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[54] **ROTOR ASSEMBLY FOR A ROTARY MACHINE**

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[52] **U.S. Cl.** ..... **418/61 A,** 418/142

[51] **Int. Cl.** **F01c 1/02,** F04c 1/02, F04c 27/00

[58] **Field of Search** ..... 418/61 R, 61 A, 113, 142, 418/270; 29/156.4 R

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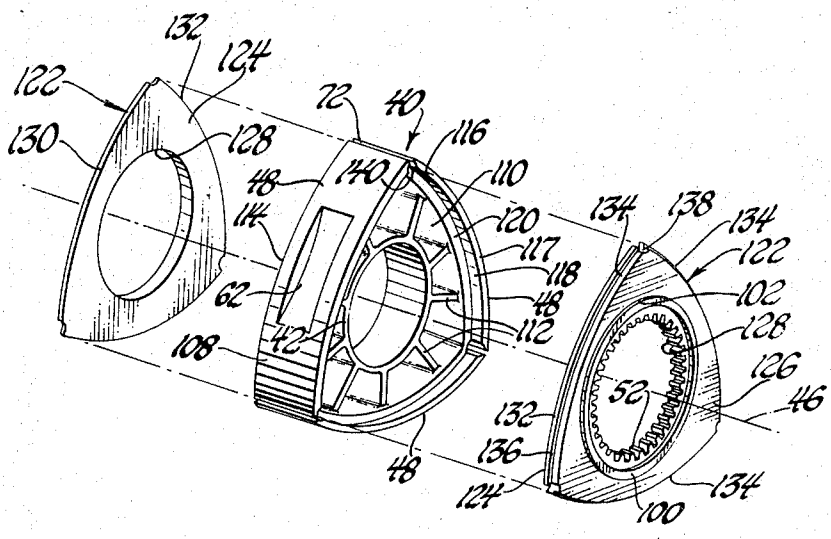
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[57] **ABSTRACT**

A rotor assembly for a rotary machine has a main body with a side plate mounted in each side thereof, the main body having a plurality of radially outwardly facing peripheral chamber faces. The rotor body and the side plates have radially inwardly and radially outwardly facing walls, respectively, that are radially spaced from each other and cooperatively provide axially outwardly facing side seal grooves of constant width and depth extending adjacent the rotor faces. The rotor body has a hub and the side plates have central openings therethrough giving access to this hub with there being formed an internal gear in the central opening of one of the side plates.

4 Claims, 4 Drawing Figures



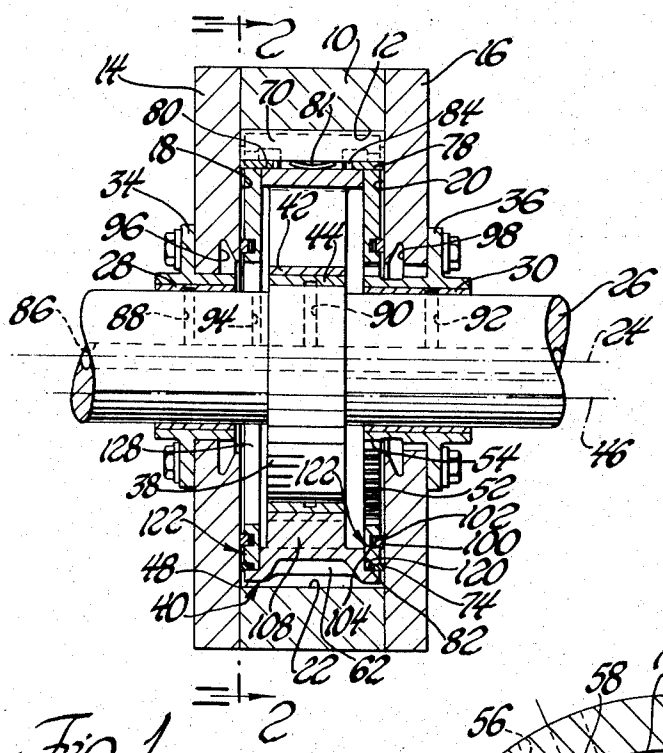


Fig. 1

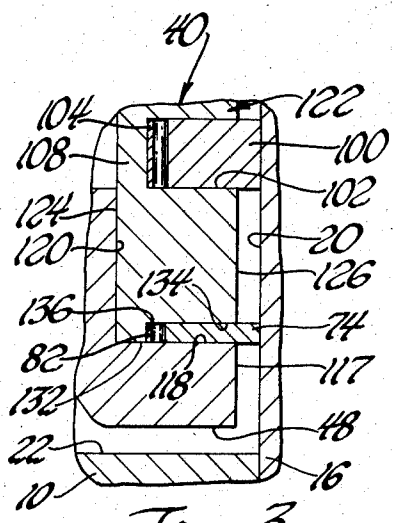


Fig. 3

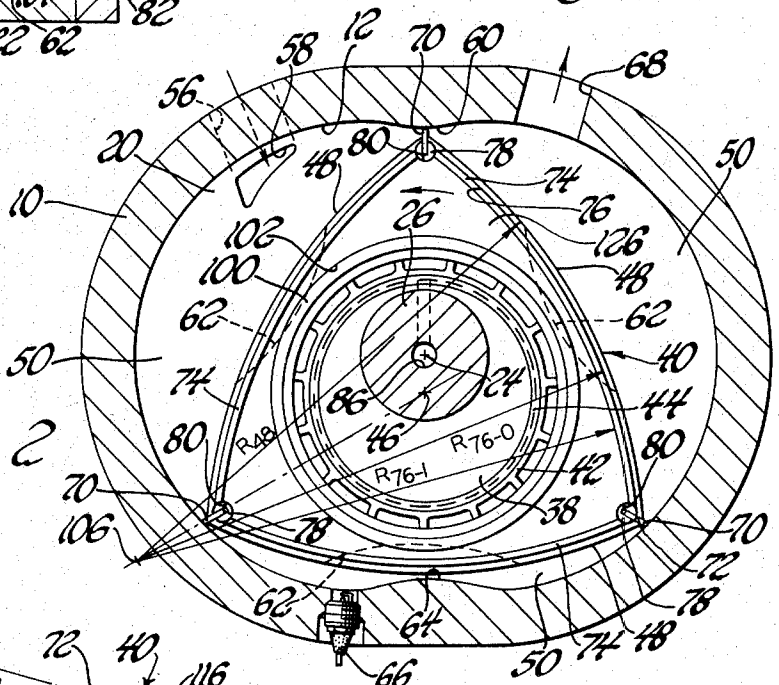


Fig. 2

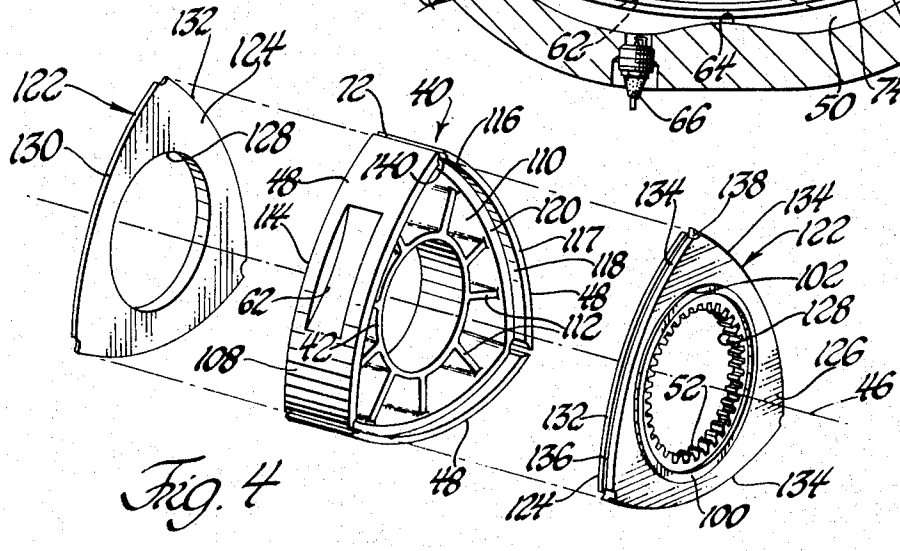


Fig. 4

ROTOR ASSEMBLY FOR A ROTARY MACHINE

This invention relates to a rotor for a rotary machine and more particularly to a rotor assembly for a rotary machine wherein side seal grooves in each rotor side are provided by cooperating walls on the parts of assembly.

One of the major problems confronting the manufacturing of rotary machines, such as the presently commercial rotary combustion engine, is the machining of the side seal grooves in the rotor. These grooves generally have a constant radius of curvature and depth-to-width ratio that is so high that conventional end mill cutters cannot satisfactorily meet either the groove requirements or reasonable tool life. One solution to this problem has been offered by a new circular milling cutter disclosed in co-pending United States patent application Ser. No. 216,212, filed Jan. 7, 1972, now abandoned by Harold W. Ferchland entitled "Milling Cutter" and assigned to the assignee of this invention. Another solution to this problem, apart from new tool design, has been offered by a new side seal groove construction which employs arcuate inserts that are mounted in arcuate grooves in the rotor sides and cooperates with the rotor groove walls to provide the side seal grooves, such construction permitting high depth-to-width ratios with conventional end mill cutters, all as disclosed in co-pending United States patent application Ser. No. 244,823, filed Apr. 17, 1972 by Alfred J. Mitchell and Mirko A. Bratkovic entitled "Rotary Machine Rotor Side Seal Groove Construction" and assigned to the assignee of this invention. The present invention is directed to a new rotor assembly of simple design suitable for mass productuion at reduced cost which provides side seal grooves having high depth-to-width ratios that do not require thin blades or cutters and instead permit machining of the groove walls with cutter cutters relatively large proportions that permit long tool life.

According to the present invention there is provided a rotor assembly for use in a presently commercial type rotary combustion engine comprising a main rotor body which has a hub and a peripheral wall joined by ribs and is rotatable about an axis determined by the hub. The peripheral wall has a plurality of radially outwardly facing chamber faces and a pair of axially spaced, oppositely axially facing sides. Each rotor body side has a recess with radially inwardly facing walls extending adjacent the rotor body faces. Each recess further has a bottom contiguous with the recess walls extending perpendicular to the rotor axis. A side plate is secured in each rotor body recess with an inboard side contacting the bottom of this recess and an outboard side extending perpendicular to the rotary axis and radially aligned with the radially outwardly located peripheral wall side. The side plates have central openings therethrough that are aligned and centered on the rotor axis and expose the rotor body hub. Each of the side plates further has a periphery with radially outwardly facing walls corresponding in number to and arranged radially opposite the recess walls. The side plate walls and the recess walls are radially spaced and cooperate to provide axially outwardly facing side seal grooves of constant large depth and constant small width extending adjacent the rotor body faces. In addition, one of the side plates has formed thereon in the opening thereof an internal tooth gear that is centered on the rotor axis.

In the rotor assembly of the present invention, each side of the side seal grooves is easily machined separately on the rotor body and side plates and with cutters of relatively large size as compared with a thin small diameter cutter which would be required to machine these grooves. Furthermore, the present invention provides substantial design flexibility in both the shape and size of the side seal grooves and with the added advantage of permitting the use of various materials and forming of the side plates and main rotor body. For example, the main rotor body may be a casting of hard metal, such as iron, or soft material, such as aluminum, or may be formed of powdered metal or may be extruded and the side plates may also be easily formed and of a different metal particularly suited for gear use where the internal gear is formed integral therewith. In addition, there is the added advantage that with the internal tooth gear formed on one of the side plates, this gear may be formed by high volume gear manufacturing methods such as broaching, which would not normally be possible if the rotor were integral with the rotor body.

An object of the present invention is to provide a new and improved rotor assembly with side seal grooves for a rotary machine.

Another object is to provide a rotor assembly for a rotary machine having a main rotor body and side plates which are inserted in recesses in the body and cooperate therewith to provide axially outwardly facing side seal grooves extending adjacent the rotor's faces in addition to forming the rotor sides radially inward of the side seal grooves.

Another object is to provide a rotor assembly for a rotary machine having a main rotor body with a central hub and a recess on each side and a side plate mounted in each recess that along its periphery has radially outwardly facing walls cooperating with radially outwardly facing walls inwardly facing walls of the recess to provide axially outwardly facing side seal grooves in each rotor side that have a constant and high depth-to-width ratio and extend adjacent the periphery of the rotor body and with one of the side plates having formed thereon an internal tooth gear centered on the rotor axis.

These and other objects of the present invention will be more apparent from the following description and drawing in which:

FIG. **1** is a longitudinal view with parts in section of a rotary combustion engine having a rotor assembly constructed according to the present invention.

FIG. **2** is a view taken along the line **2—2** in FIG. **1.**

FIG. **3** is an enlarged view of one corner of the rotor assembly as shown in FIG. **1.**

FIG. **4** is an exploded view of the rotor assembly in FIG. **1.**

The rotor assembly according to the present invention is for use in rotary machines including rotary combustion engines, compressors, pumps and the like. Referring to FIG. **1,** the rotary machine may, for example, be an internal combustion engine of present commercial type having a stationary outer body comprising a rotor housing **10** having an inwardly facing inner peripheral wall **12** and a pair of end housings **14** and **16** having parallel, oppositely facing, spaced, inner end walls **18** and **20,** respectively. The housing parts are rigidly secured together by bolts, not shown, and the

inner housing walls **12, 18** and **20** cooperatively provide a rotor cavity **22.** Referring to FIG. **2,** the peripheral wall **12** is in the shape of a two-lobed epitrochoid or a curve parallel thereto whose center line is indicated at **24.** A crankshaft **26** extends through the rotor cavity **22** and is rotatably supported in sleeve bearings **28** and **30** which are secured in collars **34** and **36** that are bolted to the end housings **14** and **16,** respectively, as shown in FIG. **1,** the crankshaft axis being coincident with the center line **24,** parallel to the peripheral wall **12** and perpendicular to the end walls **18** and **20.** The crankshaft **26** is provided in the cavity **22** with an eccentric **38.** A rotor **40** constructed according to the present invention has a hub **42** with a sleeve bearing **44** journaled on the eccentric **38** whereby the rotor **40** is supported for rotation about the eccentric's center line **46** which is thus the rotor's axis. The rotor **40** has the general shape of a triangle with three radially outwardly facing peripheral flanks or faces **48** which face the peripheral wall **12** and cooperate therewith and also with the end walls **18** and **20** to define three variable volume working chambers **50** that are spaced around the rotor and move with the rotor within the housing as the rotor rotates about its axis **46** while planetating with respect to the crankshaft axis **24.**

With the two-lobed peripheral wall **12** and the three-apex rotor **40,** each of the working chambers **50** sequentially expands the contracts between minimum and maximum volume during each rotor revolution in fixed relation to the housing by forcing the rotor **40** to rotate at one-third the speed of the crankshaft **26.** This is accomplished by gearing comprising an internal tooth gear **52** which is concentric with and a part of the rotor assembly **40.** The gear **52** meshes with an external tooth gear **54** which is received with clearance about and is concentric with the crankshaft **26** and is made stationary by being formed integral with the right-hand collar **36** as shown in FIG. **1.** The gear **52** has one and one-half times the number of teeth as the gear **54** to provide the required speed ratio of 3:1 between the crankshaft **26** and the rotor **40.**

A combustible air-fuel mixture from a suitable carburetor arrangement, not shown, is made available to each working chamber **50** by an intake passage **56** as shown in FIG. **2.** Passage **56** extends through the engine housing and opens to the cavity through aligned intake ports **58** which are located in the end walls **18** and **20** on the leading sde of cusp **60** of the peripheral wall **12** relative to the direction of rotor rotation indicated by the arrow in FIG. **2,** there being only one such intake port appearing in this view. A single channel or recess **62** is provided in the center of each chamber face **48** of the rotor **40** to provide for the transfer of working gases past the peripheral wall's other cusp **64** when a rotor face is at or near its top-dead-center position, as shown in FIG. **2,** so that the chambers are not divided by the cusp **64** at the time when combustion is to occur therein. A spark plug **66** is mounted in the rotor housing **10** adjacent the cusp **64** with its spark gap exposed to the working chambers. As the rotor **40** planetates, the working chambers successively draw in fuel mixture as the rotor sides periodically uncover the intake ports **58.** The fuel mixture is then trapped in each working chamber and compressed and when the rotor face of this chamber is in the vicinity of top-dead-center, this mixture is ignited at the completion of the compression phase; there being provided a suitable ignition system, not shown, for applying voltage to plug **66** at the proper time. Upon ignition of the mixture in each working chamber the peripheral wall **12** takes the reaction forcing the rotor **40** to continue its motion while the gas is expanding. The leading rotor apex of each working chamber eventually traverses an exhaust passage **68** on the trailing side of cusp **60** whereby the exhaust products are then expelled through the exhaust passage **68** to complete the cycle.

Sealing of the chambers **50** for such four-cycle operation is provided by three apex seals **70** which are each mounted in an axially extending radially outwardly facing groove **72** that is located at each apex or corner of the rotor **40** and extends the width thereof. Three arcuate side seals **74** are mounted in accommodating axially outwardly facing grooves **76** in each rotor side and extend adjacent the rotor faces between two apex seals **70.** Three cylindrical corner seals **78** are mounted in cylindrical holes **80** in each rotor side with each corner seal providing sealing between the adjacent ends of two side seals and one apex seal as shown in FIG. **2.** Referring to FIG. **1,** each of the apex seals **70** is biased by a spring **81** to continuously engage the peripheral wall **12** and each of the side seals **74** and corner seals **78** is biased to continuously engage the respective end walls **18** and **20** by a wave spring **82** and a C-shaped spring **84,** respectively.

Describing now the lubrication that is normally provided in such an arrangement and also cooling of the rotor, oil from the engine drains to a sump from which it is delivered by a suitable engine powered pump to an axial oil passage **86** in the crankshaft **26** as shown in FIG. **1.** Radial oil passages **88, 90** and **92** deliver oil from the passage **86** to lubricate the sleeve bearings **28, 44** and **30,** respectively. The rotor **40** has a hollow interior and is webbed for rigidity as described in more detail later, and a radial oil passage **94** in the crankshaft **26** delivers oil from the passage **86** to the rotor's interior for cooling of the rotor with the oil carrying the heat from the rotor by passing to annular cavities **96** and **98** in the respective end walls **18** and **20** that are connected to drain to the sump. In addition to the gas seals carried on the rotor **40,** there is provided in each side of the rotor a circular oil seal **100** that is located radially inwardly of the side gas seals **74** in an accommodating axially outwardly facing circular groove **102.** The oil seals **103** are each biased by a wave spring **104** to continuously engage the respective end walls **18** and **20** to prevent the oil supplied for lubrication and cooling from reaching the radially outwardly located gas seals.

In the construction of the rotor for such machines, it is common practice to cast the rotor in one piece and attach the internal tooth gear. In addition, it is conventional practice to machine each of the rotor faces **48** to an arcuate surface having a constant radius R_{48} about a center line **106** which lies on a plane passing through the rotor's axis **46** and the opposite rotor apex and is parallel to the rotor axis as shown in FIG. **2.** Furthermore, it is conventional practice that each of the side seal grooves **76** is machined to a circular arc having an arcuate outer wall with constant radius $R_{76\text{-}0}$ and an arcuate inner wall with constant radius $R_{76\text{-}I}$ also about the center line **106,** the side seal grooves **76** thus extending parallel to the respective rotor faces as shown in FIG. **2.** The side seal grooves **76** commonly have high depth-to-width ratios such as on the order of 4:1.

For example, in one actual side seal groove specifically for a rotary combustion engine, it was desired to machine the groove to a depth of about 0.170 inch and a width of about 0.040 inch which gives a depth-to-width ratio of about 4:1. In addition to this very high depth-to-width ratio, the groove was required to have a side wall surface texture of better than 30 micro inches. As a general rule of thumb, the machining of a straight groove with a depth-to-width ratio greater than 2:1 presents a tooling problem with this problem becoming amplified in the case of groove curvature. A further problem results where the groove's side walls are required to be very smooth, such as in the case presented here since this limits the type of cutters that can be used. As a general rule, end mill cutters are not satisfactory for arcuate grooves having such high depth-to-width ratios and as a result special cutting tools other than end mill cutters have been proposed to cut these grooves. According to the present invention, the rotor 40 is constructed of an assembly such that conventional cutting means may be employed in the machining of the parts of this assembly to form these grooves with these very high depth-to-width ratios and side seal texture requirements as will now be discussed.

As best shown in FIGS. 1 and 4, the rotor 40 is constructed as an assembly comprising a main rotor body 108 having a peripheral wall 110 on which the radially outwardly facing chamber faces 48 may be readily machined. The rotor body is of hollow construction having a plurality of angularly spaced radial ribs 112 that join the peripheral wall 110 with the center hub 42 in which the rotor's sleeve bearing 44 is mounted.

The rotor body 108 has in each side a recess 116 of triangular shape leaving axially spaced, oppositely axially facing sides 117 on the peripheral wall 110 radially outward of the side seal grooves that run close to the respective end walls 18 and 20 of the engine housing. Each of the rotor body's side recesses 116 has radially inwardly facing arcuate walls 118 that are equal in number to the rotor faces 48 and have a constant radius from the respective rotor face center lines 106 equal to the desired side seal grooves outer radius $R_{76\text{-}0}$. Each of the recesses 116 has, in addition, a flat bottom 120 that is contiguous with the recess walls 118, is perpendicular to the rotor axis 46 and is located axially outboard of or raised from the rotor ribs 112.

A pair of generally triangularly-shaped side plates 122 are secured such as by electron beam welding in the respective recesses 116 of the rotor body 108 with an inboard side 124 adjacent the perimeter thereof contacting the recess bottom 120 and an outboard side 126 having the oil seal groove 102 machined therein extending perpendicular to the rotor axis and radially aligned with the radially outwardly located peripheral narrow wall side 117 of the rotor body's peripheral wall 110. Each of the side plates 122 has a circular opening 128 that is centered on the rotor axis 46 and is larger in diameter than the hub 42. With the arrangement there is as best shown in FIG. 1, an annular clearance between the side plates 122 and hub 42 to permit passage of oil through the interior of the rotor body. The periphery of each side plate 122 has walls 130 corresponding in number to and arranged radially opposite the recess wall 118. Each of these side plate walls 130 has an axially inboard locating arcuate portion 132 that is of the same constant radius $R_{76\text{-}0}$ from the radially outward rotor face's center line 106 as the opposite recess wall 118 so that it contacts an axially inboard portion of this recess wall to positively center the side plate on the rotor axis. Furthermore, each of the side plate walls 130 has an axially outboard arcuate portion 134 having an axial dimension equal to the desired depth of the side seal grooves and a constant radius equal to the desired inner radius $R_{76\text{-}I}$ of the side seal groove from the radially outward rotor face's center line 106. In addition, each of the side plate walls 130 has a radial portion 136 that is flat and perpendicular to the rotor axis and extends radially between the inboard and outboard side plate wall portions 132 and 134. Thus, each of the side plate's axially outboard wall portions 134 are radially spaced from the opposite recess walls 118 a distance equal to the width of the desired side seal groove, and the axial dimension from the outboard plate side to the radial portion 136 is equal to the depth of the desired side seal groove. With this arrangement the plates 122 and the rotor body 108 by the cooperation between the outboard portions of the arcuate recess walls 118 and the radial portions 136 and radially outwardly facing outboard arcuate portions 134 of the plate walls 122 thus provide axially outwardly facing side seal grooves 76 of constant depth and constant width extending adjacent the rotor faces according to the required dimensions. Furthermore, one of the side plates 122, such as the right-hand plate, as shown in FIGS. 1 and 4, has formed thereon in the central opening 128 thereof the internal tooth gear 52. In addition, the corner seal apertures 78 which are commonly a cylindrical bore are provided by the side plates 122 and the main rotor body's peripheral wall 110 on each side having contiguous axially extending wall portions 138 and 140 that cooperate to provide the desired corner seal aperture contiguous with the end of each adjoining pair of side seal grooves 76 on each rotor side.

The above described rotor assembly is well suited for manufacturing in high volume since now each side of the side seal groove is machined separately on the respective rotor body and side plate parts. For example, the main rotor body may be simply undercut to leave a ridge whose side becomes the outer side of the side seal groove with the cooperating side plate being machined separately with a cutter of relatively large proportions. In each case it is relatively easy to provide the required surface finish requirements. It will also be appreciated by those skilled in the art that additional side seal grooves parallel to the first side seal grooves may be readily provided by inserting additional side plates in similar manner in the first side plates. In addition to removing the major machining obstacles, the present rotor assembly permits substantial flexibility in the choice of materials. For example, the main rotor body may either be cast or extruded or may be of powdered metal, and as regards to casting, there is provided a wide open area for thorough cleaning of the part. Another advantage is that with the internal tooth gear formed on a plate as compared with being formed integral with the rotor body, this gear may then be formed by broaching which is less costly than the type of machining operations that would be required if the gear were an integral part of the rotor. Furthermore, it is contemplated that the side plates can be attached to the rotor body by mechanical means such as screws, bolts, spring pins and the like instead of welding.

The above described embodiment is illustrative of the invention which may be modified within the scope of the appended claims.

I claim:

1. A rotor assembly for a rotary machine comprising a main rotor body having a hub and a peripheral wall joined by ribs rotatable about an axis determined by said hub, said peripheral wall having a plurality of radially outwardly facing chamber faces and a pair of axially spaced oppositely axially facing sides, said faces extending parallel to said axis, said sides extending perpendicular to said axis, said rotor body on each said side having a recess with radially inwardly facing walls extending in a peripheral direction adjacent each of said faces and extending in an axial direction to said sides parallel to said axis, each said recess further having a bottom contiguous with said recess walls and extending perpendicular to said axis, a side plate secured in each said recess with an inboard side contacting the bottom of this recess and an outboard side extending perpendicular to said axis, said side plates having central openings therethrough that are centered on said axis, each said side plate having a periphery with radially outwardly facing walls corresponding in number to and arranged radially opposite said recess walls, each of said side plate walls having an axially outboard portion radially spaced from an axially outboard portion of the opposite recess wall, each of said side plate walls further having a radial portion perpendicular to said axis and extending radially inward to the outboard side plate wall portion, said outboard portions of said recess walls and said radial portions and said radially outwardly facing outboard portions of said plate walls cooperating to provide axially outwardly facing side seal grooves of constant depth and constant width extending adjacent said faces.

2. A rotor assembly for a rotary machine comprising a main rotor body having a hub and a peripheral wall joined by ribs rotatable about an axis determined by said hub, said peripheral wall having a plurality of radially outwardly facing chamber faces and a pair of axially spaced oppositely axially facing sides, said faces extending parallel to said axis, said sides extending perpendicular to said axis, said rotor body on each said side having a recess with radially inwardly facing arcuate walls of constant radius extending in a peripheral direction adjacent each of said faces and extending in an axial direction to said sides parallel to said axis, each said recess further having a bottom contiguous with said recess walls and extending perpendicular to said axis, a side plate secured in each said recess with an inboard side contacting the bottom of this recess and an outboard side extending perpendicular to said axis and radially aligned with the radially outwardly located peripheral wall side, said side plates having central openings therethrough that are centered on said axis, each said side plate having a periphery with radially outwardly facing arcuate walls of constant radius corresponding in number to and arranged radially opposite said recess walls with the radii of the opposing walls having a common center line parallel to said axis, each of said side plate walls having an axially inboard locating portion engaging an axially inboard portion of the opposite recess wall whereby said plate is positively centered on said axis, each of said side plate walls also having an axially outboard portion radially spaced from an axially outboard portion of the opposite recess wall, each of said side plate walls further having a radial portion perpendicular to said axis and extending radially between the inboard and outboard side plate wall portions, and said outboard portions of said recess walls and said radial portions and said radially outwardly facing outboard portions of said plate walls cooperating to provide axially outwardly facing side seal grooves of constant depth and constant width extending adjacent said faces.

3. A rotor assembly for a rotary machine comprising a main rotor body having a hub and a peripheral wall joined by ribs rotatable about an axis determined by said hub, said peripheral wall having a plurality of radially outwardly facing chamber faces and a pair of axially spaced oppositely axially facing sides, said faces extending parallel to said axis, said sides extending perpendicular to said axis, said rotor body on each said side having a recess with radially inwardly facing walls extending in a peripheral direction adjacent each of said faces and extending in an axial direction parallel to said axis, each said recess further having a bottom contiguous with said recess walls and extending perpendicular to said axis, a side plate secured in each said recess with an inboard side contacting the bottom of this recess and an outboard side extending perpendicular to said axis and radially aligned with the radially outwardly located peripheral wall side, said side plates having central openings therethrough that are centered on said axis, each said side plate having a periphery with radially outwardly facing walls corresponding in number to and arranged radially opposite said recess walls, each of said side plate walls having an axially inboard locating portion engaging an axially inboard portion of the opposite recess wall whereby said plate is positively centered on said axis, each of said side plate walls also having an axially outboard portion radially spaced from an axially outboard portion of the opposite recess wall, each of said side plate walls further having a radial portion perpendicular to said axis and extending radially between the inboard and outboard side plate wall portions, said outboard portions of said recess walls and said radial portions and said radially outwardly facing outboard portions of said plate walls cooperating to provide axially outwardly facing side seal grooves of constant depth and constant width extending adjacent said faces, and one of said side plates having formed thereon in the central opening thereof an internal tooth gear centered on said axis.

4. A rotor assembly for a rotary machine comprising a main rotor body having a hub and a peripheral wall joined by ribs rotatable about an axis determined by said hub, said peripheral wall having a plurality of radially outwardly facing faces and a pair of axially spaced oppositely axially facing sides, said faces extending parallel to said axis, said sides extending perpendicular to said axis, said rotor body on each said side having a recess with radially inwardly facing arcuate walls of constant radius extending in a peripheral direction adjacent each of said faces and extending in an axial direction to said sides parallel to said axis, each said recess further having a bottom contiguous with said recess walls and extending perpendicular to said axis, a side plate secured in each said recess with an inboard side contacting the bottom of this recess and an outboard side extending perpendicular to said axis and radially aligned with the radially outwardly located peripheral wall side, said side plates having central openings there-

through that are centered on said axis, each said side plate having a periphery with radially outwardly facing arcuate walls of constant radius corresponding in number to and arranged radially opposite said recess walls with the radii of the opposing walls having a common center line parallel to said axis, each of said side plate walls having an axially inboard locating portion engaging an axially inboard portion of the opposite recess wall whereby the plate is positively centered on said axis, each of said side plate walls also having an axially outboard portion radially spaced from an axially outboard portion of the opposite recess wall, each of said side plate walls further having a radial portion perpendicular to said axis and extending radially between the inboard and outboard side plate wall portions, said outboard portions of said recess walls and said radial portions and said radially outwardly facing outboard portions of said plate walls cooperating to provide axially outwardly facing side seal grooves of constant depth and constant width extending adjacent said faces, one of said side plates having formed thereon in the central opening thereof an internal tooth gear centered on said axis, and said side plates and said peripheral wall on each said side having contiguous axially extending aperture wall portions cooperating to provide an axially outwardly facing corner seal aperture contiguous with the ends of each adjoining pair of said side seal grooves on each rotor side.

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