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(54) Title of the Invention: **Turbine blades**
Abstract Title: **Turbomachine with radially compressed blades**

(57) A turbomachine apparatus 100 for driving a compressor, comprising at least one rotor stage and at least one retaining element 108, wherein the at least one rotor stage comprises a plurality of blades 104 and is configured to rotate about an axis, and wherein the at least one retaining element is configured to retain the at least one rotor stage with the blades thereof at least partly or wholly in radial compression during rotation thereof. Preferably the retaining element is a shroud ring formed of a circumferentially reinforced fibre material and is configured to force the blades into radial compression. The blades may be formed of a ceramic material such as silicon nitride and be joined to the retaining element by diffusion bonding or brazing. The turbomachine may be a gas turbine engine configured to run on helium.

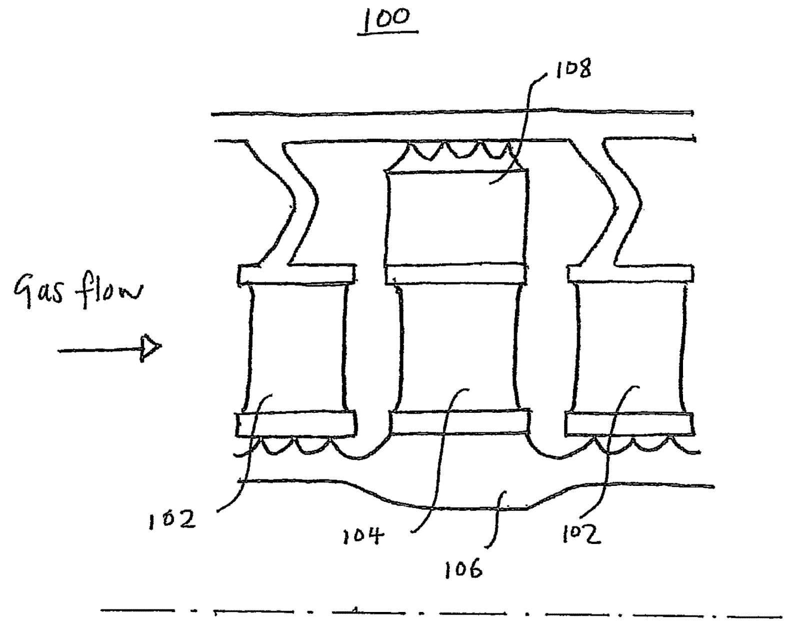

FIG. 1

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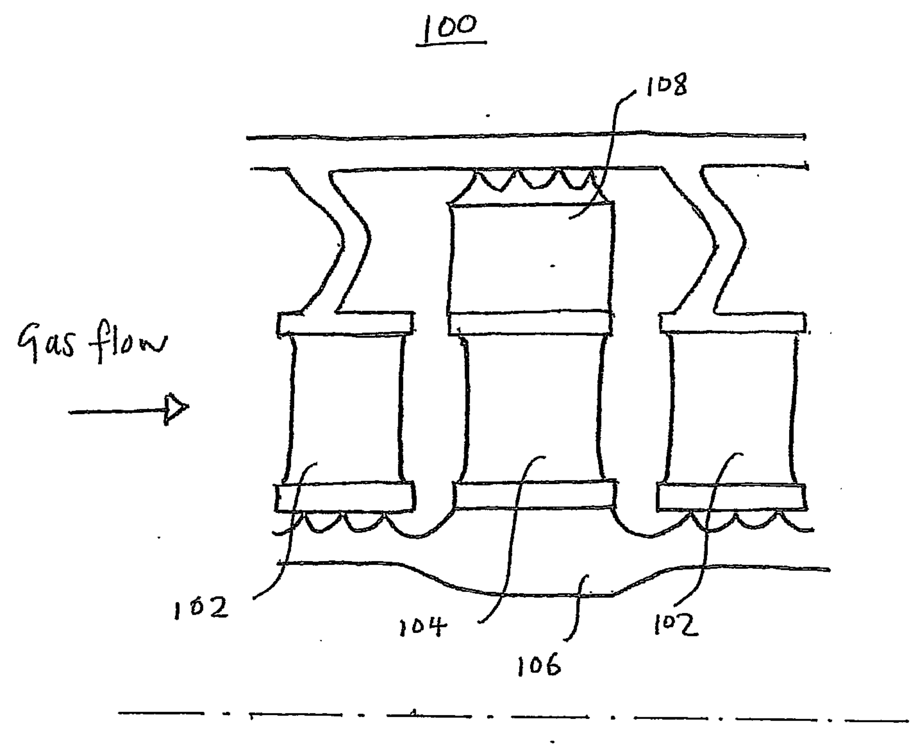

FIG. 1

TURBINE BLADES

FIELD

The present disclosure relates to rotors for turbomachines such as turbine rotors or compressor rotors and engines including such rotors.

BACKGROUND

It is commercially desirable to develop a reusable, high-speed, single stage to orbit (SSTO) aircraft. One example of this may be an aircraft having an engine with two modes of operation: an air-breathing mode and a rocket mode capable of propelling the aircraft to speeds beyond Mach 5, e.g. into orbit.

In such an engine, it is envisaged to provide a helium driven, contra-rotating turbine. The turbine drives a compressor to compress intake air taken from atmosphere when the engine is operating in air-breathing mode. It has been challenging to devise a turbine capable of operating at the very high temperatures needed in such an engine since metals cannot endure the temperatures needed by the cycle design and generally result in heavy components. Relative to metals, ceramic materials are generally of low density and can withstand the temperatures involved. However, their low tensile strength and fracture toughness preclude their use in conventional turbine rotors where the blades are attached via a root fixing at the hub, inducing tensile stresses in the blades due to the centrifugal loading.

SUMMARY

Embodiments of the present disclosure attempt to mitigate at least some of the above-mentioned problems.

In accordance with a first aspect of the disclosure there is provided a turbomachine apparatus (such as a turbine, e.g. for driving a compressor) comprising at least one rotor stage and at least one retaining element, wherein the at least one rotor stage comprises a plurality of blades and is configured to rotate about an axis, and wherein the at least one retaining element is configured to retain the at least one rotor stage with the blades thereof at least partly or wholly in radial compression during rotation thereof.

The at least one retaining element may be configured to support a centrifugal load on the at least one rotor stage.

The at least one retaining element may be a shroud ring.

The at least one retaining element may be formed of a circumferentially-reinforced fibre material.

The at least one retaining element may be formed of carbon-carbon (or a matrix of graphite reinforced with carbon fibres). Other materials of suitable strength and weight/density may also be used to form the retaining element.

The at least one retaining element may be configured to force the plurality of blades into compression.

The plurality of blades may be formed of a ceramic material.

The ceramic material may be silicon nitride.

The at least one rotor stage may further comprise a hub to which the plurality of blades may be fixed.

The turbomachine may be a gas turbine.

The gas turbine may be adapted to run on helium.

The at least one rotor stage may be adapted to receive gas, such as helium, for example between 900K and 1500K. In a typical application, the temperature may be 1200K being an example.

The blades and the at least one retaining element may be separately formed components, which may have been joined together after the separate manufacture thereof.

The blades and the at least one retaining element may be joined by diffusion bonding or brazing or any other suitable material joining process.

The blades and the hub may be separately formed components, which may have been joined together after the separate manufacture thereof.

The blades and the hub may be joined by diffusion bonding.

The blades may be configured to withstand a compressive load applied thereto by the at least one retaining element.

The blades may be configured to withstand the operational temperature of the turbine substantially without degradation due to temperature.

The turbomachine may be a contra-rotating turbine.

Another aspect provides a rotor stage having a plurality of blades and at least one retaining element configured to retain the blades in radial compression during rotation thereof.

In accordance with another aspect of the disclosure, there is provided an engine comprising a turbomachine according to previous aspects of the disclosure.

A further aspect comprises a flying machine including such an engine.

The turbomachine may be a turbine arranged for use in at least an air-breathing mode of the engine.

The turbine runs at extremely high temperatures, which traditional metal alloy parts cannot easily endure. Metal parts are also generally of high weight relative to ceramic materials. Ceramic turbine blades are useful due to the favourable temperature resistance and low density of ceramic materials relative to metallic materials. Despite low tensile strength and the brittle nature of ceramic matrix material, the devices in accordance with the embodiments disclosed herein can withstand the loads and temperatures encountered during operation.

BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments of the disclosure will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 shows in cross-section part of a turbine blade arrangement according to an embodiment.

Throughout the description and the drawings, like reference numerals refer to like parts.

DETAILED DESCRIPTION

FIG. 1 depicts a turbine blade arrangement according to an embodiment. The contra-rotating turbine 100 comprises stator blades 102, rotor blades 104, drum 106 and shroud ring 108. Although in the embodiment a contra-rotating turbine is shown, the invention is also applicable to conventional non-contra-rotating turbines or compressors. Stator blades 102 and rotor blades 104 are formed of a monolithic ceramic material, for example silicon nitride. In other embodiments, other ceramic materials are used. Shroud ring 108 is formed of a circumferential-fibre-reinforced material, specifically carbon-carbon in the form of a carbon fibre reinforced graphite matrix of material. As, in the embodiment, helium is used as the working fluid, the carbon-carbon is not oxidised during operation. Carbon-carbon also has a low density relative to metallic materials and suitably high tensile stress relative to monolithic ceramic materials. In other embodiments, other materials are used. Each of the components is manufactured separately. In other embodiments, components may be manufactured as a single unit. The blades 102 and 104 are joined to the drum 106 and to the shroud ring 108 by diffusion bonding. In other embodiments, other bonding processes are used.

In operation, helium is passed through the stator and rotor stages of the turbine. The helium may arrive at the turbine at 1200K. The rotor rotates at speeds between 5000rpm and 20000rpm. The rotor blades 104 experience a centrifugal load. The load is between 50,000N/kg and 200,000N/kg. The blades 104 are fixed at a hub, in the embodiment at around 450mm from the axis of rotation of the rotor. The hub to tip length of the blades 104, in the embodiment, is around 500mm. The rotor blades 104 are restrained at the tip by the shroud ring 108 and are forced into compression. The shroud ring 108 carries the centrifugal load of the assembly. As ceramics have poor tensile strength and fracture toughness, the shroud ring 108 reduces the risk of failure of the blades 104. The circumferential fibres of the shroud ring 108 support the circumferential load present in the shroud ring.

The excellent properties of ceramics in compression allow the rotor blades 104 to withstand the compressive force. For example, silicon nitride has a compressive strength of around 2500MPa. The risk of failure of the blades is therefore reduced. Ceramic blades 102 and 104 are able to withstand high temperatures. For example, silicon nitride is capable of withstanding temperatures over 1500K. . Therefore the temperature of the helium through the turbine 100 can be increased in relation to conventional turbines. Furthermore, there is no need for cooling of the blades 102 and 104. Higher temperatures of operation also increase the efficiency of the engine, and reduce specific fuel consumption. Silicon nitride is also of low density relative to metallic materials, thus the weight of the engine is reduced. Furthermore, silicon nitride can be manufactured easily and with a generally smooth surface.

Ceramic blades 102 and 104 are also lighter than conventional metal blades. Therefore the centrifugal load on the shroud ring 108 is reduced. The overall weight of the turbine 100 is also reduced. The increased strength to weight ratio of the system permits an increase in turbine tip speed of around 25%, resulting in further improvements in the power to weight ratio of the engine. Joints between the blades 102 and 104, the drum 106 and the shroud ring 108 may be easily manufactured due to the radial clamping load provided by the radial restraint of the shroud ring 108.

This system is applicable to any turbomachine rotor, for example, axial flow compressors and turbines or centrifugal flow compressors and turbines. Application to high hub/tip ratio turbines may be particularly relevant due to the high resistance to buckling of short turbine blades.

Various modifications may be made to the described embodiments without departing from the scope of the invention as defined by the accompanying claims.

CLAIMS:

1. A turbomachine apparatus (such as a turbine, e.g. for driving a compressor) comprising at least one rotor stage and at least one retaining element, wherein the at least one rotor stage comprises a plurality of blades and is configured to rotate about an axis, and wherein the at least one retaining element is configured to retain the at least one rotor stage with the blades thereof at least partly or wholly in radial compression during rotation thereof.

2. A turbomachine apparatus as claimed in claim 1 wherein the at least one retaining element is configured to support a centrifugal load on the at least one rotor stage.

3. A turbomachine apparatus as claimed in any preceding claim wherein the at least one retaining element is a shroud ring.

4. A turbomachine apparatus as claimed in any preceding claim wherein the at least one retaining element is formed of a circumferentially-reinforced fibre material.

5. A turbomachine apparatus as claimed in any preceding claim wherein the at least one retaining element is formed of carbon-carbon.

6. A turbomachine apparatus as claimed in any preceding claim wherein the at least one retaining element is configured to force the plurality of blades into radial compression.

7. A turbomachine apparatus as claimed in any preceding claim wherein the plurality of blades is formed of a ceramic material.

8. A turbomachine apparatus as claimed in claim 7 wherein the ceramic material is silicon nitride.

9. A turbomachine apparatus as claimed in any preceding claim wherein the at least one rotor stage further comprises a hub.

10. A turbomachine apparatus as claimed in claim 9 wherein the plurality of blades is fixed to the hub.

11. A turbomachine apparatus as claimed in any preceding claim wherein the plurality of blades and the at least one retaining element are separately formed components.

12. A turbomachine apparatus as claimed in claim 11 wherein the blades and the at least one retaining element are joined by diffusion bonding or brazing.

13. A turbomachine apparatus as claimed in claim 9, or any preceding claim where dependent upon claim 9, wherein the plurality of blades and the hub are separately formed components.

14. A turbomachine apparatus as claimed in claim 13 wherein the blades and the hub are joined by diffusion bonding or brazing or other suitable material joining process.

15. A turbomachine apparatus as claimed in any preceding claim wherein the turbine is a gas turbine.

16. A turbomachine apparatus as claimed in claim 15 wherein the gas turbine is configured to run on helium or another inert fluid.

17. A turbomachine apparatus as claimed in claim 15 or claim 16 wherein at least one of the at least one rotor stages is adapted to receive gas, such as helium, at around 1200K.

18. A turbomachine apparatus as claimed in any preceding claim wherein the plurality blades is configured to withstand a compressive load applied thereto by the at least one retaining element.

19. A turbomachine apparatus as claimed in any preceding claim wherein the blades are configured to withstand the operational temperature of the turbomachine apparatus substantially without degradation due to temperature.

20. A turbomachine apparatus as claimed in any preceding claim which comprises a contra-rotating turbine.

21. An engine including a turbomachine apparatus as claimed in any previous claim.

22. An engine as claimed in claim 21 wherein the turbomachine apparatus is a turbine arranged for use in at least an air-breathing mode of the engine.

23. A flying machine including an engine as claimed claim 21 or claim 22.

Intellectual Property Office

Application No:	GB1318103.7	**Examiner:**	Kingsley Robinson
Claims searched:	1-23	**Date of search:**	24 April 2014

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-23	WO2013/023507 A1 (UNIV TSINGHUA)
X	1-23	EP0219140 A2 (BOEING CO)
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Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Intellectual Property Office

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

F01D

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
F01D	0005/22	01/01/2006