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U1S S1848 S1987 S2006

(56) Documents Cited:
GB 2187237 A **GB 1085390 A**
GB 0936504 A **US 4558987 A**
Rolls Royce, "The jet engine," fourth edition, 1986, Rolls Royce plc, page 23

(58) Field of Search:
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INT CL^7 **B64C, F04D**
Other: **ONLINE: OPTICS, WPI, EPODOC, JAPIO**

(54) Abstract Title: **A gas turbine engine lift fan with tandem inlet guide vanes**

(57) A gas turbine engine or lift fan has an intake section provided with an array of variable inlet guide vanes 48 mounted downstream of an array of fixed guide vanes 46. For at least some angles of adjustment of the variable guide vanes 48, they have an axial partial overlap with the fixed guide vanes 46. The variable guide vanes 48 may be pivotable about an intermediate axis 84 along their chord. The variable guide vanes 48 may be spaced circumferentially such that there is a circumferential overlap between the trailing edge 82 of one variable vane 48 and the leading edge 80 of an adjacent variable vane 48 when the variable vanes 48 are adjusted to their greatest angle of incidence. There may be fewer fixed vanes 46 than variable vanes 48 in the array, typically the ratio of fixed vanes to variable vanes being 3:1.

Fig.5.

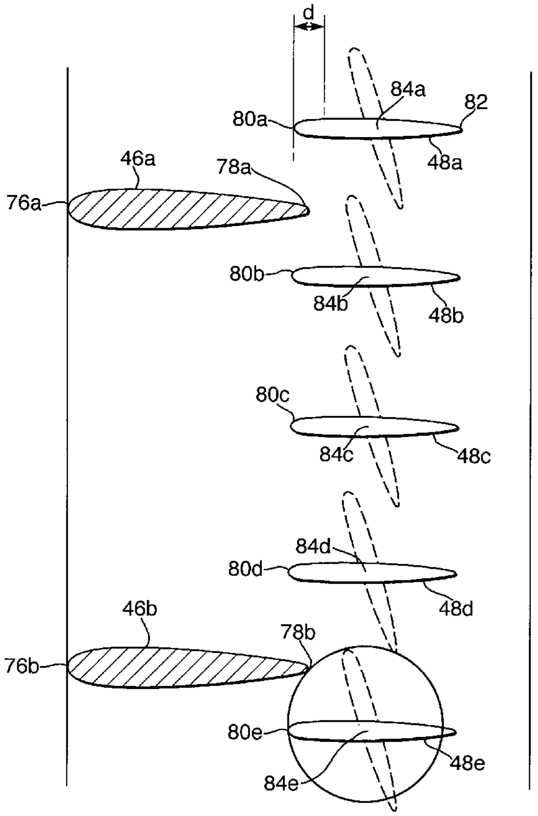

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Fig.1.

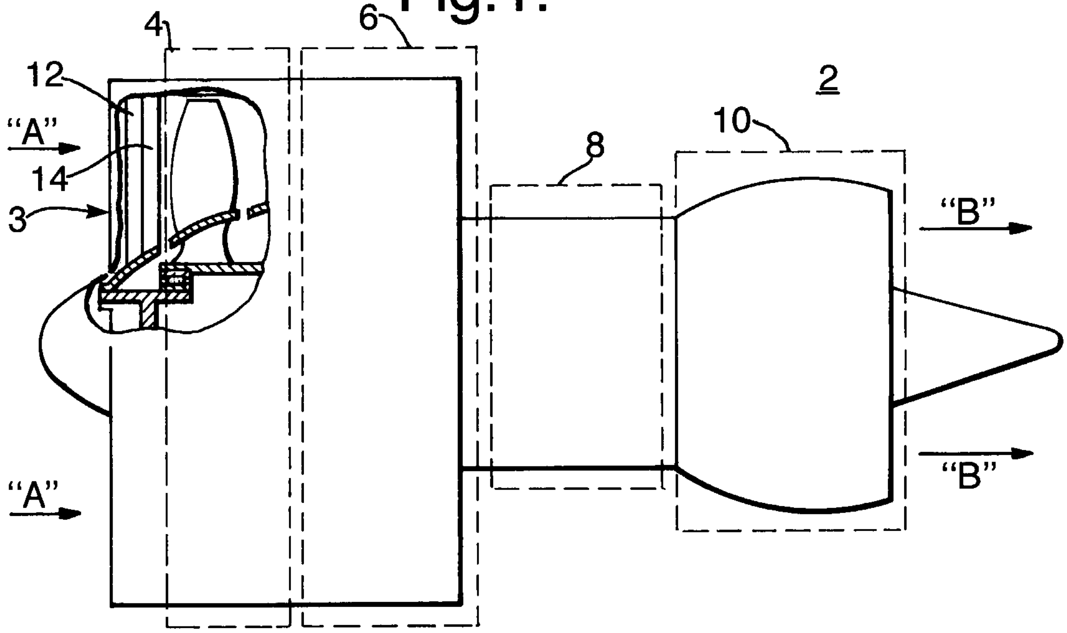


Fig.2.

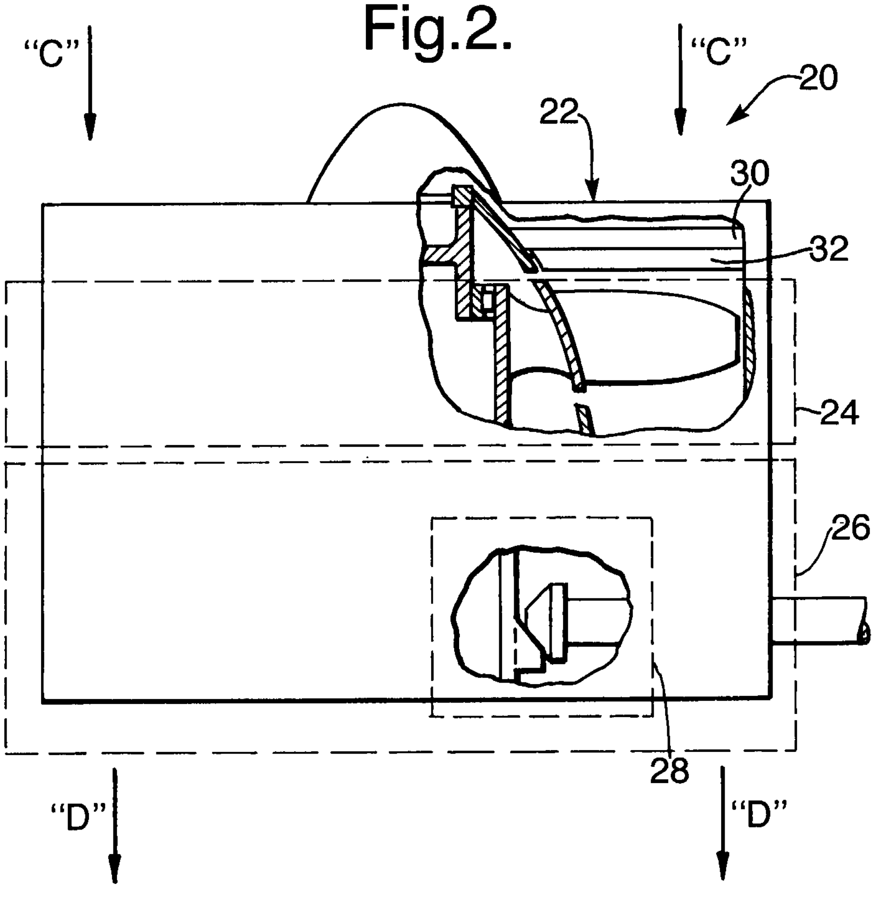


Fig.3.

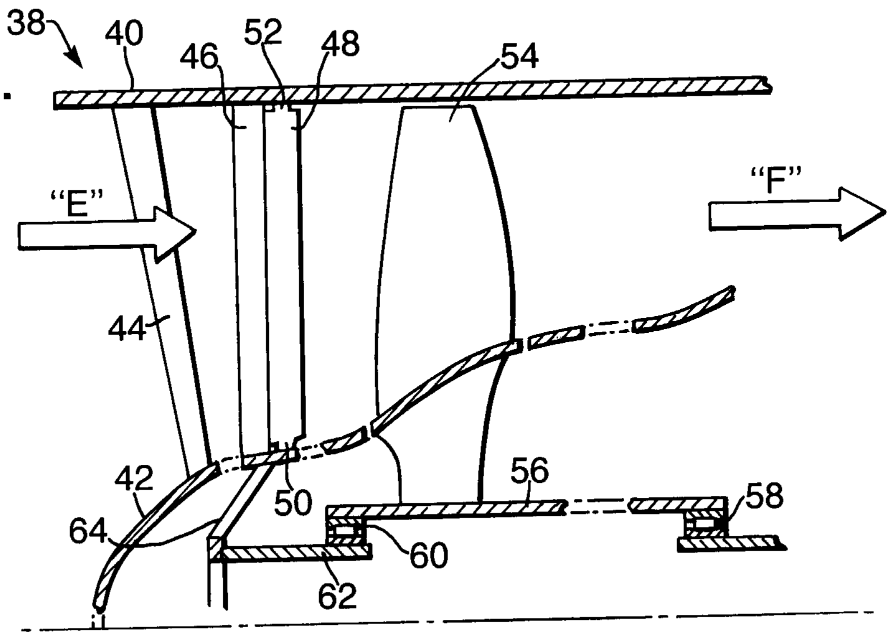


Fig.4.

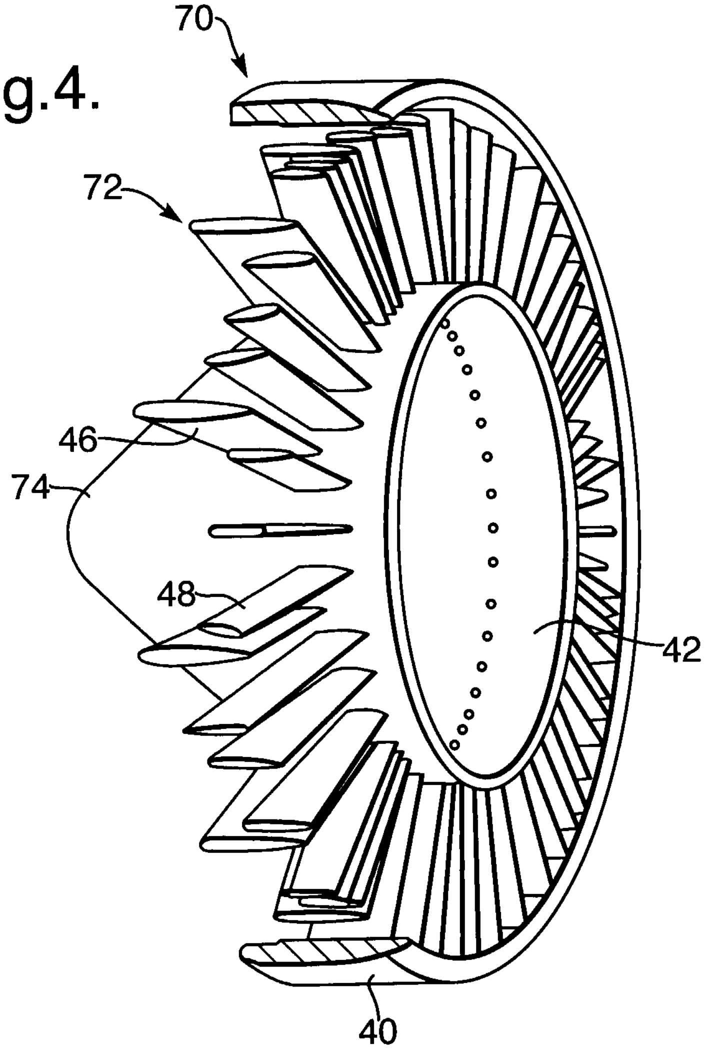
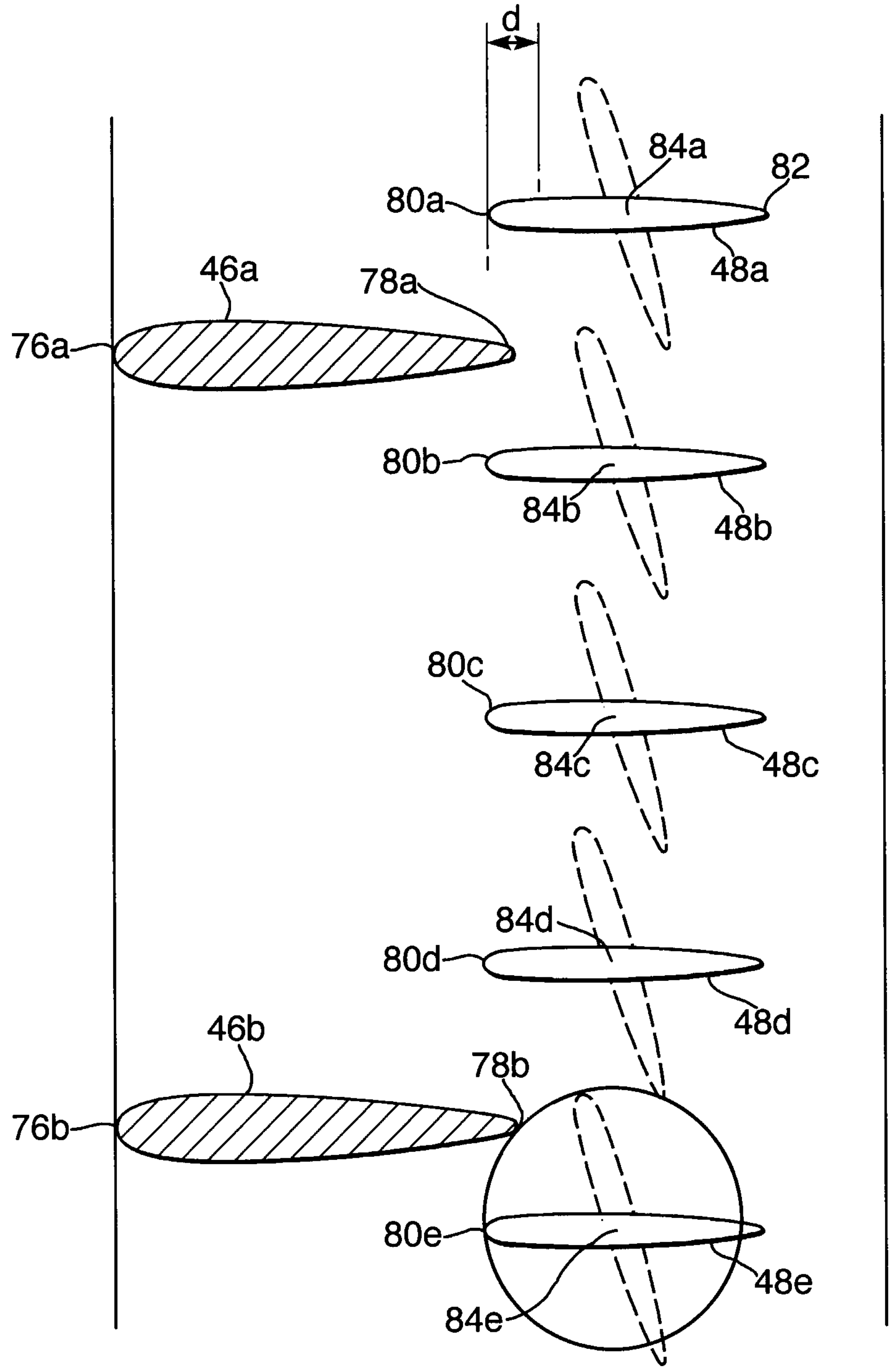


Fig.5.


d
84a
82
80a
48a
46a
78a
76a
80b
84b
48b
80c
84c
48c
84d
80d
48d
46b
78b
76b
80e
48e
84e

A GAS TURBINE ENGINE OR LIFT FAN WITH VARIABLE INLET GUIDE VANES

The present invention relates generally to a gas turbine engine or lift fan, and particularly to such an engine or fan having variable guide vanes or stator vanes. It is known that each stage of a multi stage compressor in a gas turbine engine has certain airflow characteristics that are different from those of its neighbour. In order to maximise efficiency the characteristics of any one stage must be carefully matched with those of the neighbouring stages. This is not difficult to achieve for the design mass flow, pressure ratio and rotational speed, but certain difficulties are encountered when it is desired to obtain reasonable matching between adjacent stages when the engine is to be operated over a wide range of conditions. This is frequently encountered in gas turbines used in aircraft.

It is known that if the operating conditions of the compressor blade vary too much from the design conditions the airflow over the blades will break down resulting in the blades stalling if the angle of incidence of the downstream blades becomes too great in relation to the direction in which air is delivered from the preceding stage. This can occur at either end of the range, that is a positive incidence stall or a negative incidence stall may be induced. Positive incidence stall is a typical problem of a front stage compressor blade at low speeds. It is known, in order to accommodate the changing air swirl velocity component of the inlet air to use variable inlet guide vanes (stator vanes) to match the speed of the compressor. As the compressor speed falls below its design values these stator vanes are progressively turned in order to maintain a suitable angle of incidence onto the following rotor blades.

It is known that arrangements in which the entire stator vane is turned leads to some problems because the variation of incidence angle at the leading edge causes a departure from the optimal values resulting in significant losses, including loss of some of the potential benefits. In cases where the swirl angle of air entering the front of a stator ring is substantially constant it has been known to overcome the problems relating to variation in incidence angle by the use of variable camber guide vanes with fixed leading edge incidence. Such vanes are known, for example, from GB patent 736796 of the same applicant. These known stator blades are divided longitudinally into a fixed leading edge portion and relatively pivotable trailing edge for imparting the adjustable swirl characteristics. The trailing parts of the vanes are pivotally mounted in the outer engine casing structure, and may be mounted also in the inner stator structure. The abrupt transition in the airfoil surfaces when the variable part of the vane is adjusted to its maximum inclination may, however, precipitate breakaway of the airflow as discussed above.

An attempt to overcome this problem was made in US5314301 which describes a variable camber stator vane for a gas turbine engine comprising a plurality of vane sections including a leading edge section, at least one mid-chord section and a trailing edge section, the sections being sequentially mounted wherein each section is pivotably mounted relative to its neighbour, a first of the vane sections having a shaft extending radially through the engine casing to receive an actuating input, a mechanism coupling the first vane section with the remaining vane sections for coordinated movement in a predetermined relationship, and an input lever mounted on the shaft for actuating the coupling mechanism towards the relative disposition of the vane section whereby to change the camber of the vane. Although this variable vane has some advantages, in practice the complexity of the components of each individual vane and the resultant expense militate against the adoption of such vanes in many circumstances.

The present invention seeks to provide a gas turbine engine or lift fan having variable inlet guide vanes (stator vanes) which are turnable as a whole rather than in sections, and in which arrangements are made to overcome the above-described disadvantages due to the changing angle of incidence of the air entering the compressor, at least to some extent.

According to one aspect of the present invention there is provided a gas turbine engine or lift fan having an intake section provided with an array of variable inlet guide vanes variable so as to vary the air swirl velocity component of inlet air, in which the variable inlet guide vanes are mounted downstream of an array of fixed guide vanes in such a position that, at least for some angles of adjustment of the variable inlet guide vanes they have an axial partial overlap with the fixed guide vanes.

Hereinbefore and hereafter a radial direction is taken to mean direction perpendicular to the longitudinal axis of the engine, and an axial direction is taken to mean a direction parallel to the longitudinal axis of the engine.

In the context of the present invention, the expression "axial partial overlap" of the fixed guide vanes and the variable guide vanes is taken to mean that, at least for some angles of adjustment of the variable inlet guide vanes, the leading edge of the variable guide vanes are axially forward of the trailing edge of the fixed guide vanes.

It is preferred, as discussed above, that the variable guide vanes are pivotable about an intermediate axis along their chord to provide all-moving airflow control surfaces. The overlap with the fixed stator vanes and the positioning of the pivot axis is chosen carefully such that no contact between the variable guide vanes and the fixed stator vanes occurs for any angle of adjustment of the variable guide vanes.

Moreover, it is preferred that the variable guide vanes are spaced circumferentially such that there is a circumferential overlap between the trailing edge of a variable guide vane and the leading edge of an adjacent variable guide vane in the array when the variable vanes are adjusted to their greatest angle of incidence.

Likewise, it is particularly advantageous if each fixed guide vane has an associated variable guide vane the leading edge of which lies to one side of the fixed guide vane, with respect to a radial plane passing through the axis of the array of guide vanes, when the variable guide vane is at its smallest angle of incidence, and to the other side of the fixed guide vane when it is at its greatest angle of incidence. In other words, when the variable guide vane is adjusted to its greatest angle of incidence its leading edge defines a slot between itself and the trailing edge of the associated fixed guide vane rather in the manner of a slotted flap in a wing. This, then, tends to counter any tendency of the variable guide vanes to stall as a consequence of excess angle of incidence.

As a structural measure it is preferred that the variable guide vanes are pivotally mounted between a radially inner annular support member within the compressor casing, and the casing itself.

In a preferred embodiment of the invention the array of fixed guide vanes contains fewer vanes than the array of variable guide vanes. The ratio of variable guide vanes to fixed stator vanes may, for example, be in the region of 3:1.

In another aspect, a gas turbine engine or lift fan has an intake section with fixed and variable inlet guide vanes, in which the axial dimension of the engine is reduced by positioning the fixed and variable guide vanes with a partial axial overlap.

In such an engine the arrays of fixed and variable guide vanes may have a different pitch from one another.

One embodiment of the present invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a pictorial representation of a gas turbine engine comprising a compressor unit according to the present invention;

Figure 2 is a pictorial representation of a remotely powered compressor unit ("lift fan") in accordance with the present invention;

Figure 3 shows an enlarged view of a fixed inlet guide vane and a variable inlet guide vane as shown in Figure 1 and Figure 2;

Figure 4 is a schematic perspective view of an intake section of a gas turbine engine or lift fan provided with an array of vanes in accordance with the present invention; and

Figure 5 is a developed view from a radial direction of a part of the arrays of stationary and variable stator vanes, as shown in Figure 4.

Referring now to Figures 1 to 5 there is shown a stator vane arrangement for a gas turbine engine or lift fan, having a fairly severe axial length restriction on the inlet guide vane stage. In such an engine the need for a large aerodynamic turning angle in the fan inlet cannot be accommodated using standard vane arrangements. The large turning angle dictates a variable inlet guide vane arrangement, but multiple section guide vanes of known type having a fixed leading edge and hinged trailing edge are not sufficiently efficient, especially because the hinge lines are difficult to seal and almost inevitably result in leakage flow between vane pressure and suction surfaces.

Figure 1 illustrates the main sections of a gas turbine engine 2. The overall construction and operation of the engine 2 is of a conventional kind, well known in the field, and will not be described in this specification beyond that necessary to gain an understanding of the invention. For the purposes of this description the engine is divided up into a number of sections – a compressor unit comprising an intake section 3 upstream of a fan section 4 and a compressor section 6, a combustor section 8 and a turbine section 10. Air, indicated generally by arrow “A”, enters the engine 2 via the intake section 3 and passes over a fixed inlet guide vane 12 and then a variable inlet guide vane 14, before being compressed by the fan 4 and moving downstream to the compressor 6. This further pressurises the air, a proportion of which enters the combustion section 8, the remainder of the air being employed elsewhere. Fuel is injected into the combustor airflow, which mixes with air and ignites before exhausting out of the rear of the engine, indicated generally by arrow “B”, via the turbine section 10.

Figure 2 illustrates a fan unit 20 that is driven remotely from an engine. It does not provide compressed air to the engine but is used to generate propulsive thrust remote from the propulsion unit. In figure 2 the fan unit 20 is shown mounted with its central axis vertical. This is only one embodiment, drawn here for illustrative purposes. The fan unit may be mounted in any orientation.

For the purposes of this description the fan unit 20 is divided up into a number of sections – an intake section 22 upstream of a fan rotor section 24 and a compressor section 26 and a drive shaft and gearing arrangement 28, the latter being shown in a cutaway view. Air, indicated generally by arrow "C", enters the fan unit 20 and passes over a fixed inlet guide vane 30 and then a variable inlet guide vane 32 before being compressed by the fan rotor section 24. A cutaway section reveals the location of the fixed and variable inlet guide vanes 30,32 at the entry to the fan rotor section 24. The air is compressed by the fan rotor 24 and moves downstream to the compressor section 26, where it is further pressurised before being exhausted from the fan unit 20, indicated generally by arrow "D".

An enlarged view of a fan assembly 38 common to the engine 2 and fan unit 20 is presented in Figure 3. Air, indicated generally by arrow "E", enters the fan unit 38, constrained on one side by an outer wall 40 (or casing) and on the other by a discontinuous inner wall 42 (or casing). Support for the inner wall 42 is provided by an array of support members 44 which extend radially towards, and are in communication with, the outer wall 40. Moving downstream of the support members 44, an array of fixed inlet guide vanes 46 is mounted upstream of an array of variable inlet guide vanes 48 such that the both arrays of vanes 46,48 extend radially out from the inner wall 42 towards, and are communication with, the outer wall 40. Each of the variable inlet guide vanes 48 is provided with an inner spindle 50 and an outer spindle 52 which locate in the inner wall 42 and the outer wall 40 respectively. The inner wall 42 and the outer wall 40 act as support means for the fixed and variable inlet guide vanes 46,48. The inner wall 42 comprises several static and rotatable sections, the details of which are not required here to appreciate the invention. The air is pressurised by an annular array of fan rotor blades 54 and then passes downstream, as indicated generally by arrow "F".

The fan blades 54 are fixedly joined to a shaft 56 that is rotatable about the central axis of the fan assembly 38. The shaft 56 is rotatably supported by bearings 58 and 60 at the downstream and upstream ends respectively. The bearing 60 is supported by a non-rotatable support structure 62 which is in communication with a non-rotatable section of the inner wall 42 via a static member 64.

In Figure 4 the intake section 3,22 common to the gas turbine engine 2 and fan unit 20 is generally indicated 70. Features common to the fan unit 20 presented in Figure 2 and Figure 3 and the intake section 3,22 presented in Figure 4 will be referred to using common integer numbers. For the sake of clarity the integer numbers of features common to the engine 2 will not be used in the following description. Also for clarity some of the features present in Figures 1 to 3 have been omitted.

The intake 70 is housed within the fan casing 40 and Figure 4 illustrates only a first array of stator vanes, generally indicated 72, comprising an array of fixed guide vanes 46 and an array of variable guide vanes 48, both sets being mounted between the fan casing 40 and an inner wall 42 which, as illustrated in Figure 4, may in fact incorporate a forwardly projecting inlet nacelle 74 of generally conical shape.

The connection between the fixed vanes 46 and the fan casing 40, and likewise the mounting of the variable vanes 48 on the fan casing 40 and/or on the inner wall 42 will not be described in detail. It is sufficient to state here that the fixed vanes 46 may form part of the support structure for rotatable components of the compressor, and that the variable vanes 48 are each turnable about a radial axis, parallel to their length, and are linked together by a mechanism (not shown) so that all the vanes turn through the same angle simultaneously when changes are made.

As can be seen in Figure 5, the array 48 of variable vanes (of which five are illustrated in Figure 5, identified 48a – 48e) are mounted at a closer pitch than the fixed vanes in the array 46 (two of which are illustrated in Figure 5, indicated 46a, 46b). Each of the stator vanes 46 has a leading edge 76 and a trailing edge 78 (individually identified by the subscripts a,b to identify the individual vanes illustrated in Figure 5). Likewise each of the variable vanes 48 has a leading edge 80 and a trailing edge 82 (again, individually identified with the subscripts a-e in Figure 5).

The pitch ratio between the fixed guide vanes 46 and the variable guide vanes 48 is, in this embodiment, 3:1 and the variable vanes 48 are arranged, as shown in Figure 5, such that there is an axial overlap d between the leading edge of the variable vanes 48 and the trailing edge of the fixed stator vanes 46.

The variable vanes 48 are pivoted about a respective axis, 84 (identified 84a - 84e for the respective variable vanes 48a-48e) at an approximately mid-chord location.

With the pitch ratio of 3:1 as discussed above, the variable guide vanes 48 can be considered to fall into two subgroups, namely a first subgroup represented by the vanes 48b, 48e which can each be considered to be "associated" with a respective fixed stator vane 46a, 46b respectively, and a second subgroup, comprising the two vanes between each consecutive such "associated" variable vane, represented in Figure 5 by the variable vanes 48c, 48d.

The circumferential position of the "associated" variable vanes 48b, 48e in relation to the fixed vanes 46a, 46b are such, taking account of the axial overlap d between the trailing edges 78 of the fixed vanes 46 and the leading edges 80 of the variable vanes 48, that each associated leading edge 80 sweeps past the trailing edge 78 of the associated fixed vane upon variation of the inclination of the variable vane 48. The inclination of the variable vane 48 varies between a minimum incidence angle (in relation to the axial inlet) which is approximately parallel to the stator vanes 46, and in which the leading edge 80 of the associated variable vane 48 is to one side (namely below as viewed in Figure 5) of the fixed stator vane 46, to a position on the other side of the chord line of the fixed stator vane 46 when the variable vane 48 is in its extreme inclination position of maximum incidence. In this position the two "associated" variable vanes, 48b, 48e are located with their leading edges 80b, 80e slightly behind the associated trailing edges 78a, 78b of the fixed stator vanes 46a, 46b with the chord line of the variable stators 48b, 48e crossing the rearward projection of the chord line of the associated stator 46a, 46b so that the "associated" variable vanes 48b, 48e are positioned somewhat in the manner of a slotted flap of an aerofoil section. This allows a higher inclination of the variable vanes than would otherwise be achievable without risk of stalling so that a wider range of operating conditions can be accommodated to create an appropriate swirl of the incoming air to direct it appropriately at the succeeding rotor.

CLAIMS

1 A gas turbine engine or lift fan having an intake section provided with an array of variable inlet guide vanes variable so as to vary the air swirl velocity component of inlet air, in which the variable inlet guide vanes are mounted downstream of an array of fixed guide vanes in such a position that, at least for some angles of adjustment of the variable inlet guide vanes they have an axial partial overlap with the fixed guide vanes.

2 A gas turbine engine or lift fan as claimed in Claim 1, in which the variable guide vanes are pivotable about an intermediate axis along their chord (all-moving airflow control surfaces).

3 A gas turbine engine or lift fan as claimed in Claim 1 or Claim 2, in which the variable guide vanes are spaced circumferentially such that there is a circumferential overlap between the trailing edge of one variable vane and the leading edge of an adjacent variable guide vane in the array when the variable vanes are adjusted to their greatest angle of incidence.

4 A gas turbine engine or lift fan as claimed in any preceding claim, in which each fixed guide vane has an associated variable guide vane the leading edge of which lies to one side of the fixed guide vane, with respect to a radial plane passing through the axis and the chord of the fixed guide vane, when the variable guide vane is at its smallest angle of incidence, and to the other side of the fixed guide vane when it is at its greatest angle of incidence.

5 A gas turbine engine or lift fan as claimed in any of Claims 1 to 3, in which the variable vanes are pivotally mounted on a radially inner annular support member within a fan casing.

6 A gas turbine engine or lift fan as claimed in any preceding claim, in which there

are fewer fixed vanes in the fixed vane array than variable guide vanes in the variable vane array.

7 A gas turbine engine or lift fan as claimed in Claim 5, in which the ratio of variable vanes to fixed vanes is 3:1.

8 A gas turbine engine or lift fan having an intake section with fixed and variable inlet guide vanes, in which the axial dimension of the engine or fan is reduced by positioning the fixed and variable guide vanes with a partial axial overlap.

9 A gas turbine engine or lift fan as claimed in Claim 8, in which the arrays of fixed and variable guide vanes have a different pitch from one another.

10 A gas turbine engine or lift fan as claimed in any preceding claim, in which there are eleven fixed guide vanes in the array thereof.

11 A gas turbine engine or lift fan as claimed in any preceding claim, in which there are thirty three variable guide vanes in the array thereof.

12 A gas turbine engine or lift fan substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

The Patent Office

INVESTOR IN PEOPLE

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Application No: GB 0319757.1
Claims searched: 1-12
Examiner: Dr. Simon Coldrick
Date of search: 28 January 2004

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	
Y	1-5, 8	GB 0936504 A	(Rolls)(fig. 2 noting variable vanes 22 and fixed struts 18)
Y	1,2,5-11	GB 2187237 A	(MTU)(fig. 1 noting overlapping vanes 11 and 12)
Y	1-11	US 4558987 A	(Mannesmann)(fig. 1 noting overlapping vanes 1, 2 pivoting about an intermediate axis 4)
A		GB 1085390 A	(VEB)(fig.4 noting overlapping vanes 4 and 7)
Y	1-11	Rolls Royce, "The jet engine," fourth edition, published 1986, Rolls Royce plc, see page 23 fig 3-7.	

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.

Field of Search:

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

F1V, F1C

Worldwide search of patent documents classified in the following areas of the IPC^{7}:

F04D, B64C

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

ONLINE: OPTICS, WPI, EPODOC, JAPIO