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(54) **ROTATING MACHINE**

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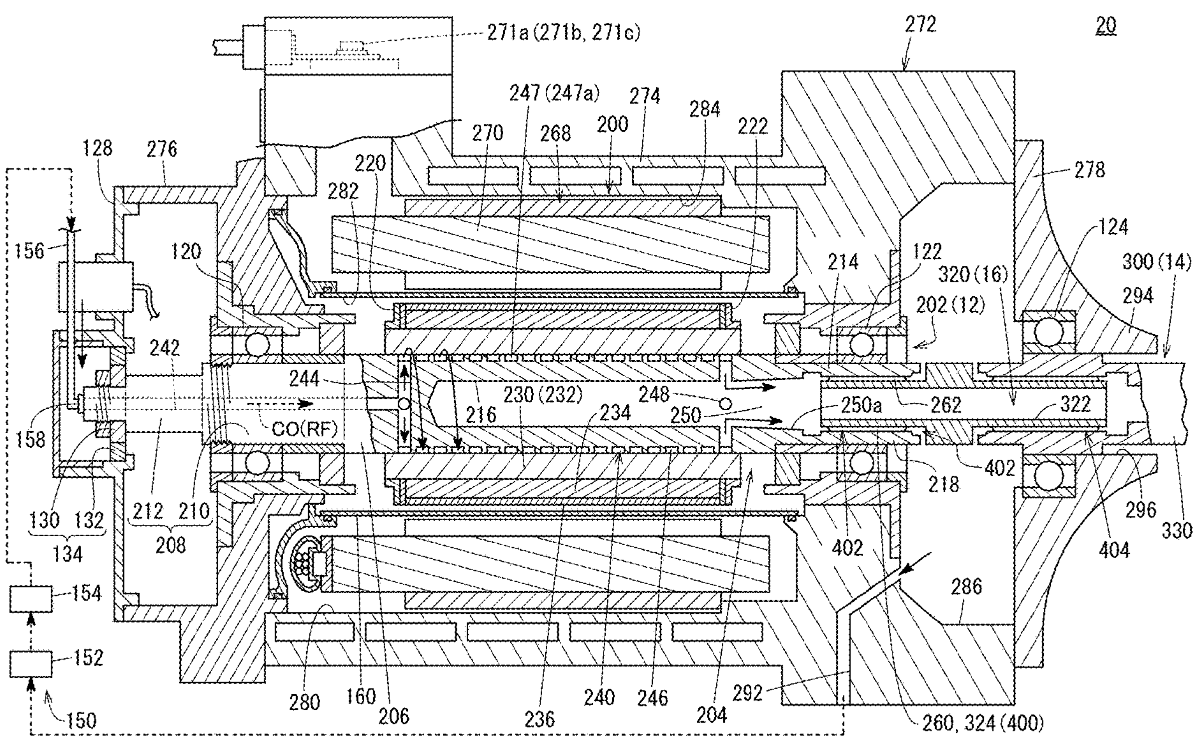
(57) **ABSTRACT**

A first rotating shaft of a rotating machine has a first engaging portion disposed at a first connecting end portion. A second engaging portion is disposed at a second connecting end portion of a second rotating shaft of the rotating machine. In the diametrical direction of the first connecting end portion, the first connecting end portion and the second connecting end portion overlap each other, and the second engaging portion is slidably engaged with the first engaging portion. A lubricant flow path is formed between the first engaging portion and the second engaging portion.



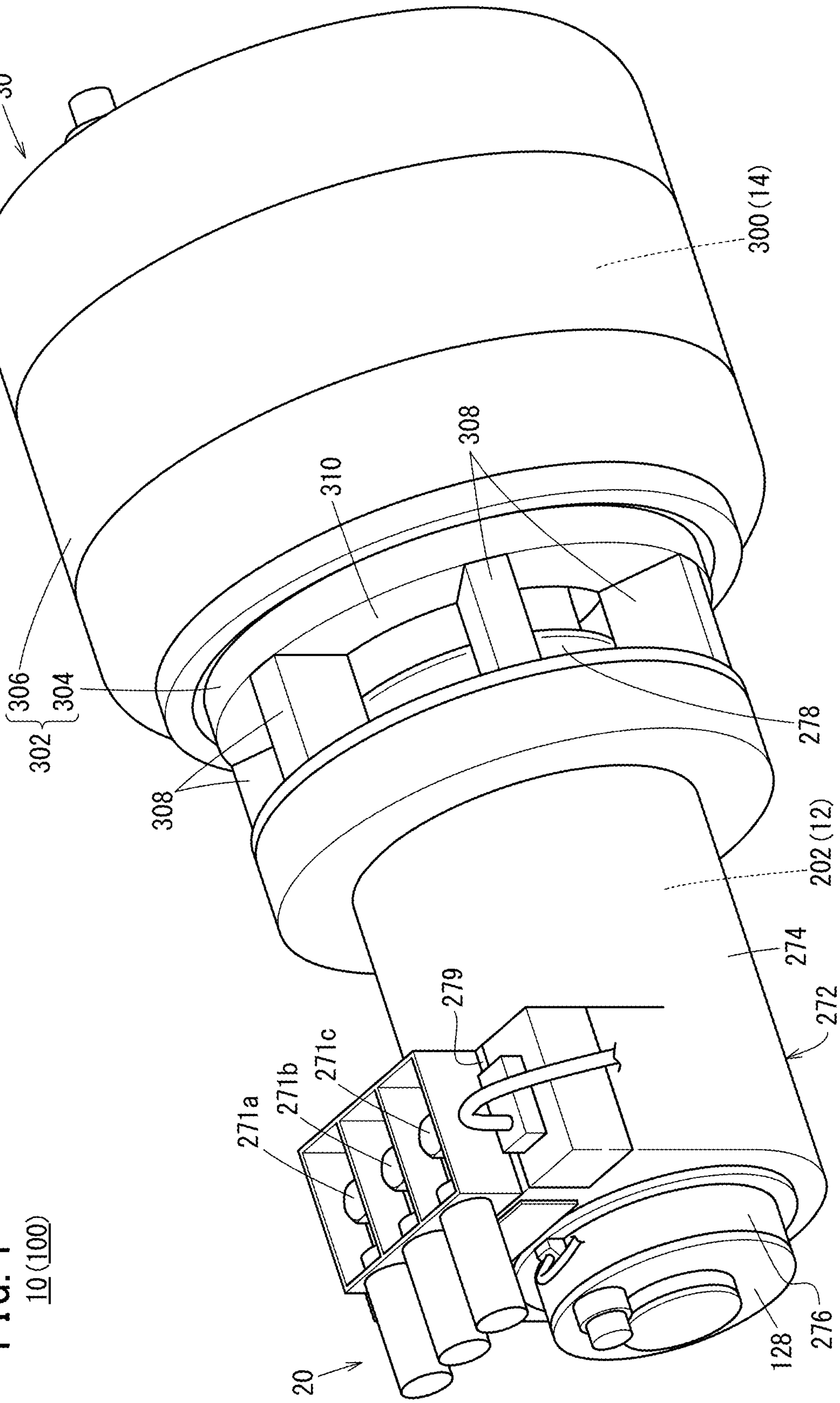

30
300(14)
310
308
308
306
304
302
278
202(12)
274
272
279
271a
271b
271c
20
128
276

FIG. 1
10(100)

FIG. 2

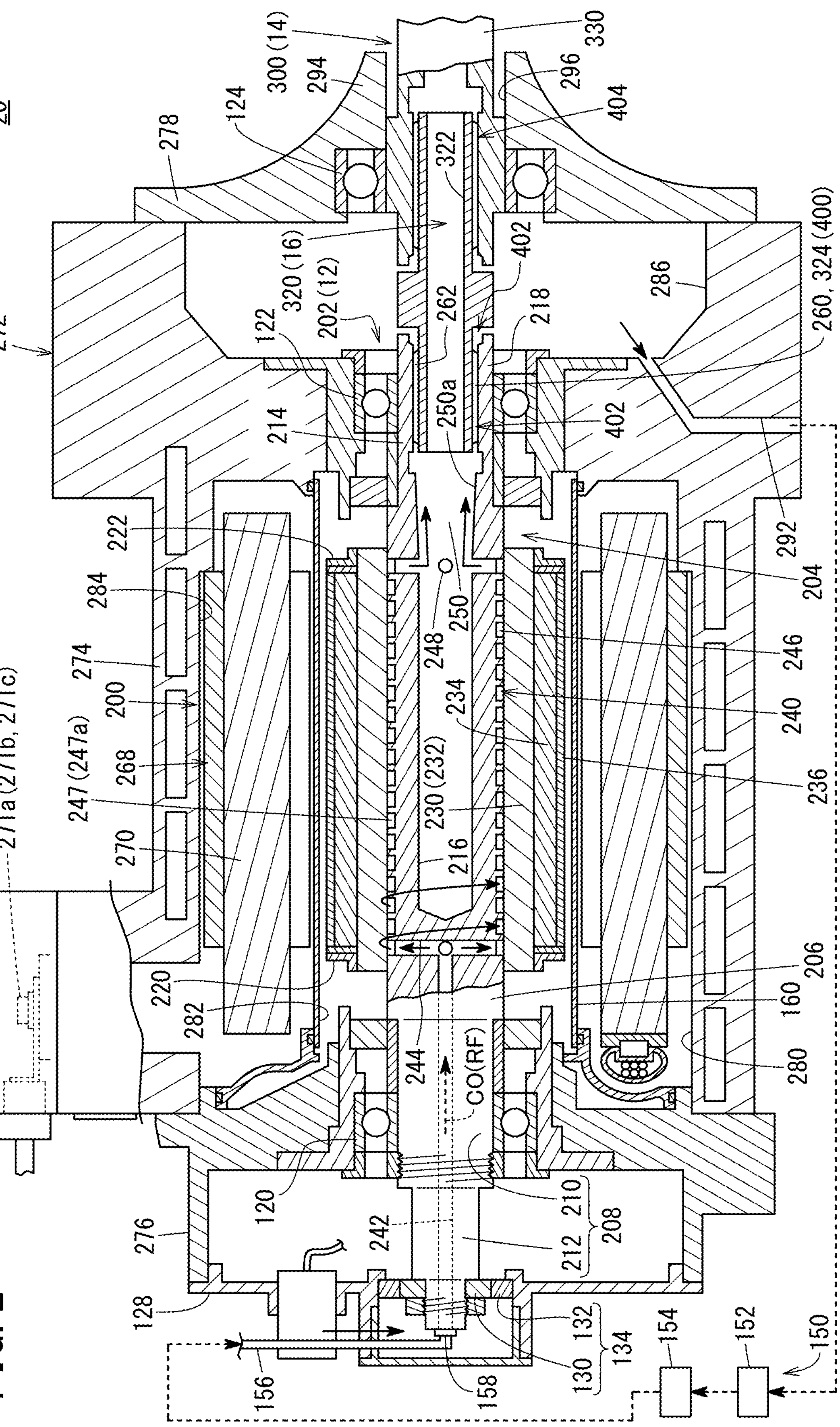
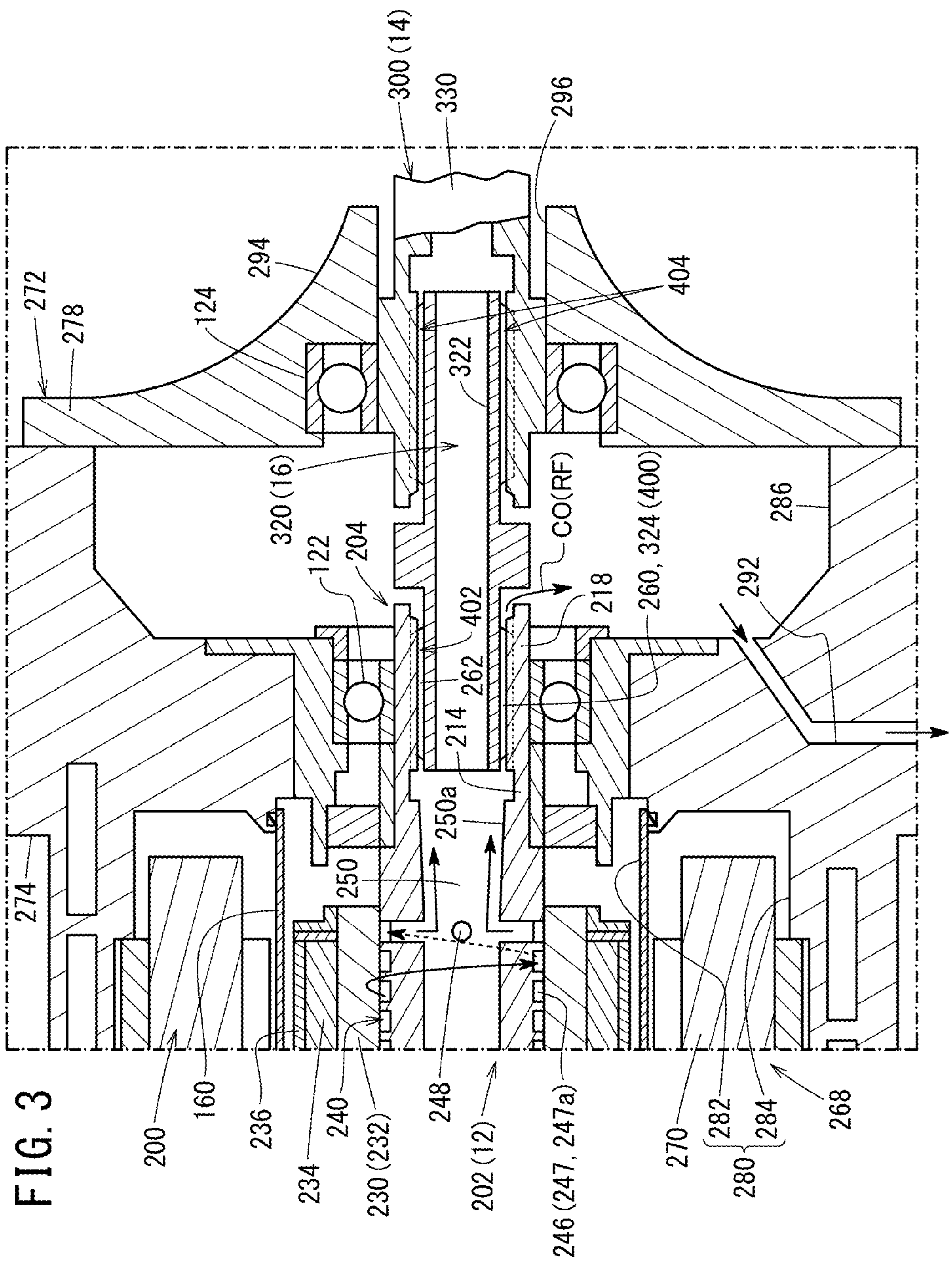
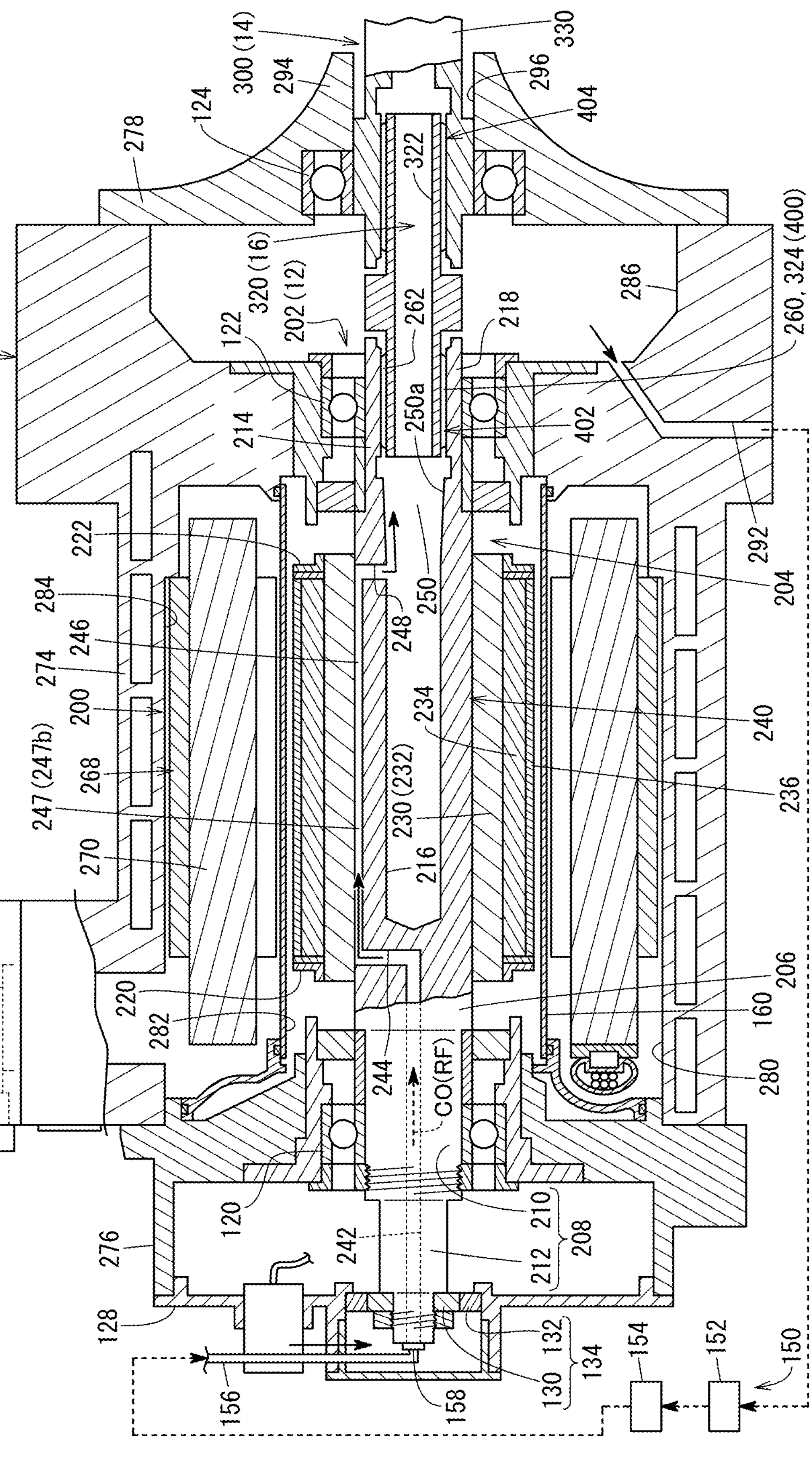

20
272
278
124
300 (14)
294
330
296
404
322
320 (16)
202 (12)
402
286
260, 324 (400)
122
262
218
250a
214
402
292
222
204
284
248
250
274
246
200
234
240
268
247 (247a)
230 (232)
236
271a (271b, 271c)
270
216
220
206
282
160
244
CO (RF)
280
120
210
208
242
212
276
128
132
134
130
158
156
154
152
150

FIG. 3


300(14)
330
296
294
404
272
278
124
322
320(16)
CO(RF)
324(400)
286
260, 324(400)
292
122
204
402
218
262
214
250a
250
274
248
200
160
236
234
240
230(232)
202(12)
246(247, 247a)
270
282
284
280
268



20
272
278
124
300 (14)
294
330
296
404
322
320 (16)
202 (12)
122
286
262
218
260, 324 (400)
250a
214
402
292
222
284
246
274
200
268
247 (247b)
271a (271b, 271c)
270
248
250
204
234
240
230 (232)
236
216
220
282
206
160
280
244
CO(RF)
120
210
208
212
242
276
128
156
158
130
132
134
154
152
150

FIG. 4

ROTATING MACHINE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2024-024768 filed on Feb. 21, 2024, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a rotating machine having a first rotating body and a second rotating body.

Description of the Related Art

[0003] A rotating electric machine rotor has a rotating shaft and permanent magnets retained by the rotating shaft. In a rotating electric machine, the temperature of the permanent magnets becomes high as the rotating electric machine rotor rotates. In view of the above, JP 2022-045542 A proposes a method of cooling permanent magnets by supplying a cooling medium into a hollow interior of a rotating shaft.

[0004] A combined power system as a rotating machine may be configured by combining a rotating electric machine and a gas turbine engine. In the combined power system, one end of the rotating shaft of a turbine rotor in the axial direction thereof is connected to one end of the rotating shaft of the rotating electric machine rotor in the axial direction thereof. Therefore, the rotating electric machine rotor and the turbine rotor rotate together integrally.

SUMMARY OF THE INVENTION

[0005] There may be a case where lubrication is required at a connected part between a rotating shaft of a rotating electric machine rotor and a rotating shaft (output shaft) of a turbine rotor. Accordingly, in the case that a rotating machine is configured by combining a gas turbine engine and the rotating electric machine having the configuration described in JP 2022-045542 A, it is necessary to supply a lubricant to a connected part of the two rotating shafts while supplying a cooling medium to the rotating shaft of the rotating electric machine rotor. Therefore, in the case that the rotating machine is configured by including the cooling medium supply device and the lubricant supply device, the configuration of the rotating machine is complicated.

[0006] An object of the present invention is to solve the aforementioned problem.

[0007] An aspect of the present disclosure is characterized by a rotating machine including a first rotating body including a first rotating shaft, and a second rotating body including a second rotating shaft configured to rotate integrally with the first rotating shaft. The first rotating shaft includes a cooling medium flow path through which a liquid cooling medium flows, a liquid feed path communicating with the cooling medium flow path, and a first engaging portion provided at a first connecting end portion that is one end portion of the first rotating shaft in an axial direction of the first rotating shaft. The second rotating shaft includes a second connecting end portion overlapping the first connecting end portion in a diametrical direction of the first connecting end portion, and a second engaging portion provided at the second connecting end portion. The first engaging portion and the second engaging portion form a connecting portion configured to transmit the rotational driving force between the first rotating shaft and the second rotating shaft.

[0008] The second engaging portion is engaged with the first engaging portion so as to be relatively slidable in the axial direction. A lubricant flow path is formed between the first engaging portion and the second engaging portion that are engaged with each other, the lubricant flow path communicating with the liquid feed path and through which the liquid cooling medium is allowed to pass as a lubricant. The liquid feed path is interposed between the cooling medium flow path and the lubricant flow path.

[0009] According to the present invention, the liquid cooling medium for cooling the first rotating body can also be used as a lubricant for lubricating the connecting portion between the first rotating shaft and the second rotating shaft.

[0010] The above and other objects, features, and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings, in which a preferred embodiment of the present invention is shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a schematic overall perspective view of a rotating machine (combined power system) according to an embodiment of the present invention;

[0012] FIG. **2** is a schematic cross-sectional side view when the combined power system in FIG. **1** is observed in a direction perpendicular to an axial direction;

[0013] FIG. **3** is an enlarged cross-sectional side view of principal components, illustrating the vicinity of a connected part between the first rotating shaft and the second rotating shaft (connecting shaft) in the combined power system of FIG. **1**; and

[0014] FIG. **4** is a schematic cross-sectional side view illustrating a cooling medium flow path in an aspect different from that of FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

[0015] In the following description, a combined power system **100** shown in FIG. **1** is exemplified as a rotating machine **10**. In this case, a rotating electric machine rotor **202** shown in FIG. **2** corresponds to a first rotating body **12**, and a turbine rotor **300** corresponds to a second rotating body **14**. However, this is merely an example, and the rotating machine **10** is not limited to the combined power system **100**. Although not shown, another example of the rotating machine **10** includes a rotary vane. In this case, the rotating electric machine rotor **202** corresponds to the first rotating body **12**, and a propeller or a fan corresponds to the second rotating body **14**.

[0016] In the following, a cooling oil CO is exemplified as a liquid cooling medium RF. However, the liquid cooling medium RF is not limited to the cooling oil CO. The liquid cooling medium RF may be an organic solvent with a high boiling point and low volatility.

[0017] Further, the respective terms "left", "right", "lower", and "upper" refer specifically to the left, right, lower and upper directions shown in FIG. **2** to FIG. **4**.

However, these directions are provided for the sake of convenience in order to simplify the description and facilitate understanding. In particular, the directions described in the specification are not limited to the directions when the combined power system **100** is actually used.

[0018] FIG. **1** is a schematic overall perspective view of the combined power system **100**, which is one example of the rotating machine **10**. The combined power system **100** includes a rotating electric machine system **20** and a gas turbine engine **30**. An axis of the rotating electric machine system **20** coincides with an axis of the gas turbine engine **30**. Stated otherwise, the rotating electric machine system **20** and the gas turbine engine **30** are arranged on the same axis.

[0019] The combined power system **100** is used, for example, as a power source for providing propulsion in a flying object, a ship, an automobile, or the like. Suitable specific examples of the flying object include a drone and a multi-copter. The combined power system **100**, when mounted on a flying object, is used as a power drive source for rotating, for example, a prop, a ducted fan, or the like. The combined power system **100**, when mounted on a ship, is used as a screw rotational force generating device. The combined power system **100**, when mounted on an automobile, is used as a power drive source for rotating a motor.

[0020] The combined power system **100** can also be used as an auxiliary power source in an aircraft, a ship, a building, or the like. Apart therefrom, it is also possible to utilize the combined power system **100** as gas turbine power generation equipment.

[0021] A description will be given concerning the rotating electric machine system **20**. As shown in FIG. **2**, the rotating electric machine system **20** includes a rotating electric machine **200** and a rotating electric machine housing **272** that accommodates the rotating electric machine **200**. The rotating electric machine housing **272** has a main housing **274** that exhibits a substantially cylindrical shape, and includes open opposite ends in the axial direction. The rotating electric machine housing **272** further includes a first sub-housing **276** connected to the left end of the main housing **274** and a second sub-housing **278** connected to the right end of the main housing **274**.

[0022] The rotating electric machine **200** includes the rotating electric machine rotor **202**, and a stator **268** that surrounds an outer circumferential side of the rotating electric machine rotor **202**. In the combined power system **100**, the rotating electric machine **200** is typically a generator. In the above-mentioned rotary vane, the rotating electric machine **200** is typically a motor. In this manner, the rotating electric machine **200** can function as a generator or a motor.

[0023] The rotating electric machine rotor **202** includes a first rotating shaft **204**. The first rotating shaft **204** has a large diameter portion **206**, a first end **208** positioned on the left side of the large diameter portion **206**, and a second end **214** positioned on the right side of the large diameter portion **206**. The large diameter portion **206** is a portion of the first rotating shaft **204** having the largest outer diameter. The first end **208** has a medium diameter portion **210** continuous with the left of the large diameter portion **206**, and a small diameter portion **212** continuous with the left of the medium diameter portion **210**. The medium diameter portion **210** is rotatably supported by a first bearing **120**. The small diameter portion **212** is positioned further on the left side than the first bearing **120** and extends in the interior of the first sub-housing **276**. The outer diameter of the second end **214** is substantially equal to the outer diameter of the medium diameter portion **210**.

[0024] A resolver rotor **130** is attached to the small diameter portion **212**. The resolver rotor **130** rotates integrally with the first rotating shaft **204**. A resolver holder **128** is attached to the first sub-housing **276**. A resolver stator **132** is retained on the resolver holder **128**. The resolver rotor **130** and the resolver stator **132** constitute a resolver **134**. For example, the resolver **134** detects an angle of rotation of the first rotating shaft **204**.

[0025] The large diameter portion **206** has a hollow shape having an inner hole **216**. A cover member **230** is positioned and fixed to the large diameter portion **206**. In the illustrated example, the cover member **230** is a sleeve **232**. A first collar **220** and a second collar **222** are positioned and fixed to the left end and the right end of the sleeve **232**, respectively. A magnet holder **234** is sandwiched between the first collar **220** and the second collar **222**. The sleeve **232** is positioned further inward than the magnet holder **234** in the diametrical direction of the rotating electric machine rotor **202**, and covers the large diameter portion **206** of the first rotating shaft **204**. The sleeve **232** may be omitted, and the large diameter portion **206** may be covered with the thick magnet holder **234**. In this case, the magnet holder **234** corresponds to the cover member **230**.

[0026] A plurality of permanent magnets **236** are retained on the outer circumferential surface of the magnet holder **234**. The sleeve **232**, which is the cover member **230**, the magnet holder **234**, and the plurality of permanent magnets **236** constitute the rotating electric machine rotor **202** together with the first rotating shaft **204**.

[0027] The second end **214** is rotatably supported by a second bearing **122**. The second end **214** includes a first connecting end portion **218**. The first connecting end portion **218** is one end in the axial direction of the first rotating shaft **204**. The first connecting end portion **218** will be described later. The second end **214** is hollow.

[0028] The first rotating shaft **204** has a cooling medium flow path **240** through which the cooling oil CO flows, and a liquid feed path **250**. In the illustrated example, the cooling medium flow path **240** includes a first flow path **242**, a communication path **244**, a second flow path **246**, and a relay path **248**. The first flow path **242** extends in the axial direction of the first rotating shaft **204**, for example, at the diametrical center of the first end **208**. One end (left end) of the first flow path **242** in the axial direction is opened at the distal end surface of the first end **208**. Another end (right end) of the first flow path **242** in the axial direction extends to the large diameter portion **206** and is connected to the communication path **244**.

[0029] The second flow path **246** is formed by covering an outer groove **247** with the sleeve **232**. Specifically, the outer groove **247** is formed as a helical groove **247*a*** on the outer circumferential surface of the large diameter portion **206**. As the helical groove **247*a*** is covered with the sleeve **232**, the helical second flow path **246** is formed between the large diameter portion **206** and the sleeve **232**.

[0030] The second flow path **246** is not limited to a helical flow path. As shown in FIG. **4**, the outer groove **247** may be a straight groove **247*b*** extending linearly in the axial direction of the first rotating shaft **204**. In this case, the second flow path **246** is a flow path extending linearly in the axial direction of the first rotating shaft **204**. Although FIG. **4** shows one straight groove **247***b*, a plurality of straight grooves **247***b* may be used.

[0031] In the large diameter portion **206**, the communication path **244** extends from the interior of the first rotating shaft **204** in the diametrical direction toward the outer circumferential surface thereof, and places the first flow path **242** and the second flow path **246** in communication with each other. In the illustrated example, the first rotating shaft **204** has the plurality of communication paths **244**. The plurality of communication paths **244** are in the form of holes extending radially from the center toward the outer circumferential surface in the diametrical direction of the large diameter portion **206**. The communication paths **244** and the inner hole **216** are not directly connected.

[0032] In the large diameter portion **206**, the relay path **248** extends from the interior of the first rotating shaft **204** in the diametrical direction toward the outer circumferential surface thereof, and places the second flow path **246** and the liquid feed path **250** in communication with each other. In the illustrated example, the first rotating shaft **204** has the plurality of relay paths **248**. The plurality of relay paths **248** are in the form of holes extending radially from the center toward the outer circumferential surface in the diametrical direction of the large diameter portion **206**. The inner hole **216** and the liquid feed path **250** are separated by the relay paths **248**.

[0033] The liquid feed path **250** is a space formed in the interior of the large diameter portion **206** and is connected to the right portion of the inner hole **216**. The liquid feed path **250** extends toward the second end **214** in the axial direction of the first rotating shaft **204**. One end (right end) of the liquid feed path **250** in the axial direction is positioned at the second end **214**. The inner diameter of the liquid feed path **250** gradually increases from the relay paths **248** toward the first connecting end portion **218**. In other words, an inner circumferential surface **250***a* of the liquid feed path **250** is a tapered surface whose diameter decreases from the first connecting end portion **218** toward the relay paths **248**.

[0034] The internal space of the first connecting end portion **218** is continuous with the right portion of the liquid feed path **250**. A first engaging portion **260** is provided on the inner circumferential surface of the first connecting end portion **218**. In the internal space of the first connecting end portion **218**, a second connecting end portion **322** constituting a second rotating shaft **16** of the turbine rotor **300** is inserted. In the illustrated example, the second rotating shaft **16** is a connecting shaft **320** interposed between the first rotating shaft **204** and an output shaft **330** of the gas turbine engine **30**, and one end portion (right end portion) of the connecting shaft **320** in the axial direction is the second connecting end portion **322**. Alternatively, the output shaft **330** may be connected to the first rotating shaft **204**. In this case, the output shaft **330** corresponds to the second rotating shaft **16**, and one end portion (left end portion) of the output shaft **330** in the axial direction corresponds to the second connecting end portion **322**.

[0035] A second engaging portion **324** is provided on the outer circumferential surface of the second connecting end portion **322**. The first rotating shaft **204** and the connecting shaft **320** are connected to each other by the second engaging portion **324** engaging with the first engaging portion **260**. In the illustrated example, the second engaging portion **324** overlaps the first engaging portion **260** on the inner side of the first engaging portion **260** in the diametrical direction of the first connecting end portion **218**. The first engaging portion **260** and the second engaging portion **324** are a connecting portion **400** for transmitting a rotational driving force between the first rotating shaft **204** and the connecting shaft **320**.

[0036] The engagement between the first engaging portion **260** and the second engaging portion **324** is, for example, spline connection **402**. In this case, the second engaging portion **324** is slidable relative to the first engaging portion **260** in the axial direction of the first rotating shaft **204**. The first engaging portion **260** and the second engaging portion **324** may be engaged with each other by engagement other than the spline connection **402** as long as the second engaging portion **324** is slidable relative to the first engaging portion **260** in the axial direction.

[0037] A lubricant flow path **262** is formed between the first engaging portion **260** and the second engaging portion **324** which overlap each other in the diametrical direction. As understood from this, the lubricant flow path **262** is a clearance that is formed between the inner circumferential surface of the first connecting end portion **218** and the outer circumferential surface of the second connecting end portion **322**, communicates with the liquid feed path **250**, and extends in the axial direction of the first rotating shaft **204**. The cooling oil CO passes through the lubricant flow path **262** as a lubricant.

[0038] Contrary to the illustrated example, the second connecting end portion **322** may be hollow, and the first connecting end portion **218** may be inserted into the interior of the second connecting end portion **322**. In this case, the first engaging portion **260** is formed on the outer circumferential surface of the first connecting end portion **218**, and the second engaging portion **324** is formed on the inner circumferential surface of the second connecting end portion **322**. The second engaging portion **324** overlaps the exterior of the first engaging portion **260** in the diametrical direction of the first connecting end portion **218**. The lubricant flow path **262** is formed between the outer circumferential surface of the first connecting end portion **218** and the inner circumferential surface of the second connecting end portion **322**.

[0039] In the present embodiment, an aspect in which the cooling oil CO flows through the cooling medium flow path **240**, the liquid feed path **250**, and the lubricant flow path **262** in this order will be described. The rotating electric machine system **20** is provided with a cooling medium supply unit **150** for supplying a cooling oil CO to the cooling medium flow path **240**. The cooling medium supply unit **150** includes a cooling medium recovery tank **152**, a cooling medium supply device **154**, and an oil discharge member **156**. The cooling medium supply device **154** is, for example, a pump, and pressure-feeds the cooling oil CO toward the cooling medium flow path **240**. The oil discharge member **156** is inserted into the internal space of the resolver holder **128**. The oil discharge member **156** has a nozzle portion **158** facing the first flow path **242**.

[0040] An accommodation chamber **280** of the main housing **274** is divided into a rotor chamber **282** and a stator chamber **284** by a cylindrical partition wall member **160**. The majority of the components of the rotating electric machine rotor **202** are accommodated in the rotor chamber **282**. The stator **268**, which constitutes the rotating electric machine **200**, is accommodated in the stator chamber **284**.

The stator **268** includes electromagnetic coils **270**. The electromagnetic coils **270** include a U-phase coil, a V-phase coil, and a W-phase coil. In the case that the rotating electric machine **200** is a generator, the rotating electric machine **200** is a so-called three-phase power source.

[0041] As shown in FIG. **1**, a terminal casing **279** is integrally provided on a side wall in the vicinity of the left end of the main housing **274**. In the terminal casing **279**, there are accommodated a U-phase terminal **271***a*, a V-phase terminal **271***b*, and a W-phase terminal **271***c* that are electrically connected to ends of a U-phase coil, a V-phase coil, and a W-phase coil, respectively.

[0042] The main housing **274** has a substantially cylindrical shape. The left open end of the main housing **274** is closed by the first sub-housing **276**. The circular opening at the left end of the first sub-housing **276** is closed by the resolver holder **128**.

[0043] The main housing **274** has a recess **286** in the right portion thereof. As shown in FIG. **3**, the recess **286** is closed by the second sub-housing **278** to form an inner chamber. A drain passage **292** formed in the main housing **274** communicates with the recess **286**.

[0044] The second sub-housing **278** includes a rectifying member **294** on the right end thereof that faces toward the gas turbine engine **30**. The flow rectifying member **294** is of a substantially truncated conical shape, and reduces in diameter in a tapered shape from the main housing **274** toward the gas turbine engine **30**. The rectifying member **294** has an insertion hole **296** at the center in the diametrical direction. The output shaft **330** is passed through the insertion hole **296**. The left end portion of the output shaft **330** is rotatably supported by a third bearing **124** provided in the interior of the second sub-housing **278**.

[0045] The rotating electric machine system **20** is basically configured as described above. Moreover, it should be noted that the configuration of the gas turbine engine **30**, for example, is similar to the configuration shown in FIG. **8** of JP 2022-157784 A. Therefore, the description of the gas turbine engine **30** will be kept brief.

[0046] As shown in FIG. **1**, the gas turbine engine **30** includes an engine housing **302**. The turbine rotor **300** (see FIG. **2**) is accommodated in the interior of the engine housing **302**. The engine housing **302** includes an inner housing **304** (see FIG. **1**) and an outer housing **306**. An inner housing **304** faces toward the second sub-housing **278** of the rotating electric machine system **20**. The outer housing **306** is connected to the inner housing **304**.

[0047] The inner housing **304** has a plurality of individual leg members **308**. Air intake spaces **310** are formed between the leg members **308** that are adjacent to each other from among the plurality of leg members **308**. A combustor (not shown) is provided in the interior of the outer housing **306**.

[0048] The turbine rotor **300** of the gas turbine engine **30** includes the connecting shaft **320** as the second rotating shaft **16** and the output shaft **330**. As shown in FIGS. **2** and **3**, the output shaft **330** is connected to the first rotating shaft **204** via the connecting shaft **320**. The right end portion of the connecting shaft **320** and the left end portion of the output shaft **330** are connected to each other via, for example, a spline connection **404**.

[0049] A non-illustrated compressor wheel and a non-illustrated turbine wheel are retained by the output shaft **330**. The compressor wheel and the turbine wheel are capable of rotating integrally together with the first rotating shaft **204**, the connecting shaft **320** and the output shaft **330**.

[0050] Next, a description will be given concerning operations of the combined power system **100**.

[0051] First, an alternating current is supplied to the electromagnetic coils **270** (the U-phase coil, the V-phase coil, and the W-phase coil) via the U-phase terminal **271***a*, the V-phase terminal **271***b*, and the W-phase terminal **271***c* shown in FIG. **2**. Accordingly, the rotating electric machine rotor **202** starts rotating. Alternatively, the rotating electric machine rotor **202** may be rotated by a well-known type of starter (not shown).

[0052] The rotational driving force of the first rotating shaft **204** is transmitted to the output shaft **330** via the connecting shaft **320**. Accordingly, the turbine rotor **300** rotates integrally with the rotating electric machine rotor **202**. In other words, the non-illustrated compressor wheel and the non-illustrated turbine wheel, which are retained on the output shaft **330**, rotate integrally together with the output shaft **330**. After the turbine rotor **300** starts rotating as described above, the turbine rotor **300** continuously rotates in accordance with the operation of the gas turbine engine **30**. Accordingly, even if the supply of the electrical current to the electromagnetic coils **270** is stopped, the rotating electric machine rotor **202** rotates integrally together with the turbine rotor **300**.

[0053] In this way, the rotating electric machine rotor **202** and the turbine rotor **300** are rotated, and the cooling medium supply device **154** is started. The cooling medium supply device **154** pressure-feeds the cooling oil CO toward the cooling medium flow path **240**.

[0054] As the rotating electric machine rotor **202** rotates, an alternating current is generated in the electromagnetic coils **270** surrounding the permanent magnets **236**. Via the U-phase terminal **271***a*, the V-phase terminal **271***b*, and the W-phase terminal **271***c*, the alternating current is supplied to an external load. The alternating current may be converted into the direct current by a current converter (not shown), and thereafter the direct current may be supplied to the external load.

[0055] In the inner housing **304** shown in FIG. **1**, as the turbine rotor **300** rotates, the atmospheric air is drawn into the inner side of the leg members **308** through the air intake spaces **310** between the adjacent leg members **308**. The atmospheric air flows toward the inner housing **304** along the rectifying member **294** shown in FIGS. **2** and **3** and flows into the interior of the inner housing **304**. The atmospheric air in the inner housing **304** is compressed by the compressor wheel. In accordance therewith, the compressed air is generated. The fuel injected into the compressed air is burned in the interior of the outer housing **306**.

[0056] A portion of the compressed air obtained by the compressor wheel may be supplied to the rotor chamber **282** (see FIG. **2**) to cool the rotating electric machine rotor **202**. Alternatively, a portion of the compressed air may cool the first bearing **120** and the second bearing **122**. In addition, a portion of the compressed air or liquid cooling medium RF may be supplied to the stator chamber **284** to cool the stator **268**. A portion of the lubricating oil supplied to the first bearing **120**, the second bearing **122**, and the third bearing **124** may be used as the liquid cooling medium RF. A portion of the lubricating oil may be supplied to the cooling medium flow path **240** as the cooling oil CO.

[0057] The electromagnetic coils **270** generate heat as the electrical current flows therethrough. Accordingly, the permanent magnets **236** facing the electromagnetic coils **270** are exposed to the radiant heat.

[0058] As described above, the cooling medium supply device **154** supplies the cooling oil CO toward the cooling medium flow path **240**. The cooling oil CO is discharged from the nozzle portion **158** of the oil discharge member **156**. Though the first rotating shaft **204** is rotated, the first flow path **242** is provided in the diametrical center of the first rotating shaft **204**, and the nozzle portion **158** faces toward the first flow path **242**. Therefore, the cooling oil CO discharged from the nozzle portion **158** easily flows into the first flow path **242**. Since the cooling medium supply device **154** pressure-feeds the cooling oil CO at a predetermined discharge pressure, the cooling oil CO moves along the first flow path **242** in the first end **208** of the first rotating shaft **204** toward the large diameter portion **206**. After reaching the large diameter portion **206**, the cooling oil Co flows from the diametrically inward side of the large diameter portion **206** toward the diametrically outward side along the communication paths **244** formed in the large diameter portion **206**. In this way, the flow direction of the cooling oil co is changed by the communication paths **244**.

[0059] The cooling oil CO moves from the communication paths **244** to the second flow path **246**. Since the second flow path **246** is formed in a helical shape, the cooling oil CO flowing in the second flow path **246** moves toward the second end **214** of the first rotating shaft **204** while turning in the helical manner. Accordingly, the permanent magnets **236** exposed to the radiant heat of the electromagnetic coils **270** can be cooled uniformly. As described above, according to the present embodiment, the permanent magnets **236** can be efficiently cooled by the cooling oil CO flowing through the cooling medium flow path **240**.

[0060] The cooling oil CO that has flowed through the second flow path **246** then moves to the relay paths **248**. In the relay paths **248**, the direction of movement of the cooling oil Co is a direction from the outside to the inside in the diametrical direction of the first rotating shaft **204**. Since the first rotating shaft **204** is rotating, a centrifugal force is acting on the cooling oil CO. However, as described above, the cooling oil CO is pressure-fed at a predetermined discharge pressure. Accordingly, the cooling oil CO can flow diametrically inward of the first rotating shaft **204** along the relay paths **248**.

[0061] The cooling oil CO then moves to the liquid feed path **250**. The inner diameter of the liquid feed path **250** gradually increases toward the first connecting end portion **218**. That is, the liquid feed path **250** gradually expands toward the first connecting end portion **218**. Since the centrifugal force acts on the cooling oil CO, the cooling oil CO is likely to flow along the inner circumferential surface **250***a* of the liquid feed path **250**. In addition, the cooling oil CO is pressure-fed at a predetermined discharge pressure. Accordingly, the cooling oil CO easily moves to the first connecting end portion **218** along the inner circumferential surface **250***a* of the liquid feed path **250**.

[0062] In the liquid feed path **250**, the downstream in the flow direction is the right portion. The right portion of the liquid feed path **250** is continuous with the lubricant flow path **262** formed between the inner surface of the first connecting end portion **218** and the outer circumferential surface of the second connecting end portion **322**. The cooling oil CO that has flowed through the liquid feed path **250** flows through the lubricant flow path **262**.

[0063] The first engaging portion **260** is provided on the inner surface of the first connecting end portion **218**, and the second engaging portion **324** is provided on the outer circumferential surface of the second connecting end portion **322**. The first engaging portion **260** and the second engaging portion **324** are the connecting portion **400** engaged with each other via the spline connection **402** or the like. The connecting portion **400** is located in the lubricant flow path **262**. Accordingly, the connecting portion **400** is lubricated by the cooling oil Co flowing through the lubricant flow path **262**. When the rotating electric machine rotor **202** and the turbine rotor **300** rotate, the second engaging portion **324** slightly slides relative to the first engaging portion **260**. In this sliding, the cooling oil Co plays a role of a lubricant. Therefore, the relative sliding of the second engaging portion **324** with respect to the first engaging portion **260** is smooth.

[0064] As described above, according to the present embodiment, the cooling oil CO for cooling the permanent magnets **236** can be used as a lubricant for lubricating the connecting portion **400**. In other words, the cooling oil CO can also be used as a lubricant. As described above, the connecting portion **400** is formed as an engaging portion between the first engaging portion **260** of the first rotating shaft **204** and the second engaging portion **324** of the connecting shaft **320** (the second rotating shaft **16**).

[0065] The cooling oil CO that has flowed through the lubricant flow path **262** is discharged into the inner chamber formed by closing the recess **286** of the main housing **274** with the second sub-housing **278**. The cooling oil CO is then discharged to the outside of the rotating electric machine housing **272** through the drain passage **292** formed in the main housing **274**. The cooling oil CO is further recovered in the cooling medium recovery tank **152**, and then is pressure-fed from the cooling medium supply device **154** to the cooling medium flow path **240**. The lubricating oil supplied to the first bearing **120**, the second bearing **122**, and the third bearing **124** and the cooling oil CO may be recovered in the cooling medium recovery tank **152**, and the oil supplied from the cooling medium supply device **154** may be divided into the lubricating oil and the cooling oil CO. In this case, since it is not necessary to separately provide the cooling medium supply device **154** and the lubricating oil supply device, the rotating electric machine system **20** can be simplified.

[0066] On the contrary, the cooling oil CO may be circulated through the lubricant flow path **262**, the liquid feed path **250**, the relay paths **248**, the second flow path **246**, the communication paths **244**, and the first flow path **242** in this order. In this case, the oil discharge member **156** is disposed in the recess **286**, and the drain passage **292** is provided in the first sub-housing **276**.

[0067] The present embodiment exhibits the following advantageous effects.

[0068] As shown in FIG. **2**, in the combined power system **100** that is the rotating machine **10**, the first rotating shaft **204** of the rotating electric machine rotor **202** (first rotating body **12**) includes the cooling medium flow path **240**, the liquid feed path **250**, and the first engaging portion **260**. In the turbine rotor **300** (second rotating body **14**), the connecting shaft **320** that is the second rotating shaft **16** includes the second engaging portion **324** engaged with the first engaging portion **260**. When the first engaging portion **260** and the second engaging portion **324** are engaged with each other, the lubricant flow path **262** is formed between the first engaging portion **260** and the second engaging portion **324**. The lubricant flow path **262** communicates with the cooling medium flow path **240** via the liquid feed path **250**.

[0069] The cooling oil CO as the liquid cooling medium RF flows through the cooling medium flow path **240**. In particular, the permanent magnets **236** constituting the rotating electric machine rotor **202** are cooled by the cooling oil CO. The cooling oil CO moves to the lubricant flow path **262** through the liquid feed path **250**, and functions as a lubricant for the first engaging portion **260** and the second engaging portion **324**. Alternatively, the cooling oil CO moves from the lubricant flow path **262** to the cooling medium flow path **240** through the liquid feed path **250**. In this case, the cooling oil CO functions as a lubricant and thereafter cools the permanent magnets **236**.

[0070] As described above, according to the present embodiment, the cooling oil CO for cooling the rotating electric machine rotor **202** (particularly the permanent magnets **236**) can also be used as a lubricant for lubricating the connecting portion **400** engaged with each other in the first rotating shaft **204** and the second rotating shaft **16**. Accordingly, it is not necessary to include a supply device for supplying the cooling oil CO and a supply device for supplying the lubricant separately in the rotating electric machine system **20**. Therefore, the configuration of the rotating electric machine system **20** can be simplified. In addition, the relative sliding of the second engaging portion **324** with respect to the first engaging portion **260** is smooth due to the lubricant.

[0071] In an exemplary aspect, the engagement of the first engaging portion **260** and the second engaging portion **324** is the spline connection **402**. The lubricant can provide good lubrication of the spline connection **402**.

[0072] The liquid feed path **250** is formed in the interior of the second end **214**, which is one end in the axial direction of the first rotating shaft **204**. The second end **214** includes the hollow first connecting end portion **218**. The connecting shaft **320** includes the second connecting end portion **322** at one end thereof in the axial direction. The second connecting end portion **322** is inserted into the hollow first connecting end portion **218**. In this configuration, the first engaging portion **260** is formed on the inner circumferential surface of the first connecting end portion **218**, and the second engaging portion **324** is formed on the outer circumferential surface of the second connecting end portion **322**.

[0073] By making the liquid feed path **250** continuous with the interior of the first connecting end portion **218**, it is possible to place the liquid feed path **250** and the lubricant flow path **262** in communication with each other easily.

[0074] The cooling medium flow path **240** includes the first flow path **242**, the second flow path **246**, the communication paths **244**, and the relay paths **248**. The first flow path **242** is formed in the interior of the other end (first end **208**) of the first rotating shaft **204** in the axial direction. The second flow path **246** is formed in a side portion of the first rotating shaft **204**. The communication paths **244** place the first flow path **242** and the second flow path **246** to communicate with each other. The relay paths **248** place the second flow path **246** and the liquid feed path **250** in communication with each other. The communication paths **244** and the relay paths **248** extend from the inside in the diametrical direction of the first rotating shaft **204** toward the outer circumferential surface of the first rotating shaft **204**.

[0075] In accordance with such a configuration, it is easy to cause the cooling oil CO to flow from the cooling medium flow path **240** toward the engaging portion between the first engaging portion **260** and the second engaging portion **324**, or in the opposite direction thereto.

[0076] The first rotating body **12** includes the cover member **230** covering the outer circumference of the first rotating shaft **204**. In the above aspect, the cover member **230** is the sleeve **232**. The first rotating shaft **204** includes the outer groove **247** in the outer circumferential surface thereof. The second flow path **246** is formed by covering the outer groove **247** with the sleeve **232**.

[0077] The first flow path **242**, the communication paths **244**, the relay paths **248**, and the liquid feed path **250** are formed in the interior of the first rotating shaft **204**, and the outer groove **247** forming the second flow path **246** is covered with the sleeve **232**. Therefore, the cooling oil CO is prevented from being mixed with foreign substance. Further, since the second flow path **246** is close to the permanent magnets **236**, the permanent magnets **236** can be sufficiently cooled.

[0078] In one aspect, the outer groove **247** is the helical groove **247*a*** that turns in a helical shape in the outer circumferential surface of the first rotating shaft **204**. Therefore, the cooling oil co turns in a helical manner when flowing through the second flow path **246**. Consequently, the permanent magnets **236** can be cooled uniformly.

[0079] The inner diameter of the liquid feed path **250** gradually increases as the liquid feed path **250** comes closer to the first engaging portion **260**. Since the centrifugal force acts on the cooling oil CO flowing through the liquid feed path **250** as the first rotating shaft **204** rotates, the cooling oil CO easily moves toward the first engaging portion **260** along the inner circumferential surface in the liquid feed path **250**. Accordingly, it is easy to supply the cooling medium to the lubricant flow path **262**.

[0080] The combined power system **100** is provided with the cooling medium supply device **154** for pressure-feeding the cooling oil CO. The cooling medium supply device **154** applies pressure to the cooling oil CO and supplies the cooling oil CO to the cooling medium flow path **240** or the lubricant flow path **262**. Accordingly, the cooling oil CO can move from the outer circumferential surface of the first rotating shaft **204** to the interior thereof against the centrifugal force. Therefore, the degree of freedom in the flow direction of the cooling oil co is large. Therefore, the degree of freedom in the shape of the cooling medium flow path **240** and the like is increased.

[0081] In an exemplary aspect, the cooling medium supply device **154** pressure-feeds the cooling oil CO so as to move the cooling oil CO from the cooling medium flow path **240** toward the lubricant flow path **262**.

[0082] The pressure loss in the cooling medium flow path **240** is smaller than the pressure loss in the lubricant flow path **262**. Therefore, when the cooling oil CO is caused to flow in the above-described direction, the cooling oil CO moves more smoothly than when the liquid cooling medium RF is caused to flow from the lubricant flow path **262** toward the cooling medium flow path **240**.

[0083] The second rotating body **14** is the turbine rotor **300** constituting the gas turbine engine **30**.

[0084] In this configuration, when the turbine rotor **300** rotates, the rotational driving force of the turbine rotor **300** is transmitted to the first rotating shaft **204**. Therefore, the rotating electric machine rotor **202** rotates integrally with the turbine rotor **300**, and power generation occurs in the rotating electric machine **200**.

[0085] The output shaft **330** of the turbine rotor **300** is connected to the first rotating shaft **204** via the connecting shaft **320** as the second rotating shaft **16**. Since the connecting shaft **320** serves as a spacer, the output shaft **330** can be connected to the first rotating shaft **204** while the rotating electric machine housing **272** is prevented from interfering with the engine housing **302**.

[0086] In an exemplary aspect, the cooling oil Co is used as the liquid cooling medium RF. The oil sufficiently reduces the frictional resistance between the first engaging portion **260** and the second engaging portion **324** and sufficiently cools the first engaging portion **260** and the second engaging portion **324**. That is, oil is suitable as the liquid cooling medium RF having both the lubricating action and the cooling action.

[0087] The following supplementary notes are further disclosed in relation to the above-described embodiments.

Supplementary Note 1

[0088] The rotating machine (**10**) according to the present disclosure is equipped with the first rotating body (**12**) including the first rotating shaft (**204**), and the second rotating body (**14**) including the second rotating shaft (**16**) configured to rotate integrally with the first rotating shaft. The first rotating shaft includes the cooling medium flow path (**240**) through which the liquid cooling medium (RF) flows, the liquid feed path (**250**) communicating with the cooling medium flow path, and the first engaging portion (**260**) provided at the first connecting end portion (**218**) that is one end portion of the first rotating shaft in an axial direction of the first rotating shaft. The second rotating shaft includes the second connecting end portion (**322**) overlapping the first connecting end portion in the diametrical direction of the first connecting end portion, and the second engaging portion (**324**) provided at the second connecting end portion.

[0089] The first engaging portion and the second engaging portion form the connecting portion (**400**) configured to transmit the rotational driving force between the first rotating shaft and the second rotating shaft. The second engaging portion is engaged with the first engaging portion so as to be relatively slidable in the axial direction. The lubricant flow path (**262**) is formed between the first engaging portion and the second engaging portion that are engaged with each other, the lubricant flow path communicating with the liquid feed path and through which the liquid cooling medium is allowed to pass as the lubricant. The liquid feed path is interposed between the cooling medium flow path and the lubricant flow path.

[0090] In accordance with such a configuration, the liquid cooling medium for cooling the first rotating body can also serve as a lubricant for lubricating the connected part between the first rotating shaft and the second rotating shaft (the engagement part between the first engaging portion and the second engaging portion).

Supplementary Note 2

[0091] In the rotating machine according to the supplementary note 1, the first engaging portion and the second engaging portion may be engaged by the spline connection (**402**).

[0092] In this case, the spline connection can be lubricated well.

Supplementary Note 3

[0093] In the rotating machine according to the supplementary note 1 or 2, the liquid feed path may be formed in the interior of the one end portion of the first rotating shaft, the first connecting end portion may be hollow, the second connecting end portion may be inserted into the first connecting end portion, the first engaging portion may be formed on the inner circumferential surface of the first connecting end portion, and the second engaging portion may be formed on the outer circumferential surface of the second connecting end portion.

[0094] In accordance with such a configuration, it is easy to place the liquid feed path and the lubricant flow path in communication with each other.

Supplementary Note 4

[0095] In the rotating machine described in the supplementary note 3, the cooling medium flow path may include the first flow path (**242**) formed in the interior of the other end portion of the first rotating shaft in the axial direction, the second flow path (**246**) formed in the side portion of the first rotating shaft, the communication path (**244**) placing the first flow path and the second flow path in communication with each other, and the relay path (**248**) placing the second flow path and the liquid feed path in communication with each other, and the communication path and the relay path may extend from the inside toward the outer circumferential surface of the first rotating shaft in the diametrical direction of the first rotating shaft.

[0096] It is easy to cause the liquid cooling medium to flow from the cooling medium flow path toward the connected part between the first rotating shaft and the second rotating shaft or in the opposite direction thereto.

Supplementary Note 5

[0097] In the rotating machine described in the supplementary note 4, the first rotating body may include the cover member (**230**) covering the outer circumference of the first rotating shaft, the first rotating shaft including the outer groove (**247**) in the outer circumferential surface, and the second flow path may be formed by covering the outer groove with the cover member.

[0098] The cover member and the members around the cover member can be cooled by the liquid cooling medium flowing through the second flow path.

Supplementary Note 6

[0099] In the rotating machine described in the supplementary note 5, the outer groove may be the helical groove (**247***a*) that turns in the helical shape in the outer circumferential surface of the first rotating shaft.

[0100] Since the flow trajectory of the liquid cooling medium forms a helix, the liquid cooling medium can be uniformly distributed over the outer circumferential surface of the first rotating shaft.

Supplementary Note 7

[0101] In the rotating machine according to any one of the supplementary notes 4 to 6, the inner diameter of the liquid feed path may gradually increase as the liquid feed path is closer to the first engaging portion.

[0102] When the first rotating shaft rotates, a centrifugal force acts on the liquid cooling medium flowing through the liquid feed path. When the liquid cooling medium flows from the liquid feed path toward the lubricant flow path, the liquid cooling medium easily moves along the inner circumferential surface of the liquid feed path due to the gradual increase in diameter of the inner circumferential surface of the liquid feed path. Accordingly, it is easy to supply the cooling medium to the lubricant flow path.

Supplementary Note 8

[0103] The rotating machine according to any one of the supplementary notes 1 to 7 may further include the cooling medium supply device (**154**) configured to pressure-feed the liquid cooling medium.

Supplementary Note 9

[0104] In the rotating machine according to the supplementary note 8, the cooling medium supply device may pressure-feed the liquid cooling medium so as to move the liquid cooling medium from the cooling medium flow path toward the lubricant flow path.

[0105] The cooling medium supply device applies pressure to the liquid cooling medium and supplies the liquid cooling medium to the cooling medium flow path. Accordingly, the liquid cooling medium can move from the outer circumferential surface of the first rotating shaft to the interior thereof against the centrifugal force. Therefore, the degree of freedom in the flow direction of the liquid cooling medium is large. Therefore, the degree of freedom in the shape of the cooling medium flow path is increased.

Supplementary Note 10

[0106] In the rotating machine according to any one of the supplementary notes 1 to 9, the first rotating body may be the rotating electric machine rotor (**202**) constituting the rotating electric machine (**200**).

[0107] The permanent magnets constituting the rotor of the rotating electric machine can be cooled by the liquid cooling medium flowing through the cooling medium flow path.

Supplementary Note 11

[0108] In the rotating machine according to the supplementary note 10, the second rotating body may be the turbine rotor (**300**) constituting the gas turbine engine (**30**).

[0109] When the turbine rotor rotates, the rotational driving force of the turbine rotor can be transmitted to the first rotating shaft via the second rotating shaft. Therefore, the first rotating shaft rotates together with the second rotating shaft, and electric power is generated in the rotating electric machine.

Supplementary Note 12

[0110] In the rotating machine according to supplementary note 11, the turbine rotor may include the output shaft (**330**), the output shaft being connected to the first rotating shaft via the second rotating shaft.

[0111] The second rotating shaft serves as a spacer. Therefore, the rotating electric machine system and the gas turbine engine can be easily combined while avoiding interference of the engine housing with the rotating electrical machine housing.

Supplementary Note 13

[0112] In the rotating machine according to any one of the supplementary notes 1 to 12, the liquid cooling medium may be oil (CO).

[0113] The oil sufficiently reduces the frictional resistance between the first engaging portion and the second engaging portion and sufficiently cools the first engaging portion and the second engaging portion. That is, oil is suitable as the liquid cooling medium having both the lubricating action and the cooling action.

[0114] It should be noted that the present invention is not limited to the disclosure described above, and various additional or alternative configurations could be adopted therein without departing from the essence and gist of the present invention.

1. A rotating machine comprising: a first rotating body including a first rotating shaft; and a second rotating body including a second rotating shaft configured to rotate integrally with the first rotating shaft,

wherein the first rotating shaft includes a cooling medium flow path through which a liquid cooling medium flows, a liquid feed path communicating with the cooling medium flow path, and a first engaging portion provided at a first connecting end portion that is one end portion of the first rotating shaft in an axial direction of the first rotating shaft,

the second rotating shaft includes a second connecting end portion overlapping the first connecting end portion in a diametrical direction of the first connecting end portion, and a second engaging portion provided at the second connecting end portion,

the first engaging portion and the second engaging portion form a connecting portion configured to transmit a rotational driving force between the first rotating shaft and the second rotating shaft,

the second engaging portion is engaged with the first engaging portion so as to be relatively slidable in the axial direction,

a lubricant flow path is formed between the first engaging portion and the second engaging portion that are engaged with each other, the lubricant flow path communicating with the liquid feed path and through which the liquid cooling medium is allowed to pass as a lubricant, and

the liquid feed path is interposed between the cooling medium flow path and the lubricant flow path.

2. The rotating machine according to claim **1**, wherein the first engaging portion and the second engaging portion are engaged via a spline connection.

3. The rotating machine according to claim **1**, wherein the liquid feed path is formed in an interior of the one end portion of the first rotating shaft, the first connecting end portion is hollow, the second connecting end portion is inserted into the first connecting end portion, the first engaging portion is formed on an inner circumferential surface of the first connecting end portion, and the second engaging portion is formed on an outer circumferential surface of the second connecting end portion.

4. The rotating machine according to claim **3**, wherein the cooling medium flow path includes a first flow path formed in an interior of another end portion of the first rotating shaft in the axial direction, a second flow path formed in a side portion of the first rotating shaft, a communication path placing the first flow path and the second flow path in communication with each other, and a relay path placing the second flow path and the liquid feed path in communication with each other, and

the communication path and the relay path extend from inside toward an outer circumferential surface of the first rotating shaft in a diametrical direction of the first rotating shaft.

5. The rotating machine according to claim **4**, wherein the first rotating body includes a cover member covering an outer circumference of the first rotating shaft, the first rotating shaft including an outer groove in the outer circumferential surface, and

the second flow path is formed by covering the outer groove with the cover member.

6. The rotating machine according to claim **5**, wherein the outer groove is a helical groove that turns in a helical shape in the outer circumferential surface of the first rotating shaft.

7. The rotating machine according to claim **4**, wherein an inner diameter of the liquid feed path gradually increases as the liquid feed path is closer to the first engaging portion.

8. The rotating machine according to claim **1**, further comprising a cooling medium supply device configured to pressure-feed the liquid cooling medium.

9. The rotating machine according to claim **8**, wherein the cooling medium supply device pressure-feeds the liquid cooling medium so as to move the liquid cooling medium from the cooling medium flow path toward the lubricant flow path.

10. The rotating machine according to claim **1**, wherein the first rotating body is a rotating electric machine rotor constituting a rotating electric machine.

11. The rotating machine according to claim **10**, wherein the second rotating body is a turbine rotor constituting a gas turbine engine.

12. The rotating machine according to claim **11**, wherein the turbine rotor includes an output shaft, the output shaft being connected to the first rotating shaft via the second rotating shaft.

13. The rotating machine according to claim **1**, wherein the liquid cooling medium is oil.

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