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(71) Applicant: **BORGWARNER INC.** [US/US]; Patent Department, 3850 Hamlin Road, Auburn Hills, Michigan 48326 (US).

(72) Inventor: **FRASER, Brock**; 506 Sugar Maple Lane, Asheville, NC 28805 (US).

(74) Agents: **BROOKS, Cary W.** et al.; Brooks Group, 48685 Hayes, Shelby Township, Michigan 48315 (US).

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(54) Title: MIM-FORMED TiAl TURBINE WHEEL SURROUNDING A CAST/MACHINED CORE

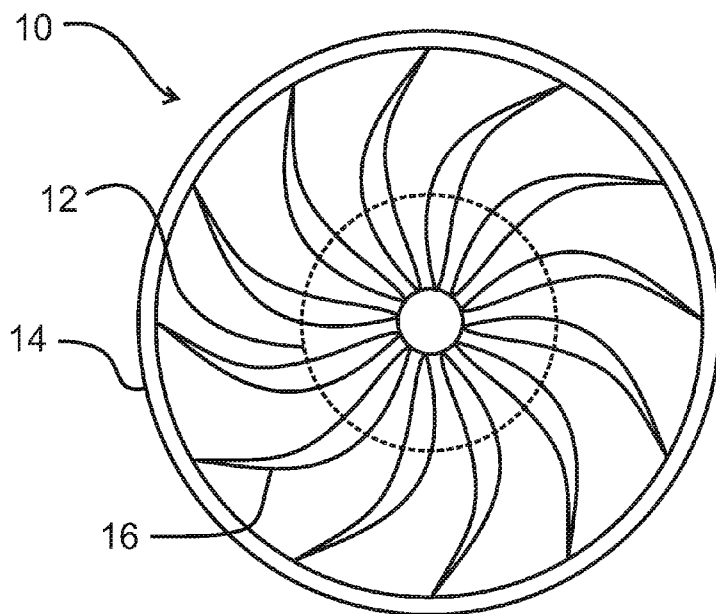


Fig. 1

(57) Abstract: A number of variations may include a method that may include casting or providing a central core comprising titanium aluminide; and metal injection molding a shell comprising titanium aluminide around the central core to produce a rotor assembly.



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

— of inventorship (Rule 4.17(iv))

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MIM-FORMED TiAl TURBINE WHEEL
SURROUNDING A CAST/MACHINED CORE

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit of United States Application No.
14/808,305 filed July 24, 2015.

TECHNICAL FIELD

The field to which the disclosure generally relates includes metal-
10 injection-molded (MIM) turbine wheels.

BACKGROUND

Manufacturing turbine wheels or rotor assemblies including a core and
turbine blades may have poor yield and high scrap rate due to difficulties in the
15 manufacturing process.

SUMMARY OF ILLUSTRATIVE VARIATIONS

A number of variations may include a method that may include casting
or providing a central core that may include titanium aluminide and metal injection
20 molding a shell that may include titanium aluminide around the central core to
produce a rotor assembly.

Another variation may include a method that may include machining a
central core that may include titanium aluminide and metal injection molding a shell
that may include titanium aluminide around the central core to produce a rotor
25 assembly.

Another variation may include a product that may include a rotor
assembly that may include a cast titanium aluminide central core and a metal injection
molded titanium aluminide shell radially surrounding the central core.

Another variation may include a product that may include a rotor assembly
30 that may include a machined titanium aluminide central core and a metal injection
molded titanium aluminide shell radially surrounding the central core wherein the
shell may include a plurality of blades.

Other illustrative variations within the scope of the invention will
become apparent from the detailed description provided hereinafter. It should be

understood that the detailed description and enumerated variations, while disclosing optional variations, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Select examples of variations within the scope of the invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

Figure 1 depicts a top-down view of one variation of a MIM-formed turbine
10 wheel surrounding a core; and

Figure 2 depicts a cross-sectional view of one variation of a MIM-formed turbine wheel surrounding a core.

DETAILED DESCRIPTION OF ILLUSTRATIVE VARIATIONS

15 The following description of the variations is merely illustrative in nature and is in no way intended to limit the scope of the invention, its application, or uses. The following description of variants is only illustrative of components, elements, acts, products, and methods considered to be within the scope of the invention and are not in any way intended to limit such scope by what is specifically
20 disclosed or not expressly set forth. The components, elements, acts, products, and methods as described herein may be combined and rearranged other than as expressly described herein and still are considered to be within the scope of the invention.

Referring to Figure 1; a rotor assembly 10 may include a core 12 surrounded by a shell 14 wherein the shell may include a plurality blades 16.

25 Referring to Figure 2; the core 12 may be generally cone-like in shape. Alternatively, the core 12 may be generally cylindrical in shape or in the shape of a truncated cone. One of ordinary skill in the art will appreciate that other shapes of the core 12 are contemplated by and fall within the scope of this disclosure.

The rotor assembly 10 may be a propeller, impeller (as depicted in
30 Figures 1 and 2), fan, or rotor for use in a pump, turbine, or similar device. The rotor assembly 10 may include a core 12 which is surrounded by a shell 14. The shell 14 may make up a portion of the rotor assembly 10 including at least a plurality of blades 16 but may include additional structure such as a base of an impeller, and through-channel, or other similar structures.

The plurality of blades 16 may be the blades of propeller, impeller, fan, or rotor for use in a pump, turbine, or similar device which may be constructed and arranged to facilitate the flow of fluid.

5 According to one variation, a method of forming the rotor assembly 10 may include first cast, machining, or casting and machining a core 12 of titanium aluminide (TiAl) in a generally cone, truncated cone, or cylindrical shape. The method may further include metal injection molding the shell 14 around the core 12 where in the shell is made up of TiAl. The method may further include machining or sintering the shell 12 to complete the rotor assembly.

10 According to variation 1, a method may include casting a central core that may include titanium aluminide and metal injection molding a shell that may include titanium aluminide around the central core to produce a rotor assembly.

Variation 2 may include a product as set forth in variation 1 wherein the shell may include a plurality of blades.

15 Variation 3 may include a product as set forth in variation 1 or 2 wherein the central core may be generally cone shaped.

Variation 4 may include a product as set forth in any of variations 1 through 3 wherein the central core may be generally shaped like a truncated cone.

20 Variation 5 may include a product as set forth in any of variations 1 through 4 wherein the central core may be generally cylinder shaped.

Variation 6 may include a product as set forth in any of variations 1 through 5 and may further include sintering the rotor assembly.

25 According to variation 7, a method may include machining a central core that may include titanium aluminide and metal injection molding a shell that may include titanium aluminide around the central core to produce a rotor assembly.

Variation 8 may include a product as set forth in variation 7 wherein the shell may include a plurality of blades.

Variation 9 may include a product as set forth in any of variations 7 through 8 wherein the central core may be generally cone shaped.

30 Variation 10 may include a product as set forth in any of variations 7 through 9 wherein the central core may be generally shaped like a truncated cone.

Variation 11 may include a product as set forth in any of variations 7 through 10 wherein the central core may be generally cylinder shaped.

Variation 12 may include a product as set forth in any of variations 7 through 11 and may further include sintering the rotor assembly.

According to variation 13, a product may include a rotor assembly that may include a cast titanium aluminide central core and a metal injection molded
5 titanium aluminide shell radially surrounding the central core.

Variation 14 may include a product as set forth in variation 13 wherein the shell may include a plurality of blades.

Variation 15 may include a product as set forth in any of variations 13 through 14 wherein the central core may be generally cone shaped.

10 Variation 16 may include a product as set forth in any of variations 13 through 15 wherein the central core may be generally shaped like a truncated cone.

Variation 17 may include a product as set forth in any of variations 13 through 16 wherein the central core may be generally cylinder shaped.

According to variation 18, a product may include a rotor assembly that
15 may include a machined titanium aluminide central core and a metal injection molded titanium aluminide shell radially surrounding the central core wherein the shell may include a plurality of blades.

Variation 19 may include a product as set forth in variation 18 wherein the central core may be generally cone shaped.

20 Variation 20 may include a product as set forth in any of variations 18 through 19 wherein the central core may be generally shaped like a truncated cone.

Variation 21 may include a product as set forth in any of variations 18 through 20 wherein the central core may be generally cylinder shaped.

The above description of variations within the scope of the invention is
25 merely demonstrative in nature and, thus, variations thereof are not to be regarded as a departure from the spirit and scope of the inventions disclosed within this document.

CLAIMS

What is claimed is:

- 5 1. A method comprising:
 casting a central core comprising titanium aluminide; and
 metal injection molding a shell comprising titanium aluminide around the
 central core to produce a rotor assembly.
- 10 2. A method as set forth in claim 1 wherein the shell comprises a plurality of
 blades.
3. A method as set forth in claim 1 wherein the central core is generally cone
 shaped.
- 15 4. A method as set forth in claim 1 wherein the central core is generally
 shaped like a truncated cone.
5. A method as set forth in claim 1 wherein the central core is generally
 cylinder shaped.
- 20 6. A method as set forth in claim 1 further comprising sintering the rotor
 assembly.
7. A method comprising:
25 machining a central core comprising titanium aluminide; and
 metal injection molding a shell comprising titanium aluminide around the
 central core to produce a rotor assembly.
8. A method as set forth in claim 7 wherein the shell comprises a plurality of
30 blades.
9. A method as set forth in claim 7 wherein the central core is generally cone
 shaped.

10. A method as set forth in claim 7 wherein the central core is generally shaped like a truncated cone.

5 11. A method as set forth in claim 7 wherein the central core is generally cylinder shaped.

12. A method as set forth in claim 7 further comprising sintering the rotor assembly.

10 13. A product comprising:

A rotor assembly comprising a cast titanium aluminide central core; and a metal injection molded titanium aluminide shell radially surrounding the central core.

15 14. A product as set forth in claim 13 wherein the shell comprises a plurality of blades.

15. A product as set forth in claim 13 wherein the central core is generally cone shaped.

20 16. A method as set forth in claim 13 wherein the central core is generally shaped like a truncated cone.

17. A method as set forth in claim 13 wherein the central core is generally cylinder shaped.

25 18. A product comprising:

A rotor assembly comprising a machined titanium aluminide central core; and a metal injection molded titanium aluminide shell radially surrounding the central core wherein the shell comprises a plurality of blades.

30 19. A product as set forth in claim 12 wherein the central core is generally cone shaped.

20. A method as set forth in claim 1 wherein the central core is generally shaped like a truncated cone.

21. A method as set forth in claim 1 wherein the central core is generally
5 cylinder shaped.

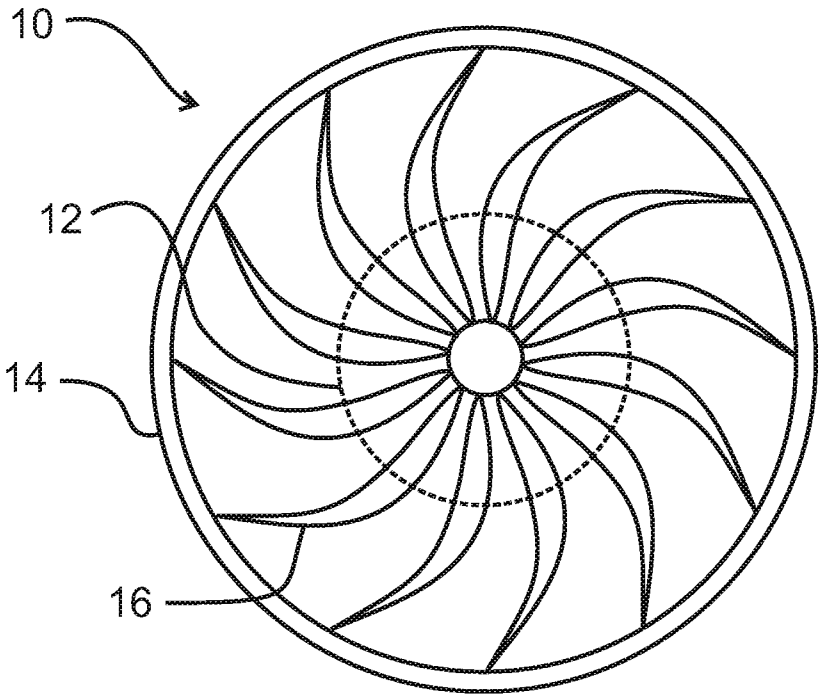


Fig. 1

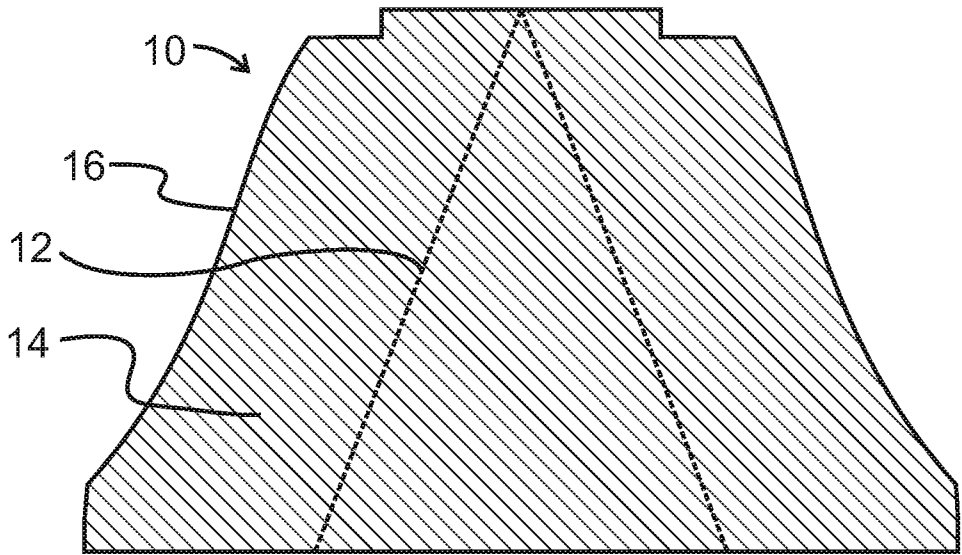


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/042876

A. CLASSIFICATION OF SUBJECT MATTER INV. B22F3/17 B22D21/02 B22F3/22 B22F5/00 B23P15/00 B29C45/00 ADD. C22C14/00 C22C21/00 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) B22F B22D B23P B29C C22C Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data																				
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">X</td> <td>US 2011/142653 A1 (HAGSHENAS BEHZAD [US] ET AL) 16 June 2011 (2011-06-16)</td> <td style="text-align: center;">13-19</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>paragraphs [0005], [0009] - [0010], [0014]; claims 1-4,8,11-15; figures 1-2 -----</td> <td style="text-align: center;">1-12,20,21</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>JP 2010 275878 A (IHI CORP) 9 December 2010 (2010-12-09) paragraphs [0006] - [0008], [0036], [0051] - [0055]; claims 1-4; figures 3-6 -----</td> <td style="text-align: center;">1-12,20,21</td> </tr> <tr> <td style="text-align: center;">X</td> <td>US 2006/034695 A1 (HALL JAMES A [US] ET AL) 16 February 2006 (2006-02-16)</td> <td style="text-align: center;">13-19</td> </tr> <tr> <td style="text-align: center;">Y</td> <td>paragraphs [0003], [0011], [0020], [0022]; claims 1-37; figures 2-5 paragraphs [0030], [0036] ----- -/-</td> <td style="text-align: center;">1-12,20,21</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	US 2011/142653 A1 (HAGSHENAS BEHZAD [US] ET AL) 16 June 2011 (2011-06-16)	13-19	Y	paragraphs [0005], [0009] - [0010], [0014]; claims 1-4,8,11-15; figures 1-2 -----	1-12,20,21	Y	JP 2010 275878 A (IHI CORP) 9 December 2010 (2010-12-09) paragraphs [0006] - [0008], [0036], [0051] - [0055]; claims 1-4; figures 3-6 -----	1-12,20,21	X	US 2006/034695 A1 (HALL JAMES A [US] ET AL) 16 February 2006 (2006-02-16)	13-19	Y	paragraphs [0003], [0011], [0020], [0022]; claims 1-37; figures 2-5 paragraphs [0030], [0036] ----- -/-	1-12,20,21
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																				
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Date of the actual completion of the international search 14 October 2016		Date of mailing of the international search report 21/10/2016																		
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Aliouane, Nadir																		

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/042876

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 124 325 A1 (GARRETT CORP [US]) 7 November 1984 (1984-11-07) claims 1-17; figures 1-3 -----	1-12
A	JP S60 128902 A (KOBE STEEL LTD) 10 July 1985 (1985-07-10) abstract; figures 1-7 -----	2-6, 8-12, 14-17, 19-21
A	US 2010/215978 A1 (RICE DEREK ANTHONY [US]) 26 August 2010 (2010-08-26) paragraphs [0009] - [0013], [0029] - [0031], [0033]; claims 1-22; figures 1-7 -----	1-21

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/042876

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011142653	A1	16-06-2011	NONE
JP 2010275878	A	09-12-2010	JP 2010275878 A 09-12-2010
		WO 2010137610 A1	02-12-2010
US 2006034695	A1	16-02-2006	NONE
EP 0124325	A1	07-11-1984	EP 0124325 A1 07-11-1984
		JP H0115719 B2	20-03-1989
		JP S60104798 A	10-06-1985
		US 4850802 A	25-07-1989
JP S60128902	A	10-07-1985	NONE
US 2010215978	A1	26-08-2010	NONE