



(51) International Patent Classification:

F01D 25/24 (2006.01) *F02B 37/00* (2006.01)
F02B 39/00 (2006.01)

(21) International Application Number:

PCT/US2013/068222

(22) International Filing Date:

4 November 2013 (04.11.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/723,943 8 November 2012 (08.11.2012) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

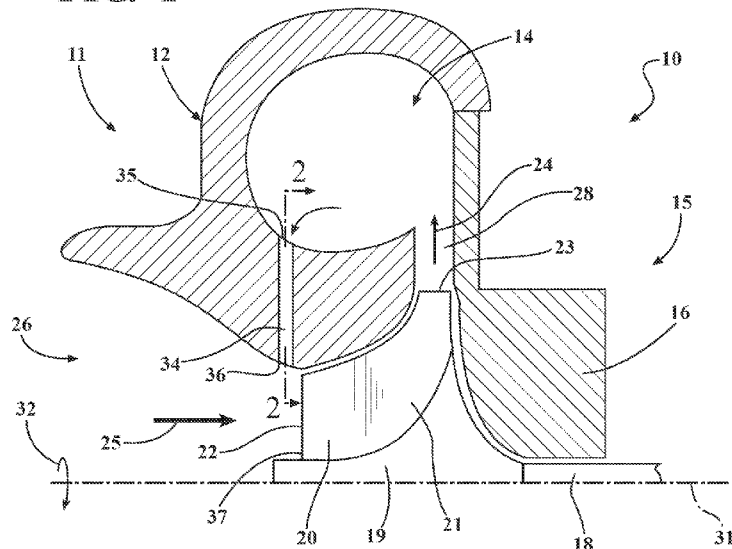
Declarations under Rule 4.17:

- 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))
- of inventorship (Rule 4.17(iv))

[Continued on next page]

(54) Title: CENTRIFUGAL COMPRESSOR WITH INLET SWIRL SLOTS

FIG. 1



(57) Abstract: A turbocharger 10 has an improved compressor 11 that generates a pre-swirl flow within the inlet air flow prior to entry of the inlet air into the compressor wheel 19 wherein the swirl flow increases the compressor map width at surge. The compressor 11 redirects a small portion of the compressed or pressurized air flowing through the volute 14 back into the compressor inlet 26 to generate the swirl flow. The swirl flow is supplied to the compressor inlet 26 upstream of the compressor wheel 19 by radial slots or swirl passages, which are provided in the compressor housing 12. The swirl passages are preferably angled in the direction of wheel rotation to provide a swirl flow that is pressurized and discharges at an angle into the compressor inlet 26 so that a circumferentially directed swirl is formed in the flow of inlet air prior to entering the compressor 11.



Published:

— *with international search report (Art. 21(3))*

CENTRIFUGAL COMPRESSOR WITH INLET SWIRL SLOTS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and all benefits of
5 U.S. Provisional Application No. 61/723,943, filed on November
8, 2012, and entitled "Centrifugal Compressor With Inlet Swirl
Slots."

FIELD OF THE INVENTION

The invention relates to a turbocharger with an improved
10 compressor and more particularly, to a compressor having swirl
slots each having an inlet in a compressor volute and an outlet
discharging into a compressor inlet wherein the swirl slots
direct swirling flow of compressed air within the inlet and
generate a pre-swirl within the inlet air prior to entry into
15 the compressor wheel.

BACKGROUND OF THE INVENTION

Turbochargers are provided on an engine to deliver air to
the engine intake at a greater density than would be possible in
20 a normal aspirated configuration. This allows more fuel to be
combusted, thus boosting the engine's horsepower without
significantly increasing engine weight.

Generally, turbochargers use the exhaust flow from the
engine exhaust manifold, which enters the turbine housing at a
25 turbine inlet, to thereby drive a turbine wheel, which is
located in the turbine housing. The turbine wheel is affixed to
one end of a shaft, wherein the shaft drives a compressor wheel
mounted on the other end of the shaft. As such, the turbine
wheel provides rotational power to drive the compressor wheel
30 and thereby drive the compressor of the turbocharger. This
compressed air is then provided to the engine intake as
referenced above.

The compressor stage of the turbocharger comprises the
compressor wheel and its associated compressor housing.
35 Filtered air is drawn axially into a compressor inlet which
defines a passage extending axially to the compressor wheel.
Rotation of the compressor wheel forces pressurized air flow

radially outwardly from the compressor wheel into the compressor volute for subsequent pressurization and flow to the engine.

In modern turbocharger applications, the turbochargers require a wide compressor map width in order to cover operating conditions. The invention relates to an improved compressor construction for increasing the map width at surge. This is accomplished by providing a pre-swirl flow to the compressor's inlet flow prior to entry of the inlet air into the compressor wheel.

The invention redirects a small portion of the compressed or pressurized air flowing through the volute back into the compressor inlet to generate a swirl flow. The swirl flow is supplied to the compressor inlet upstream of the compressor wheel. In this regard, radial slots or swirl passages are provided in the compressor housing which passages extend from inlets in the volute to outlets that discharge into the compressor inlet on the upstream side of the compressor wheel. These slots are preferably angled in the direction of wheel rotation and thereby provide a swirl flow that is pressurized and discharges at an angle into the compressor inlet so that a circumferentially directed swirl is formed in the flow of inlet air entering the compressor. This improves turbocharger performance.

Other objects and purposes of the invention, and variations thereof, will be apparent upon reading the following specification and inspecting the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional side view of a turbocharger with a compressor thereof showing inventive swirl slots or passages.

Figure 2 is a cross-sectional end view of the compressor housing showing the swirl slots.

Certain terminology will be used in the following description for convenience and reference only, and will not be limiting. For example, the words "upwardly", "downwardly", "rightwardly" and "leftwardly" will refer to directions in the drawings to which reference is made. The words "inwardly" and

"outwardly" will refer to directions toward and away from, respectively, the geometric center of the arrangement and designated parts thereof. Said terminology will include the words specifically mentioned, derivatives thereof, and words of similar import.

DETAILED DESCRIPTION

Referring to Figure 1, a turbocharger 10 is shown which includes a compressor 11 that defines a compressor casing 12 having a volute 14 extending circumferentially therein. Turbocharger 10 further includes a turbine which is provided in combination with the compressor 11 in a conventional manner. An example of a turbocharger is disclosed in Published Application No. US 2012/0144824A1 (Schall), the disclosure of which is incorporated herein by reference in its entirety.

The turbocharger 10 of the present invention is substantially similar to the turbocharger disclosed in the '824 publication wherein it is understood by the skilled artisan that the turbocharger 10 of the present invention would have the basic combination of a turbine and compressor which are joined together by bearing assembly 15 with a bearing housing 16 being illustrated in Figure 1. The bearing assembly 15 rotatably supports a shaft 18 that is operatively driven by a turbine (not illustrated) of the turbocharger 10. In turn the shaft 18 is connected to and supports a compressor wheel 19 which includes a plurality of compressor vanes 20 extending circumferentially about the compressor wheel 19. The vanes 20 define slots 21 which receive air on an upstream side 22 and discharge air radially outwardly from an outer wheel diameter 23 as indicated by reference arrow 24. The compressor wheel 19 therefore receives air axially in the direction of reference arrow 25 as shown in Figure 1, wherein the air is supplied through a compressor inlet 26.

As seen in Figure 1, the bearing housing 16 and the compressor housing 12 define a throat 28 which opens radially from the compressor wheel 19 into the volute 14 for discharging pressurized air to the volute 14. This pressurizes air in the

volute 14, wherein the compressor 11 supplies such pressurized air to the engine in a conventional manner.

With respect to modern turbocharger applications, these turbochargers are increasingly being challenged to provide a wide operating range to meet various engine conditions. In some instances, turbocharger operation is limited by the compressor operating range due to surge at low mass flow conditions and choke at high mass flow conditions. Therefore it is desirable to increase the operating conditions at either surge or choke.

As to the particular inventive turbocharger 10, this turbocharger 10 increases the operating range of the compressor 11 at surge or under surge conditions. In this regard, the compressor housing 12 is designed to create swirling flow of the air entering the upstream side of the compressor 19.

Preferably, this swirling flow of inlet air is swirled in the direction of wheel rotation which changes the inlet flow angles and thus, delays the onset of surge.

More particularly, as seen in Figure 1, the compressor wheel 19 typically will be designed to rotate in a rotation direction about rotation axis 31, wherein the rotation direction is generally indicated by reference arrow 32 in Figures 1 and 2. The swirling flow of inlet air is designated in Figure 2 by additional reference arrow 33.

Some compressors generate a swirling type of flow through several methods, such as inlet guide vanes, although such guide vanes are an expensive addition to a turbocharger system. The inventive turbocharger 10, however, provides a more efficient solution which scavenges a portion of high pressure air flow from the volute 14 and supplies or feeds this swirling flow to the compressor inlet 26 through a plurality of swirl slots or passages 34.

The swirl slots 34 each have an inlet port 35 at the outer radial end thereof which inlet port 35 opens radially into the volute 14 and receives pressurized air therefrom. Each swirl slot 34 also includes an outlet port 36 on the radial inner end thereof, wherein the outlet port 36 opens into and discharges radially inwardly into the compressor inlet 26 at a location located axially adjacent to the upstream end face of the

compressor wheel 19. The swirl flow therefore has radial and circumferential flow components so as to intermix with the inlet air flow and impart a circumferentially directed swirling flow to the inlet air as the inlet air flows in the axial direction
5 25 toward the compressor wheel 19.

Preferably, the outlet ports 36 are axially spaced from the compressor wheel end face 37 (Figure 1) so as to generate the swirling flow of the inlet air before such air reaches the compressor wheel 19. As seen in the end-cross sectional view of
10 Figure 2, the swirl slots 34 are skewed at an acute angle A relative to a radial direction R extending radially outwardly from the rotation axis 31 so that each swirl slot 34 is angled and extends both radially inwardly and circumferentially.

Since each swirl slot 34 extends both radially inwardly and
15 circumferentially between the inlet port 35 and outlet port 36, the outlet port 36 thereby is circumferentially offset relative to the inlet port 35 which generates the skewed angle A for the slots 34 relative to a radial direction R. As seen in Figure 2, the slots 34 discharge pressurized air that has been bled or
20 scavenged from the volute 14 in an angled direction indicated by reference arrows 38. The angled direction 38 of this discharge flow from the slots 34 therefore creates the circumferential swirl within the inlet air as indicated by reference arrow 33 so that this swirling flow then improves the operating range of the
25 compressor wheel 19 and delays surge as referenced above.

Since the slots 34 are angled in the direction of compressor rotation 32, this angle not only facilitates formation of the circumferential swirl in the inlet air through the discharge flow 38 but the inlet flow 39 also improves the
30 ability of the inlet ports 34 to receive air flow from the volute 14 since the volute air tends to travel circumferentially within the volute 14 in the same direction as wheel rotation 32.

The swirl slots 34 can be machined into the compressor housing 12 so as to have the linear shape extending radially
35 through the thickness of the compressor housing 12. These slots 34 are preferably maintained in a normally open condition to provide continuous flow of air therethrough.

However, a valve mechanism may be provided in each of the slots 34, which valve is diagrammatically shown in phantom outline and is identified by reference numeral 40 in Figure 2. This or another similar valve mechanism could be controlled so as to only allow flow through the slots 34 at low mass flow conditions, which thereby would minimize efficiency losses that may be associated with the flow through the slots 34 at other operating conditions. Thus, the slot flow through the swirl slots 34 may be continuous or controlled.

During operation of the compressor 12, the shaft 18 rotates to drive the compressor wheel 19 generally in the rotation direction 32. This generates a pressurized air flow radially through the compressor throat 28 into the volute 14 in a normal manner. To delay the onset of surge, the pressurized air within the volute 14 also is able to flow through the inlet ports 35 of the multiple swirl slots 34 wherein this slot flow then exits through outlet ports 36 into the compressor inlet 26. The skewed exit and entry angles of the slot flow is indicated by flow arrows 38 and 39 and creates a swirling or spiral flow 33 within the compressor inlet 26 on the upstream side of the compressor wheel 19. This is believed to provide significant advantages over known compressor designs.

Although particular preferred embodiments of the invention have been disclosed in detail for illustrative purposes, it will be recognized that variations or modifications of the disclosed apparatus, including the rearrangement of parts, lie within the scope of the present invention.

CLAIMS

We claim:

- 5 1. A turbocharger 10 comprises:
 a compressor 11 having a compressor casing 12 that defines
 a volute 14 extending circumferentially, and having a compressor
 wheel 19 rotatably supported within said casing 12 for rotation
 in a rotation direction about a rotation axis 31, said
10 compressor 11 defining a compressor inlet 26 extending axially
 which supplies inlet air to an end face of said compressor wheel
 19, and said compressor wheel 19 discharging air radially
 outwardly from an outer wheel diameter 23 into said volute 14;
 and
15 said compressor 11 including a plurality of swirl slots 34
 which receive and redirect a portion of high pressure volute air
 from said volute 14 and generate a swirl flow of volute air
 through said swirl slots 34, said swirl slots extending between
 said volute 14 and said compressor inlet 26 and feeding said
20 swirl flow to said compressor inlet 26, said swirl flow flowing
 radially inwardly and circumferentially from said swirl slots 34
 to create a circumferentially swirling flow of the inlet air
 entering the end face of the compressor 19.
- 25 2. The turbocharger according to Claim 1, wherein said
 swirling flow of inlet air is swirled circumferentially in the
 rotation direction of said compressor wheel 19.
3. The turbocharger according to Claim 1, wherein
30 said compressor housing 12 defines a throat 28 which opens
 radially outwardly from said compressor wheel 19 into said
 volute 14 for discharging pressurized air to said volute 14.
4. The turbocharger according to Claim 1, wherein said
35 swirl slots 34 each have an inlet port 35 at the outer radial
 end thereof which inlet 35 opens into the volute 14 and receives
 pressurized air therefrom.

5. The turbocharger according to Claim 4, wherein each said swirl slot 34 includes an outlet port 36 on a radial inner end thereof, wherein said outlet port 36 opens into and discharges radially inwardly into said compressor inlet 26.

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6. The turbocharger according to Claim 5, wherein said swirl flow intermixes with said inlet air flow and imparts a circumferentially directed flow to said inlet air which is flowing axially toward the compressor wheel 19.

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7. The turbocharger according to Claim 6, wherein each said swirl slot 34 extends both radially inwardly and circumferentially between said inlet port 35 and said outlet port 36, said outlet port 36 being circumferentially offset relative to said inlet port 35.

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8. The turbocharger according to Claim 1, wherein said swirl slots 34 are skewed at an acute angle A relative to a radial direction R extending radially outwardly from the rotation axis 31 so that each said swirl slot 34 is angled and extends both radially inwardly and circumferentially.

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9. A turbocharger 10 comprises:

a compressor 11 having a compressor casing 12 that defines a volute 14 extending circumferentially, and having a compressor wheel 19 rotatably supported within said casing 12 for rotation in a rotation direction about a rotation axis 31, said compressor 11 defining a compressor inlet 26 extending axially which supplies inlet air to an end face of said compressor wheel 19, and defining a throat 28 which opens radially outwardly from said compressor wheel 19 into said volute 14 for discharging pressurized air to said volute 14; and
said compressor 11 including a plurality of swirl slots 34 which receive and redirect a portion of high pressure volute air from said volute 14 and generate a swirl flow of volute air through said swirl slots 34, wherein each said swirl slot 34 has an inlet port 35 at the outer radial end thereof which inlet 35 opens into said volute 14 and receives said volute air

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therefrom, and has an outlet port 36 on a inner radial end thereof which opens into and discharges said swirl flow radially inwardly into said compressor inlet 26, said swirl flow flowing radially inwardly and circumferentially from said swirl slots 34 to create a circumferentially swirling flow of said inlet air entering the end face of the compressor 19.

10. The turbocharger according to Claim 9, wherein said swirling flow of said inlet air is swirled circumferentially in the rotation direction of said compressor wheel 19.

11. The turbocharger according to Claim 10, wherein said swirl flow intermixes with said inlet air flow to impart a circumferentially directed flow to said inlet air as said inlet air flows axially toward the compressor wheel 19.

12. The turbocharger according to Claim 6, wherein each said swirl slot 34 extends both radially inwardly and circumferentially between said inlet port 35 and said outlet port 36, said outlet port 36 being circumferentially offset relative to said inlet port 35.

13. The turbocharger according to Claim 9, wherein said swirl slots 34 are skewed at an acute angle A relative to a radial direction R extending radially outwardly from the rotation axis 31 so that each said swirl slot 34 is angled and extends both radially inwardly and circumferentially.

14. The turbocharger according to Claim 12, wherein said inlet ports 35 are located in said volute 14 to receive said volute air directly therefrom, and said outlet ports 36 are located in said compressor inlet at a location located axially adjacent to the upstream end face of the compressor wheel 19

15. The turbocharger according to Claim 14, wherein said swirl slots 34 are angled in the rotation direction to facilitate entry of volute air into said inlet ports 35 within

said volute 14 and to facilitate formation of the circumferential swirl in the compressor inlet 26.

FIG. 1

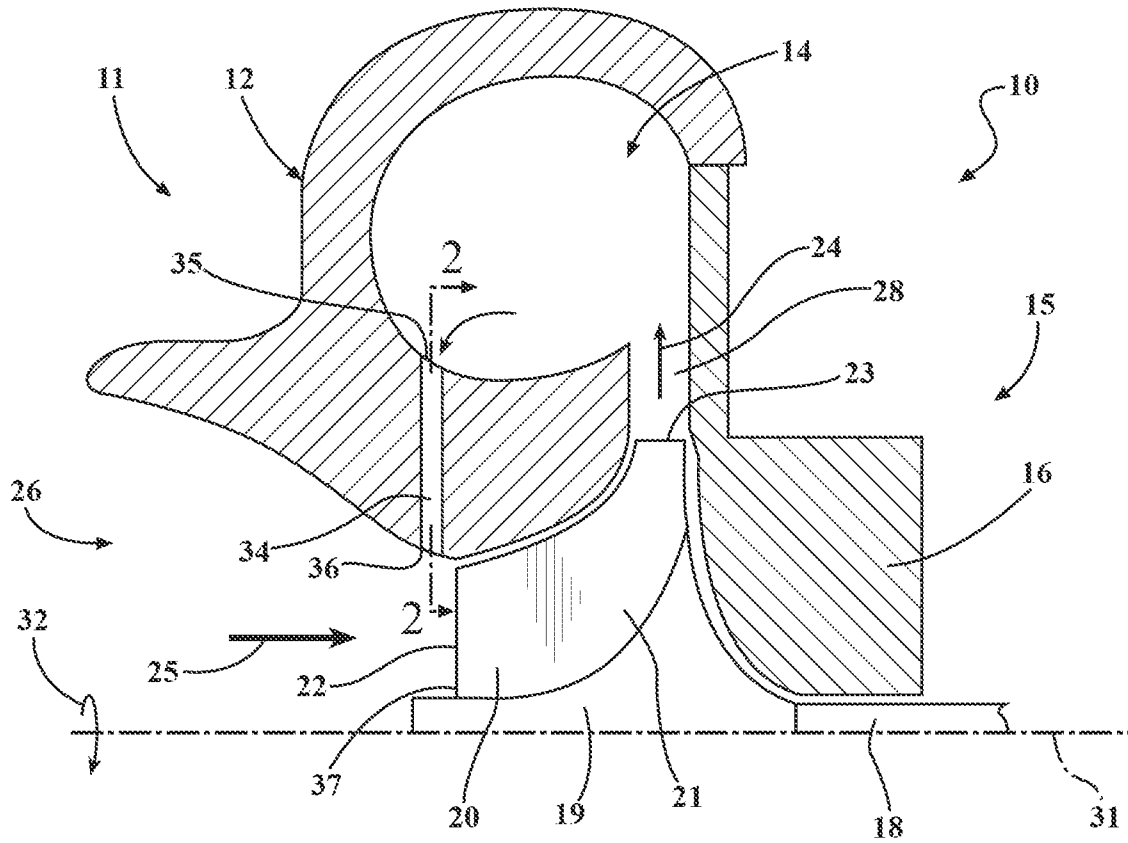
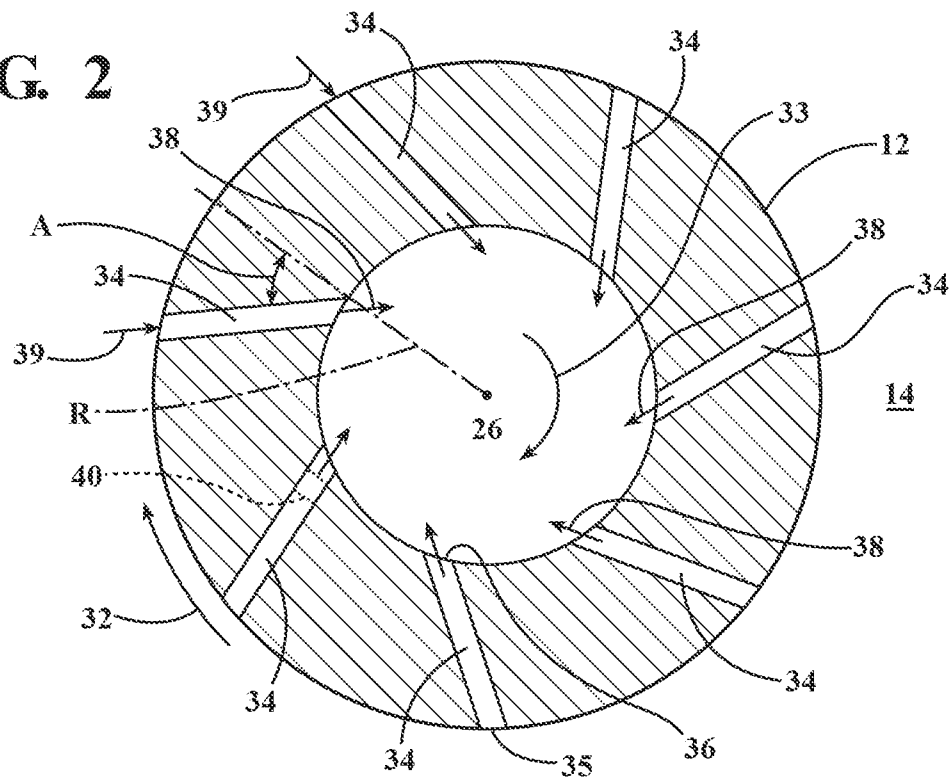


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/068222**A. CLASSIFICATION OF SUBJECT MATTER****F01D 25/24(2006.01)i, F02B 39/00(2006.01)i, F02B 37/00(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)

F01D 25/24; F04D 29/66; F02C 6/12; F04D 29/42; F04D 25/04; F04D 29/44; F02B 33/40; F02B 39/00; F02B 37/00

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, swirl slot, volute and inlet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011-0088392 A1 (SUMSER et al.) 21 April 2011 See paragraph [0022] and figure 1.	1-15
A	KR 10-2004-0094328 A (HOLSET ENGINEERING COMPANY, LIMITED) 09 November 2004 See page 3, line 18-page 5, line 51 and figures 1-2.	1-15
A	US 2009-0013689 A1 (SUMSER et al.) 15 January 2009 See paragraphs [0025]-[0045] and figure 2.	1-15
A	KR 10-2012-0013460 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 14 February 2012 See paragraphs [0048]-[0063] and figure 1.	1-15
A	US 2012-0039702 A1 (SHARP, NICHOLAS KENNETH) 16 February 2012 See paragraphs [0046]-[0050] and figures 1-2.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"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

"&" document member of the same patent family

Date of the actual completion of the international search

24 February 2014 (24.02.2014)

Date of mailing of the international search report

24 February 2014 (24.02.2014)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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