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(54) **Title:** TITANIUM ALUMINIDE TURBINE EXHAUST STRUCTURE

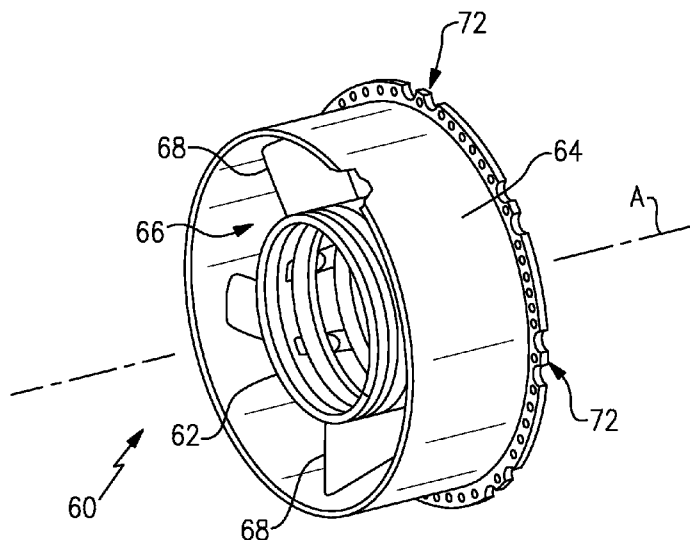


FIG. 2

(57) **Abstract:** A turbine engine exhaust structure includes a first annular case and a second annular case arranged radially outwards of the first annular case such that there is an annular space there between. A plurality of struts extend radially in the annular space. The first annular case, the second annular case and the struts include a base material of titanium aluminide.

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TITANIUM ALUMINIDE TURBINE EXHAUST STRUCTURE

BACKGROUND

[0001] A gas turbine engine typically includes a fan section, a compressor section, a combustor section and a turbine section. Air entering the compressor section is compressed and delivered into the combustion section where it is mixed with fuel and ignited to generate a high-speed exhaust gas flow. The high-speed exhaust gas flow expands through the turbine section to drive the compressor and the fan section. The compressor section typically includes low and high pressure compressors, and the turbine section includes low and high pressure turbines.

[0002] The high pressure turbine drives the high pressure compressor through an outer shaft to form a high spool, and the low pressure turbine drives the low pressure compressor through an inner shaft to form a low spool. The fan section may also be driven by the low inner shaft. A speed reduction device, such as an epicyclical gear assembly, may be utilized to drive the fan section such that the fan section may rotate at a speed different than the turbine section.

SUMMARY

[0003] A turbine engine exhaust structure according to an example of the present disclosure includes a first annular case, a second annular case arranged radially outwards of the first annular case such that there is an annular space there between and a plurality of struts extending radially in the annular space. The first annular case, the second annular case and the plurality of struts include a base material of titanium aluminide.

[0004] In a further embodiment of any of the foregoing embodiments, the titanium aluminide is gamma titanium aluminide, TiAl.

[0005] In a further embodiment of any of the foregoing embodiments, the struts are static airfoils that are circumferentially spaced around the annular space.

[0006] In a further embodiment of any of the foregoing embodiments, the struts are bonded to the first annular case and the second annular case.

[0007] In a further embodiment of any of the foregoing embodiments, the struts are metallurgically bonded to the first annular case and the second annular case.

[0008] In a further embodiment of any of the foregoing embodiments, the struts are hollow.

[0009] In a further embodiment of any of the foregoing embodiments, the second annular case includes a plurality of circumferentially-spaced mounting lugs.

[0010] A turbine engine according to an example of the present disclosure includes a compressor section, a combustor in fluid communication with the compressor section, a turbine section in fluid communication with the combustor, and an exhaust structure arranged aft of the turbine section and configured to receive exhaust flow from the turbine section. The exhaust structure includes a first annular case, a second annular case arranged radially outwards of the first annular case such that there is an annular space there between, and a plurality of struts extending radially in the annular space. The first annular case, the second annular case and the plurality of struts include a base material of titanium aluminide.

[0011] In a further embodiment of any of the foregoing embodiments, the titanium aluminide is gamma titanium aluminide, TiAl.

[0012] In a further embodiment of any of the foregoing embodiments, the struts are static airfoils that are circumferentially spaced around the annular space.

[0013] In a further embodiment of any of the foregoing embodiments, the struts are bonded to the first annular case and the second annular case.

[0014] In a further embodiment of any of the foregoing embodiments, the struts are metallurgically bonded to the first annular case and the second annular case.

[0015] In a further embodiment of any of the foregoing embodiments, the struts are hollow.

[0016] In a further embodiment of any of the foregoing embodiments, the second annular case includes a plurality of circumferentially-spaced mounting lugs.

[0017] A method of fabricating a turbine engine exhaust structure according to an example of the present disclosure includes providing a first annular case, a second annular case and a plurality of struts as separate pieces, the first annular case, the second annular case and the plurality of struts including a base material of titanium aluminide, and attaching the plurality of struts to the first annular case and the second annular case such that the second annular case is arranged radially outwards of the first annular case with an annular space there between and the plurality of struts extending radially in the annular space.

[0018] In a further embodiment of any of the foregoing embodiments, the forming includes forging.

[0019] In a further embodiment of any of the foregoing embodiments, the forming includes using an additive fabrication process.

[0020] In a further embodiment of any of the foregoing embodiments, the attaching includes metallurgically bonding the struts to the first annular case and the second annular case.

[0021] In a further embodiment of any of the foregoing embodiments, the attaching includes holding the struts in a fixture to align the struts with respect to predetermined attachment locations on at least one of the first annular case and the second annular case, and then metallurgically bonding the struts to at least one of the first annular case and the second annular case.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The various features and advantages of the present disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

[0023] Figure 1 illustrates an example gas turbine engine.

[0024] Figure 2 illustrates an example turbine engine exhaust structure of the engine of Figure 1.

[0025] Figure 3 illustrates components of the turbine engine exhaust structure of Figure 2.

[0026] Figure 4 illustrates a method of fabricating a turbine engine exhaust structure.

[0027] Figure 5 illustrates an example of aligning a strut with a predetermined attachment location using a fixture.

[0028] Figure 6 illustrates a further example of aligning a strut with a predetermined attachment location.

DETAILED DESCRIPTION

[0029] Figure 1 schematically illustrates a gas turbine engine 20. The gas turbine engine 20 is disclosed herein as a two-spool turbofan that generally incorporates a fan section 22, a compressor section 24, a combustor section 26 and a turbine section 28. Alternative engines might include an augmentor section (not shown) among other systems or features. The fan section 22 drives air along a bypass flowpath while the compressor section 24 drives air along a core flowpath for compression and communication into the combustor section 26 then expansion through the turbine section 28. Although depicted as a turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts

described herein are not limited to use with turbofans as the teachings may be applied to other types of turbine engines, including ground-based engines and single- or three-spool architectures.

[0030] The engine 20 generally includes a first spool 30 and a second spool 32 mounted for rotation about an engine central axis A relative to an engine static structure 36 via several bearing systems 38. It should be understood that various bearing systems 38 at various locations may alternatively or additionally be provided.

[0031] The first spool 30 generally includes a first shaft 40 that interconnects a fan 42, a first compressor 44 and a first turbine 46. The first shaft 40 is connected to the fan 42 through a gear assembly of a fan drive gear system 48 to drive the fan 42 at a lower speed than the first spool 30. The second spool 32 includes a second shaft 50 that interconnects a second compressor 52 and second turbine 54. The first spool 30 runs at a relatively lower pressure than the second spool 32. It is to be understood that “low pressure” and “high pressure” or variations thereof as used herein are relative terms indicating that the high pressure is greater than the low pressure. An annular combustor 56 is arranged between the second compressor 52 and the second turbine 54. The first shaft 40 and the second shaft 50 are concentric and rotate via bearing systems 38 about the engine central axis A which is collinear with their longitudinal axes.

[0032] The core airflow is compressed by the first compressor 44 then the second compressor 52, mixed and burned with fuel in the annular combustor 56, then expanded over the second turbine 54 and first turbine 46. The first turbine 46 and the second turbine 54 rotationally drive, respectively, the first spool 30 and the second spool 32 in response to the expansion.

[0033] The engine 20 is a high-bypass geared aircraft engine that has a bypass ratio that is greater than about six (6), with an example embodiment being greater than ten (10), the gear assembly of the fan drive gear system 48 is an epicyclic gear train, such as a planetary gear system or other gear system, with a gear reduction ratio of greater than about 2.3:1 and the first turbine 46 has a pressure ratio that is greater than about 5. The first turbine 46 pressure ratio is pressure measured prior to inlet of first turbine 46 as related to the pressure at the outlet of the first turbine 46 prior to an exhaust nozzle. The first turbine 46 has a maximum rotor diameter and the fan 42 has a fan diameter such that a ratio of the maximum rotor diameter divided by the fan diameter is less than 0.6. It should be understood, however, that the above parameters are only exemplary.

[0034] A significant amount of thrust is provided by the bypass flow due to the high bypass ratio. The fan section 22 of the engine 20 is designed for a particular flight condition -- typically cruise at about 0.8 Mach and about 35,000 feet. The flight condition of 0.8 Mach and 35,000 feet, with the engine at its best fuel consumption - also known as "bucket cruise Thrust Specific Fuel Consumption ('TSFC')" - is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. To make an accurate comparison of fuel consumption between engines, fuel consumption is reduced to a common denominator, which is applicable to all types and sizes of turbojets and turbofans. The term is thrust specific fuel consumption, or TSFC. This is an engine's fuel consumption in pounds per hour divided by the net thrust. The result is the amount of fuel required to produce one pound of thrust. The TSFC unit is pounds per hour per pounds of thrust (lb/hr/lb Fn). When it is obvious that the reference is to a turbojet or turbofan engine, TSFC is often simply called specific fuel consumption, or SFC. "Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.45. "Low corrected fan tip speed" is the actual fan tip speed in feet per second divided by an industry standard temperature correction of $[(T_{\text{ram}} \text{ } ^\circ\text{R}) / (518.7 \text{ } ^\circ\text{R})]^{0.5}$. The "Low corrected fan tip speed" as disclosed herein according to one non-limiting embodiment is less than about 1150 feet per second.

[0035] As shown schematically in Figure 1, the engine 20 also includes a turbine engine exhaust structure 60 (hereafter "structure 60") arranged aft of the turbine section 28 at a trailing end of the engine 20. Figure 2 illustrates an isolated view of the structure 60. In this example, the structure 60 includes a first annular case 62 and a second annular case 64 that is arranged radially outwards of the first annular case 62 such that there is an annular space 66 there between. A plurality of struts 68 extend radially in the annular space 66. In this example, the structure 60 includes four such struts 68. It is to be understood however, that fewer or additional struts 68 could alternatively be used. The first annular case 62, the second annular case 64 and the struts 68 include a base material of titanium aluminide. The base material forms the structural walls of each of these components and does not rely upon conformance to an underlying substrate for shape. In one further example, the titanium aluminide is gamma titanium aluminide, TiAl.

[0036] The titanium aluminide, especially gamma titanium aluminide, is relatively lightweight in comparison to many other metallic alloys and has high temperature resistance. Thus, the structure 60 can be used in place of similar structures that are made from other

materials, such as other metallic alloys, to reduce the weight of the engine 20 and enhance high temperature performance.

[0037] In this example, the struts 68 are static airfoils that are circumferentially spaced around the annular space 66. Additionally, the struts 68 are bonded to the first annular case 62 and the second annular case 64. For example, the struts 68 are metallurgically bonded to the first annular case 62 and the second annular case 64. The metallurgical bonding can be achieved by brazing or welding the struts 68 to the first annular case 62 and a second annular case 64 to form distinct joints. A distinct joint is a discontinuity that is perceptible either visually or microscopically. For example, a distinct joint can be fully or partially visually imperceptible but is at least perceptible microscopically, as indicated by a microstructural discontinuity that would not be present in an indistinct, monolithic joint.

[0038] In this example, the struts 68 are hollow and thus include interior cavities 70 (Figure 3). Conduits for conveying cooling fluid, such as air, oil or both, can be provided through the cavities 70. It is to be understood however, that the struts 68 can also be solid.

[0039] In a further example, the second annular case 64 can include a plurality of circumferentially-spaced mounting lugs 72, which can be used to attach exhaust hardware to engine 20 for example.

[0040] The structure 60, if made from another type of metallic alloy, could be fabricated as a single, monolithic piece in a casting process. However, in one example, the first annular case 62, the second annular case 64 and the struts 68 are individually formed as separate pieces and then later assembled to fabricate the structure 60. Figure 3 illustrates the individual, separate pieces of the structure 60, however, it is to be understood that some of the pieces could be integrated together into more complex functional pieces in other examples.

[0041] Figure 4 illustrates an example method 80 of fabricating the turbine engine exhaust structure 60. The method 80 generally includes steps 82 and 84. As can be appreciated, the steps 82/84 can be used in conjunction with other processing steps. At step 82, the first annular case 62, the second annular case 64 and the struts 68 are provided as separate pieces. The separate pieces are not limited to the first annular case 62, the second annular case 64 and the struts 68. That is, any or each of the first annular case 62, the second annular case 64 and the struts 68 could be further provided in sub-pieces, or a pieces could include one of the cases 62 or 64 and one or more of the struts 68 integrated together. The separate pieces can be formed individually from titanium aluminide by forging, additive

manufacturing or even casting. Ultimately however, the pieces are attached together to form the structure 60.

[0042] Referring also to Figures 5 and 6, the struts 68 are then attached to the first annular case 62 and the second annular case 64 at step 84. For example, as shown in Figure 5, one or more of the struts 68 and the first annular case 62 are held within a fixture 90 (schematically shown) such that the struts 68 align with respect to predetermined attachment locations 92 on the first annular case 62 (or the second annular case 64, Figure 6). Once aligned and brought into proximity with the first annular case 62 (or the second annular case 64), the struts 68 are attached, such as by metallurgical bonding. In one example, the struts 68 are first attached to the first annular case 62, as depicted in Figure 5. The first annular case 62, with the bonded struts 68, is then inserted into the interior of the second annular case 64 such that the struts 68 align with the predetermined attachment locations 92 on the second annular case 64 (Figure 6). The struts 68 are then attached, such as by metallurgical bonding, to the second annular case 64.

[0043] Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

[0044] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

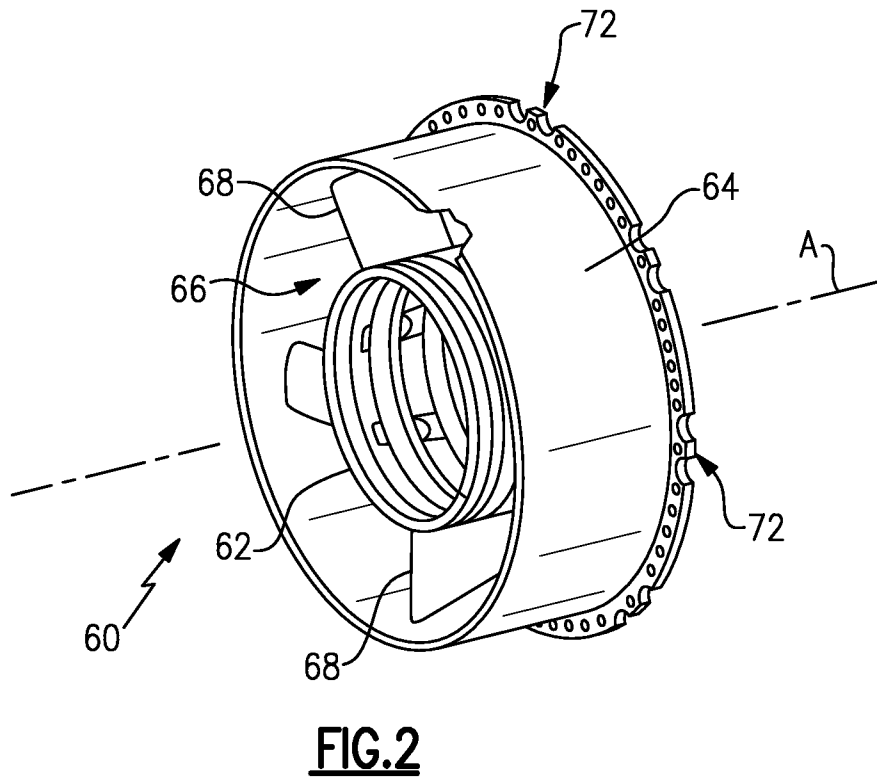
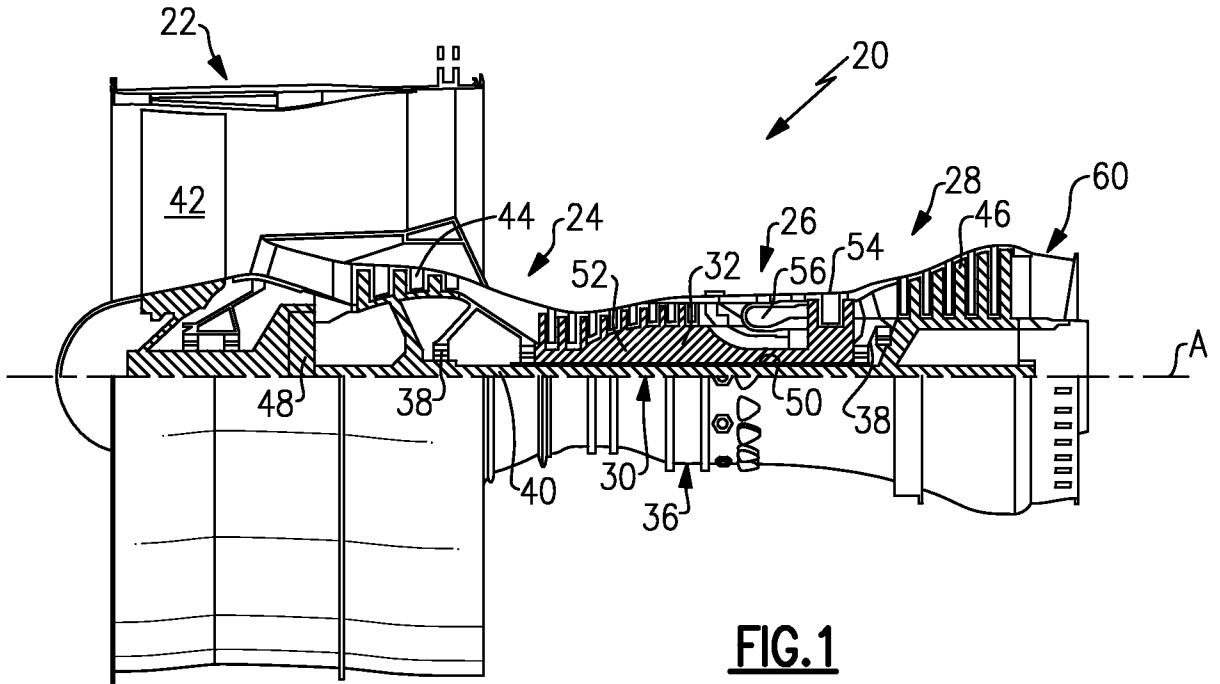
CLAIMS

What is claimed is:

1. A turbine engine exhaust structure comprising:
 - a first annular case;
 - a second annular case arranged radially outwards of the first annular case such that there is an annular space there between;
 - a plurality of struts extending radially in the annular space,
 - the first annular case, the second annular case and the plurality of struts including a base material of titanium aluminide.
2. The turbine engine exhaust structure as recited in claim 1, wherein the titanium aluminide is gamma titanium aluminide, TiAl.
3. The turbine engine exhaust structure as recited in claim 1, wherein the struts are static airfoils that are circumferentially spaced around the annular space.
4. The turbine engine exhaust structure as recited in claim 1, wherein the struts are bonded to the first annular case and the second annular case.
5. The turbine engine exhaust structure as recited in claim 1, wherein the struts are metallurgically bonded to the first annular case and the second annular case.
6. The turbine engine exhaust structure as recited in claim 1, wherein the struts are hollow.
7. The turbine engine exhaust structure as recited in claim 1, wherein the second annular case includes a plurality of circumferentially-spaced mounting lugs.

8. A turbine engine comprising:
 - a compressor section;
 - a combustor in fluid communication with the compressor section;
 - a turbine section in fluid communication with the combustor;
 - an exhaust structure arranged aft of the turbine section and configured to receive exhaust flow from the turbine section, the exhaust structure including a first annular case, a second annular case arranged radially outwards of the first annular case such that there is an annular space there between, a plurality of struts extending radially in the annular space, the first annular case, the second annular case and the plurality of struts including a base material of titanium aluminide.
9. The turbine engine as recited in claim 8, wherein the titanium aluminide is gamma titanium aluminide, TiAl.
10. The turbine engine as recited in claim 8, wherein the struts are static airfoils that are circumferentially spaced around the annular space.
11. The turbine engine as recited in claim 8, wherein the struts are bonded to the first annular case and the second annular case.
12. The turbine engine as recited in claim 8, wherein the struts are metallurgically bonded to the first annular case and the second annular case.
13. The turbine engine as recited in claim 8, wherein the struts are hollow.
14. The turbine engine as recited in claim 8, wherein the second annular case includes a plurality of circumferentially-spaced mounting lugs.

15. A method of fabricating a turbine engine exhaust structure, the method comprising:
providing a first annular case, a second annular case and a plurality of struts as separate pieces, the first annular case, the second annular case and the plurality of struts including a base material of titanium aluminide; and
attaching the plurality of struts to the first annular case and the second annular case such that the second annular case is arranged radially outwards of the first annular case with an annular space there between and the plurality of struts extending radially in the annular space.
16. The method as recited in claim 15, wherein the forming includes forging.
17. The method as recited in claim 15, wherein the forming includes using an additive fabrication process.
18. The method as recited in claim 15, wherein the attaching includes metallurgically bonding the struts to the first annular case and the second annular case.
19. The method as recited in claim 15, wherein the attaching includes holding the struts in a fixture to align the struts with respect to predetermined attachment locations on at least one of the first annular case and the second annular case, and then metallurgically bonding the struts to at least one of the first annular case and the second annular case.



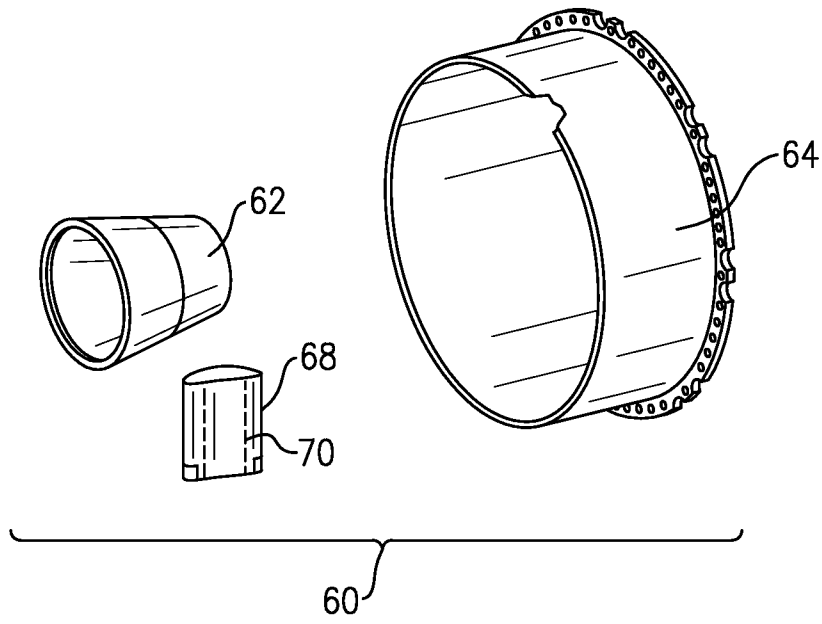


FIG. 3

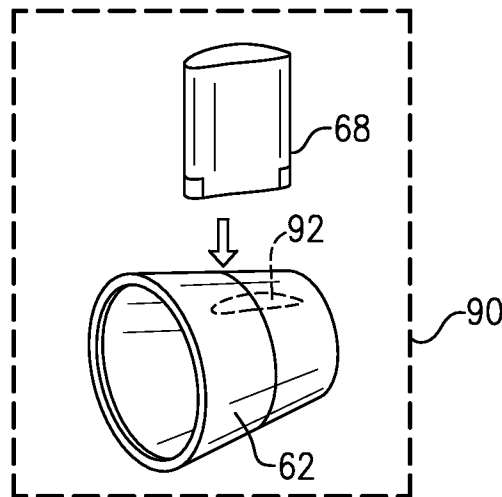


FIG. 5

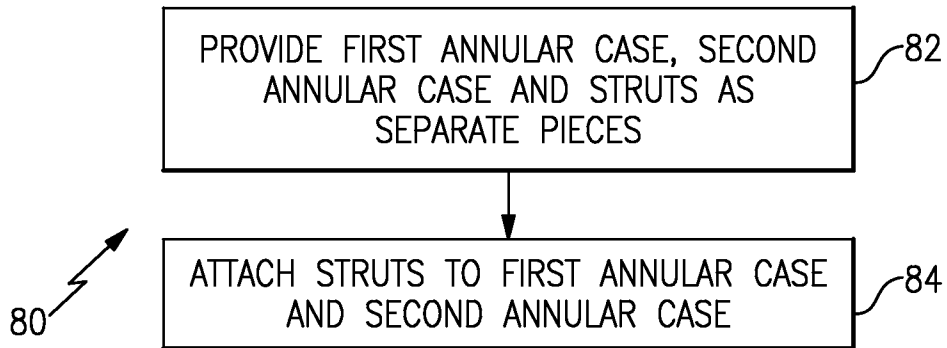


FIG.4

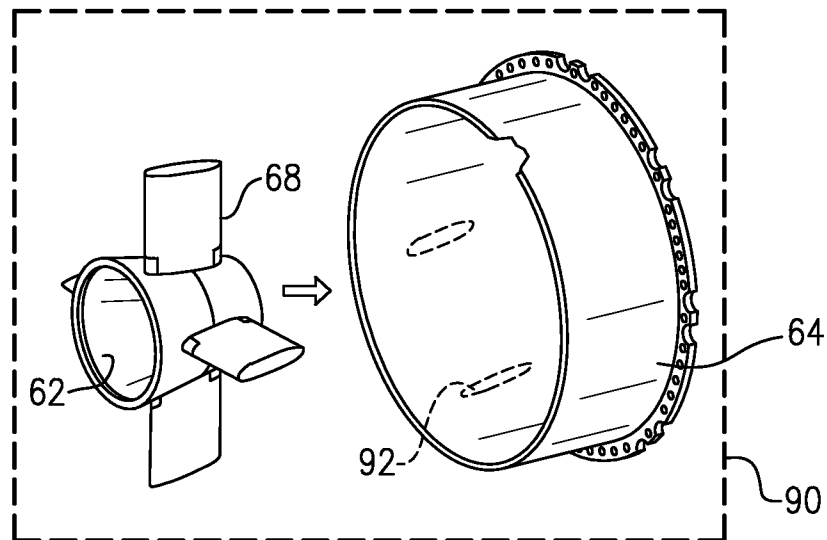


FIG.6

A. CLASSIFICATION OF SUBJECT MATTER**F01D 25/30(2006.01)i, F02C 7/20(2006.01)i, F02K 1/78(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 25/30; F02C 7/20; F01D 25/00; F01D 25/24; B23P 11/00; B64D 27/26; B22F 7/00; B22F 3/15; F02K 1/78

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: turbine engine, exhaust structure, annular case, strut, and gamma titanium aluminide

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0275614 A1 (FONTAINE et al.) 04 November 2010 See abstract; paragraphs [0020], [0021], [0023], [0025], [0026], [0033]; and figures 1, 2.	1-19
Y	US 5,413,871 A (NELSON et al.) 09 May 1995 See abstract; column 3, lines 53-59; and figure 2.	1-19
Y	EP 2447157 A2 (UNITED TECHNOLOGIES CORPORATION) 02 May 2012 See abstract; paragraph [0009]; and figure 2.	7, 14
A	US 2011-0103947 A1 (RUIZ et al.) 05 May 2011 See abstract; paragraph [0012]; and figure 1(a).	1-19
A	US 2006-0083653 A1 (DAS, GOPAL) 20 April 2006 See abstract; paragraph [0027]; and figure 1.	1-19

 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

09 June 2014 (09.06.2014)

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Name and mailing address of the ISA/KR

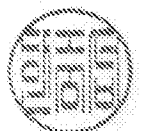
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/016767

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