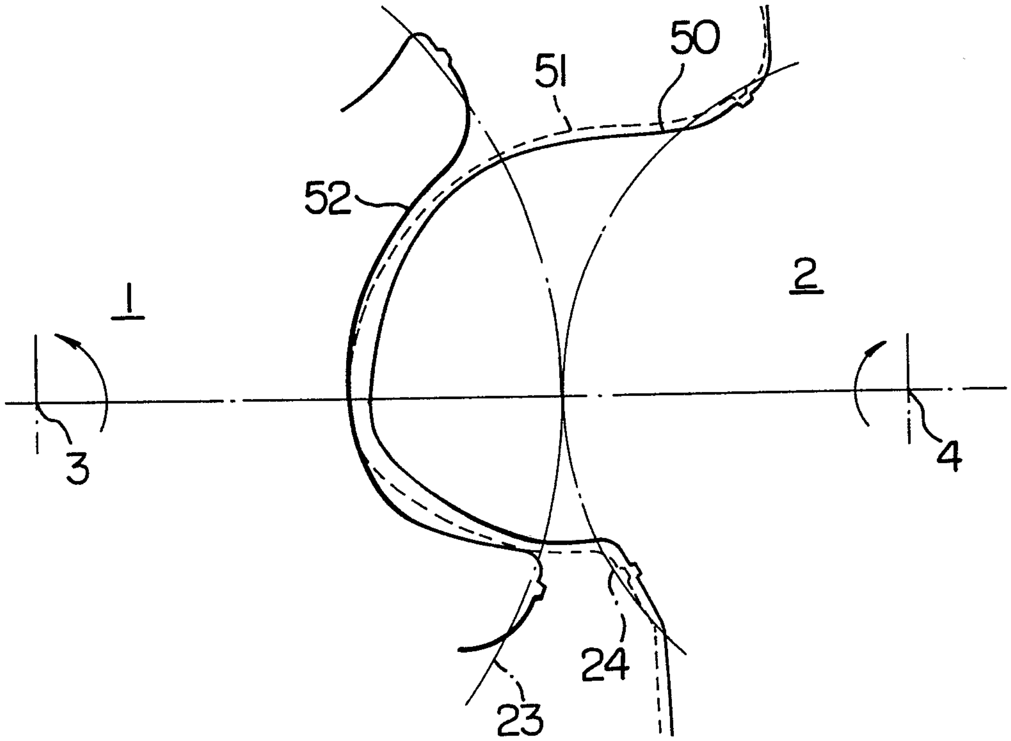



FIG. 7

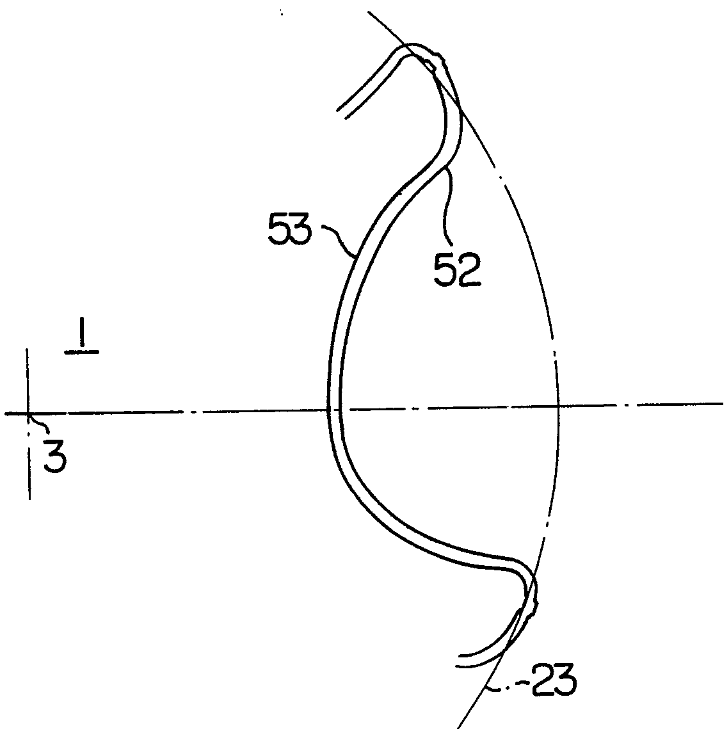


FIG. 8

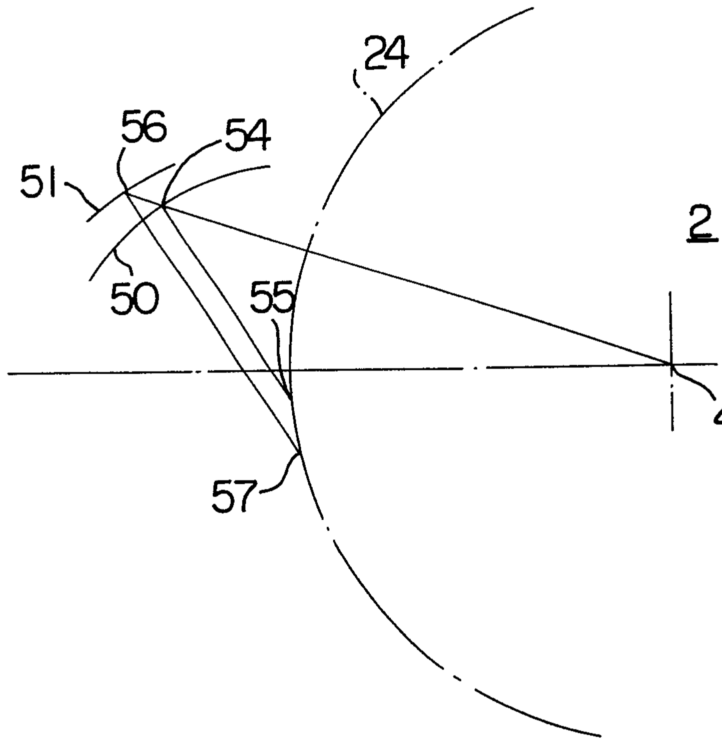



FIG. 9

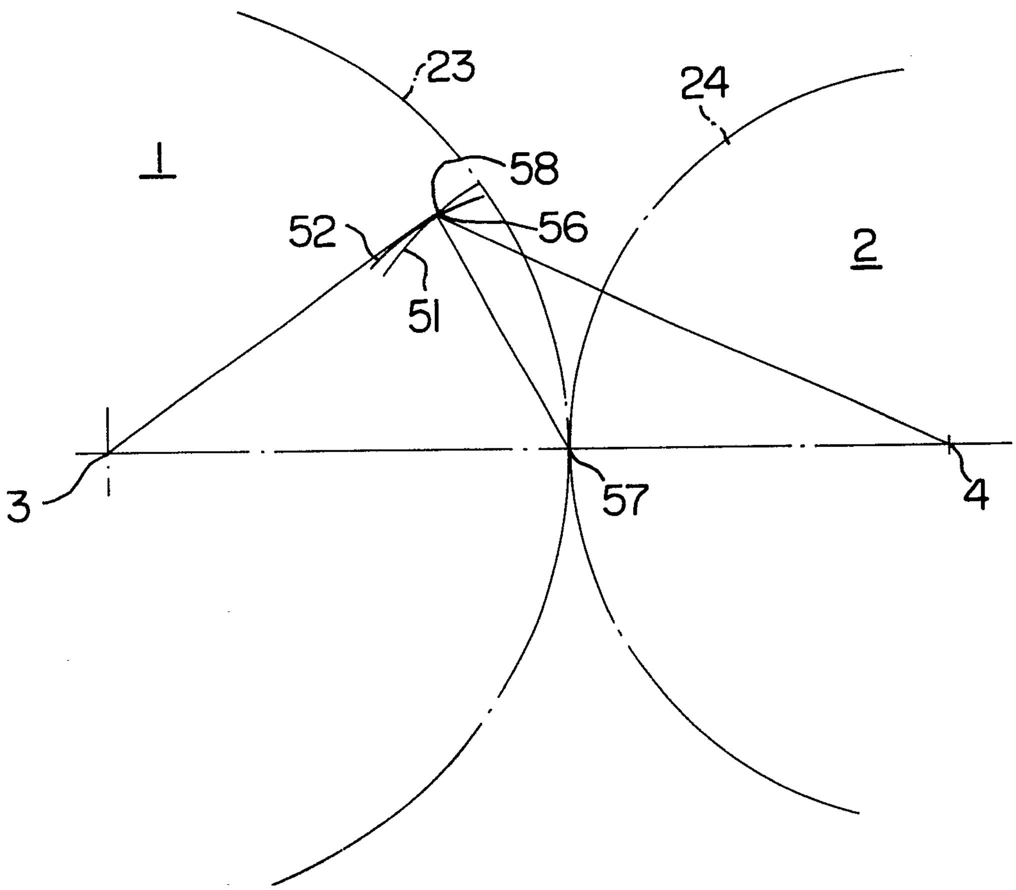


FIG. 10

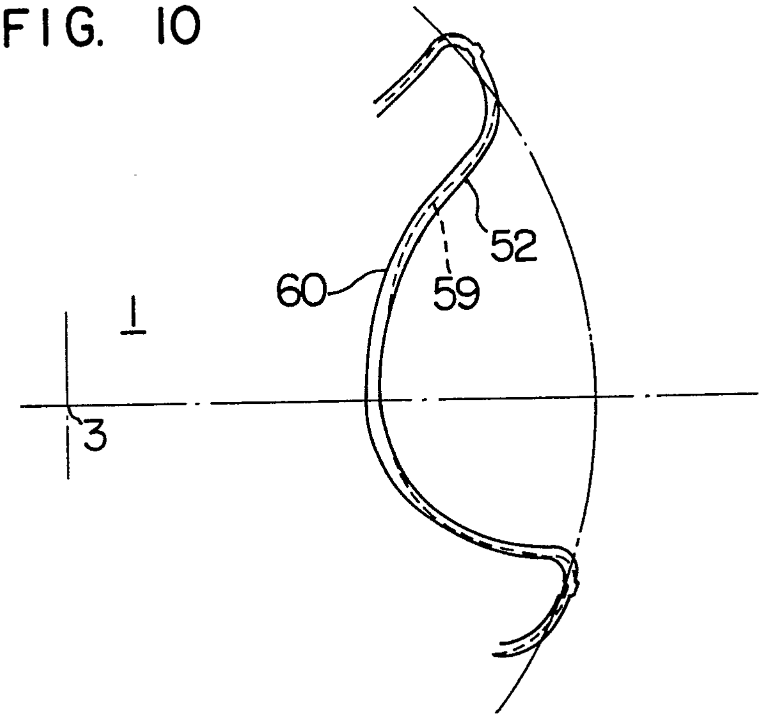



FIG. 11

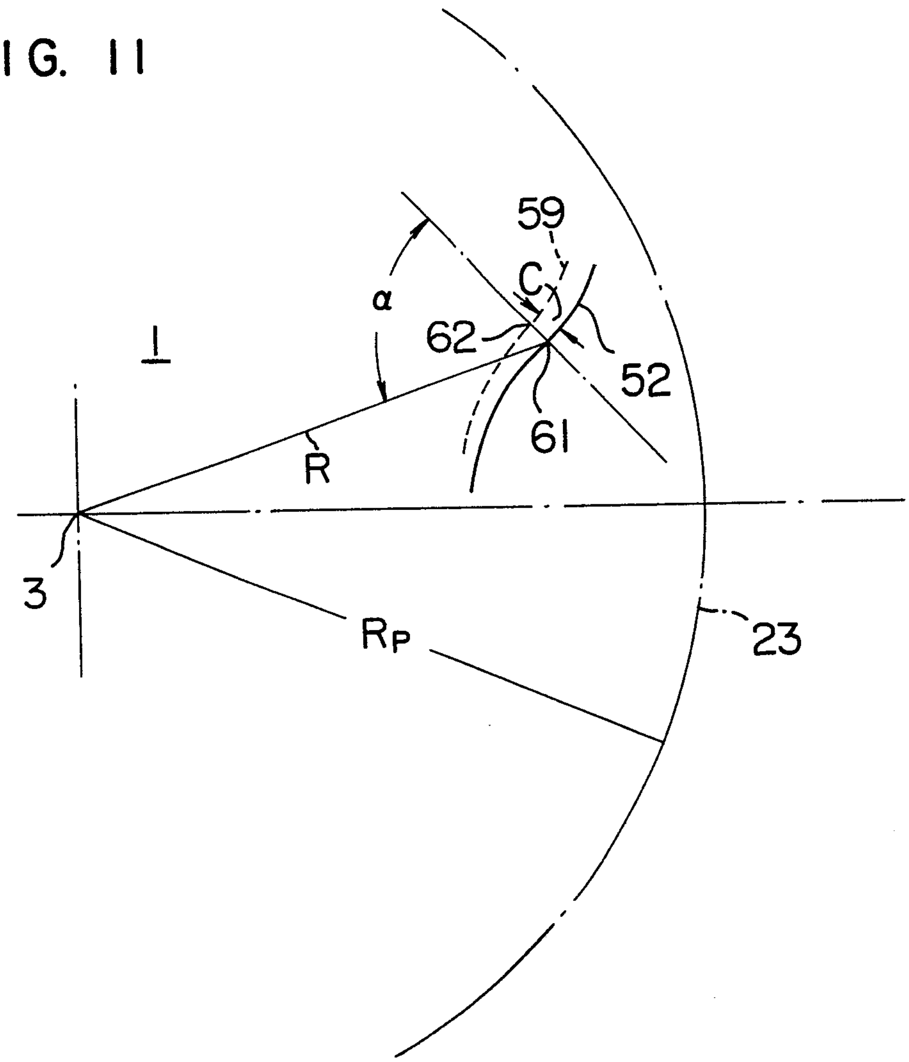


FIG. 12

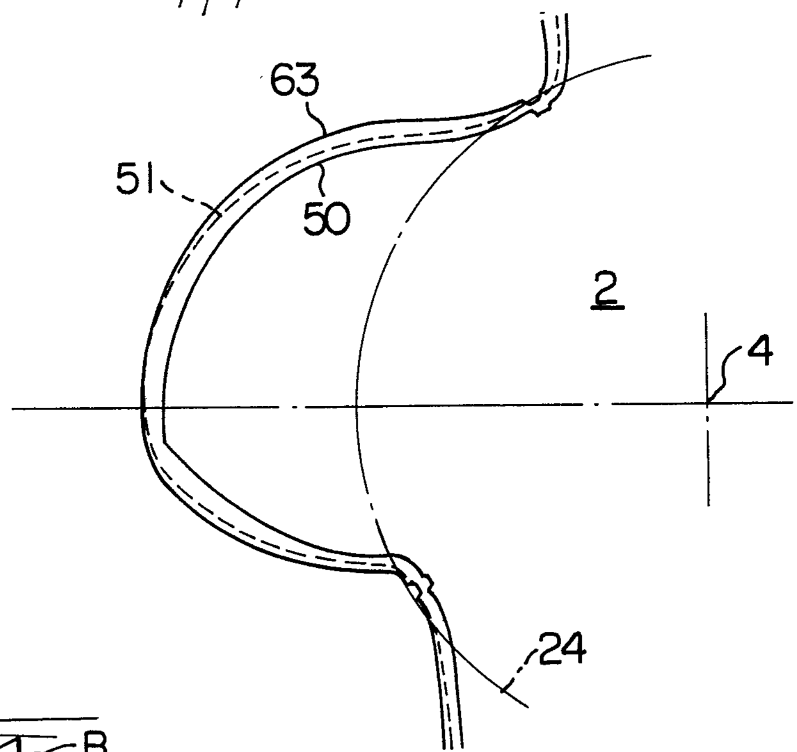



FIG. 14

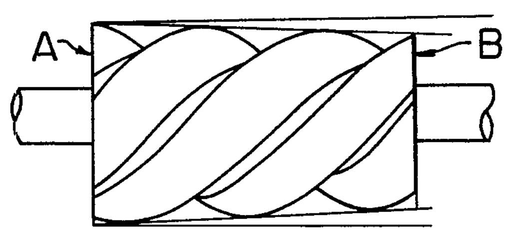
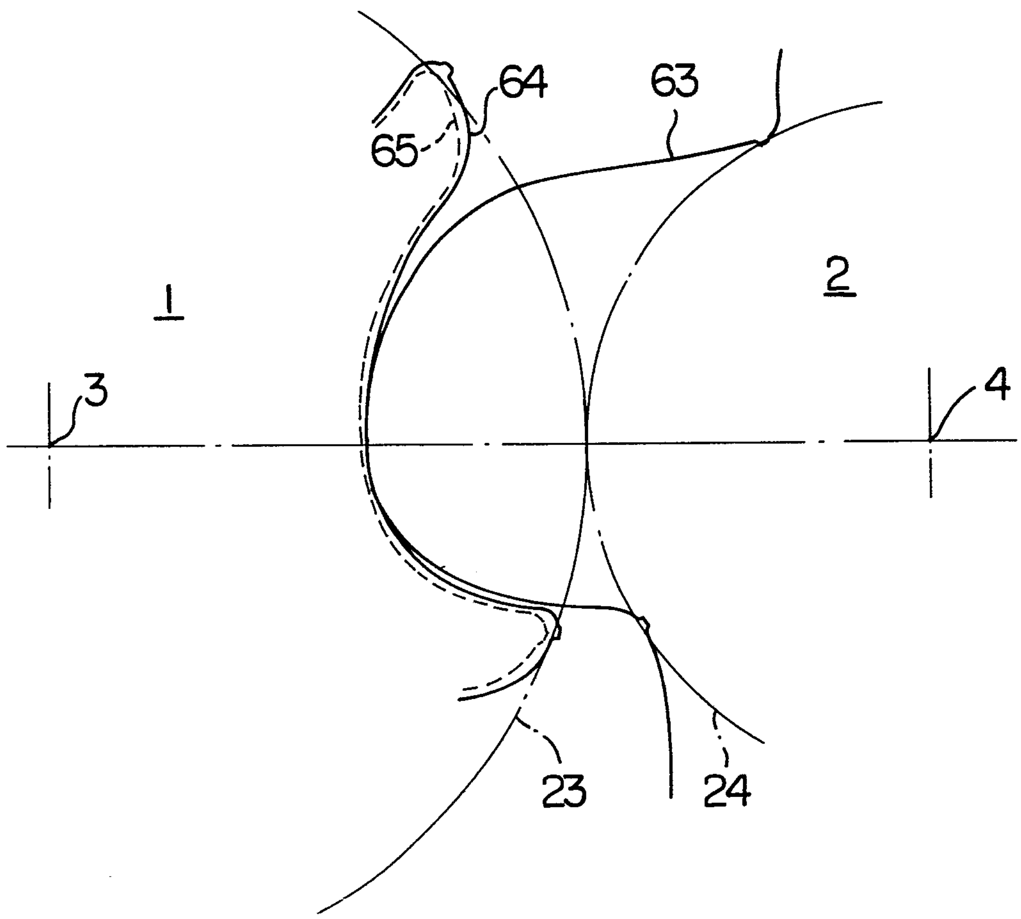



FIG. 13



European Patent Office

# EUROPEAN SEARCH REPORT

0106912

Application number

EP 82 10 9850

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl. 3) |
|---|---|---|---|
| A | EP-A-0 053 342 (HITACHI)<br>* Abstract; figures * | 1-3,8-10,15-17 | F 01 C 1/16 |
| A | GB-A-2 058 928 (HITACHI)<br>* Abstract; figures * | 1,3,5,6,8,10,12,13,15,17,19,20 | |
| A | US-A-4 140 445 (SVENSKA ROTOR)<br>* Column 3, lines 25-63; figure 3; column 4, line 59 - column 5, line 63 * | 1,4,5,7,8,11,14,15,18,19,21 | |
| A | FR-A-2 253 930 (DEMAG)<br>* Pages 2,4; figures * | 1,8,15 | |
| A | DE-A-1 403 534 (HOWDEN & CO.)<br>* Pages 3,7,8; figures * | 1,8,15 | |

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

F 01 C
F 04 C

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 24-06-1983 | KAPOULAS T. |

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding document