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- (71) **Applicant:** BORGWARNER INC. [US/US]; Patent Department, 3850 Hamlin Road, Auburn Hills, Michigan 48326 (US).
- (72) **Inventor:** JENKS, Gordon; 443 Monte Vista Rd., Candler, North Carolina 28715 (US).
- (74) **Agents:** ASHER, Robin W. et al.; Miller, Canfield, Paddock and Stone, P.L.C., 150 West Jefferson, Suite 2500, Detroit, Michigan 48226 (US).
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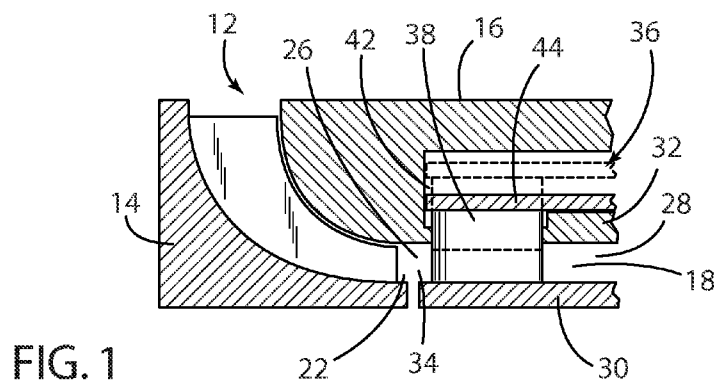
Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
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(54) **Title:** RETRACTABLE VANE DIFFUSER FOR COMPRESSORS



(57) **Abstract:** A retractable vane diffuser system (36) for a compressor stage (12) of a turbocharger with selectively retractable vanes (38). The retractable vane diffuser system (36) includes a retractable vane (38) or a set of vanes (40) that can extend into a flow path (34) of a diffuser (18) to help control airflow and change the operating characteristics of the compressor stage (12), such as improving surge margin or improving peak stage efficiency. The vanes (38) can retract preferably with a vane ring (44) into a cavity (42) of a wall (30 or 32) of the diffuser (18) when operation as a vaneless diffuser is desired to maximize flow, such as to slow onset of diffuser stall or surge. The retractable vane diffuser system (36) combines superior pressure ratio, efficiency, and lower mass air-flow operating characteristics of a diffuser having vanes with higher mass airflow capacity of a vaneless diffuser.

RETRACTABLE VANE DIFFUSER FOR COMPRESSORS**CROSS-REFERENCE TO RELATED APPLICATION**

This application claims priority to and all the benefits of U.S. Provisional Application No. 61/676,467, filed on July 27, 2012, and entitled "Retractable Vane Diffuser for Compressors," which is incorporated herein by reference.

BACKGROUND**1. Field of the Disclosure**

This disclosure relates to a component for turbochargers for internal combustion engines. More particularly, this disclosure relates to a retractable vane diffuser system for a radial or mixed flow compressor stage of a turbocharger.

2. Description of Related Art

Advantages of turbocharging include increased power output, lower fuel consumption and reduced pollutant emissions. The turbocharging of engines is no longer primarily seen from a high power performance perspective, but is rather viewed as a means of reducing fuel consumption and environmental pollution on account of lower carbon dioxide (CO₂) emissions. Currently, a primary reason for turbocharging is using the exhaust gas energy to reduce fuel consumption and emissions. In turbocharged engines, the combustion air is pre-compressed before being supplied to the engine. The engine aspirates the same volume of air-fuel mixture as a naturally aspirated engine, but due to the higher pressure, thus higher density, more air and fuel mass is supplied into the combustion chamber. Consequently, more fuel can be burned, so that the engine's power output increases relative to the speed and swept volume.

In exhaust gas turbocharging, some of the exhaust gas energy, which would normally be wasted, is used to drive a turbine wheel mounted on a shaft. The turbocharger returns some of this normally wasted exhaust energy back into the engine, contributing to the engine's efficiency and saving fuel. A compressor impeller, which is mounted on the same shaft as the turbine wheel, draws in filtered ambient air, compresses it, and then supplies it to the engine.

A turbocharger is a type of forced induction system used with internal combustion engines. Turbochargers deliver compressed air to an engine intake, allowing more fuel to be combusted, thus boosting an engine's horsepower without significantly increasing engine weight. Thus, turbochargers permit the use of smaller engines that develop the same amount of

horsepower as larger, naturally aspirated engines. Using a smaller engine in a vehicle has the desired effect of decreasing the mass of the vehicle and enhancing fuel economy. Moreover, the use of turbochargers permits more complete combustion of the fuel delivered to the engine, which contributes to the highly desirable goal of a cleaner environment.

5 Turbochargers include a turbine stage and a compressor stage. More specifically, turbochargers typically include a turbine housing connected to the engine's exhaust manifold, a compressor housing connected to the engine's intake manifold, and a center bearing housing coupling the turbine and compressor housings together. A turbine wheel in the turbine housing is rotatably driven by an inflow of exhaust gas supplied from the exhaust manifold. A shaft
10 rotatably supported in the center bearing housing connects the turbine wheel to a compressor wheel (an impeller) in the compressor housing so that rotation of the turbine wheel causes rotation of the compressor impeller. The shaft connecting the turbine wheel and the compressor impeller defines an axis of rotation.

This disclosure focuses on the compressor stage of the turbocharger. The compressor
15 stage is designed to help increase the intake manifold air pressure and density to allow the engine cylinders to ingest a greater mass of air during each intake stroke. The compressor stage, specifically the compressor housing, preferably includes a diffuser. The diffuser converts high-velocity airflow leaving the compressor impeller to lower velocity, higher pressure airflow. The diffuser is defined by two walls. One is called a hub wall and is closest to the center bearing
20 housing of the turbocharger. The other is called a shroud wall. These two walls form a flow path for air as it leaves the compressor impeller and guides the airflow into a volute.

Vanes in diffusers are known. Providing vanes in the diffuser can improve efficiency. Full vanes that extend fully between the shroud wall and the hub wall have been utilized. Slotted wall type diffusers where full vanes are accepted by slots in one of the walls are also known.
25 Ribbed vanes that do not extend fully between the walls of the diffuser are also known.

Vanes help control airflow at lower mass airflow, and can slow the onset of diffuser stall and surge caused by flow reversal. Traditional movable vanes are known as pivoting vanes. The walls of the diffuser can move to adjust the airflow over the vanes.

Vaneless diffusers are also known. At higher mass airflows, vanes can block airflow
30 through the diffuser. This occurs because a leading edge of the vanes causes a sonic shock. Under certain operating conditions, vanes blocking any airflow is not preferred. At higher mass

airflows, a vaneless diffuser is more effective than at lower mass airflows; whereas, a ribbed wall can be more effective at lower mass airflow conditions.

Higher mass airflows would indicate that the compressor stage is near its operational limit in terms of airflow capacity. Lower mass airflows would indicate that the compressor stage is near its operational limit in terms of compressing air in a stable fashion. Near surge, a compressor blade stalls like an airplane wing and stops being able to compress air as effectively. Vortices are shed off part of the compressor blade, diffuser, or volute tongue, causing the pressure and mass flowrate to fluctuate. When these vortices get big enough, they cause such large fluctuations through the compressor stage that the flow actually reverses and comes out an inlet of the compressor housing. This is called “hard surge” or “surge.”

It is desirable therefore to provide a compressor stage of a turbocharger with both the superior pressure ratio, efficiency, and lower mass airflow operating characteristics of a diffuser having vanes with the higher mass airflow capacity of a vaneless diffuser.

SUMMARY

A turbocharger has a compressor impeller and a turbine wheel connected by a rotating shaft. The compressor impeller is operably connected and adjacent to a retractable vane diffuser system with vanes that retract into a wall of a diffuser and selectively extend from the wall of the diffuser into a flow path of the diffuser based on activation of the retractable vane diffuser system. The vanes can be fully retracted with a vane ring into a cavity in the wall of the diffuser when operation as a vaneless diffuser is desired to maximize flow capacity. The vanes can extend from the wall of the diffuser when the efficiency of vanes is beneficial, such as at lower mass airflow conditions to increase efficiency and pressure ratio and to slow the onset of diffuser stall or surge.

The retractable vane diffuser system improves operating characteristics of the compressor stage of the turbocharger and effectively and efficiently controls airflow from the compressor impeller with these retractable vanes.

BRIEF DESCRIPTION OF THE DRAWINGS

Advantages of the present disclosure will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Figure 1 is a cross-sectional partial side view of a compressor stage of a turbocharger;

Figure 2 is a cross-sectional side view of the compressor stage of the turbocharger showing vanes in each wall of a diffuser;

Figure 3 is an end view of a portion of a vane ring relative to a compressor impeller; and

5 Figure 4 is an end view of a portion of a vane ring with separate vanes adjacent to a compressor impeller according to another embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring to Figures 1-4, a turbocharger for an internal combustion engine is generally understood to include a compressor stage 12. The compressor stage 12 of the turbocharger can
10 include a compressor impeller 14 and a compressor housing 16. A rotating shaft is driven by a turbine wheel such that rotation of the turbine wheel causes rotation of the compressor impeller 14.

The compressor housing 16 includes a diffuser 18 leading to a volute 20. The compressor impeller 14 is mounted on one end of the shaft and is housed within the compressor
15 housing 16. As is known in the art, the turbine wheel is rotatably driven by an inflow of exhaust gas supplied from an exhaust manifold, which rotates the shaft, thereby causing the compressor impeller 14 to rotate. As the compressor impeller 14 rotates, air is drawn into the compressor housing 16, compressed by the compressor impeller 14, forced into the diffuser 18, and then enters the volute 20 to be delivered at an elevated pressure to an intake manifold of the engine.
20 After driving the turbine wheel, the exhaust gas can be discharged or in some cases recirculated.

The diffuser 18 and the volute 20 establish fluid communication between an impeller chamber 22 (containing a portion of the compressor impeller 14) and the engine. The volute 20 may be formed along an outer region of the compressor housing 16 and is radially remote from the compressor impeller 14. The volute 20 can be standard with an air passage 24 that gets
25 larger as it approaches discharge for more static pressure. The diffuser 18 is associated with an entrance of the volute 20.

The diffuser 18 has an inlet 26 in close proximity to the compressor impeller 14, preferably at a tip of the compressor impeller 14. The diffuser 18 includes an outlet 28 at an opposite end of the inlet 26. The diffuser 18 is confined by two walls called a hub wall 30 and a
30 shroud wall 32 forming a flow path 34 for air as it leaves the compressor impeller 14. The

shroud wall 32 is part of the compressor housing 16, and the hub wall 30 is typically part of a bearing housing, but also may be a back plate of the compressor housing 16.

The diffuser 18 includes a retractable vane diffuser system 36 suitable for a radial or mixed flow compressor stage 12. The retractable vane diffuser system 36 includes a retractable vane 38 or preferably a set of vanes 40 that can be inserted into the flow path 34 of the diffuser 18 to change the operating characteristics of the compressor stage 12, such as improving the surge margin or improving peak stage efficiency. Figure 1 shows how the vanes 38 extend from the shroud wall 32 into the flow path 34 from a retracted position (as shown in dashed lines). The vanes 38 can be retracted into a cavity 42 on either or both the hub wall 30 and the shroud wall 32 of the diffuser 18 when operation as a vaneless diffuser is desired. The vanes 38 can be fully retractable to be completely out of the flow path 34 to avoid any blockage of airflow. On the other hand, the vanes 38 can be extended into the flow path 34 singly or as a group to further optimize performance of the compressor stage 12. With the retractable vane diffuser system 36, it is appreciated that a length of the diffuser 18 can be shorter than typical, allowing for a more compact turbocharger.

The retractable vane diffuser system 36 allows the vanes 38 to operate when efficient such as at lower mass airflows but can avoid flow restrictions at higher mass airflows. When the vanes 38 are extended into the flow path 34, the vanes 38 can help build pressure after air leaves the compressor impeller 14 to increase the efficiency of the compressor stage 12. The vanes 38 help control flow at lower mass airflow, and the vanes 38 extended into the flow path 34 can slow the onset of diffuser stall and surge with flow reversal. At higher mass airflows, the vanes 38 can block total airflow that could cause earlier compression choke. Thus, to avoid blockage of airflow, the vanes 38 can be totally removed from the flow path 34 when fully retracted. The vanes 38 when retracted increase choke flow with less obstructed flow of air, such as preferred at higher operating speeds.

The vanes 38 are preferably mounted on a movable vane ring 44. It is preferred that multiple vane rings 44 are used to control movement of the vanes 38.

The diffuser 18 may have two sets of vanes 40 optimized for different operating points. The sets of vanes 40 may be staggered so as to not overlap in the shroud wall 32. As such, a ring of vanes in the hub wall 30 and a ring of vanes in the shroud wall 32 may be extended into the flow path 34.

Also, two sets of vanes 40 may be on each side of the diffuser 18. As such, a shroud set of vanes 40 and a hub set of vanes 140 may retract and extend from each wall, namely the shroud wall 32 and the hub wall 30. As shown in Figure 2, the vanes 38 are retracted into the hub wall 30 and the shroud wall 32, and the vanes 38 can be extended from the hub wall 30 and the shroud wall 32 into the flow path 34. In another embodiment, the vanes 38 can be staggered or offset on the hub wall 30 or the shroud wall 32 or both walls.

As shown in Fig. 4, each vane 38 can be separate so that the solidity of the diffuser 18 could be changed. Alternating vanes 38 can be retracted or extended. One set of vanes 40 can be attached to the vane ring 44 in the shroud wall 32, i.e. an upper ring in the compressor housing 16. Another set of vanes 140 can be attached to a vane ring 144 in the hub wall 30, i.e. a lower ring in the bearing housing. Each vane of the set of vanes 140 can alternate and be between vanes of the other set of vanes 40 as shown in Figure 4.

Activation of the retractable vane diffuser system 36 can vary depending on the diffuser 18 and characteristics sought. The retractable vane diffuser system 36 could be activated by mass airflow. As such, lower mass airflow would cause the vanes 38 to extend into the flow path 34. Higher mass airflow would cause the vanes 38 to retract.

Also, the retractable vane diffuser system 36 could be activated by acceleration or deceleration of the turbocharger. As such, rapid acceleration or deceleration would cause the vanes 38 to extend into the flow path 34. Thus, at steady high speed, the vanes 38 would be retracted.

The retractable vane diffuser system 36 could be controlled by a single actuator that also controls a set of Variable Turbine Geometry (VTG) vanes. For example, when the set of VTG vanes is closed, the vanes 38 of the compressor stage 12 could be extended into the flow path 34. It is appreciated that the single actuator can be operably connected to a VTG actuation mechanism and the retractable vane diffuser system 36.

The retractable vane diffuser system 36 in the compressor stage 12 of the turbocharger uses selectively retractable vanes 38 or sets of vanes 40, which can be extended into the flow path 34 of the diffuser 18, to help control airflow and to change the operating characteristics of the compressor stage 12, such as making the compressor stage 12 operate in a stable fashion at lower mass airflow rates or improving peak stage efficiency. The vanes 38 can be retracted into the cavity 42 in a wall (30 and/or 32) of the diffuser 18 to maximize flow capacity as a vaneless system.

The invention has been described here in an illustrative manner, and it is to be understood that the terminology used is intended to be in the nature of words of description rather than limitation. Many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims,
5 the invention may be practiced other than as specifically enumerated within the description.

What is claimed:

1. A turbocharger having a compressor impeller (14) and a turbine wheel connected by a rotating shaft, the improvement comprising a retractable vane diffuser system (36) including:

5 a diffuser (18) defined by a hub wall (30) and a shroud wall (32) forming a flow path (34) for air as it leaves the compressor impeller (14); and

a vane (38) retractable into the hub wall (30) or the shroud wall (32).

2. The turbocharger of claim 1 wherein operational stability at low mass airflows is improved by controlling airflow.

10 3. The turbocharger of claim 1 wherein the vane (38) is one of a plurality of vanes.

4. The turbocharger of claim 1 further comprising a set of vanes (40) on a vane ring (44), the set of vanes (40) retractable into each of the hub wall (30) and the shroud wall (32).

5. The turbocharger of claim 1 wherein the vane (38) is separate from adjacent vanes.

15 6. The turbocharger of claim 5 wherein the vane (38) can be retracted while adjacent vanes are extended.

7. The turbocharger of claim 1 further comprising a vane ring (44) in a cavity (42) of the shroud wall (32) of the diffuser (18), the vane ring (44) including a plurality of vanes (38) retractable into the shroud wall (32).

20 8. The turbocharger of claim 1 wherein activation of the retractable vane diffuser system (36) is caused by mass airflow, wherein lower mass airflow causes the vane (38) to extend into the flow path (34), and wherein higher mass airflow causes the vane (38) to retract.

9. The turbocharger of claim 1 wherein activation of the retractable vane diffuser system (36) is caused by acceleration or deceleration of the turbocharger, wherein rapid
25 acceleration or deceleration causes the vane (38) to extend into the flow path (34), and wherein the vane (38) is retracted at steady high speed.

10. The turbocharger of claim 1 wherein a single actuator controls the retractable vane diffuser system (36) and a set of Variable Turbine Geometry (VTG) vanes, wherein the

single actuator causes the vane (38) to extend into the flow path (34) when the VTG vanes are in a closed position, and wherein the single actuator is operably connected to the turbine wheel.

11. A turbocharger for an internal combustion engine comprising a compressor impeller (14) and a turbine wheel connected by a rotating shaft, the compressor impeller (14) operably connected and adjacent to a retractable vane diffuser system (36) with vanes (38) that fully retract into a wall (30 or 32) of a diffuser (18) and selectively extend from the wall (30 or 32) of the diffuser (18) into a flow path (34) of the diffuser (18).

12. The turbocharger of claim 11 wherein activation of the retractable vane diffuser system (36) is driven by mass airflow wherein lower mass airflow causes the vanes (38) to extend into the flow path (34) and higher mass airflow causes the vanes (38) to retract.

13. The turbocharger of claim 11 wherein activation of the retractable vane diffuser system (36) is caused by acceleration or deceleration of the turbocharger, wherein rapid acceleration or deceleration causes the vanes (38) to extend into the flow path (34), and wherein the vanes (38) are retracted when acceleration is slower.

14. The turbocharger of claim 11 including a movable vane ring (44) in a cavity (42) of the wall (30 or 32) of the diffuser (18).

15. The turbocharger of claim 11 including a movable vane ring (44) in each wall (30 and 32) of the diffuser (18) wherein alternating vanes (38) can be retracted or extended.

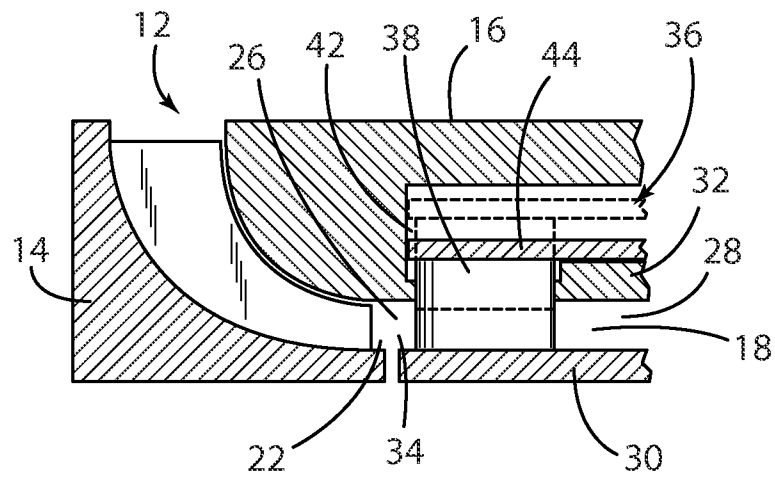


FIG. 1

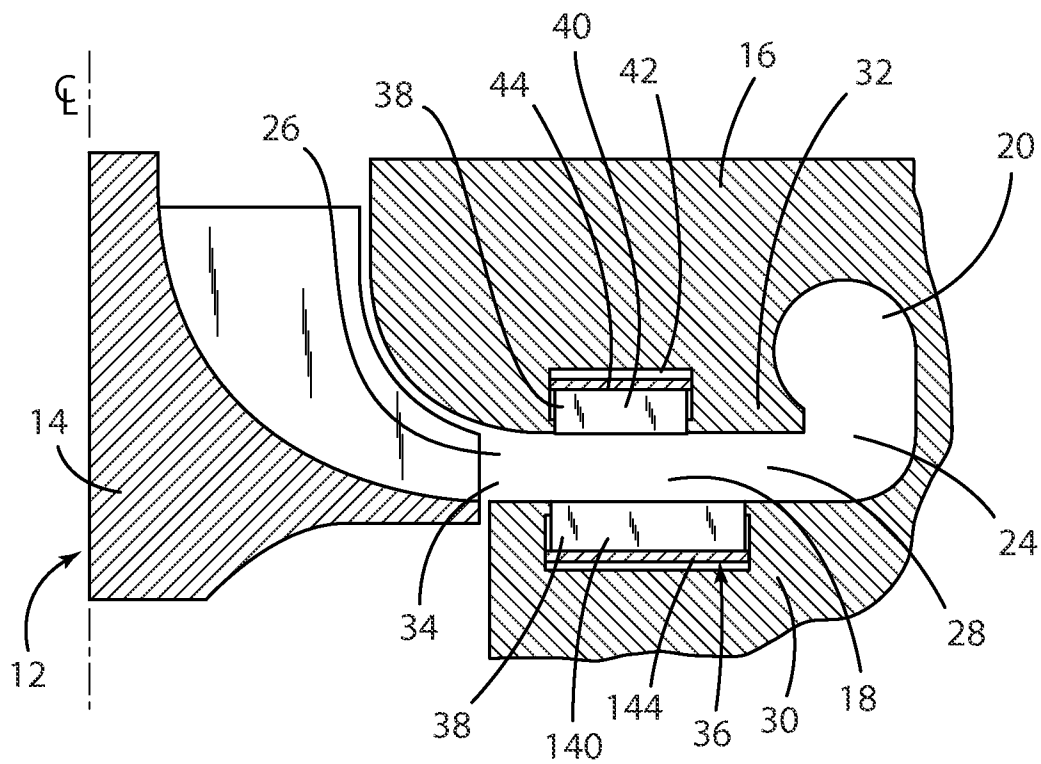


FIG. 2

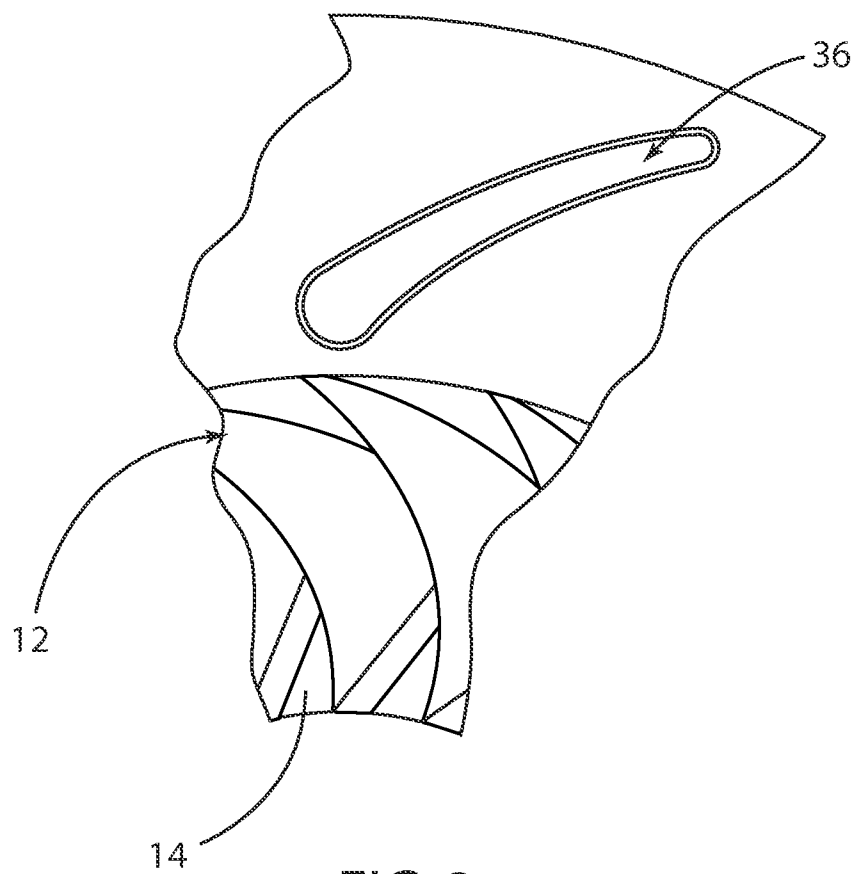


FIG. 3

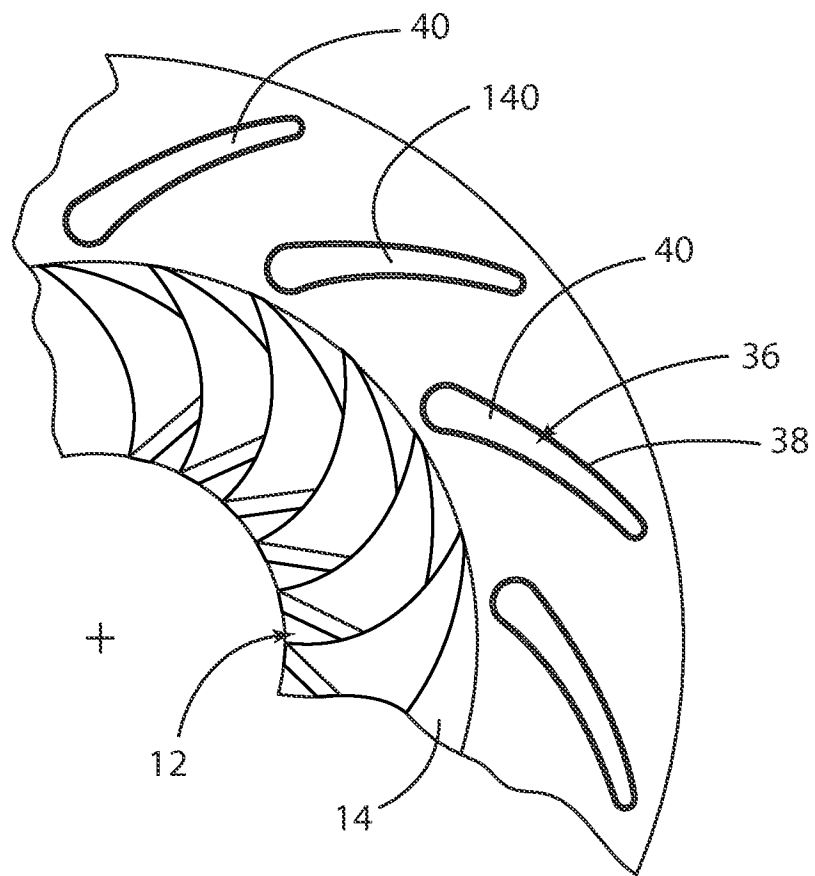


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/050010**A. CLASSIFICATION OF SUBJECT MATTER****F02B 37/12(2006.01)i, F02B 37/24(2006.01)i, F02B 39/00(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 37/12; F04D 27/00; F02B 37/24; F04D 29/46; F02B 37/00; F02M 25/07; F02B 39/00

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, compressor, diffuser, retract, movable, sliding and vane**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,452,986 A (OSBORNE et al.) 26 September 1995 See abstract; column 2 lines 26-33,67, column 3 lines 1-12, column 4 lines 8-11,35-45, column 5 lines 33-38, column 6 lines 20-23; figures 1-9.	1-8
Y		9-15
Y	JP 2012-082760 A (TOYOTA MOTOR CORP.) 26 April 2012 See abstract; paragraphs [0015],[0016],[0030]-[0034],[0049],[0050],[0054],[0055]; figures 1-7.	9-15
A		1-8
A	US 2012-0111002 A1 (TABATA, MASAKAZU) 10 May 2012 See abstract; paragraphs [0016]-[0020]; figures 1-4.	1-15
A	US 6,435,167 B1 (FINGER et al.) 20 August 2002 See abstract; column 5, lines 28-65; figures 1-3.	1-15
A	JP 2011-179477 A (TOYOTA MOTOR CORP.) 15 September 2011 See abstract; paragraphs [0017]-[0019]; figures 1-3.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

14 October 2013 (14.10.2013)

Date of mailing of the international search report

15 October 2013 (15.10.2013)

Name and mailing address of the ISA/KR

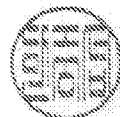
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Authorized officer

HAN Joong Sub

Telephone No. +82-42-481-5606



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/050010

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5452986 A	26/09/1995	DE 69527582 D1 DE 69527582 T2 EP 0688398 A1 EP 0688398 A4 EP 0688398 B1 JP 08-507588 A WO 95-19499 A2 WO 95-19499 A3	05/09/2002 21/11/2002 19/12/2001 29/07/1998 31/07/2002 13/08/1996 20/07/1995 17/08/1995
JP 2012-082760 A	26/04/2012	None	
US 2012-0111002 A1	10/05/2012	CN 102472298 A EP 2549122 A1 WO 2011-114487 A1	23/05/2012 23/01/2013 22/09/2011
US 6435167 B1	20/08/2002	DE 19956896 C1	29/03/2001
JP 2011-179477 A	15/09/2011	None	