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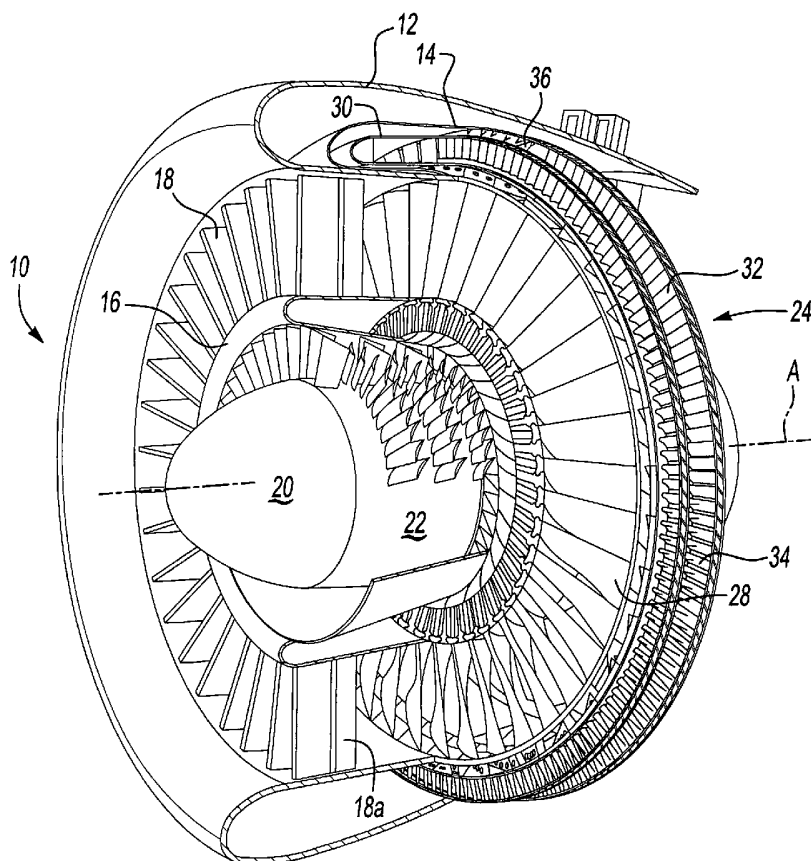
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[Continued on next page]

(54) Title: FAN ROTOR ASSEMBLY FOR A TIP TURBINE ENGINE



(57) Abstract: A fan-turbine rotor assembly (24) for a tip turbine engine (10) includes a fan hub (64) with an outer periphery (112) scalloped by a multitude of elongated openings (114) which extend into a fan hub web (115). Each elongated opening defines an inducer receipt section (117) to receive an inducer section (66) and a hollow fan blade section (72). An inducer exhaust from each inducer section is located adjacent a core airflow passage (80) within each fan blade section to provide communication therebetween.

WO 2006/060001 A1



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## FAN-TURBINE ROTOR ASSEMBLY FOR A TIP TURBINE ENGINE

### BACKGROUND OF THE INVENTION

The present invention relates to a tip turbine engine, and more particularly to  
5 a fan-turbine rotor assembly which provides mechanical retention between a  
multitude of rotational components.

An aircraft gas turbine engine of the conventional turbofan type generally  
includes a forward bypass fan a compressor, a combustor, and an aft turbine all  
located along a common longitudinal axis. A compressor and a turbine of the engine  
10 are interconnected by a shaft. The compressor is rotatably driven to compress air  
entering the combustor to a relatively high pressure. This pressurized air is then  
mixed with fuel in a combustor and ignited to form a high energy gas stream. The  
gas stream flows axially aft to rotatably drive the turbine which rotatably drives the  
compressor through the shaft. The gas stream is also responsible for rotating the  
15 bypass fan. In some instances, there are multiple shafts or spools. In such instances,  
there is a separate turbine connected to a separate corresponding compressor through  
each shaft. In most instances, the lowest pressure turbine will drive the bypass fan.

Although highly efficient, conventional turbofan engines operate in an axial  
flow relationship. The axial flow relationship results in a relatively complicated  
20 elongated engine structure of considerable longitudinal length relative to the engine  
diameter. This elongated shape may complicate or prevent packaging of the engine  
into particular applications.

A recent development in gas turbine engines is the tip turbine engine. Tip  
turbine engines locate an axial compressor forward of a bypass fan which includes  
25 hollow fan blades that receive airflow from the axial compressor therethrough such  
that the hollow fan blades operate as a centrifugal compressor. Compressed core  
airflow from the hollow fan blades is mixed with fuel in an annular combustor and  
ignited to form a high energy gas stream which drives the turbine integrated onto the  
tips of the hollow bypass fan blades for rotation therewith as generally disclosed in  
30 U.S. Patent Application Publication Nos.: **20030192303**; **20030192304**; and  
**20040025490**.

The tip turbine engine provides a thrust to weight ratio equivalent to conventional turbofan engines of the same class within a package of significantly shorter length.

One significant rotational component of a tip turbine engine is the fan-turbine rotor assembly. The fan-turbine rotor assembly includes intricate components, which rotate at relatively high speeds to generate bypass airflow while communicating a core airflow through each of the multitude of hollow fan blades. A large percentage of the expense associated with a tip turbine engine is the manufacture of the fan-turbine rotor assembly.

Accordingly, it is desirable to provide an assembly arrangement for a fan-turbine rotor assembly, which is relatively inexpensive to manufacture yet provides a high degree of reliability.

#### **SUMMARY OF THE INVENTION**

The fan-turbine rotor assembly for a tip turbine engine according to the present invention includes a fan hub, which has an outer periphery scalloped by a multitude of elongated openings, which extend into a fan hub web. Each elongated opening defines an inducer receipt section to receive an inducer section and a blade receipt section to retain a hollow fan blade section. The blade receipt section retains each of the hollow fan blade sections adjacent each inducer section. An inner fan blade mount is located adjacent an inducer exhaust from each inducer section to engage the inducer hub with the fan hub and provide a core airflow communication path from the inducer passages within each inducer section into the core airflow passage within each fan blade section.

The inducer sections and fan blade sections are directionally mounted within the fan hub such that the forces exerted upon the fan-turbine rotor assembly during operation further lock the inducer sections and fan blade sections into the fan hub. That is, operational forces maintain the fan-turbine rotor assembly in an assembled condition rather than operating to disassemble the components.

The present invention therefore provides an assembly arrangement for a fan-turbine rotor assembly which is relatively inexpensive to manufacture yet provides a high degree of reliability.

### BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:

Figure 1 is a partial sectional perspective view of a tip turbine engine;

Figure 2 is a longitudinal sectional view of a tip turbine engine along an engine centerline;

Figure 3 is an exploded view of a fan-turbine rotor assembly;

Figure 4 is an assembled view of a fan-turbine rotor assembly;

Figure 5 is an expanded perspective view of an inducer section;

Figure 6 is an expanded perspective view of the fan-turbine rotor assembly;

Figure 7 is an expanded perspective view of a partially assembled fan-turbine rotor assembly; and

Figure 8 is a rear sectional view of the engagement between an inducer receipt section, a blade receipt section, an inducer section and a fan blade section.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a general perspective partial sectional view of a tip turbine engine type gas turbine engine 10. The engine 10 includes an outer nacelle 12, a nonrotatable static outer support structure 14 and a nonrotatable static inner support structure 16. A multitude of fan inlet guide vanes 18 are mounted between the static outer support structure 14 and the static inner support structure 16. Each inlet guide vane preferably includes a variable trailing edge 18A.

A nose cone 20 is preferably located along the engine centerline A to smoothly direct airflow into an axial compressor 22 adjacent thereto. The axial compressor 22 is mounted about the engine centerline A behind the nose cone 20.

A fan-turbine rotor assembly 24 is mounted for rotation about the engine centerline A aft of the axial compressor 22. The fan-turbine rotor assembly 24 includes a multitude of hollow fan blades 28 to provide internal, centrifugal compression of the compressed airflow from the axial compressor 22 for distribution

to an annular combustor 30 located within the nonrotatable static outer support structure 14.

5 A turbine 32 includes a multitude of tip turbine blades 34 (two stages shown) which rotatably drive the hollow fan blades 28 relative to a multitude of tip turbine stators 36 which extend radially inwardly from the static outer support structure 14. The annular combustor 30 is axially forward of the turbine 32 and communicates with the turbine 32.

10 Referring to Figure 2, the nonrotatable static inner support structure 16 includes a splitter 40, a static inner support housing 42 and an static outer support housing 44 located coaxial to said engine centerline A.

The axial compressor 22 includes the axial compressor rotor 46 from which a plurality of compressor blades 52 extend radially outwardly and a compressor case 50 fixedly mounted to the splitter 40. A plurality of compressor vanes 54 extend radially inwardly from the compressor case 50 between stages of the compressor blades 52. The compressor blades 52 and compressor vanes 54 are arranged circumferentially about the axial compressor rotor 46 in stages (three stages of compressor blades 52 and compressor vanes 54 are shown in this example). The axial compressor rotor 46 is mounted for rotation upon the static inner support housing 42 through a forward bearing assembly 68 and an aft bearing assembly 62.

20 The fan-turbine rotor assembly 24 includes a fan hub 64 that supports a multitude of the hollow fan blades 28. Each fan blade 28 includes an inducer section 66, a hollow fan blade section 72 and a diffuser section 74. The inducer section 66 receives airflow from the axial compressor 22 generally parallel to the engine centerline A and turns the airflow from an axial airflow direction toward a radial airflow direction. The airflow is radially communicated through a core airflow passage 80 within the fan blade section 72 where the airflow is centrifugally compressed. From the core airflow passage 80, the airflow is turned and diffused toward an axial airflow direction toward the annular combustor 30. Preferably the airflow is diffused axially forward in the engine 10, however, the airflow may  
25  
30 alternatively be communicated in another direction.

A gearbox assembly 90 aft of the fan-turbine rotor assembly 24 provides a speed increase between the fan-turbine rotor assembly 24 and the axial compressor

22. Alternatively, the gearbox assembly 90 could provide a speed decrease between the fan-turbine rotor assembly 24 and the axial compressor rotor 46. The gearbox assembly 90 is mounted for rotation between the static inner support housing 42 and the static outer support housing 44. The gearbox assembly 90 includes a sun gear shaft 92 which rotates with the axial compressor 22 and a planet carrier 94 which rotates with the fan-turbine rotor assembly 24 to provide a speed differential therebetween. The gearbox assembly 90 is preferably a planetary gearbox that provides co-rotating or counter-rotating rotational engagement between the fan-turbine rotor assembly 24 and an axial compressor rotor 46. The gearbox assembly 90 is mounted for rotation between the sun gear shaft 92 and the static outer support housing 44 through a forward bearing 96 and a rear bearing 98. The forward bearing 96 and the rear bearing 98 are both tapered roller bearings and both handle radial loads. The forward bearing 96 handles the aft axial loads while the rear bearing 98 handles the forward axial loads. The sun gear shaft 92 is rotationally engaged with the axial compressor rotor 46 at a splined interconnection 100 or the like.

In operation, air enters the axial compressor 22, where it is compressed by the three stages of the compressor blades 52 and compressor vanes 54. The compressed air from the axial compressor 22 enters the inducer section 66 in a direction generally parallel to the engine centerline A and is turned by the inducer section 66 radially outwardly through the core airflow passage 80 of the hollow fan blades 28. The airflow is further compressed centrifugally in the core airflow passage 80 of the hollow fan blades 28 by rotation of the hollow fan blades 28. From the core airflow passage 80, the airflow is turned and diffused axially forward in the engine 10 into the annular combustor 30. The compressed core airflow from the hollow fan blades 28 is mixed with fuel in the annular combustor 30 and ignited to form a high-energy gas stream. The high-energy gas stream is expanded over the multitude of tip turbine blades 34 mounted about the outer periphery of the fan blades 28 to drive the fan-turbine rotor assembly 24, which in turn drives the axial compressor 22 through the gearbox assembly 90. Concurrent therewith, the fan-turbine rotor assembly 24 discharges fan bypass air axially aft to merge with the core airflow from the turbine 32 in an exhaust case 106. A multitude of exit guide

vanes 108 are located between the static outer support housing 44 and the nonrotatable static outer support structure 14 to guide the combined airflow out of the engine 10 to provide forward thrust. An exhaust mixer 110 mixes the airflow from the turbine blades 34 with the bypass airflow through the fan blades 28.

5 Referring to Figure 3, the fan-turbine rotor assembly 24 is illustrated in an exploded view. The fan hub 64 is the primary structural support of the fan-turbine rotor assembly 24 (Figure 4). The fan hub 64 is preferably forged and then milled to provide the desired geometry. The fan hub 64 defines a bore 110 and an outer periphery 112. The outer periphery 112 is preferably scalloped by a multitude of  
10 elongated openings 114 located about the outer periphery 112. The elongated openings 114 extend into a fan hub web 115.

Each elongated opening 114 defines an inducer receipt section 117 to receive each inducer section 66. The inducer receipt section 117 generally follows the shape of the inducer section 66. That is, the inducer receipt section 117 receives the more  
15 complicated shape of the inducer section 66 without the necessity of milling the more complicated shape directly into the fan hub 64.

The inducer sections 66 are essentially conduits that define an inducer passage 118 between an inducer inlet 120 and an inducer exit 128 (also illustrated in Figure 5). Preferably, the inducer sections 66 are formed of a composite material.

20 The inducer sections 66 together form an inducer 116 of the fan-turbine rotor assembly 24. The inducer inlet 120 of each inducer passage 118 extends forward of the fan hub 64 and is canted toward a rotational direction of the fan hub 64 such that inducer inlet 120 operates as an air scoop during rotation of the fan-turbine rotor assembly 24 (Figure 6). Each inducer passage 118 provides separate airflow  
25 communication to each core airflow passage 80 when each fan blade section 72 is mounted within each elongated opening 114.

Inducer sections 66 are preferably uni-directionally assembled into the fan hub 64 from the front such that the forces exerted upon the fan-turbine rotor assembly 24 during operation correspond with further locking of the inducer  
30 sections 66 into the fan hub 64. Each inducer inlet 120 preferably at least partially overlaps the next inducer inlet 120 when assembled into the fan hub 64 (Figure 4) through the overlapped orientation the inducer inlets 120 lock the inducer sections



66 into the fan hub 64. That is, operational forces maintain the inducer sections 66 within the fan hub 64 in an assembled condition rather than operating to disassemble the components. Alternatively, or in addition the inducer sections 66 may be mounted to the fan hub 64 through an attachment such as bonding, welding, rivets, threaded fasteners, and the like.

Referring to Figure 6, the fan hub 64 retains each hollow fan blade section 72 within each elongated opening 114 through a blade receipt section 122. The blade receipt section 122 preferably forms an axial semi-cylindrical opening 125 (also illustrated in Figure 7) formed along the axial length of the elongated openings 114. It should be understood that other retention structures will likewise be usable with the present invention.

Referring to Figure 7, each hollow fan blade section 72 includes an inner fan blade mount 124 that corresponds with the blade receipt section 122 to retain the hollow fan blade section 72 within the fan hub 64. The inner fan blade mount 124 preferably includes a semi-cylindrical portion 127 to radially retain the fan blade 28 through a dove-tail, fir-tree, or bulb-type engagement structure (Figure 8). The fan hub 64 supports the hoop load required to retain the integrity of the disk/blade structure.

The inner fan blade mount 124 is preferably uni-directionally mounted into the blade receipt section 122 from the rear face of the fan hub 64. The inner fan blade mount 124 engages the blade receipt section 122 during operation of the fan-turbine rotor assembly 24 to provide a directional lock therebetween. That is, the inner fan blade mount 124 and the blade receipt section 122 may be frustoconical or axially non-symmetrical such that the forward segments 124a, 127a form a smaller engagement surface than the rear segment 124b, 127b to provide a wedged engagement therebetween when assembled.

Referring to Figure 8, each inducer section 66 is further retained within the fan hub 64 by interaction with the inner fan blade mount 124. That is, the inner fan blade mount 124 engages the inducer exit 126 (Figure 5) to further retain the inducer sections 66 into the fan hub 64 to provide core airflow communication through the inducer passages 118 and into the core airflow passage 80. Seals 128 may be

additionally located between each inducer section 66 and each hollow fan blade section 72

5 It should be understood that relative positional terms such as "forward," "aft," "upper," "lower," "above," "below," and the like are with reference to the normal operational attitude of the vehicle and should not be considered otherwise limiting.

10 The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

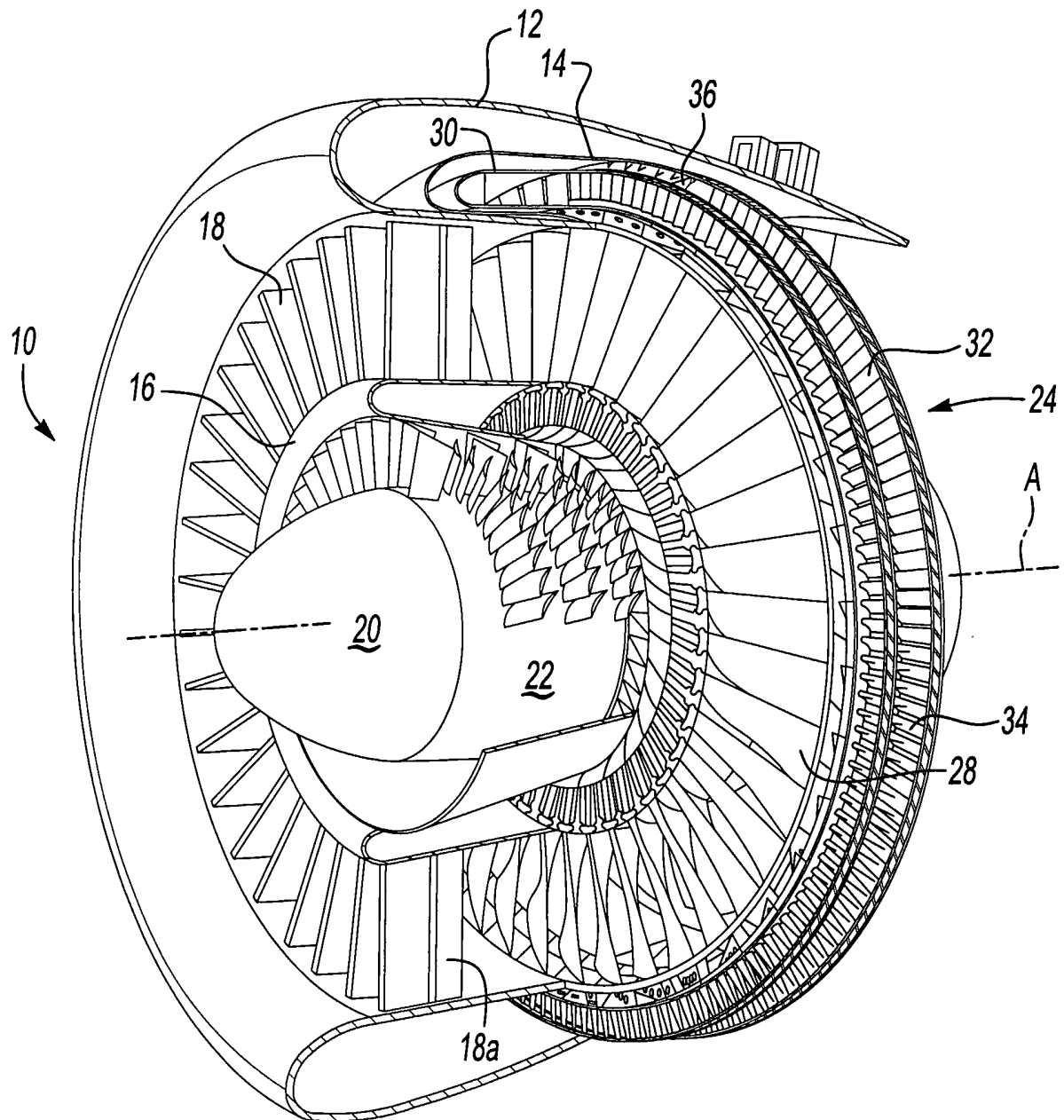
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## CLAIMS

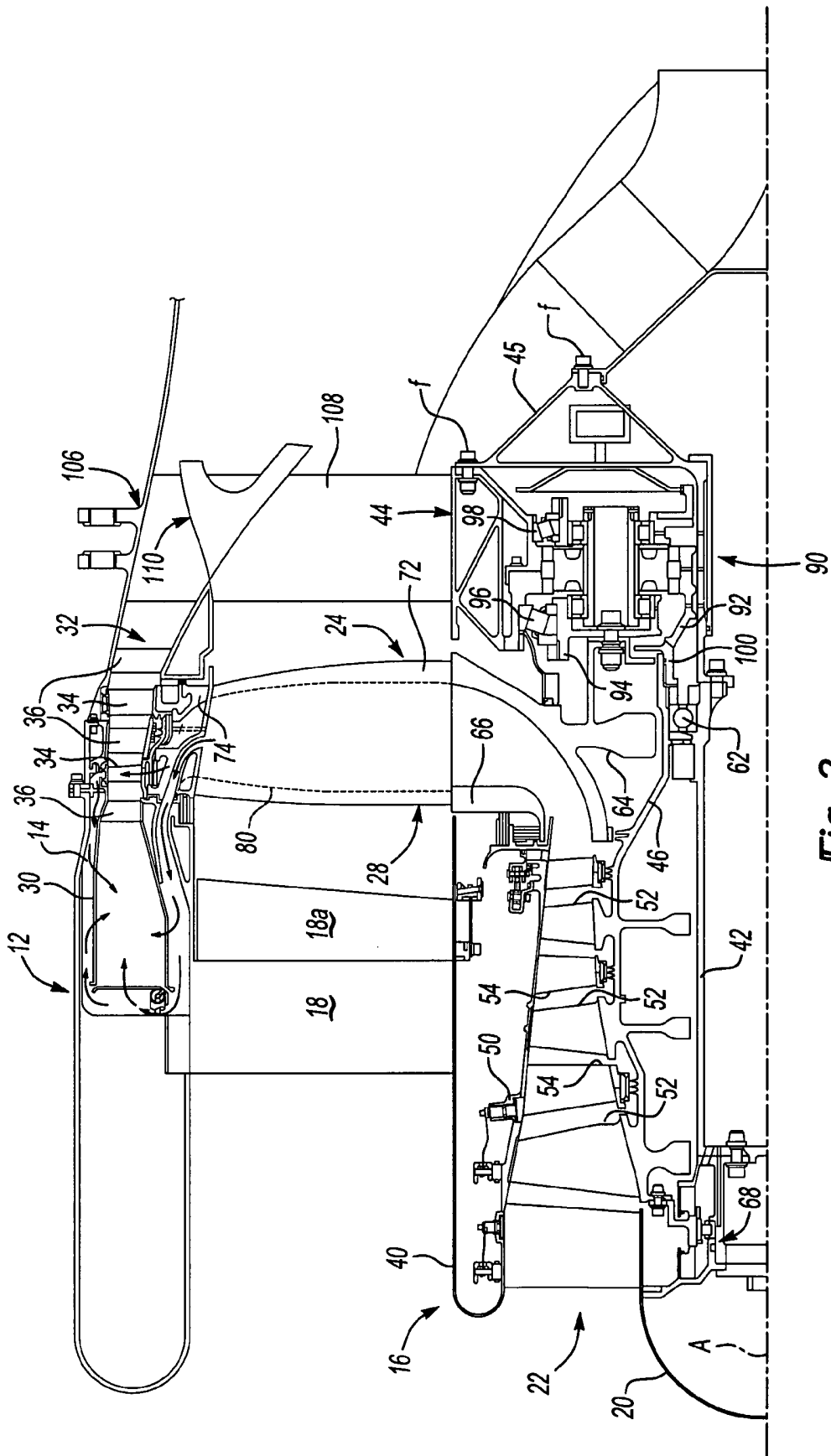
1. A fan assembly for a tip turbine engine comprising:  
a fan hub defining an axis of rotation, said fan hub defining a multitude of  
5 elongated openings located about an outer periphery of said fan hub; and  
an inducer mounted within said multitude of elongated openings to provide a  
directional lock therebetween, said inducer defining a multitude of inducer passages  
which turn an airflow from an axial airflow direction generally along said fan axis of  
rotation to a radial airflow direction.
- 10
2. The fan assembly as recited in claim 1, wherein said inducer includes a  
multitude of inducer sections each of which are independently receivable within one  
of said multitude of elongated openings.
- 15
3. The fan assembly as recited in claim 1, wherein said inducer sections defines  
an inducer passage inlet.
4. The fan assembly as recited in claim 3, wherein each of said inducer passage  
inlets communicates with each of said inducer passages.
- 20
5. The fan assembly as recited in claim 4, wherein said inducer passage inlets  
are canted toward a rotational direction of said fan hub, each of said inducer passage  
inlets at least partially overlapping an adjacent inducer passage inlet.
- 25
6. The fan assembly as recited in claim 1, further comprising a fan blade  
section having a tip turbine, each of said fan blade sections mounted within each of  
said elongated openings, each of said fan blade sections defining a fan blade core  
airflow passage to receive said airflow from a respective inducer passages  
therethrough.
- 30
7. The fan assembly as recited in claim 6, wherein each of said elongated  
openings defines a blade receipt section to retain each of said fan blade sections.

8. The fan assembly as recited in claim 7, wherein said blade receipt section includes a dove tail engagement.
9. A fan hub for a tip turbine engine comprising:  
5 a fan hub defining an axis of rotation, said fan hub defining a multitude of elongated openings located about an outer periphery of said fan hub, each of said elongated openings extends into a fan hub web to provide a directional lock between an inducer receipt section and an inducer section.
- 10 10. The fan hub as recited in claim 9, wherein each of said elongated openings defines an inducer receipt section to receive an inducer section therein.
11. The fan assembly as recited in claim 10, wherein each of said elongated openings defines a blade receipt section to retain a hollow fan blade section within  
15 each of said elongated openings adjacent each of said inducer sections.
12. The fan hub as recited in claim 9, wherein each of said elongated openings extends through a front face and an aft face of said fan hub to define a scalloped outer periphery.  
20
13. The fan hub as recited in claim 9, wherein each of said elongated openings is non-parallel to said axis of rotation.
14. A method of assembling a fan assembly for a tip turbine engine comprising  
25 the steps of:  
(1) mounting an inducer section within each of a multitude of elongated openings formed in a fan hub, the fan hub defining an axis of rotation;  
(2) mounting a fan blade section within each of the multitude of elongated openings, each of the fan blade sections located adjacent and radially  
30 outboard of each of the inducer sections; and  
(3) mounting a tip turbine about an outer periphery of each fan blade section.

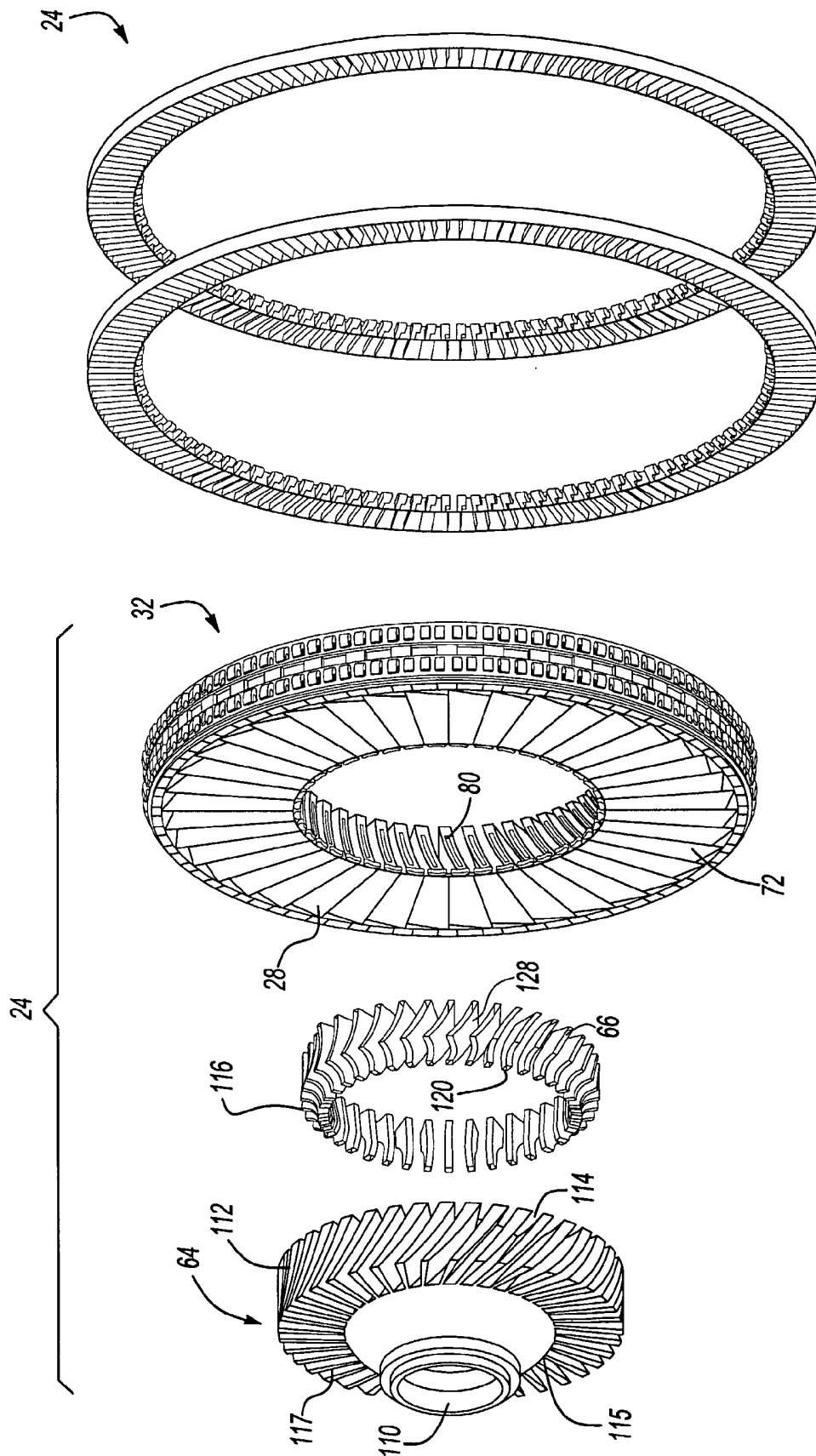
15. A method as recited in claim 14, further comprising the step of:  
fitting the inducer sections into the elongated openings from a front face of  
the fan hub.
- 5 16. A method as recited in claim 14, further comprising the step of:  
fitting the fan blade sections into the elongated opening from a rear face of  
the fan hub.
17. A fan assembly for a tip turbine engine comprising:  
10 a fan hub defining an axis of rotation, said fan hub defining a multitude of  
elongated openings located about an outer periphery of said fan hub; and  
an inducer mounted within said multitude of elongated openings, said  
inducer defining a multitude of inducer passages which turn an airflow from an axial  
airflow direction generally along said fan axis of rotation to a radial airflow  
15 direction, each of said multitude of inducer passages defining an inducer passage  
inlet canted toward a rotational direction of said fan hub at least partially  
overlapping an adjacent inducer passage inlet to provide a directional lock  
therebetween.
- 20 18. The fan hub as recited in claim 17, wherein each of said elongated openings  
defines axially non-symmetrical engagement surface to provide a wedged  
engagement between each of said multitude of elongated openings and a fan blade  
section.



**Fig-1**



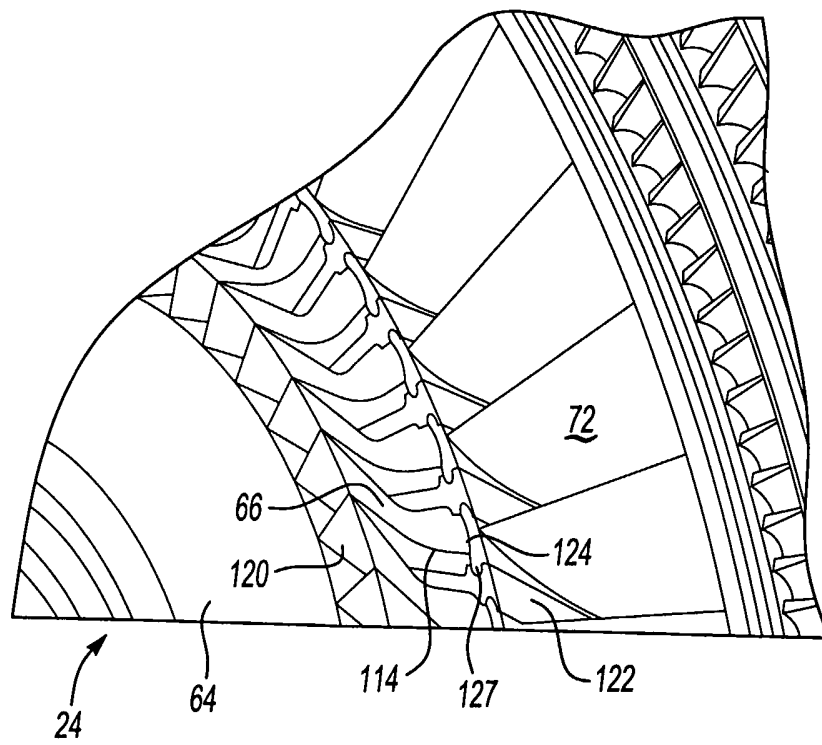
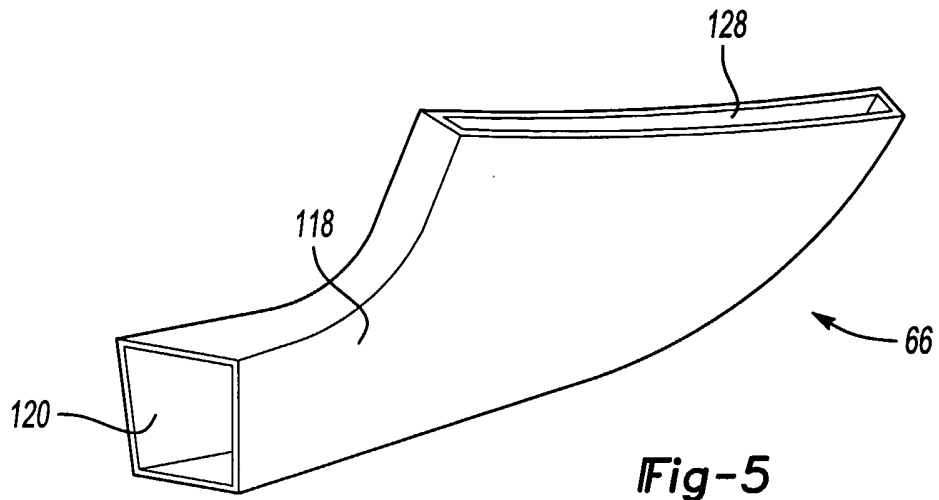
**Fig-2**



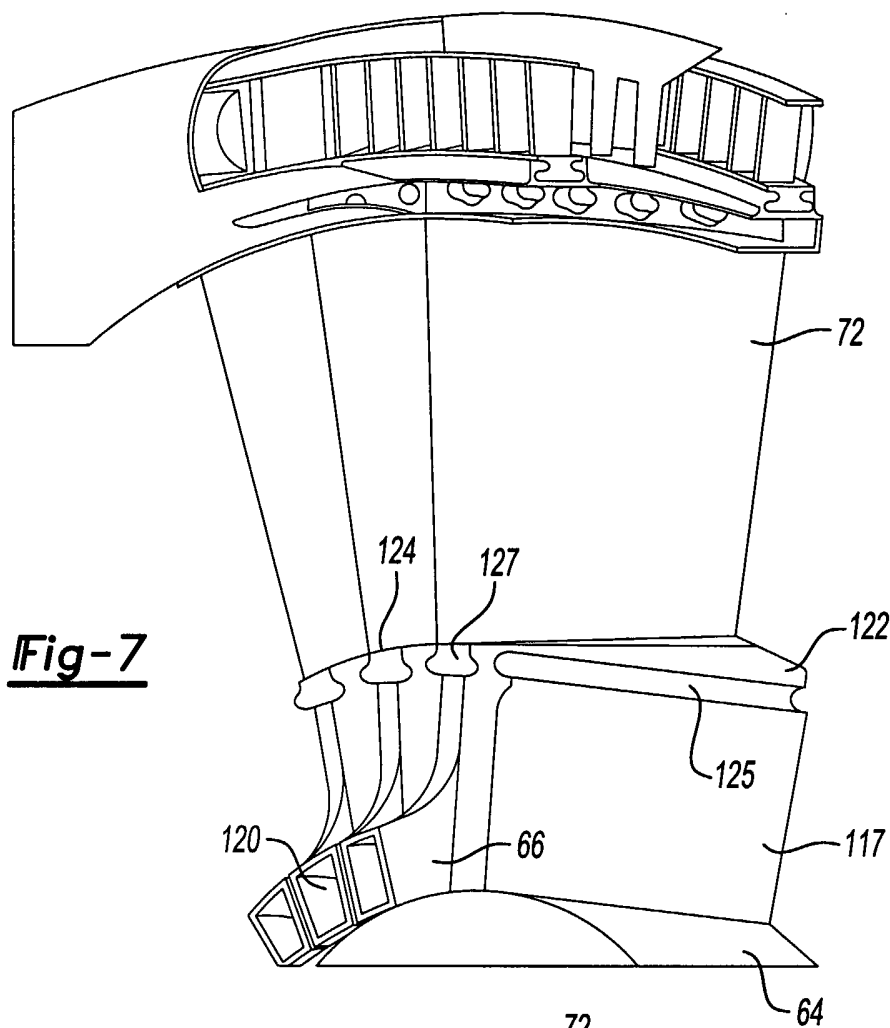
**Fig-4**

**Fig-3**

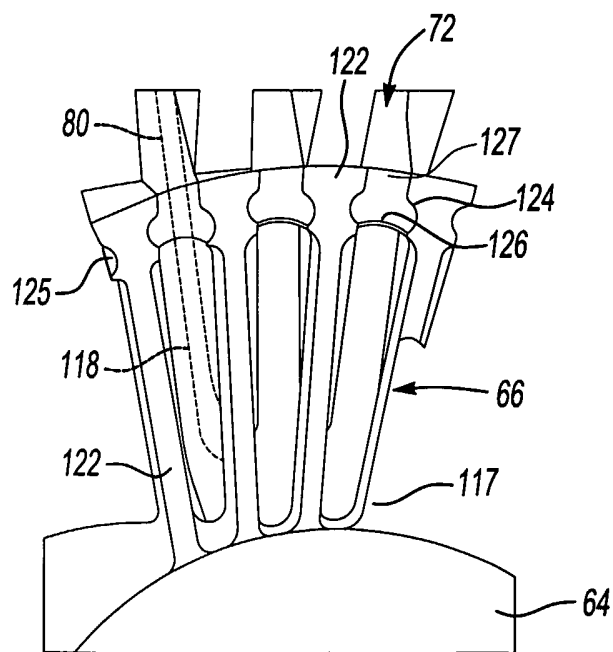




**Fig-6**



**Fig-7**



**Fig-8**

INTERNATIONAL SEARCH REPORT

International Application No  
PCT, JS2004/040168

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> F02C3/073 F02K3/068		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols) F02C F02K F01D F04D F01P		
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 practical, search terms used) EPO-Internal, WPI Data, PAJ		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	the whole document	6, 11
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<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.		
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Date of the actual completion of the international search  15 December 2005		Date of mailing of the international search report  22/12/2005
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer  Koch, R

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International Application No  
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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Information on patent family members

International Application No.

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