ABSTRACT
Asymmetric rotor profiles for cooperating helical screw type rotors for use in fluid compressors and motors. One flank of each gate rotor groove is formed partially as a concave curved surface defined by a circular arc having its radius center located outside the pitch circle of the gate rotor. The radially outermost portions of the gate rotor grooves are formed as convex curved surfaces defined by circular arcs. The other flank of each gate rotor groove and the flanks of the main rotor lobes are largely formed by traveling generation.

15 Claims, 6 Drawing Figures
ROTOR PROFILES FOR HELICAL SCREW ROTOR MACHINES

BACKGROUND OF THE INVENTION

Helical screw type fluid working machines are well known in the art of expandable chamber devices. Helical screw compressors, both liquid injected and so-called dry types, have been well developed and special attention has been given to the development of the form of the cooperating screw rotors in seeking to provide more efficient and reliable machines. The shape or profile of the grooves of the main and gate rotors, sometimes called male and female rotors, respectively, in the plane transverse to the rotational axes of the rotors are of special importance. The efficiency of helical screw fluid machines is dependent to a great extent on an effective fluid seal being provided by the engagement of the lobes of one rotor with the cooperating grooves of the other rotor, and by the proximity of the radial tips of the cooperating rotors to the bore walls of the rotor housing. For certain types of compressors in which one rotor drivably engages the other rotor it is also important that the rotor profiles provide for suitable rotor engagement without causing undue wear or friction losses.

The aforementioned problems together with others including reduction of the size of "pockets" of trapped fluid which are formed between the rotor mesh and the end walls of the rotor housing, reduction of the size of the so-called "blow-hole," and providing the desired torque acting on the gate rotor have resulted in several inventions dealing with rotor profiles. In particular, for rotors for use in helical screw compressors and fluid motors some of the abovementioned problems are discussed in U.S. Pat. No. 3,414,189 to J.E. Persson and U.S. Pat. No. 3,423,017 to L.B. Schibbye wherein rotor profiles are proposed which are basically asymmetric. U.S. Pat. No. 3,245,612 to Nilsson et al discloses profiles for helical screw rotors in which traveling generation is used to form the main rotor lobe flanks. However, a longstanding problem in the art of helical screw rotor machines has been the inability to provide a set of rotors having profiles which will give satisfactory solutions to the abovementioned problems and at the same time be capable of reasonably economical manufacture. This latter problem concerns the provision of a profile which will be tolerant of manufacturing errors without sacrificing performance and long life of a rotor pair.

Moreover, prior art rotor profiles have for the most part been designed for specific applications such as, for example, liquid injected compressors operating without synchronizing gears. Then, rotors with the same profiles have been used, largely unsuccessfully, in attempting to meet the diverse requirements of dry type compressors operating with synchronizing gears. A substantial saving in engineering and manufacturing expense can be realized when designing profiles to be used in the abovementioned diverse applications if the general form of the profiles is substantially similar regardless of the application if also the proportions of the profiles can be altered to satisfy the performance requirements of the machine using the rotor profiles. This is particularly true when consideration is given to the use of electronic computers programmed to provide for rotor profiles in terms of sets of coordinate points, and to the use of numerically controlled grinding apparatus for shaping the form milling cutters used to manufacture helical screw rotors. Additionally, in consideration of the long-standing problem of helical screw rotors being difficult to manufacture by conventional form milling it is desirable to provide a profile which will eliminate undesirable sharp corners on the cutter and also provide for more uniform cutter wear and longer cutter life. Furthermore, improvements in manufacturing processes such as precision casting and high pressure forming or extrusion have presented a need for rotor profiles which are more adaptable to these processes without a loss of the aforementioned desired features for helical screw rotors.

SUMMARY OF THE INVENTION

The present invention provides an improved rotor profile for helical screw rotor fluid machines which results in machines of high efficiency and for certain applications negligible rotor wear due to improved conditions of rotor interengagement. In addition to providing the aforementioned desired characteristics of helical screw rotors the rotor profile of the present invention comprises a basic profile which may be easily modified to suit different applications of screw rotor machines without causing undue expense in design and manufacturing.

By providing rotor profiles which are formed by traveling generation over substantially the entire main rotor profile and a major portion of the gate rotor profile a more effective fluid seal is formed resulting in more efficient helical screw rotor machines. The profiles of the present invention also provide for relatively large area contact between the flanks of engaged rotors and the development of a suitable liquid lubricant film on the contact area when used in liquid injected compressors operating without synchronizing gears.

The rotor profiles of the present invention are formed largely of curved surfaces each of which is tangent to the adjacent curved surface at the meeting point. By providing for this tangency condition as well as making substantially all profile portions formed by a radius of curvature it is possible to manufacture rotors having profiles according to the present invention with form milling cutters which are easy to manufacture themselves and which are subject to more uniform cutting forces over the entire cutting surface. Accordingly, wear on the cutter is reduced and is more uniform thereby resulting in fewer errors in the rotor profiles.

Moreover, the rotor profiles of the present invention comprise a basic profile form, the proportions of which may be easily modified to provide desired characteristics for rotors used in various types of compressors and expanders. The provision of a basic profile form which may be altered in proportion reduces the expense and time involved in calculating profiles in terms of sets of coordinate points for use in checking profile accuracy and in programming numerically controlled cutter grinding equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal section view of a rotary helical screw compressor having rotors with profiles according to the present invention;

FIG. 2 is a transverse section taken along the line 2-2 of FIG. 1;
FIG. 3 is a view taken along the line 2—2 of FIG. 1 showing on a larger scale a portion of a pair of main and gate rotors having profiles according to the present invention;

FIG. 4 is a detail view of the main rotor tip and a portion of the gate rotor groove showing both a theoretical profile and a modified profile with clearances and is taken along the same line as the view of FIG. 3;

FIG. 5 is a view taken in the same direction as the view of FIG. 3 and showing an embodiment of the present invention suitable for use in dry type compressors; and,

FIG. 6 is a detail view of a modification of the gate rotor tip portion of the profile of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 2 of the drawings, helical screw rotors having rotor profiles according to the present invention are shown in use in a compressor 10. The compressor 10 includes a housing 12 having parallel intersecting bores 14 and 16, and a housing portion 18 forming a low pressure end wall 20. A separate housing portion 22 forms a high pressure end wall of the bores 14 and 16. The compressor 10 also includes an inlet opening 24 and an outlet opening 26 for respectively admitting compressible fluid to and conducting compressible fluid from the bores 14 and 16. A pair of cooperating main and gate rotors 28 and 30 are disposed in the bores 14 and 16, respectively, and are supported for rotation by suitable bearings 31. In a known way the rotors 28 and 30 cooperate with the housing 12 to form chambers which decrease in volume as the rotors rotate to compress fluid admitted through the inlet opening 24 and discharge fluid through the opening 26 when the aforementioned chambers are in registration with the latter opening. The compressor 10 is suitable for injection of liquid into the bores 14 and 16 for sealing the spaces formed between the rotors 28 and 30, for cooling the compressor, and for lubricating the rotor flanks which are interengaged.

The compressor 10 is exemplary of helical screw rotor compressors. The rotor 28 is provided with four lobes 32 and intervening grooves 34 having a wrap angle or twist of approximately 300°. The gate rotor 30 is provided with six lobes 36 and intervening grooves 38 having a wrap angle of approximately 200°. It will be understood that the basic profile form of the present invention can be advantageously used on helical screw rotors having other combinations of lobes and grooves and wrap angles.

Referring to FIG. 3 the profiles of the flanks of the grooves 34 and 38 of the main and gate rotors 28 and 30 respectively are shown in the plane perpendicular to the rotational axes of the rotors. The direction of rotation of the respective rotors 28 and 30 are indicated by arrows 40 and 42, respectively. The tips 43 of the gate rotor lobes are defined by the pitch circle 44 having its center on the rotational axis 46. A first flank 47 of a gate rotor groove 38 is defined in part by a concave curved portion comprising a circular arc of radius R1 having its center 50 on a line 52 extending from the axis 46 to the main rotor axis 48 and lying outside the pitch circle 44. The radius R1 extends from a point of intersection with the line 52 through a predetermined angle A to a point 54. The remaining radially outermost portion of the flank 47 is defined by a convex curved portion formed by a radius R2 having its center 56 on the straight line passing through points 50 and 54. Thus the curved portions formed by the radii R1 and R2 are tangent at point 54.

A second flank 58, defining the remaining portion of the gate rotor groove 38, extends from the point of intersection with the line 52 to the pitch circle 44 of the gate rotor. Referring to FIG. 4 also, a small portion of the flank 58 is formed by a circular arc having its radius center at the axis 48 and extending from line 52 to a point 60. A further small portion of the flank 58 extending from the point 60 to a point 62 is generated by point 64 on the tip of the main rotor lobe 32. In the portion of the rotors 28 and 30 shown in FIGS. 3 and 4 the points 62 and 64 are coincident. The flank portion formed between the line 52 and point 60 is tangent to the flank 47 and the flank portion formed between the points 60 and 62 is tangent to the first mentioned flank portion at point 60. The profile of the bottom of the gate rotor groove from point 62 to the line 52 is exaggerated somewhat for clarity as shown in FIG. 4. Accordingly, the flank 58 may be defined between the line 52 and point 62 by a circular arc having its radius center at the axis 48 of the main rotor. The deviation from a true tangency condition at point 62 is negligible.

A major portion of the flank 58 from the point 62 to a point 66 is traveling generated by a portion of the main rotor lobe trip which, in FIG. 3, is a curved surface comprising a circular arc portion of radius R3 extending from point 64 to a point 68 on the main rotor lobe 32. The radius R3 has its center at 70 on a straight line extending from a point 72 which is on the pitch circle 74. The radially outermost portion of the flank 58 from the point 66 to the pitch circle 44 is formed as a convex curved portion defined by a radius R4 having its center at 76 on a line extending from the pitch point 72 at an angle A3 with respect to the line 52. The curved portion formed by the radius R4 is tangent to the traveling generated portion of the flank 58 at point 66. Accordingly, the entire profile of the gate rotor groove 38 is formed by curved surfaces which, for the most part, are tangent to one another at their respective meeting points.

The flanks 78 and 80 of the main rotor 28 are largely traveling generated by the flank portions of the gate rotor 30. Traveling generation is discussed in some detail in U.S. Pat. No. 3,245,612 to Nilsson et al. The flank 78 is traveling generated from the pitch circle 74 of the main rotor to point 68 as by the convex curved portion of the gate rotor flank between the point 66 and the main pitch circle 44. As previously mentioned the tip of the main rotor lobe 32 is formed by the radius R3. The line on which the radius center 70 is located is disposed at an angle A3 with respect to the line 52 and intersects point 64. The location of the center 70 provides for a curved portion extending from point 64 to line 52, see FIG. 4, which is a circular arc having its radius center at the axis 48. This circular arc tip portion between point 64 and line 52 provides a surface which may be ground to its final dimension before the main rotor profiles are cut and thereafter serve as a visual indicator to aid in preventing the cutting of the main rotor groove too deeply.

The flank 80 of the main rotor from the line 52 to a point 82 of traveling generated by the circular arc portion of the gate rotor formed by the radius R4. The flank 80 of the main rotor from the point 82 to the
pitch circle 74 is traveling generated by the convex circular arc portion between the point 54 and the pitch circle 44. The main rotor 28 thus has a lobe profile which is formed entirely of curved surfaces which for the most part are tangent to each other at their meeting points.

By providing a gate rotor profile which is made up entirely of curved surfaces which traveling generates a major portion of the main rotor profile, and also a main rotor profile which traveling generates a large portion of one flank of a gate rotor groove, more effective sealing “areas” for the enmeshed rotors are provided than is the case for point generated profiles. Moreover, for rotors which are not provided with synchronizing gears the convex curved flank portions of the gate rotor formed by the radii Rg and Rg provide more uniform movement of the contact point between the rotor lobes 32 and 36 and greater distribution of the driving forces of one rotor against the other than is the case with straight line flank portions as found in prior art asymmetric profiles. Those skilled in the art of screw rotor profiles will also recognize, when practicing the present invention, that the provision of the convex curved portions on the gate rotor flanks together with the curved portion formed by the radius Rg on the main rotor tip will result in smaller pockets of trapped fluid than can be obtained with certain prior art asymmetric profiles. The aforementioned curved flank portions also provide favorable conditions, in oil injected compressors, for the development of an oil film on the interengaging flank portions of the rotors 28 and 30 which is important for rotors which drivingly engage each other.

Significantly, it has been determined that with the profiles disclosed herein that rotor manufacturing by form milling is more economical than with prior art profiles. The continuous tangent condition at each point on the profile provides for milling cutters which have exhibited reduced as well as more uniform wear after long periods of use. Furthermore, the curved flank portions formed by the radii Rg and Rg provide for intersection angles of the radially innermost flank portions of the main rotor with the pitch circle 74 which are greater than 90 degrees. This provides for more open grooves and on the main rotor at the pitch circle 74 and, accordingly, reduces the tendency for the milling cutter tips to wear rapidly or be susceptible to breakage. Moreover, the angle formed between the milling cutter axis and the rotor longitudinal axis can be varied slightly without spoiling the desired profile shape. The rotor tip portions on the main and gate rotors can also be accurately formed by a grinding operation rather than by milling.

Referring to FIG. 6 an embodiment of a gate rotor lobe tip is shown wherein a portion between points 86 and 88 is formed by the radius of the pitch circle 44. Additional tip portions 90 and 92 are formed between the point 86 and a point 94, respectively. The tip portions 90 and 92 may be formed as straight line portions or as curved surfaces each having a radius of curvature equal to the pitch radius but having their radius centers located off-set slightly from the axis 46 as shown by points 98 and 100 in FIG. 6. Thus, the tip portions 90 and 92 slope radially inwardly from the pitch circle 44 from their meeting points with the tip portion between points 86 and 88. The gate rotor lobe tip shown in FIG. 6 further has a curved portion 101 extending from point 94 to a point 102 on the flank 58. The opposite corner of the lobe tip from point 96 to a point 103 is similarly formed. The curved portions 101 are equivalent to a circular arc portion formed on a milling cutter, said cutter being used for cutting the gate rotor flanks and the tip portions from point 102 to point 86 and from point 103 to point 88. Correspondingly, the main rotor profile at the bottom of the groove 34 is traveling generated by the gate rotor tip. As shown in FIG. 6, the groove portion from a point 106 to a point 108 is on the pitch circle 74, the portion from point 108 to point 110 is traveling generated by the tip portion 96 and the curved corner portion from point 110 to a point 112 is traveling generated by the curved portion 101 on the gate rotor tip. The opposite bottom corner portion of the groove 34 is similarly traveling generated by the gate rotor tip portion between points 88 and 103.

The modification of the profile as shown in FIG. 6 does result in a slight increase in the area of the well known blowhole formed at the intersection of the housing bores 14 and 16. However, the provision of a curved portion 101 on both corners of the gate rotor lobe tip which is equivalent to a circular arc radius on the milling cutter used to cut the gate rotors eliminates sharp corners on the milling cutter for the main rotor which are subject to concentrated wear and frequent breakage. Moreover, the tip portion of the gate rotor between points 86 and 88 may be used as a visual indicator to aid in determining if the milling cutter forming the flanks of the gate rotor groove is cutting too deep. The tip portion between points 86 and 88 also can operate as a wear strip for certain rotor applications.

The rotor profiles as shown in FIG. 3 are provided without clearance between the generating portions of the curved surfaces. In actual practice, however, to compensate for unavoidable errors in manufacturing and thermal expansion of the rotor lobes, it is desirable to provide predetermined clearances by modifying the theoretical profiles. For the profile shown in FIG. 4 all of the clearance is provided by modifying the profile of the main rotor and is provided by a measurement perpendicular to the profile. Referring to FIG. 4, the main rotor tip profile is modified, as shown by the dashed line, by providing clearance on a curved portion formed by the radius Rg’. The main rotor profile is further modified by forming a straight line portion between points 116 and 118 which is tangent to the flank 80’ at point 118. Point 118 is located on a straight line passing through point 72 and disposed at an angle A, with respect to the line 52. The straight line portion between points 116 and 118 intersects a curved portion formed between points 116 and 64’ and having a radius center at the axis 48. This straight line portion is provided to allow for some amount of error in setting the depth of the cutting or milling operation when forming the main rotor flank 80’ without, for example, forming a ledge or severe discontinuity in the profile at point 116 if the milling cutter is set to cut too deep. The dashed line designated by numeral 117 defines the outline of the bottom portion of a milling cutter which could be used to cut the flank 80’ of the main rotor in a position which would produce the minimum cutting depth. If the cutter 117 were set to cut deeper than the minimum cutting depth shown the point 116 would be located closer to point 64’ and the curved portion between points 116 and 64’ would be shortened. However, no abrupt step, ledge, or similar discontinuity
would be formed in the profile of the main rotor flank 80°. The modified main rotor profile may be provided with suitable clearances along the flanks 78° and 80° from the respective points 68° and 118° to the pitch circle 74. The curved portion between point 116 and point 64 also serves as the aforementioned visual indicator of cutting depth referred to for the portion between point 64 and line 52.

As previously mentioned, the basic rotor profiles disclosed herein can be modified to suit the diverse requirements of, for example, liquid injected gas compressors versus dry type compressors. Primarily by selection of the proportions of the radii $R_1$, $R_2$, $R_3$, and $R_4$ and the angles $\alpha_1$ and $\alpha_2$ a profile can be obtained which has a small blowhole which is desirable for liquid injected compressors operating without synchronizing gears. Such a profile for liquid injected compressors without synchronizing gears can also be formed to yield a so-called negative torque on the gate rotor which reduces the clearance along the relatively long portion of the rotor sealing line, the latter necessarily resulting from selection of a small blowhole profile. By changing the proportions of the abovementioned radii of curvature while maintaining tangency at the respective meeting points of these portions a profile can be obtained which is suitable for dry type compressors. In dry type compressors the temperature conditions of the working fluid require large clearances and therefore it is desirable to have a short sealing line in the rotor mesh at the expense of the size of the blowhole. Moreover, the shape of the gate rotor lobe from the pitch circle toward the rotor rotational axes should be constant or increasing in thickness to facilitate heat transfer away from the rotor tips. This is particularly advantageous for rotors which are cooled by circulating cooling fluid through interior passages formed in the rotor. Additionally, consideration of the amount and direction of torque acting on the gate rotor is of less importance because synchronizing gears are normally used to keep the rotors from contacting each other.

Referring to FIG. 5 rotor profiles are shown in the plane transverse to the axes of rotation which are advantageously used in relatively high pressure and high temperature dry type compressors. A main rotor 116 having four lobes 118 and intervening grooves 120 and a gate rotor 122 having six lobes 124 and intervening grooves 126 are discouled. The rotors 122 and 116 include longitudinal passages 125 and 123 for circulating cooling fluid through the interior of the rotor. The gate rotor profile is formed in part by a concave circular arc portion of radius $R_4$, said radius having its center at point 127 which is the point of tangency of the respective main and gate rotor pitch circles 128 and 130. The radius $R_3$ extends through an angle $\alpha_3$ on one side of the line 132 to a point 134 and through angle $\alpha_4$ on the other side of the line 132 to a point 136. The line 132 is a straight line intersecting the axes of rotation 137 and 139 of the main and gate rotors 116 and 122, respectively. The radius center for the arc portion between points 134 and 136 is located at point 127 rather than at the axis of rotation 137 of the main rotor 116 so that the main rotor tip may be suitably relieved to form a sealing strip 138 while retaining sealing points at points 134 and 136 also. A first flank 140 of the gate rotor groove is formed in part by a concave curved portion of radius $R_5$ having a radius center at point 142 slightly off the line 132 so as to be tangent to the circumferential arc portion of radius $R_2$ at point 136. The circular arc formed by radius $R_2$ extends from point 136 to a point 144. The remaining portion of the flank 140 is formed largely by a convex curved portion comprising a circular arc of radius $R_5$ having its center at a point 146 on a line through the points 142 and 144 and forming the angle $\alpha_2$ with respect to line 132. The radius $R_2$ extends from point 144 toward the pitch circle 130.

The gate rotor 122 is formed with addendum portions 148 extending radially outside the pitch circle 130 to provide for increased displacement of a compressor using the rotors 116 and 122, as is well known. This addendum portion 148 may be used in dry type compressors wherein the increase in the blowhole and the effects of addendum on gate rotor torque are relatively unimportant. The addendum portions 148 are formed with curved portions 150 similar to the curved portions 101 of the gate rotor tip shown in FIG. 6. The gate rotor tip of FIG. 5 is also formed with sealing strips 152.

A second flank 154 of the gate rotor groove 126 comprises a concave curved portion formed from point 134 to a point 156 by traveling generation by a curved portion on the tip of the main rotor lobe 118. The curved portion on the lobe 118 is formed by a radius $R_5$ with its center 158 on a line defining, in part, the angle $\alpha_3$. The remaining portion of flank 154 from point 156 to a point approximately on the pitch circle 130 is a convex curved portion defined by a radius $R_5$ tangent to the traveling generated portion at point 156. The radius $R_5$ has a center 160 on a line through point 127 and forming an angle $\alpha_3$ with the line 132.

Corresponding substantially to the profile of the main rotor of FIG. 3 the main rotor 116 has a profile on the flank 162 formed between the pitch circle 128 and a point 164 which is traveling generated by the gate rotor circular arc portion defined by radius $R_5$. The traveling generated portion of the flank 162 of the main rotor is tangent to the radius $R_3$ at point 164. The main rotor tip from point 164 to point 134 is formed by the radius $R_3$. The flank portion of the main rotor 116 from point 136 to a point 166 is traveling generated by the portion of the gate rotor formed by the radius $R_5$, and the flank portion of the main rotor from point 166 toward the pitch circle 128 is traveling generated by the gate rotor portion defined by the radius $R_5$. The curved portions 168 radially inward of the pitch circle 128 are generated by the corresponding curved portions 150 on the gate rotor 122. The profiles shown in FIG. 5 are the theoretical zero clearance profiles. These profiles may also be modified to provide suitable clearances.

Accordingly, it may be appreciated from the foregoing that the major portions of the profiles of FIGS. 3 and 5 are similar. As previously stated, by altering the proportions of these major portions, a profile suitable for liquid injected compressors as shown in FIGS. 3 and 4 may be provided or a profile suitable for dry type compressors as shown in FIG. 5 may be provided. By way of examples only, proportions of the various radii and angles defined in FIGS. 3 and 5 are shown in the following table and are expressed in terms of the straight line distance $C$ between rotor rotational axes.

<table>
<thead>
<tr>
<th>TABLE I</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROFILE</td>
</tr>
<tr>
<td>Radius:</td>
</tr>
<tr>
<td>$R_4$</td>
</tr>
</tbody>
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What is claimed is:

1. A pair of cooperating main and gate rotors having helical lobes and intervening grooves and adapted for rotation about parallel axes within a chamber formed in a helical screw rotor machine, said rotors having profiles defining the shape of said grooves and lobes formed in such a way that, in a plane transverse to the axes of rotation, said gate rotor grooves are formed to have:
   a. a concave curved portion forming at least a part of a first groove flank and defined by a radius having its center outside the gate rotor pitch circle;
   b. a convex curved portion on said first flank extending radially inwardly from said gate rotor pitch circle;
   c. a concave curved portion forming at least a part of a second groove flank and being generated by a portion of said main rotor lobe tip; and,
   d. a convex curved portion on said second flank extending radially inwardly from said gate rotor pitch circle; and,
   
   said main rotor lobes having flanks which are substantially formed by traveling generation by said concave curved portion of said first flank and said convex curved portions forming said gate rotor grooves.

2. The invention set forth in claim 1 wherein:
   said convex curved portion on said first flank extends from said gate rotor pitch circle to a meeting point with said concave curved portion on said first flank.

3. The invention set forth in claim 2 wherein:
   said concave and convex curved portions on said first flank are tangent at said meeting point.

4. The invention set forth in claim 1 wherein:
   said convex curved portion on said first flank is formed as a circular arc.

5. The invention set forth in claim 1 wherein:
   said convex curved portion on said second flank extends from said gate rotor pitch circle to a meeting point with said concave curved portion which is traveling generated.

6. The invention set forth in claim 5 wherein:
   said concave and convex curved portions on said second flank are tangent at said meeting point.

7. The invention set forth in claim 1 wherein:
   said convex curved portion on said second flank is formed as a circular arc.

8. The invention set forth in claim 1 wherein:
   said profile on said gate rotor groove comprises a concave curved portion forming the radially innermost part of said gate rotor groove which meets said concave curved portions on said first and second flanks and is tangent to said concave curved portions on said first and second flanks.

9. The invention set forth in claim 1 wherein:
   said portion of said main rotor lobe tip comprises a curved portion which traveling generates said concave curved portion on said second flank.

10. The invention set forth in claim 9 wherein:
   said curved portion on said main rotor lobe tip comprises a circular arc having a radius center located on a line which passes through the meeting point of the main and gate rotor pitch circles, on said line forming an angle with a straight line passing through the main and gate rotor axes of rotation.

11. The invention set forth in claim 1 wherein:
   the profile of a gate rotor lobe includes a lobe tip portion formed as a curved surface defined by the pitch circle of said gate rotor and portions on said lobe tip on each side of said curved surface which slope radially inwardly from said pitch circle from respective meeting points with said curved surface.

12. A pair of cooperating main and gate rotors having helical lobes and intervening groove and adapted for rotation about parallel axes within a chamber formed in a helical screw rotor machine, said rotors having profiles defining the shape of said grooves and lobes formed in such a way that, in a plane transverse to the axes of rotation, said gate rotor grooves are formed to have:
   a. a concave curved portion forming at least a part of a first groove flank and defined by a radius having its center outside the gate rotor pitch circle;
   b. a convex curved portion on said first flank;
   c. a concave curved portion forming at least a part of a second groove flank and being generated by a curved portion of said main rotor lobe tip; and,
   d. a convex curved portion on said second flank; said main rotor lobes having flanks which are substantially formed by traveling generation by said convex curved portion of said first flank and said convex curved portions forming said gate rotor grooves;

said convex curved portion on said main rotor lobe tip comprises a circular arc having a radius center located on a line which passes through the meeting point of the main and gate rotor pitch circles, on said line forming an angle with a straight line passing through the main and gate rotor axes of rotation, and said profile of said main rotor lobe is defined by a radius center at the main rotor axis of rotation.

15. A pair of cooperating main and gate rotors having helical lobes and intervening grooves and adapted for rotation about parallel axes within a chamber formed in a helical screw rotor machine, said rotors having profiles defining the shape of said grooves and lobes formed in such a way that, in a plane transverse to the axes of rotation, said gate rotor grooves are formed to have:
   a. a concave curved portion forming at least a part of a first groove flank and defined by a radius having its center outside the gate rotor pitch circle;
   b. a convex curve portion on said first flank;
c. a concave curved portion forming at least a part of a second groove flank and being generated by a curved portion of said main rotor lobe tip; and,
d. a convex curved portion on said second flank;
said main rotor lobes have flanks which are substantially formed by traveling generation by said concave curved portion of said first flank and said convex curved portions forming said gate rotor grooves; and,
said profile of said main rotor includes a flank portion which is traveling generated by said first flank and a straight line portion formed on said main rotor lobe tip, said straight line portion meeting said flank portion.

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