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(54) Title: TURBOCHARGER COMPRESSOR-END CARBON FACE SEAL

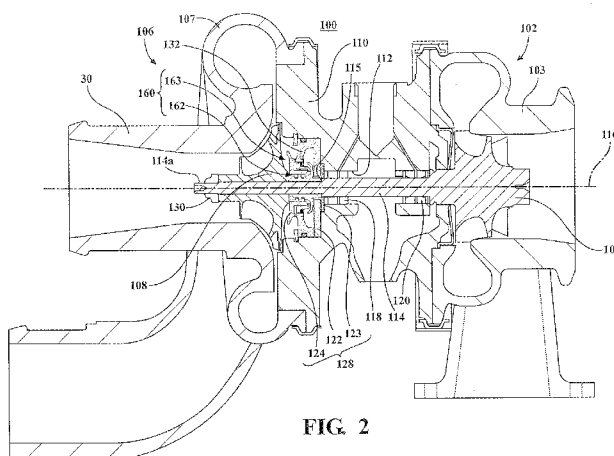


FIG. 2

(57) Abstract: A passive, progressively-applied contact face seal assembly (163) is used to address blowby between the rotating assembly (104, 108, 114, 124) and housing (110) of a turbocharger (100). The seal assembly (163) is configured to avoid seal contact at low rotational speeds, resulting in less friction at start-up and improved turbocharger (100) transient response. In addition, the seal assembly (163) is configured to provide increasing seal contact with increasing rotational speeds, whereby a full seal is applied under high speed, high pressure conditions when blow-by potential is maximum. The seal assembly (163) is used along with a clearance seal (162).



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TURBOCHARGER COMPRESSOR-END CARBON FACE SEAL**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims priority to and all benefits of U.S. Provisional Application No. 61/840,725 filed on June 28, 2013, and entitled "Turbocharger Compressor-End Carbon Faced Seal."

BACKGROUND**1. Field of the Invention**

This invention addresses the need for an improved shaft sealing design for the dynamic fluid joint between a turbocharger rotating assembly and the bearing housing in which it resides.

2. Description of Related Art

Turbochargers are a type of forced induction system. They deliver air, at greater density than would be possible in the normally aspirated configuration, to the engine intake, allowing more fuel to be combusted, thus boosting the engine's horsepower without significantly increasing engine weight. Alternatively, use of turbochargers allow engine manufacturers to provide engines having reduced displacement in order to increase fuel economy and reduce CO₂ emissions, while maintaining the same engine power level and vehicle performance.

Referring to Fig. 1, an exhaust gas turbocharger 5 uses the exhaust flow from the engine exhaust manifold to drive a turbine wheel 10 located in the turbine housing 2. The turbine wheel 10 drives a compressor wheel 9 located in the compressor housing 30 via a shaft 3 that extends between the turbine and compressor housings 2, 30. The shaft 3 is rotatably supported in a bearing housing 20 disposed between the turbine and compressor housings 2, 30. Air compressed within the compressor housing 30 is then provided to the engine intake as described above. Unwanted flow of gas between the bearing housing 20 and either end housing 2, 30 is known as "blowby". Compressor-end as well as turbine-end oil passage is to be avoided as both can result in poisoning of the catalysts and unwanted emissions. With ever more stringent emissions standards, coupled with the more common use of closed crankcase ventilation, the propensity for gas and/or oil passage across the piston ring seal is becoming a greater issue.

Various types of passive seals are used in turbochargers to address blowby. However, some conventional passive seals are associated with rapid wear, generation of heat which must be removed by increased oil flow, and high power loss due to parasitic drag. There is a need for a passive design for enhancing the seal between bearing housing and section housings 2, 30,

thereby minimizing the passage of exhaust gas, oil and/or particulates across the seal ring(s) for turbochargers.

There is a demand to improve turbocharger effectiveness at low speed and/or the transition time from low speed to medium speeds. This is historically known as turbo “lag” and more recently termed transient response. Turbocharger manufacturers have improved output over the turbo speed range by minimizing bearing system power losses, improved aerodynamic efficiency and by staging small and large turbochargers to provide optimal boost for a wider range of engine operating conditions. In the case of multiple stage turbochargers, blow-by leakage is physically doubled but the leakage rate expectation remains at single turbo levels. There is a need for bearing system seals that reduce blow-by without increasing low speed power loss as contacting seals are applied.

SUMMARY

In some aspects, a turbocharger includes a housing; a rotating assembly mounted for rotation within said housing and defining an axis of rotation, and a passive contact face seal assembly provided in said housing. The contact face seal assembly is configured so that a contact surface of the contact face seal assembly does not contact the rotating assembly when the rotating assembly is at rest, and the contact surface contacts the rotating assembly with increasing contact pressure as the rotational speed of the rotating assembly increases.

The turbocharger may include one or more of the following features: The contact surface is configured to contact a seal-receiving surface of said rotating assembly, where the seal-receiving surface of the rotating assembly is oriented perpendicular to the rotational axis. The seal-receiving surface of said rotating assembly is located on a flinger. The contact face seal assembly further comprises a device configured to progressively urge the contact surface axially against a seal-receiving surface of said rotating assembly as the rotational speed of the rotating assembly increases, where the seal-receiving surface of the rotating assembly is oriented perpendicular to the rotational axis. The device is configured to be actuated by pneumatic pressure supplied by a compressor stage of the turbocharger. The device comprises a mechanism that is responsive to the rotational speed of the rotating assembly. The contact surface is comprised of a carbon based seal material. A clearance seal is disposed between the rotating assembly and the housing.

In some aspects, a turbocharger includes a housing; a rotating assembly mounted for rotation within said housing and defining an axis of rotation and an annular contact face seal assembly provided in said housing. The contact face seal assembly includes a contact surface configured to contact a seal-receiving surface of one of a stationary member of the turbocharger

and a member of the rotating assembly. The contact face seal assembly is further configured so that the contact surface does not contact the seal-receiving surface when the rotating assembly is at rest, and the contact surface contacts the seal-receiving surface (140) with increasing contact pressure as the rotational speed of the rotating assembly increases.

5 The turbocharger may include one or more of the following features: The seal receiving surface is formed on a flinger of the rotating assembly. The seal-receiving surface is formed on an insert disposed between the flinger and the housing. The seal-receiving surface is oriented perpendicular to the rotational axis. The contact face seal assembly further comprises a device configured to progressively urge the contact surface axially against the seal-receiving surface of
10 the stationary member as the rotational speed of the rotating assembly increases, where the seal-receiving surface of the stationary member is oriented perpendicular to the rotational axis. The contact face seal assembly further comprises a device configured to progressively urge the contact surface axially against the seal-receiving surface of the rotating assembly as the rotational speed of the rotating assembly increases, where the seal-receiving surface of the
15 rotating assembly is oriented perpendicular to the rotational axis.

The invention is accomplished by supplementing a conventional clearance or labyrinth seal with a progressively-applied, passive contact face seal. The progressively-applied, passive contact face seal does not make contact with a rotating assembly that is stationary or rotating at low rotational speeds. As a result, there is less friction at turbocharger start-up and thus transient
20 response is improved. As the rotational speed increases, the contact face seal is urged against the flinger or thrust bearing. The contact pressure between the contact face seal and the rotating assembly increases with increasing rotational speed. The progressively-applied, passive contact face seal makes contact with a rotating assembly at high rotational speeds with highest contact pressures at the highest rotational speeds, whereby a full seal is applied under high speed, high
25 pressure conditions when blow-by potential is maximum. The progressively-applied, passive contact face seal advantageously improves low speed transient response and low speed efficiency relative to some conventional non-progressive contact face seals that are in contact with the rotating assembly at all speeds, and are associated with rapid wear, generation of heat which must be removed by increased oil flow, and high power loss due to parasitic drag. The
30 progressively-applied, passive contact face seal is also advantageous relative to some conventional lift off seals, since such lift off seals can be associated with high friction prior to lift-off that may affect transient response of the turbocharger.

As used herein, references to relative rotational speeds (e.g., low speeds and high speeds) are understood to depend on the particular application. For example, when used in a commercial
35 diesel vehicle, a turbocharger is considered to be operating at high speeds for rotating assembly

rotational speeds in a range of about 120,000 rpm to 180,000 rpm, and operating at low speeds for rotating assembly rotational speeds in a range of about 30,000 rpm to 50,000 rpm. The rotating assembly rotational speeds are much lower than 30,000 rpm at diesel engine idle. When used in a passenger automobile, a turbocharger is considered to be operating at high speeds for rotating assembly rotational speeds in a range of about 220,000 rpm to 300,000 rpm, and operating at low speeds for rotating assembly rotational speeds in a range of about 110,000 rpm to 150,000 rpm. The rotating assembly rotational speeds are much lower than 150,000 rpm at engine idle.

Further advantageously, use of a main seal and an auxiliary seal provides redundancy. For example, if one of the seals becomes less effective due to wear, the other of the seals will continue to reduce or eliminate blowby.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the accompanying drawings in which like reference numbers indicate similar parts, and in which:

Fig. 1 is a cross sectional view of a conventional turbocharger;

Fig. 2 is a cross sectional view of a turbocharger including a progressively-applied, passive contact face seal;

Fig. 3 is a cross-sectional view of a compressor-end of a bearing housing including the progressively-applied, passive contact face seal of Fig. 2; and

Fig. 4 is a cross-sectional view of a compressor-end of a bearing housing including another embodiment progressively-applied, passive contact face seal.

DETAILED DESCRIPTION

Referring to Fig. 2, an exhaust gas turbocharger 100 includes a turbine section 102, a compressor section 106, and a center bearing housing 110 disposed between, and connecting, the turbine section 102 to the compressor section 106. The turbine section 102 includes a turbine housing 103 and a turbine wheel 104 disposed in the turbine housing 103. The compressor section 106 includes a compressor housing 107 and a compressor wheel 108 disposed in the compressor housing 107. The turbine wheel 104 is connected to the compressor wheel 108 via a shaft 114. The shaft 114 is supported for rotation about a rotational axis 116 via a pair of axially spaced journal bearings 118, 120 within in a bore 112 formed in the bearing housing 110. In addition, a thrust bearing assembly 128 is disposed in the bearing housing 110 so as to provide axial support for the shaft 114.

The shaft 114 is reduced in diameter on the compressor side of the compressor-side journal bearing 118, and a shoulder 115 is formed at the transition between diameters. The

compressor wheel 108 and the thrust bearing assembly 128, including a thrust bearing 122, a thrust washer assembly 123, and an oil flinger 124, are all disposed about the shaft 114 in the reduced diameter portion. The terminal end 114a of the shaft 114 extends axially beyond the compressor wheel 108 and includes an external thread. A nut 130 engages the thread, and is
5 tightened sufficiently to clamp the compressor wheel 108 and the flinger 124 against the shoulder 115. A stationary insert 132 and the thrust bearing 122 are clamped against the bearing housing 110 by a snap ring. In addition, the turbocharger 100 includes a seal assembly 160 for addressing compressor-end blowby that combines a main seal 162 such as a clearance seal or labyrinth seal in combination with a passive auxiliary seal assembly 163. In particular, the
10 passive auxiliary seal assembly 163 includes a contact face seal 164 that is configured to be applied progressively, as discussed further below.

In use, the turbine wheel 104 in the turbine housing 103 is rotatably driven by an inflow of exhaust gas supplied from the exhaust manifold of an engine (not shown). Since the shaft 114 connects the turbine wheel 104 to the compressor wheel 108 in the compressor housing 107, the
15 rotation of the turbine wheel 104 causes rotation of the compressor wheel 108. As the compressor wheel 108 rotates, it increases the air mass flow rate, airflow density and air pressure delivered to the engine's cylinders via an outflow from the compressor section 106, which is connected to the engine's air intake manifold.

Referring to Fig. 3, the flinger 124 is fixed to the shaft 114, and includes a cylinder
20 portion 124a that faces the compressor wheel 108, and a flange portion 124b that runs against a compressor-facing side of the thrust bearing 122. An insert 132 is disposed in the bore 112 between the compressor wheel 108 and the thrust bearing 122, and is also disposed radially outwardly of the flinger cylinder portion 124a. The seal assembly 160 is disposed between the flinger 124 and the insert 132. In particular, the main seal (e.g., a clearance seal) 126 is
25 positioned between the rotating cylinder portion 124a of the flinger 124 and the stationary bearing housing bore 112. In the illustrated embodiment, a set of piston rings 146, 147 serve as the main seal 162. The piston rings 146, 147 are supported on a radially-inward facing surface of the insert 132, and are received within grooves formed in a radially-outward facing surface of the flinger cylinder portion 124a.

In addition, the auxiliary seal assembly 163 is supported for axial movement in a vacancy
30 134 formed in a turbine-facing side of the insert 132. The auxiliary seal assembly 163 includes an annular contact face seal 164, a pair of flip seals 165a, 165b disposed between radial-side surfaces of the contact face seal 164 and the insert 132, a retainer 167 that is secured to the turbine-facing side of the insert 132, and a spring 166 disposed between the retainer and the
35 contact face seal 164. The contact face seal 164 is urged axially toward the compressor-end via

the spring 166 so that when the shaft 114 is not rotating or is rotating at low speeds, a contact surface 164a of the contact face seal 164 is axially-spaced apart from the flinger flange portion 124b. As the shaft 114 rotates at higher speeds, the rotation of the compressor wheel 108 causes the air pressure in the vicinity of the compressor wheel backwall 108a to increase. An air passageway 136 formed in the insert 132 directs the pressurized air (e.g., P2 pressure) to the vacancy 134 on the compressor-facing side of the contact face seal 164. At sufficient rotational speeds, the pressure on the compressor-facing side of the contact face seal 164 is sufficient to overcome the spring force of the spring 166, whereby the contact surface 164a of the contact face seal 164 is urged against the flinger flange portion 124b. Moreover, the contact pressure between the contact face seal 164 and the flinger flange portion 124b increases with increasing rotational speed, whereby the force applied by the contact face seal 164 can be considered to be progressively-applied. When using the progressively-applied contact face seal 164 in combination with the piston rings 146, 147, compressor-end blowby is minimized or eliminated. Since the blow-by gas pressure is reduced by the piston rings 146, 147, only minimal pressure is necessary for the progressively-applied contact face seal 164 to form an effective seal.

Since boost pressure P2 typically increases as the turbocharger speed increases, the force exerted on the contact face seal 164 also will increase with increased turbocharger speed, providing a more positive sealing interface at higher P2 pressures. Compressor-end blowby past the clearance seal 162 typically increases at higher speeds. The efficacy of the seal assembly 160, including the auxiliary seal assembly 160, improves at increased speed, countering the potential for increased blowby past the main seal piston rings (146, 147) at higher speeds and pressures, thus maintaining the sealing efficacy.

In the embodiment of the invention shown in Fig. 3, the pressurized air delivered to the vacancy 134 forces the contact face seal 164 to move as depicted by the directional arrows, towards a compressor-facing axial surface of the flinger flange portion 124b. As used here, the term "axial surface" refers to a surface that is perpendicular to the axis of rotation 116. The contact surface 164a of the contact face seal 164 is configured to make contact with an axial seal-receiving surface 140 of the rotating assembly in order to maintain a reliable seal in the context of use in a turbocharger, in which the shaft 114 typically experiences large excursions in the radial direction. However, in some embodiments, the auxiliary seal assembly 163 can be configured so that the contact surface 164a comes into contact with a radially, or generally-radially extending seal-receiving surface of the rotating assembly to provide a self-centering conical seal.

In some embodiments, only the contact surface 164a of the contact face seal 164 is formed of carbon. For example, the contact face seal 164 can be manufactured with a non-

carbon backing and a carbon facing so that the seal interface with the flinger 124 or thrust bearing 122 is always carbon-on-metal. In other embodiments, the contact face seal 164 is fully manufactured (e.g, substantially the entire contact face seal 164 is manufactured) from carbon or a carbon based material, such as amorphous carbon or crystalline graphite.

5 For contact surfaces, carbon graphite strengthened by high temperature thermoplastic resins such as PEEK (Polyether ether ketone), PAEK (Polyaryletherketone), polyimide, or PTFE (polytetrafluoroethylene) are currently established to provide strength, temperature resistance and lubricity needed for intermittent sliding contact, such as occurs in the contact seal 164. Carbon creates a protective layer that resists further wear. It is also possible to sinter or over
10 mold the carbon graphite feature onto a lower cost steel substrate.

The rotating member is typically a low-alloy carbon steel hardened and ground to a very low surface roughness. Material and coating advances may make other material couples possible in the future to increase service life of such intermittent contact seals.

Factors to be considered in selecting seal material include coefficient of friction between
15 the two faces, which is responsible for heat generation and thermal expansion, as well as flatness and finish. In some embodiments, the contact surface 164a is lapped and polished to achieve a high degree of flatness. In some embodiments, both the contact surface 164a and the seal-receiving surface 140 are lapped and polished to achieve a high degree of flatness. Surface finish plays an important role in the film thickness between the seal faces and in the interfacial
20 heat generation.

The seal assembly 160, including the contact face seal 164, provides improved sealing without the expected power losses, which are mathematically rolled into the turbine stage power and are typically measured as a component of turbine stage efficiency. Power losses due to, i.e., friction in the bearing systems, range from approximately 10% of the total turbine stage power at
25 low speed to 2% at high speed; whereas turbine aerodynamic efficiency ranges from 40% at low speed to greater than 50% at high speed. As a consequence, the total actual efficiency of the turbine stage at low speed is more affected by the bearing system power losses than it is at high speed. In the interest of maximizing low speed turbocharger efficiency and the resulting improved transient response which accompanies it, the low speed bearing mechanical losses
30 should be kept to a minimum. By applying low force to the contact face seal 164 only at low turbocharger speed changes and high force to the contact face seal 164 when turbocharger speeds are high, the low speed losses due to the contact face seal 164 are kept to a minimum and the resultant turbine stage efficiency is maximized.

Referring to Fig. 4, an alternative embodiment seal assembly 260 is included in the
35 turbocharger 100. The seal assembly 260 includes the main seal 162 in combination with a

passive auxiliary seal assembly 263, and is disposed between the flinger 224 and the insert 232. As in the previous embodiment, the main seal (e.g., a clearance seal) 162 is in sealing engagement between the rotating cylinder portion 224a of the flinger 224 and the stationary bearing housing bore 112. A set of piston rings 146, 147 serve as the main seal 162. The piston
5 rings 146, 147 are supported on a radially-inward facing surface of the insert 232, and are received within grooves formed in a radially-outward facing surface of the flinger cylinder portion 224a.

In addition, the passive auxiliary seal assembly 263 is supported for axial movement within in an annular vacancy 226 formed in a compressor-facing side of the flinger flange
10 portion 224b. The auxiliary seal assembly 263 includes an annular contact face seal 264, a pair of flip seals 265a, 265b disposed between radial-side surfaces of the contact face seal 264 and the flinger 224, and centrifugal biasing device 268 disposed between a turbine-facing surface of the contact face seal 264 and a compressor-facing surface of the flinger flange portion 124b.

The centrifugal biasing device 268 includes a mass 270 that is connected via a first
15 pivotable link 272 to the turbine-facing side of the contact face seal 264 and via a second pivotable link 274 to the compressor-facing side of the flinger flange portion 224b. In use, the mass 270 creates a radial centrifugal force proportional to the square of the shaft rotational speed. In addition, the links 272, 274 provide a spring force opposing the centrifugal force, and serve to convert the radial displacement of the mass 270 into an axial displacement of the contact
20 face seal 264.

When the shaft 114 is not rotating or is rotating at low speeds, a contact surface 264a of the contact face seal 264 is urged axially toward the turbine-end via centrifugal biasing device 268 so that the contact surface 264a is axially-spaced apart from a turbine-facing, seal-receiving surface 240 of the insert 232. As the shaft 114 rotates at higher speeds, the rotation of the flinger
25 224 causes mass 270 to move radially. As a result, the centrifugal biasing device 268 urges the contact surface 264a to move axially against the seal-receiving surface 240 of the insert 232. Moreover, the contact pressure between the contact surface 264a and the seal-receiving surface 240 increases with increasing rotational speed, whereby the force applied by the contact face seal 264 can be considered to be progressively-applied. When using the progressively-applied
30 contact face seal 264 in combination with the piston rings 146, 147, compressor-end blowby is minimized or eliminated.

In the embodiment depicted in Fig. 4, the auxiliary seal assembly 263 is transposed from the static side (i.e., from the insert 232) to the dynamic side (i.e., to the flinger 224) so that the dynamic sealing face (e.g., the contact surface 264a) is now on the flinger 224, and the static
35 sealing face (e.g., the seal-receiving surface 240) is on the insert 232.

Although the auxiliary seal assembly 163 described above with respect to Figs. 2 and 3 provides a pneumatically-actuated contact face seal 164 on the static side (i.e., is supported on the insert 132), the auxiliary seal assembly 163 including the pneumatically-actuated contact face seal 164 can be configured to be supported on the dynamic side (i.e., supported on the flinger 124 or thrust bearing 122). Likewise, the auxiliary seal assembly 263 described above with respect to Fig. 4 provides a centrifugally-actuated contact face seal 164 on the dynamic side (i.e., is supported on the flinger 224), the auxiliary seal assembly 263 including the centrifugally-actuated contact face seal 264 can be configured to be supported on the static side (i.e., supported on the insert 232).

As in the previous embodiment, the low contact force at low turbocharger speed and the high contact force at high turbocharger speeds act to maintain an effective sealing interface with minimal effect on turbocharger efficiency.

What is claimed:

1. A turbocharger (100) comprising
a housing (110);
a rotating assembly (104, 108, 114, 124) mounted for rotation (116) within said housing
5 (110) and defining an axis of rotation (116),
a passive contact face seal assembly (163) provided in said housing (110), the contact
face seal assembly (163) configured so that
a contact surface (164a) of the contact face seal assembly (163) does not contact
the rotating assembly (104, 108, 114, 124) when the rotating assembly (104, 108, 114,
10 124) is at rest, and
the contact surface (164a) contacts the rotating assembly (104, 108, 114, 124)
with increasing contact pressure as the rotational speed of the rotating assembly (104,
108, 114, 124) increases.

15 2. The turbocharger (100) of claim 1, wherein the contact surface (164a) is configured to
contact a seal-receiving surface (140) of said rotating assembly (104, 108, 114, 124), where the
seal-receiving surface (140) of the rotating assembly (104, 108, 114, 124) is oriented
perpendicular to the rotational axis (116).

20 3. The turbocharger (100) of claim 2, wherein the seal-receiving surface (140) of said
rotating assembly (104, 108, 114, 124) is located on a flinger (124).

4. The turbocharger (100) of claim 1, wherein the contact face seal (164) assembly further
comprises a device (164, 165, 166, 167) configured to progressively urge the contact surface
25 (164a) axially against a seal-receiving surface (140) of said rotating assembly (104, 108, 114,
124) as the rotational speed of the rotating assembly (104, 108, 114, 124) increases, where the
seal-receiving surface (140) of the rotating assembly (104, 108, 114, 124) is oriented
perpendicular to the rotational axis (116).

30 5. The turbocharger (100) of claim 4, wherein the device (164, 165, 166, 167) is configured
to be actuated by pneumatic pressure supplied by a compressor stage of the turbocharger (100).

6. The turbocharger (100) of claim 4, wherein the device (164, 165, 166, 167) comprises a
mechanism that is responsive to the rotational speed of the rotating assembly (104, 108, 114,
35 124).

7. The turbocharger (100) of claim 1, wherein the contact surface (164a) is comprised of a carbon based seal material.

8. The turbocharger (100) of claim 1, comprising a clearance seal (162) disposed between the rotating assembly (104, 108, 114, 124) and said housing (110).

9. A turbocharger (100) comprising

a housing (110);

a rotating assembly (104, 108, 114, 124) mounted for rotation (116) within said housing (110) and defining an axis of rotation (116), and

an annular contact face seal assembly (163, 263) provided in said housing (110), the contact face seal assembly (163, 263) including a contact surface (164a, 264a) configured to contact a seal-receiving surface (140, 240) of one of a stationary member (232) of the turbocharger (100) and a member of the rotating assembly (104, 108, 114, 124, 224), the contact face seal assembly (163, 263) further configured so that

the contact surface (164a, 264a) does not contact the seal-receiving surface (140, 240) when the rotating assembly (104, 108, 114, 124, 224) is at rest, and

the contact surface (164a, 264a) contacts the seal-receiving surface (140) with increasing contact pressure as the rotational speed of the rotating assembly (104, 108, 114, 124, 224) increases.

10. The turbocharger (100) of claim 9, wherein the seal receiving surface (140) is formed on a flinger (124) of the rotating assembly (104, 108, 114, 124).

11. The turbocharger (100) of claim 9, wherein the seal-receiving surface (240) is formed on an insert (232) disposed between the flinger (224) and the housing (110).

12. The turbocharger (100) of claim 9, wherein the seal-receiving surface (140, 240) is oriented perpendicular to the rotational axis (116).

13. The turbocharger (100) of claim 9, wherein the contact face seal assembly (263) further comprises a device (268) configured to progressively urge the contact surface (264a) axially against the seal-receiving surface (240) of the stationary member (232) as the rotational speed of

the rotating assembly (104, 108, 114, 224) increases, where the seal-receiving surface (240) of the stationary member (232) is oriented perpendicular to the rotational axis (116).

14. The turbocharger (100) of claim 9, wherein the contact face seal assembly (163) further
5 comprises a device (164, 165, 166, 167) configured to progressively urge the contact surface
(164a) axially against the seal-receiving surface (140) of the rotating assembly (104, 108, 114,
124) as the rotational speed of the rotating assembly (104, 108, 114, 124) increases, where the
seal-receiving surface (140) of the rotating assembly (104, 108, 114, 124) is oriented
perpendicular to the rotational axis (116).

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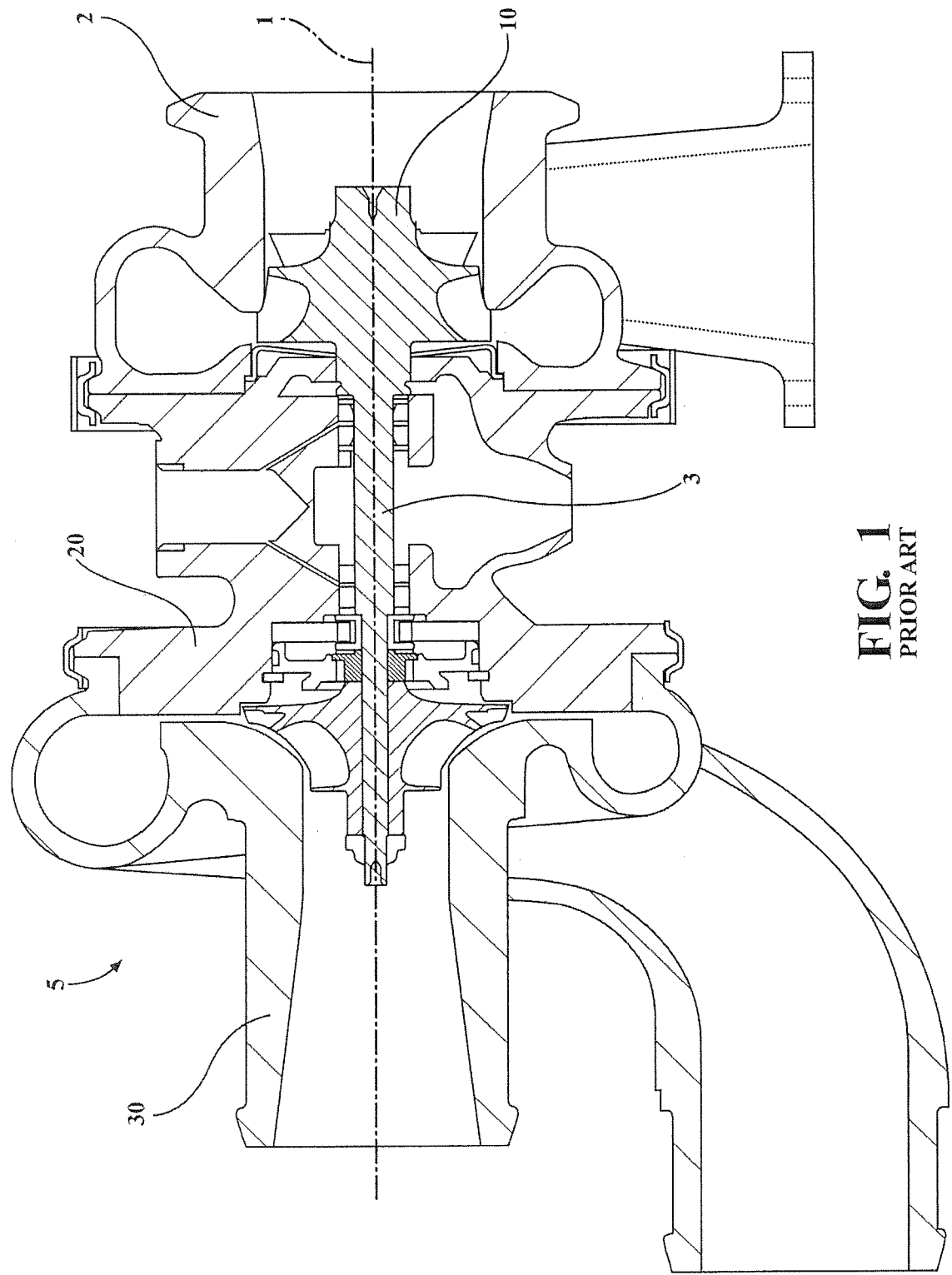


FIG. 1
PRIOR ART

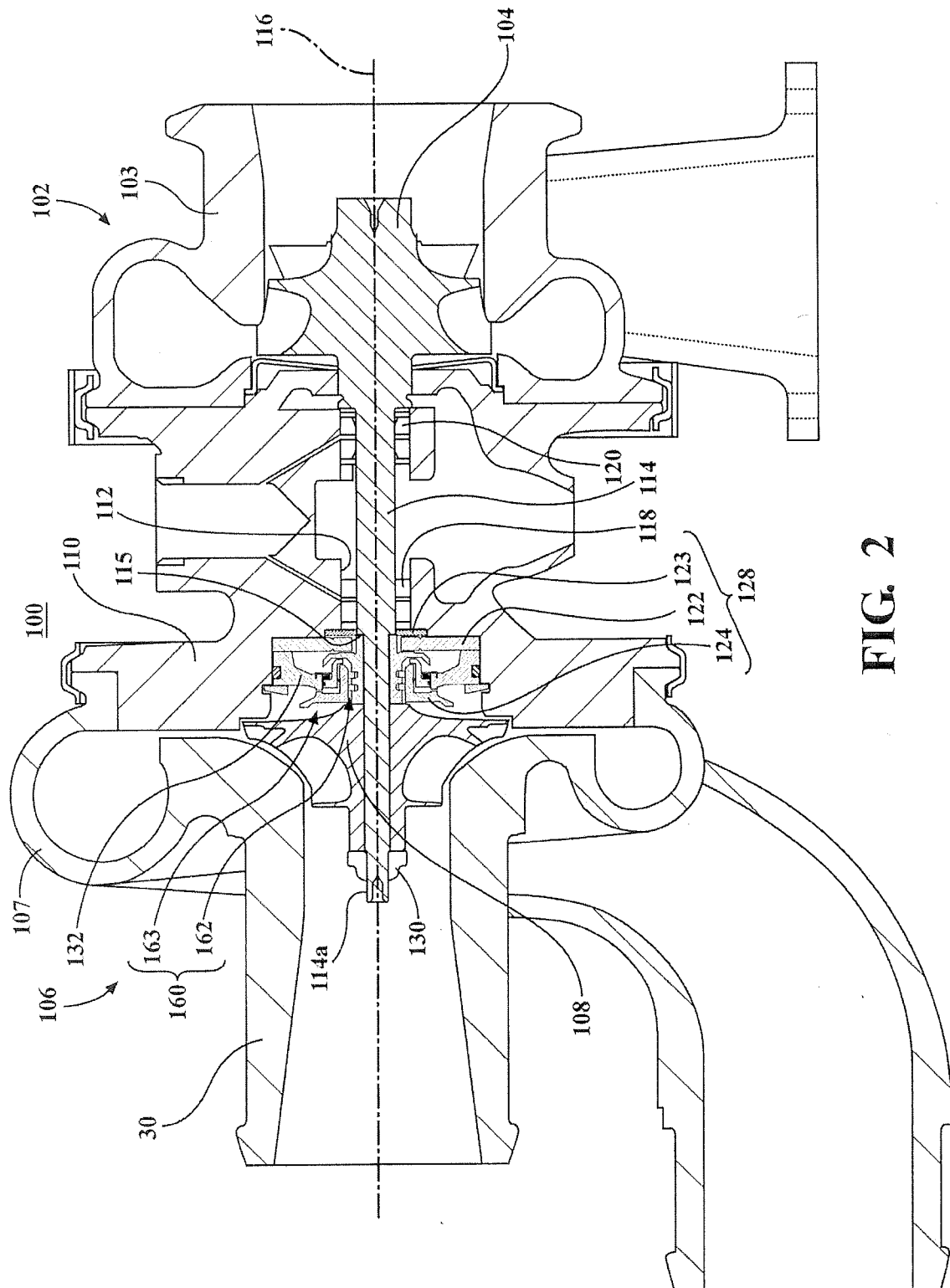


FIG. 2

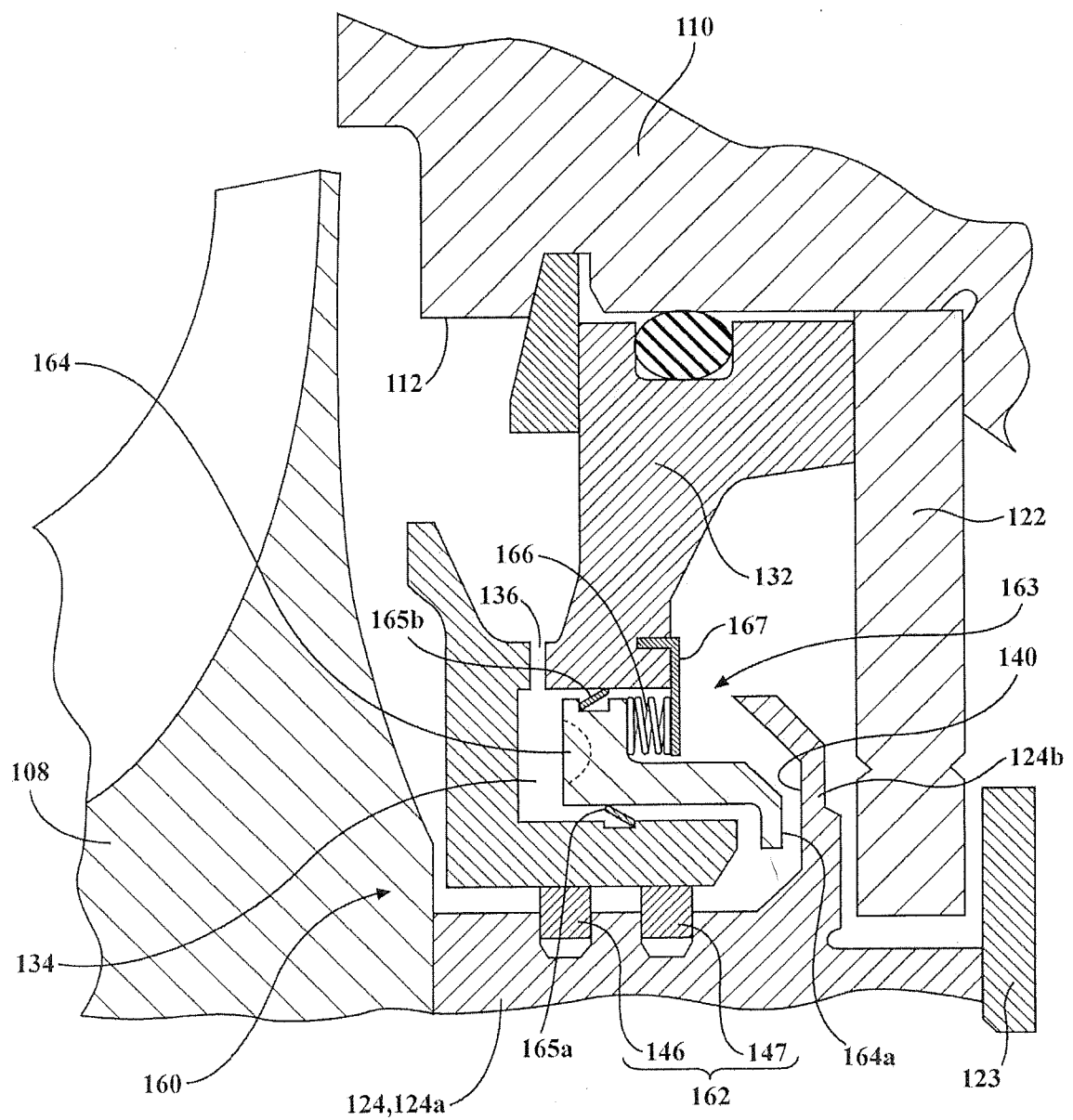


FIG. 3

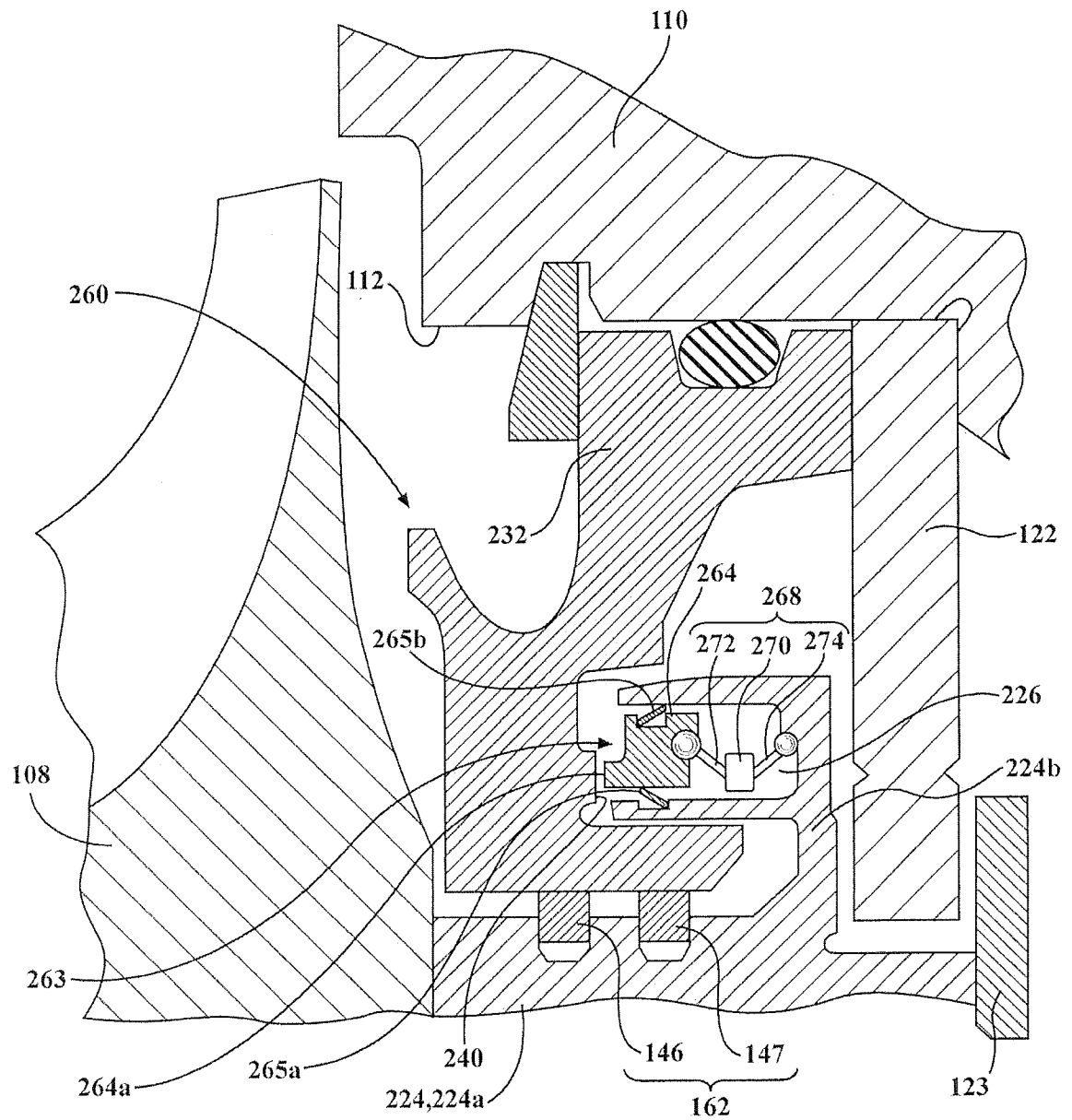


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/043605**A. CLASSIFICATION OF SUBJECT MATTER****F02B 39/00(2006.01)i, F01D 11/00(2006.01)i, F16J 15/16(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F02B 39/00; F16J 15/447; F01D 25/00; F01D 11/08; F16J 15/08; F01D 11/00; F16J 15/42; F16J 15/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: turbocharger, housing, rotating assembly, passive seal, contact face, and rotational speed

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-285887 A (TOYOTA MOTOR CORP.) 14 October 2004 See paragraphs [0032]-[0058] and figures 4-5.	1-14
A	US 2010-0202875 A1 (SCHLIENGER et al.) 12 August 2010 See paragraphs [0022]-[0029] and figure 2.	1-14
A	JP 2006-145034 A (MAN B & W DIESEL GMBH) 08 June 2006 See paragraphs [0014]-[0023] and figures 1-2.	1-14
A	US 5066192 A (HONDA et al.) 19 November 1991 See abstract, column 2, line 22 - column 3, line 31 and figures 1-2.	1-14
A	JP 2011-241835 A (BENTELER AUTOMOBILTECHNIK GMBH) 01 December 2011 See paragraphs [0028]-[0032] and figures 1-2.	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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