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[Continued on next page]

(54) Title: TURBINE WHEEL OF AN EXHAUST-GAS TURBOCHARGER

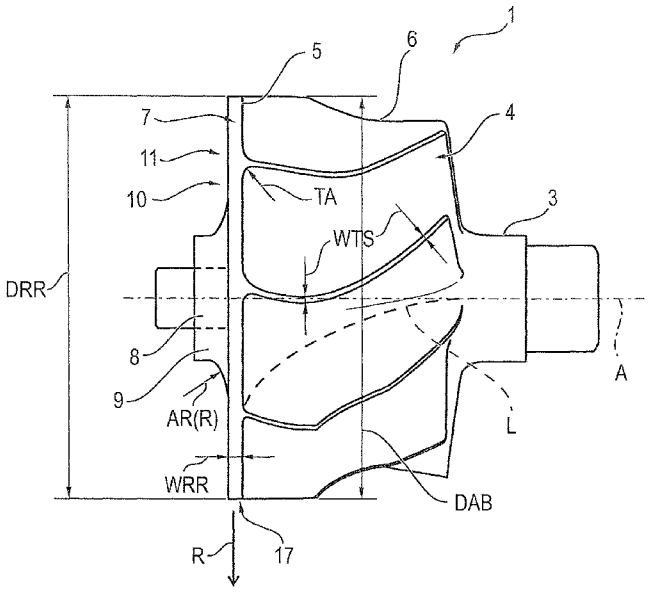

FIG. 2

(57) Abstract: The invention relates to a turbine wheel (1) of an exhaust-gas turbocharger (2), formed from a titanium aluminide material, having a wheel back (7) which is of closed configuration as viewed from an axial direction (A) and which has an outer contour (17), and having a hub (3) which extends from the wheel back (7) and which tapers along the axial direction (A), having a multiplicity of turbine blades (4) which extend from the wheel back (7) and from the hub (3) and which extend outward in a radial direction (R), as far as a connection region outer diameter (DAB) at least in a connection region (5), the wheel back (7) having, in an outer region (11) adjoining the connection region (5), a wheel back outer diameter (DRR) which is greater than or equal to the connection region outer diameter (DAB).

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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))*

— *of inventorship (Rule 4.17(iv))*

Published:

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

TURBINE WHEEL OF AN EXHAUST-GAS TURBOCHARGER

DESCRIPTION

The invention relates to a turbine wheel for the supercharging of a combustion engine, in particular of an internal combustion engine.

A turbine wheel of said type is known from DE 10 2005 050 707 A1. In said document, it is described that an Ni-based material of the turbine wheel has an adverse effect on the acceleration of the rotor (assembly formed from the turbine wheel, the compressor wheel and the shaft) because turbine wheels composed of said material have a high mass moment of inertia.

As a measure for reducing the mass moment of inertia, said document describes the use of titanium-aluminum alloys which have a lower density, such that the mass moment of inertia of a turbine wheel composed of a material of said type can be reduced.

It is an object of the present invention to provide a turbine wheel composed of titanium aluminide (TiAl) which is of simple dimensioning and thus construction, wherein a high level of efficiency of the turbine can be achieved.

This object is achieved by the features of claim 1. The dependent claims relate to preferred refinements of the invention. These may be combined with one another in a technologically expedient manner, whereby to some extent effects may be realized which go beyond the sum total of the individual effects.

By virtue of the wheel back outer diameter being greater than or equal to the connection region outer diameter of the turbine blades, a closed wheel back is formed, resulting in lower ventilation losses. In this way, the efficiency of the turbine composed of a titanium aluminide material can be increased.

In one refinement, the wheel back has, at least adjacent to the connection region, a wall thickness which is in a ratio of 1.5 : 1 to 2.5 : 1, in particular of 1.7 : 1 to 2.3 : 1, particularly preferably of 1.8 : 1 to 2.2 : 1 with respect to a wall thickness of the turbine blade.

When the internal combustion engine is in overrun operation, the internal combustion engine remains in rotation owing to its mass inertia. During this time, no fuel is injected, and as a result cold exhaust gas or air flows to the turbocharger, such that the turbine wheel cools down relatively quickly. The cooling of the turbine wheel

results in internal stresses in the turbine wheel. In the case of turbine wheels composed of Ni-based materials from the prior art, said internal stresses are non-critical. The ductility, that is to say the ability of the titanium aluminide material to be deformed without damage, however decreases with falling temperature in the relevant temperature range. Furthermore, owing to a coefficient of expansion of titanium aluminide materials being non-constant with respect to temperature, more intensely cooled regions cause high internal stresses. In the case of turbine wheels composed of titanium aluminide materials, a combination of the non-constant coefficient of expansion and the decreasing ductility can result in the formation of cracks in the turbine wheel. It has surprisingly been found that, if the ratio of the wall thickness of the turbine blades with respect to the wall thickness of the wheel back is the ratio mentioned in the preceding paragraph, it is ensured that adequate material is provided, which yields slower and thus more homogeneous cooling in overrun operation.

With the stated ratio, the mass inertia of the turbine wheel is, owing to the low density of the titanium aluminide material, still low enough that an expedient acceleration characteristic of the exhaust-gas turbocharger can be achieved.

In one refinement, a wheel hub region extending in the axial direction merges in continuous fashion, in a chamfer region with radially outwardly increasing connection radii, into an intermediate region, extending in the radial direction, of the wheel back.

The configuration of the wheel back as described in the preceding paragraph yields a turbine wheel of high strength.

In a further refinement, the turbine blades extend from the wheel back and from the hub of the turbine wheel with a turbine blade connection radius, the turbine blade connection radius being constant over an entire length of extent of the turbine blade.

Owing to this refinement, a heat transfer rate from the wheel back and the hub to the turbine blade is achieved which is substantially constant over the length of extent of the turbine blade. In this way, during the cooling process, the wheel back and the hub can release the heat stored therein to the turbine blade in uniform fashion, such that non-uniform temperature distributions along the length of extent, and thus internal stresses along the line of extent, are reduced to a level tolerable for titanium aluminide materials.

In a further refinement, a ratio of the wall thickness of the turbine blades to the connection region outer diameter lies in the range of up to 0.7 : 40; particularly preferably between 0.3 : 40 and 0.5 : 40; in particular between 0.35 : 40 and 0.45 : 40.

It has been found that, with the stated ratio, an adequately stable turbine blade can be formed.

Further details, features and advantages of the invention become apparent from the following description of exemplary embodiments with reference to the drawing, in which:

Figure 1 shows a schematically greatly simplified diagrammatic illustration of an exhaust-gas turbocharger according to the invention,

Figure 2 shows a side view of a first embodiment of a turbine wheel according to the invention,

Figure 3 is a sectional illustration through a second embodiment of the turbine wheel according to the invention, wherein only the upper half of the turbine wheel is illustrated in the illustration selected in figure 3, and

Figure 4 is a sectional illustration of the embodiment of the turbine wheel according to the invention illustrated in Figure 1.

Figure 1 is a schematically highly simplified illustration of an exhaust-gas turbocharger 2 according to the invention for the supercharging of an internal combustion engine (not illustrated), said exhaust-gas turbocharger having a turbine wheel 1 which is arranged in a turbine housing 12. The turbine wheel 1 is fastened to one end of a shaft 14, on the other end of which there is mounted a compressor wheel 15 which is arranged in a compressor housing 16. The turbine wheel 1, the shaft 14 and the compressor wheel 15 form an assembly which is also referred to as rotor. The shaft 14 is mounted in a bearing housing 13 which is arranged between the compressor housing 16 and the turbine housing 12.

Figure 2 illustrates a first embodiment of the turbine wheel 1 according to the invention composed of a titanium aluminide (TiAl) material. The turbine wheel 1 may be cast from a titanium aluminide alloy in a casting process. The turbine wheel 1 may also be milled from a forged titanium aluminide blank.

The turbine wheel 1 has a circular outer contour 17 and a hub 3 on which there is arranged a multiplicity of turbine blades, one of which is denoted, as a representative of all of the turbine blades, by the reference sign 4. The turbine blades 4 extend along a

length of extent L. Each of the turbine blades 4 has a connection region 5 in which an imaginary circle drawn around the turbine blades 4 at the radially outer tips thereof has an outer diameter DAB. The connection region 5 is adjoined by an outlet region 6 of the turbine blades 4, which in the case of the embodiment of figure 2 has a smaller outer diameter than the connection region 5.

The turbine wheel 1 also has a wheel back 7 which adjoins the connection region 5 and which is formed on the hub 3, as can be seen from Figure 2.

The wheel back 7 has, in an outer region 11, an outer diameter DRR which at least substantially corresponds to the diameter DAB but preferably has the same value as the diameter DAB.

Furthermore, the wheel back 7 has a wall thickness WRR. The turbine wheel blades have a wall thickness WTS, wherein Figure 2 shows, by way of example, two regions of the turbine blades 4 in which the stated wall thickness region WTS is indicated. The wheel back 7 is thickened slightly and has, at least adjacent to the connection region 5, a wall thickness WRR which is in a ratio of 1.5 : 1 to 2.5 : 1, in particular of 1.7 : 1 to 2.3 : 1, particularly preferably of 1.8 : 1 to 2.2 : 1 with respect to a wall thickness WTS of the turbine blade 4. Owing to the slight thickening, it is ensured that the cooling of the turbine wheel 1 in a period of overrun operation following a period of normal or elevated engine load of the internal combustion engine is slowed. The slowed cooling has proven to be advantageous, in the case of turbine wheels composed of titanium aluminide, for a long service life. The reason for this may be seen in the fact that high internal stresses in the turbine wheel 1 that may arise as a result of non-homogeneous cooling when a temperature at which the ductility of the titanium aluminide material decreases is reached can be eliminated, or at least reduced to a tolerable level.

Figure 3 illustrates a second embodiment of the turbine wheel 1 according to the invention, in which all elements that correspond to those in Figure 2 are denoted by the same reference signs, such that, in this regard, reference may be made to the above description of Figure 2.

The turbine wheel 1 of the embodiment as per Figure 3 is a so-called "mixed-flow turbine wheel", the connection region 5 of which has, as in the case of the embodiment of Figure 2, an outer diameter DAB which corresponds to the outer diameter DRR of the wheel back 7. The outlet region 6 is, as shown in Figure 3,

extended upward in a radial direction R, giving rise to the special geometry of the mixed-flow turbine wheel which can be driven by an exhaust-gas stream impinging on the turbine wheel 1 obliquely with respect to the axial direction A.

Furthermore, Figures 3 and 4 show, in section, the design of the wheel back 7, in which a wheel hub region 8 extending in the axial direction A merges, in a rounded chamfer region 9 with a connection radius A(R), into an intermediate region 10, which extends in the radial direction R, of the wheel back 7. Here, a connection radius AR(R) increases continuously with increasing distance outward from the axis of rotation A. This yields a rigid and thus dimensionally stable turbine wheel 1 which stores heat, and releases said heat to the outer region 11 of the wheel back 7, over a relatively long period of time. In this way, both the wheel back 7 in the outer region 11 and also regions of the turbine blades 4 adjoining said outer region cool down correspondingly more slowly in overrun operation.

Figure 4 shows the embodiment of the turbine wheel 1 according to the invention shown in Figure 1, in a sectional illustration, corresponding to Figure 3, of only the upper region, that is to say the region above the longitudinal axis A. This embodiment concerns a radial wheel which has, adjoining the connection region 5, an outlet region 6 which has the same outer diameter as the connection region 5.

In addition to the above written disclosure, reference is hereby explicitly made, for supplementation thereof, to the diagrammatic illustration of the invention in Figures 1 to 4.

List of reference signs

1	Turbine wheel
2	Exhaust-gas turbocharger
3	Hub
4	Turbine blades
5	Connection region
6	Outlet region
7	Wheel back
8	Wheel hub region
9	Chamfer region
10	Intermediate region
11	Outer region
12	Turbine housing
13	Bearing housing
14	Shaft
15	Compressor wheel
16	Compressor housing
17	Outer contour
DAB	Connection region outer diameter
DRR	Wheel back outer diameter
A	Axial direction/longitudinal axis
AR(R)	Connection radii
TA	Turbine blade connection radius
R	Radial direction
WRR	Wall thickness of the wheel back
WTS	Turbine blade wall thickness

CLAIMS

1. A turbine wheel (1) of an exhaust-gas turbocharger (2), formed from a titanium aluminide material,

- having a wheel back (7) which is of closed configuration as viewed from an axial direction (A) and which has an outer contour (17), and
- having a hub (3) which extends from the wheel back (7) and which tapers along the axial direction (A),
- having a multiplicity of turbine blades (4) which extend from the wheel back (7) and from the hub (3) and which extend outward in a radial direction (R), as far as a connection region outer diameter (DAB) at least in a connection region (5),
- the wheel back (7) having, in an outer region (11) adjoining the connection region (5), a wheel back outer diameter (DRR) which is greater than or equal to the connection region outer diameter (DAB).

2. The turbine wheel as claimed in claim 1, wherein the wheel back (7) has, at least adjacent to the connection region (5), a wall thickness (WRR) which is in a ratio of 1.5 : 1 to 2.5 : 1, in particular of 1.7 : 1 to 2.3 : 1, particularly preferably of 1.8 : 1 to 2.2 : 1 with respect to a wall thickness (WTS) of the turbine blade (4).

3. The turbine wheel as claimed in either of claims 1 and 2, wherein a wheel hub region (8) extending in the axial direction (A) merges in continuous fashion, in a chamfer region (9) with radially outwardly increasing connection radii (AR(R)), into an intermediate region (10), extending in the radial direction (R), of the wheel back (7).

4. The turbine wheel as claimed in one of claims 1 to 3, wherein the turbine blades (4) extend from the wheel back (7) and from the hub (3) of the turbine wheel with a turbine blade connection radius (TA), the turbine blade connection radius (TA) being substantially constant over an entire length of extent (L) of the turbine blade (4).

5. The turbine wheel as claimed in one of claims 1 to 4, wherein a ratio of the wall thickness (WTS) of the turbine blades (4) to the connection region outer diameter

(DAB) lies in the range of up to 0.7 : 40; particularly preferably between 0.3 : 40 and 0.5 : 40; in particular between 0.35 : 40 and 0.45 : 40.

6. The turbine wheel as claimed in one of claims 1 to 5, wherein it is formed as a forged and milled turbine wheel.

7. The turbine wheel as claimed in one of claims 1 to 5, wherein it is formed as a cast turbine wheel.

8. The turbine wheel as claimed in one of claims 1 to 5, wherein it can be driven by an exhaust-gas stream flowing inward in the radial direction (R).

9. The turbine wheel as claimed in one of claims 1 to 5, wherein it can be driven by an exhaust-gas stream flowing obliquely both in the radial direction (R) and also in the axial direction (A).

10. An exhaust-gas turbocharger (2) for the supercharging of an internal combustion engine, having a turbine wheel (1) as claimed in one of claims 1 to 9.

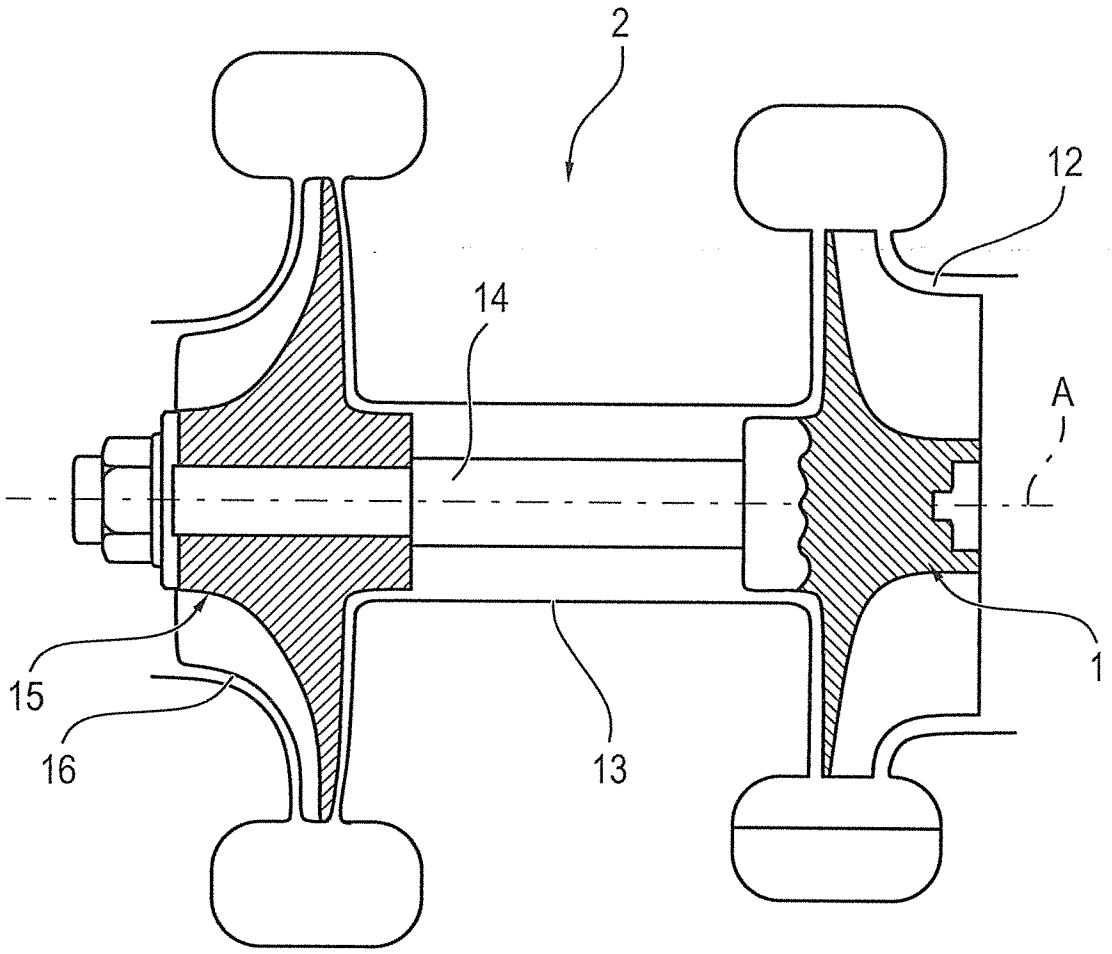

FIG. 1

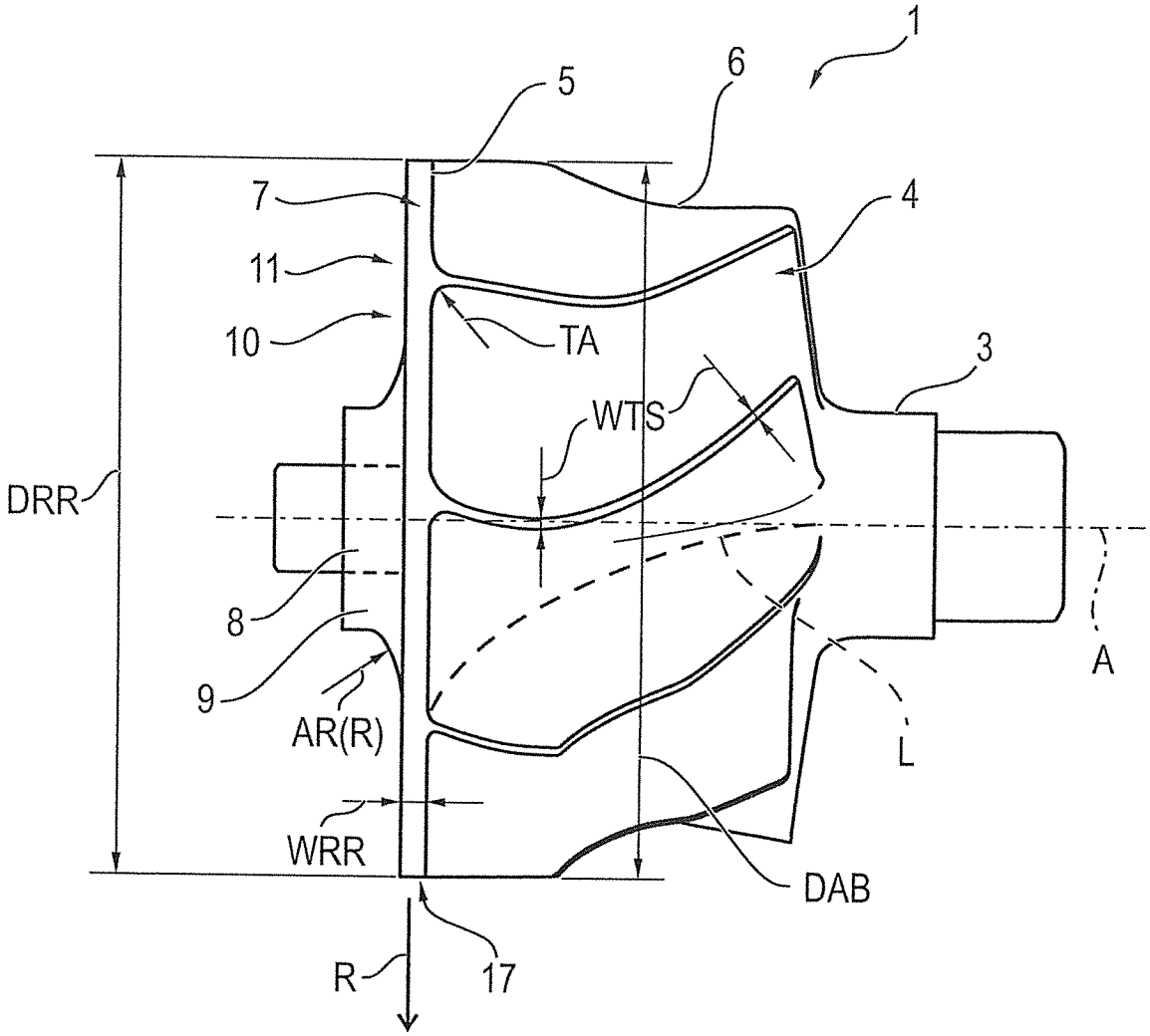

FIG. 2

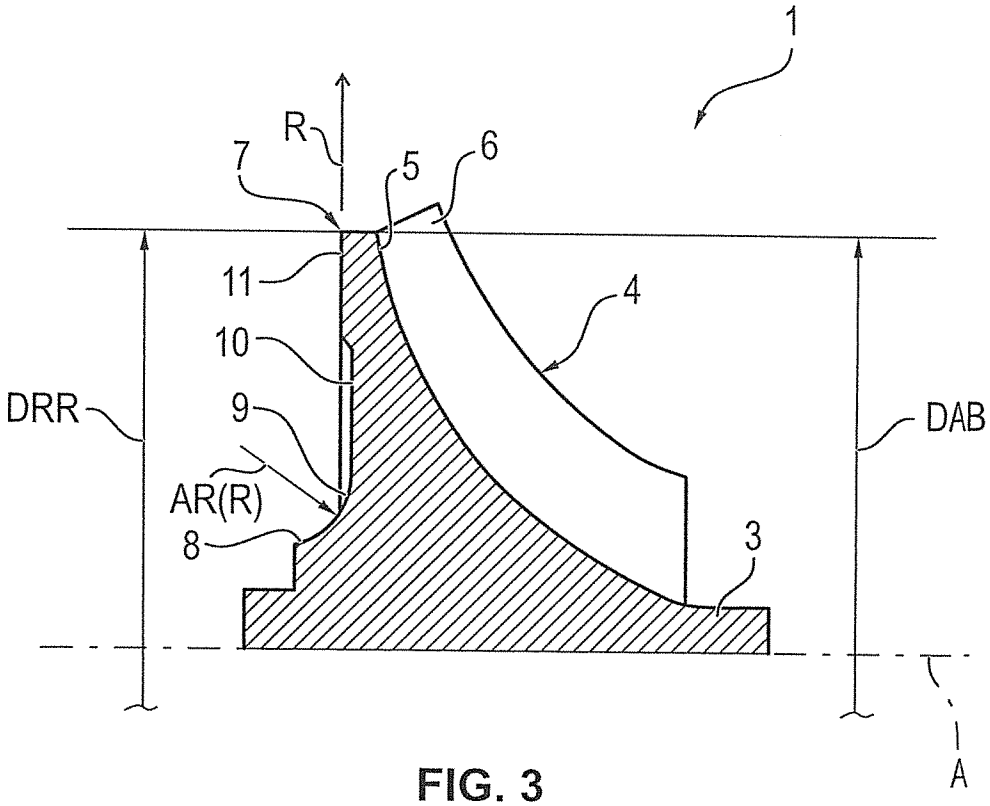

FIG. 3

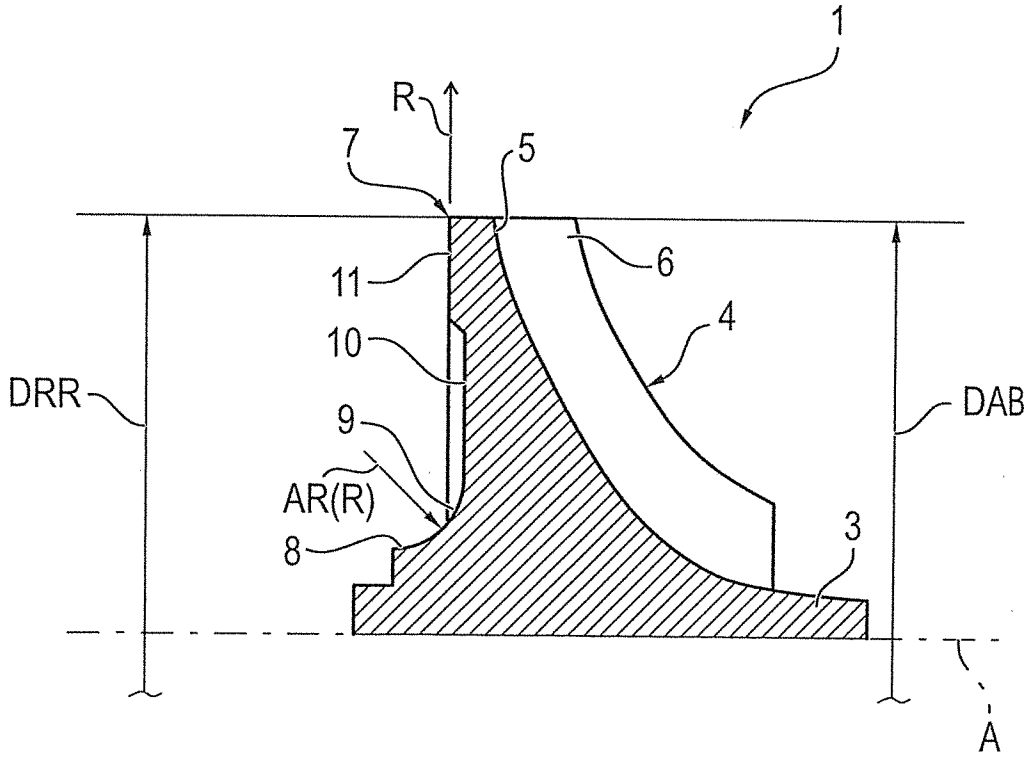

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/031724

A. CLASSIFICATION OF SUBJECT MATTER

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)
F02B 39/00; B23P 15/04; F01D 5/34; F02B 33/44; F04D 29/00; F01D 1/02; B23K 31/02; 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, turbine, wheel, rotor, blade, vane, hub, wheel back, connection region, and diameter

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007-0128018 A1 (SUMSER et al.) 07 June 2007 See paragraphs [0021]-[0026] and figure 2.	1-3
Y	US 2011-0091324 A1 (HOLZSCHUH, CHRISTIAN) 21 April 2011 See paragraphs [0083]-[0084],[0110] and figures 1,21.	1-3
A	US 4408959 A (LONG et al.) 11 October 1983 See column 3, lines 1-68 and figures 1-2.	1-3
A	US 2007-0119908 A1 (RENAUD et al.) 31 May 2007 See paragraph [0020] and figure 1.	1-3
A	US 2008-0092538 A1 (FLEDERSBACHER et al.) 24 April 2008 See paragraphs [0034]-[0042] and figures 3a-5.	1-3

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"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	Date of mailing of the international search report
17 July 2014 (17.07.2014)	**18 July 2014 (18.07.2014)**

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/031724

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 4-10
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/031724

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007-0128018 A1	07/06/2007	DE 102004029830 A1	29/12/2005
		DE 502005001999 D1	27/12/2007
		EP 1759091 A2	07/03/2007
		EP 1759091 B1	14/11/2007
		EP 1759091 B8	23/01/2008
		JP 04636287 B2	23/02/2011
		JP 2008-503677 A	07/02/2008
		US 7798770 B2	21/09/2010
		WO 2005-124107 A2	29/12/2005
		WO 2005-124107 A3	06/04/2006
US 2011-0091324 A1	21/04/2011	CN 102046960 A	04/05/2011
		DE 112009001230 T5	28/04/2011
		JP 2011-524961 A	08/09/2011
		KR 10-2011-0019415 A	25/02/2011
		WO 2010-036425 A2	01/04/2010
		WO 2010-036425 A3	24/06/2010
US 04408959 A	11/10/1983	EP 0050117 A1	28/04/1982
		EP 0050117 A4	13/07/1982
		EP 0050117 B1	26/06/1985
		WO 81-03047 A1	29/10/1981
US 2007-0119908 A1	31/05/2007	EP 1954436 A2	13/08/2008
		US 7156282 B1	02/01/2007
		WO 2007-047096 A2	26/04/2007
		WO 2007-047096 A3	08/11/2007
US 2008-0092538 A1	24/04/2008	DE 102005019938 A1	09/11/2006
		JP 04719269 B2	06/07/2011
		JP 2008-539357 A	13/11/2008
		US 7870731 B2	18/01/2011
		WO 2006-117073 A1	09/11/2006