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Demolis et al.(10) **Pub. No.: US 2014/0147278 A1**(43) **Pub. Date: May 29, 2014**(54) **VARIABLE-PITCH NOZZLE FOR A RADIAL TURBINE, IN PARTICULAR FOR AN AUXILIARY POWER SOURCE TURBINE****Publication Classification**(51) **Int. Cl.**
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USPC **416/147**(75) Inventors: **Jacques Demolis**, Lons (FR); **Laurent Minel**, Pau (FR); **Hubert Hippolyte Vignau**, Nay (FR)(73) Assignee: **TURBOMECA**, Bordes (FR)(21) Appl. No.: **14/122,490**(22) PCT Filed: **May 31, 2012**(86) PCT No.: **PCT/FR2012/051217**

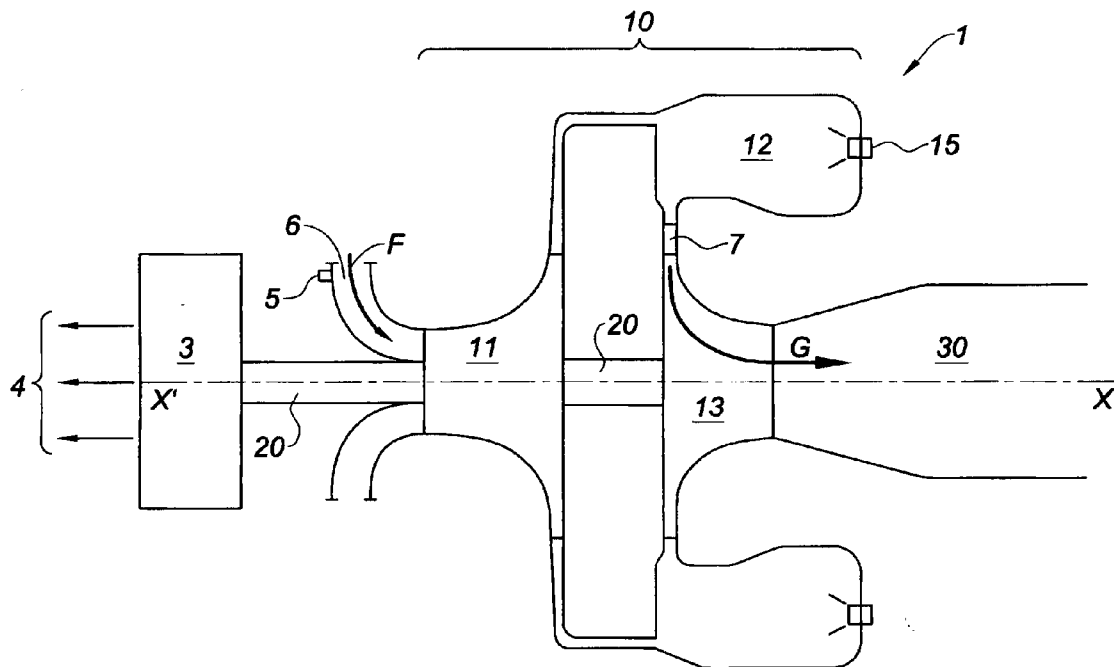
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(57) **ABSTRACT**

A radial turbine nozzle of a turbine engine rotating about a central axis includes a first annular array of fixed blades and a second annular array with a same number of variable-pitch blades. The blades have pressure and suction surfaces. Each variable-pitch blade is connected to cups and is configured to be rotated by a controller about a geometric axis connecting centers of the cups. Each variable-pitch blade is mounted at a distance from the axis of the cups such that this axis of rotation is positioned facing the suction surface of the blade and substantially closer to a trailing edge than to a leading edge of that blade. The nozzle can modify the reduced flow admitted by a radial turbine in accordance with requirements of a thermodynamic cycle and produce a seal in an area of maximum load of the nozzle blades.



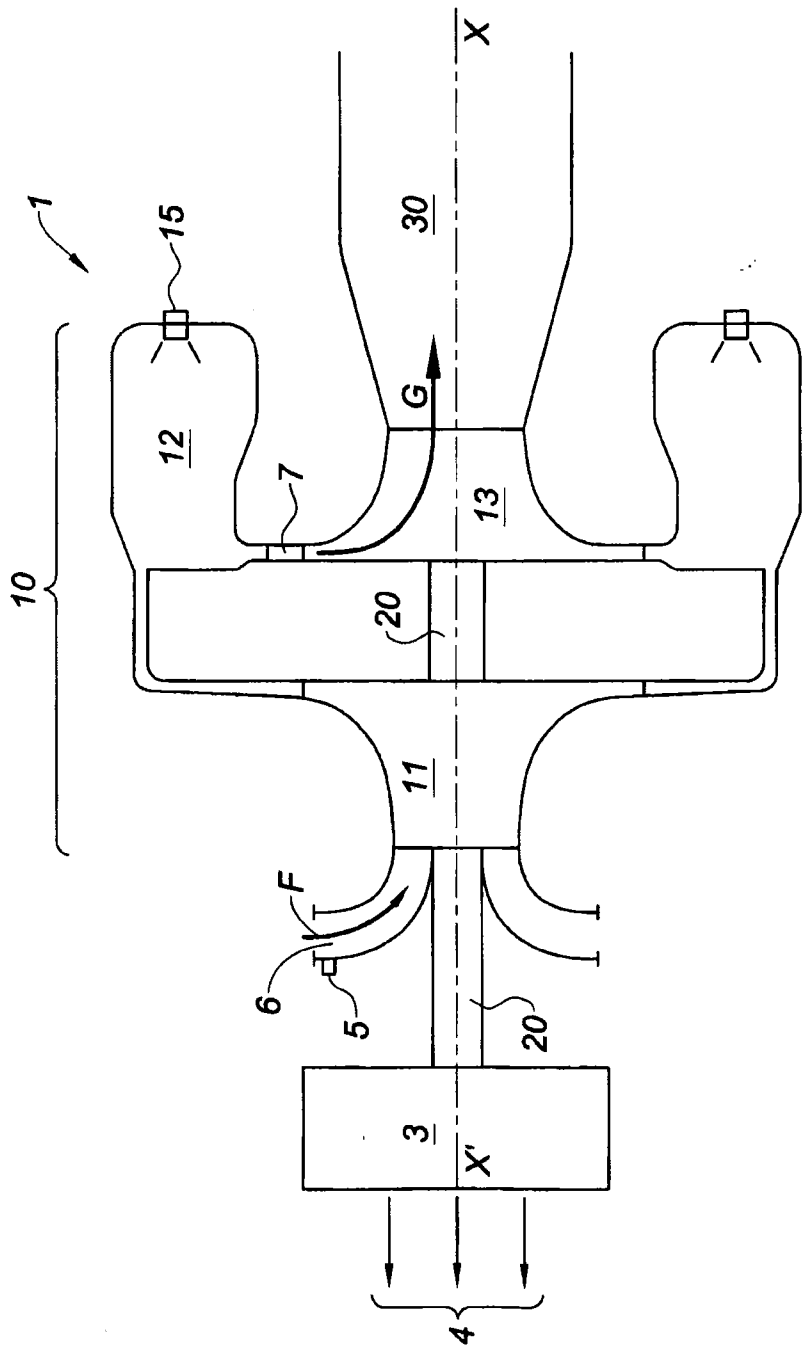


Fig. 1

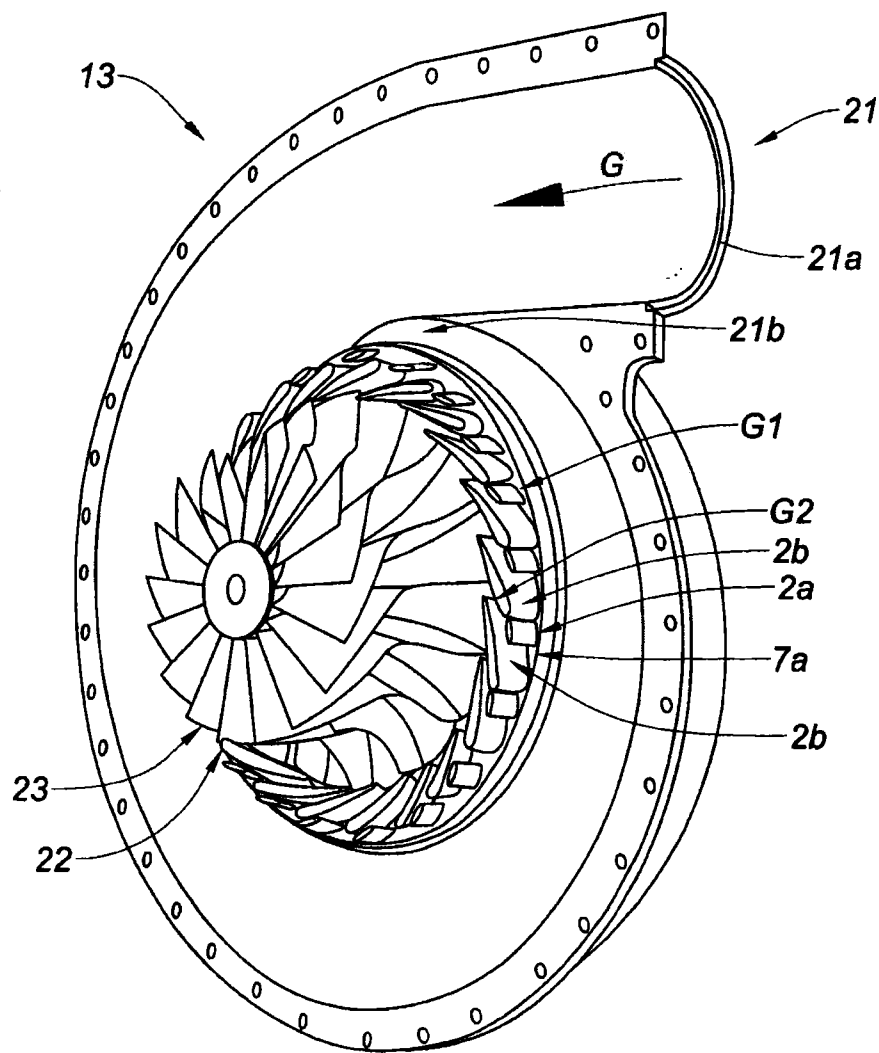


Fig. 2

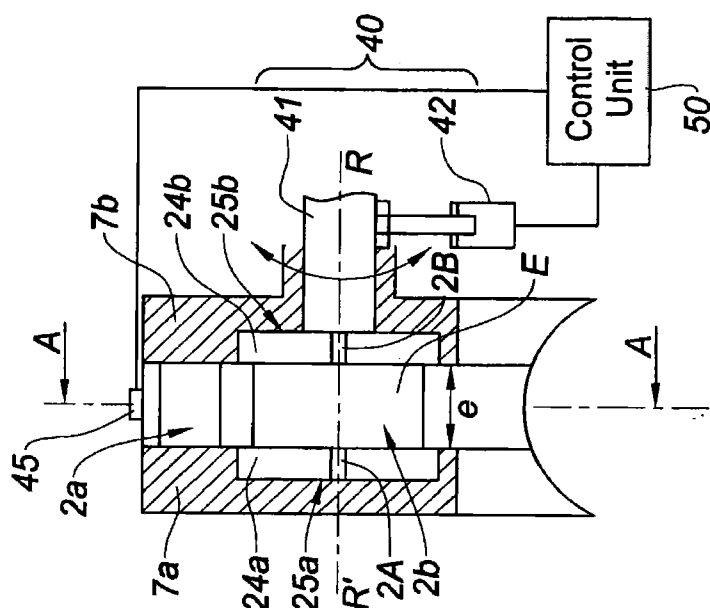


Fig. 3b

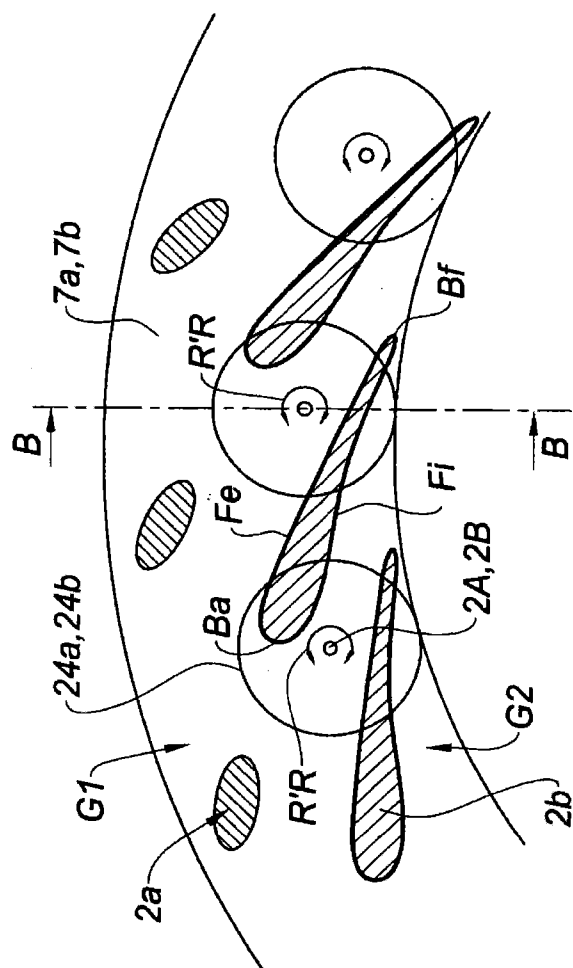


Fig. 3a

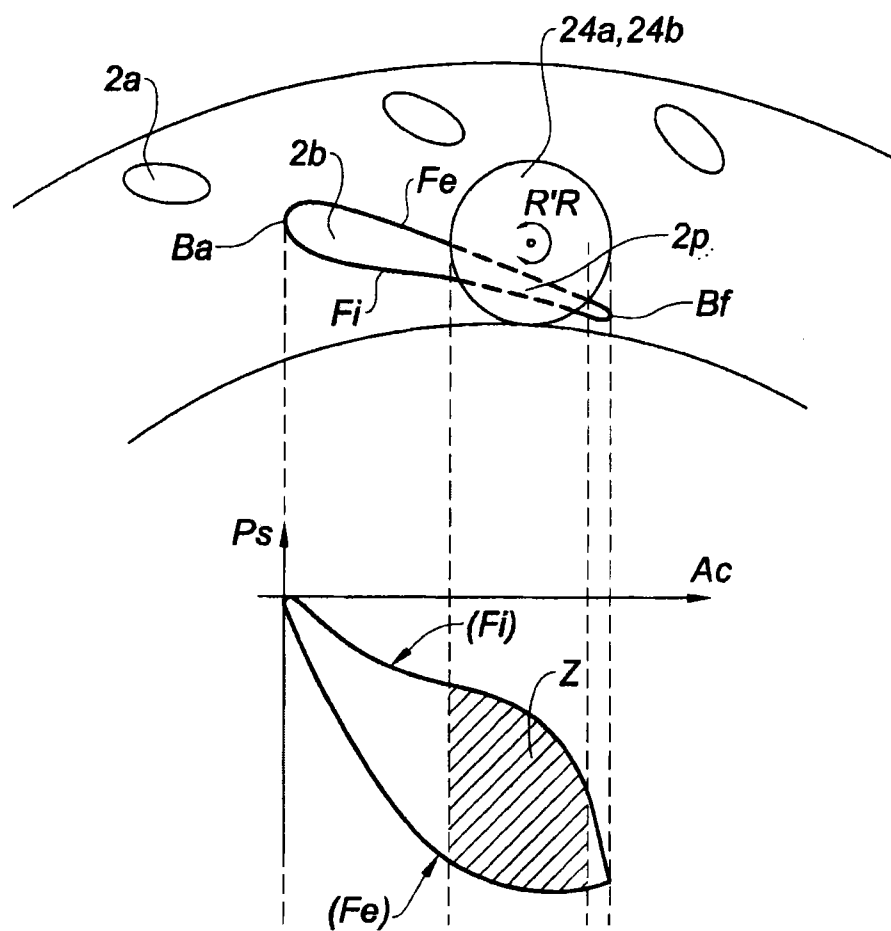


Fig. 4

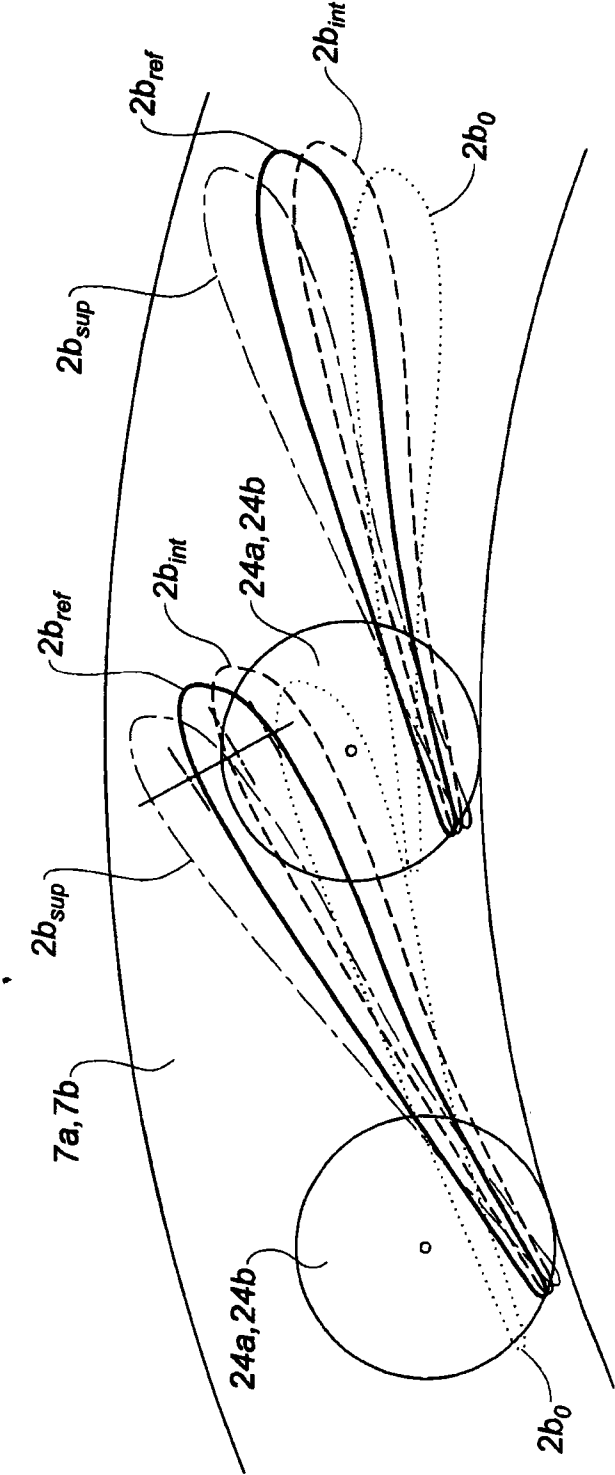


Fig. 5

VARIABLE-PITCH NOZZLE FOR A RADIAL TURBINE, IN PARTICULAR FOR AN AUXILIARY POWER SOURCE TURBINE

TECHNICAL FIELD

[0001] The invention relates to a variable-pitch radial turbine nozzle and particularly, but not exclusively, a nozzle for a turboshaft engine or auxiliary power source turbine.

[0002] The field of the invention is that of gas distribution in the turbines of turbine engines and, particularly, adapting fluid flow to reduce fuel consumption, particularly specific fuel consumption (abbreviated to Cs) under partial load, and improving the operability of engines, particularly turboshaft engines or auxiliary power units (abbreviated to APUs). The term turbine engine refers to turboshaft engines, APU-type units and turbochargers.

[0003] An APU is an energy source that makes it possible, for instance, to start the main engines of aircraft and provide non-propulsive power (cabin pressurisation power, electrical and/or hydraulic power). Some secure APUs can also act while in flight, in the case of engine failure, to attempt to restart the engine and/or to provide power to equipment.

[0004] A turboshaft engine or an APU is generally composed, first of a single or dual primary shaft, on which are mounted, on the one hand, compressor stages (high- and low-pressure, hereinafter HP and LP, for a two-spool or just HP for a single-spool engine) and, on the other hand, turbines (HP and LP or solely HP), and a secondary shaft on which an LP power turbine is mounted. The power turbine is formed of rotor blade discs and discs with stator blading or nozzle. The turbines can be radial, with inward flow of gases. In this case, the stator blading is mounted on the periphery of the rotor blading. The nozzle makes it possible to regulate the gas flow by deflection, using stator blades.

[0005] The compressor and the HP turbine, linked to a combustion chamber, form the gas generator. In operation, the compressed air is mixed with the fuel in the chamber, leading to combustion. The exhaust gases are then partially expanded in the HP turbine (or the HP and LP turbines) so as to drive the compressors, then in the power turbine via the nozzle.

[0006] The power turbine is coupled to direct drive means for equipment (load compressor, fuel and hydraulic pumps, electrical generator and/or electrical starter/generator etc.), or via a power transfer box with adaptation of rotation speeds. Air taken at the outlet of the load compressor or turboshaft engine compressor can be used for cabin air conditioning and/or for main engine air start.

BACKGROUND ART

[0007] A fixed-geometry turbine engine has the disadvantage of having unattractive thermal efficiency under partial load. Indeed, the engine is conventionally designed for optimal operation in conditions close to its mechanical and thermal limits. When it supplies power very much below these optimal points, the compression rate and the temperature are then substantially lower, as is the compression efficiency, in general. This leads to thermal efficiency very much inferior to that of the theoretical value, and therefore to mediocre specific consumption—i.e., fuel consumption per unit of power.

[0008] One possible solution to mitigate this effect is to use variable geometry. In this case, in order to lessen the airflow passing through the engine without excessively reducing the

compression rate or the combustion temperature, the delivery section of the high-pressure turbine—located just downstream of the combustion chamber—is decreased by using variable-pitch blades for the stator (called the nozzle in a turbine).

[0009] It is also possible, on a civilian aircraft, to envisage exploiting the pressure energy available in the pressurised cabin by installing a turbine in the air discharge opening (cabin air being constantly renewed for passenger safety, at a pressure exceeding external ambient pressure). The outlet port is generally a variable-section valve, slaved to the cabin pressure control system.

[0010] Such a turbine must, just like a conventional valve, be able to ensure a variable reduced rate in accordance with pressure settings produced by the cabin pressure control system, and on the pressure difference between the cabin and the exterior (defining the expansion ratio of the turbine). Here too, a variable-section turbine nozzle managed by variable-pitch nozzle blades is one solution.

DISCLOSURE OF THE INVENTION

[0011] The object of the invention is to improve the mechanical strength of the nozzles and the overall efficiency of the turboshaft engine. To this end, it proposes to produce a nozzle incorporating variable-pitch blades to regulate and control the gas flow rate, it being possible to rotate each blade into a specific position. To improve the performance of the nozzle, the seal between the nozzle blades and their spacing system is produced in the area of maximum load of the nozzle blades. This seal then makes it possible to limit any unwanted gap flows in the area where they would be most intense.

[0012] More specifically, the invention relates to a radial turbine nozzle for a turbine engine, rotating about a central axis, and comprising a first annular array of fixed blades and a second annular array with the same number of variable-pitch blades, the blades having pressure and suction surfaces. Each blade in the second array, which is rigidly connected to cups extending at each end of the blade facing the pressure and suction surfaces of the blade, is capable of being rotated by pitch control means about a central geometric axis connecting the centres of the cups. Each of these blades has a trailing edge and a leading edge for the flows of gas linked to the pressure and suction surfaces, it being possible and advantageous for the leading edge of each variable-pitch blade to be placed substantially in the wake of a fixed blade, to guide the flows of gas radially towards the central axis of rotation of the turbine. Each variable-pitch blade is mounted at a distance from the axis of the cups such that this axis of rotation is positioned facing the pressure surface of the blade and substantially closer to the trailing edge than the leading edge of each blade.

[0013] Under these conditions, the blades are mounted on the cups at the point where the aerodynamic load is greatest because of the difference in maximum pressure between the pressure and suction surfaces of the blade.

[0014] The incidence of the flows of air is adapted by the blade pitch control means to allow the airflow demanded by the operating point to be matched with the flow passing into the turbine in accordance with this demand. Adaptation such as this undoubtedly leads to a loss of efficiency and performance of the turbine taken in isolation—because of the reduction brought about by the matching process—but it does optimise the thermodynamic cycle of the turbine engine. In

the particular case of the turboshaft engine, the specific fuel consumption is reduced by matching the flow rate.

[0015] According to specific embodiments, the leading edge of each variable-pitch blade has a thickness substantially greater than that of the trailing edge and an aerodynamic curved shape optimised for absorption of a wake of air generated by the blade of the fixed array facing it. In particular, the average thickness of the portion of variable-pitch blade between the mounting cups is substantially less than the thickness of the remainder of the blade located on the leading edge side. Furthermore, the blades pivot between two extreme positions about a reference position corresponding to 100% of the aerodynamic flow area: a closed position cutting off the air flow, corresponding to 0% of the reference flow area, and an open position of maximum air-flow opening, corresponding to 150% of the reference flow area.

[0016] Advantageously, fixed pitch blades are thick enough to ensure the passage of structural loads. Adequate passage of structural loads makes it possible to limit play and misalignment between the cups and the casings, and therefore to limit deteriorations in performance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Other characteristics and advantages of the invention will become apparent on reading the following description, with reference to the attached drawings, in which, respectively:

[0018] FIG. 1 is a diagrammatic view in partial axial section of an example APU fitted with a nozzle according to the invention;

[0019] FIG. 2 is a perspective view of the turbine with the nozzle mounted on a first side plate;

[0020] FIGS. 3a and 3b are views in partial section of the nozzle according to the invention, in a wheel plane and in a longitudinal plane of the turbine along its axis of rotation;

[0021] FIG. 4 is a diagram of static pressure exerted on the suction and pressure surfaces as a function of the curvilinear abscissa of a blade, and

[0022] FIG. 5 is a view of nozzle blades in a wheel plane in the reference pivoting position and different positions.

DETAILED DESCRIPTION OF AN EXEMPLARY EMBODIMENT

[0023] With reference to the general diagrammatic view in FIG. 1, an example APU 1 comprises a gas generator 10 composed of a centrifugal compressor 11, a combustion chamber 12 and a turbine 13, the turbine driving the compressor in rotation via a transmission shaft 20 about the central axis X'X. The gases leaving the chamber are expanded in the turbine 13, which also provides power to the equipment. The residual gases then leave via an exhaust pipe 30.

[0024] This power is delivered via a through shaft 20 to an accessory gearbox 3 connected to said shaft 20. The accessory gearbox 3 drives, by appropriate speed adaptation means (pinions, reduction gears etc.) the power plant accessories of the APU and auxiliary equipment 4 specific to the functioning of the aircraft: alternator, injector, fuel pump, load compressor, hydraulic pump etc.

[0025] In operation, a throttle governor 5 adjusts the airflow F coming from an air inlet 6, to be compressed in the compressor 11. The compressed air is mixed with the fuel in an injector 15 fitted to the chamber 12. After expansion in the turbine 13, the gases G are ejected into the exhaust pipe 30.

[0026] In the example illustrated, the power turbine 13 is a connected turbine. In other examples, the power turbine can be a free turbine or another turbine of some attached equipment, linked to the accessory gearbox 3.

[0027] The turbine 13 is illustrated in greater detail in the perspective view in FIG. 2. This inward-flow turbine comprises a mobile impeller 22 fitted with vanes 23 and a fixed nozzle 7 mounted on the periphery of the impeller 22 on appropriate casings, only the casing 7a being illustrated in this FIG. 2 (see the casings 7a and 7b in FIG. 3b).

[0028] The radial turbine 13 is fitted with a volute 21—a semi-volute is visible in the figure—the diameter of which decreases between its inlet 21a and its end 21b at the vanes 23. This volute allows a tangential component of the flow of air to be generated, which makes it possible to limit the deflection of the flow produced by the nozzle in order to supply the wheel 22.

[0029] According to the invention, the nozzle 7 comprises two arrays of blades, a first peripheral array G1 with fixed blades 2a, for keeping the walls parallel, and a second array G2 with orientable blades 2b, for adjusting the flow area. The airflows then drive in rotation the vanes 23 and the shaft 20 rigidly connected to the impeller 22.

[0030] FIGS. 3a and 3b, in the respective sections BB and AA, illustrate the organisation of the arrays G1 and G2, and their fixed 2a and orientable 2b blades, in the space separating the two assembly casings 7a and 7b. The fixed blades 2a are rigidly connected to the casings 7a and 7b. Their dimension defines the spacing “e” between these casings, in other words the width of the space E between the parallel casings 7a and 7b. The blades 2a are advantageously thick enough to ensure the passage of structural loads between the casings 7a and 7b.

[0031] The ends of each blade 2b are rigidly connected to the circular, parallel cups 24a and 24b, arranged in opposite housings 25a and 25b formed in the casings 7a and 7b. The blades 2b are mounted at a distance from the geometric axis of rotation R'R passing through the cups 24a and 24b at their centres 2A and 2B. The cups are here perpendicular to the pressure and suction surfaces of each blade 2b, Fi and Fe.

[0032] Each blade 2b is capable of being driven in rotation about the geometric axis R'R by means 40 for controlling the variable pitch of the blades, particularly during the transient phases of the aircraft. These control means comprise a stem 41 rigidly connected to the cup 24b, coupled to mechanical links (arms, pinions, bearings) linked to electric or electro-magnetic actuators 42. A single actuator can be configured for all the blades.

[0033] The actuator(s) are driven by a central processing unit 50 for engine control. The control can be numerical, electronic or hydromechanical. The incidence of the flows of air defined by the orientation of the blades 2b is adapted by the control means 40 so as to allow adjustment of flow rate. In the example illustrated, a pressure sensor 45 provides data to the central processing unit 50, which regulates the opening and closing of the blades 2b of the nozzle 7 via the control means 40.

[0034] Each of these blades 2b has a trailing edge Bf and a leading edge Ba for the flow of air, linked to the faces Fi and Fe of the blade 2b. The leading edge Ba of each blade 2b of the second array is located substantially in the wake of a fixed blade 2a of the first array, so as to guide the air flows radially towards the central axis of rotation X'X of the turbine 22. The wake of a fixed blade corresponds to the aerodynamic trace

that it leaves in an undisturbed flow. This wake defines a highly disrupted low-speed area.

[0035] Each blade **2b** is mounted off the axis R'R and is off-centred such that the axis of rotation R'R is positioned facing the pressure face Fi of the blade **2b** and substantially closer to the trailing edge Bf than the leading edge Ba of each blade **2b**.

[0036] Under these conditions, the cups **24a** and **24b** are positioned at the point where the aerodynamic load is greatest because of the difference in maximum pressure between the pressure and suction surfaces of the blade. FIG. 4 illustrates the variation in static pressure Ps as a function of the curvilinear abscissa Ac corresponding to each of the faces Fi and Fe of a blade **2b**.

[0037] A maximum pressure variation is therefore located in the hatched area Z, in the blade portion **2p** situated inside a space "E" delimited by the cups, on the trailing edge side Bf of the blade **2b**. The cups eliminate any play in the area Z where the effect of play is greatest. The optimised choice of position of the axis of rotation R'R, offset towards the trailing edge Bf, makes it possible to limit the clearance of the trailing edge Bf itself with respect to its position relative to the leading edge of the vanes **23** of the turbine **22**, while limiting the mechanical torque required to counteract the aerodynamic torque linked to the blade and therefore to optimise the absorption of aeromechanical constraints.

[0038] The leading edge Ba of each blade **2b** has a thickness substantially greater than the trailing edge Bf, and an aerodynamic curved shape optimised for absorption of a wake of air generated by the blade of the fixed array facing it. In particular, the average thickness of the portion of blade **2p** (in dotted lines in the figure), between the portions of the pressure Fi and suction Fe faces, is substantially less than the thickness of the remainder of the blade **2b** located on the leading edge side Ba.

[0039] The rotation of the blades **2b** is advantageously limited by an amplitude of pivoting between two extreme positions. FIG. 5 illustrates the extreme positions **2b_{sup}** and **2b₀** about a reference position **2b_{ref}** corresponding to 100% of the aerodynamic flow area. The extreme position **2b₀** corresponds to the complete closing of the flow area. The position **2b_{inf}** corresponds to a closed position, with 70% of the reference flow area, intended for low load demands. The position **2b_{sup}** corresponds to the open position, with 150% of the reference flow area, intended for high load demands.

[0040] The invention is not limited to the examples described and illustrated. For example, it is possible to carry out the spacing of the mobile blades solely by mechanical adjustment, whether individual or centralised, or by electrical or electronic control, with or without numerical control.

1-8. (canceled)

9. A radial turbine nozzle for a turbine engine, rotating about a central axis, comprising:

a first annular array of fixed blades and a second annular array with a same number of variable-pitch blades, the fixed blades and variable-pitch blades including pressure and suction faces,

each variable-pitch blade of the second array is rigidly connected to cups extending at each end of the variable-pitch blade, is configured to be driven in rotation by control means about a geometric axis connecting centers of the cups, and includes a trailing edge and a leading edge of gas flows linked to the suction and pressure faces,

wherein each variable-pitch blade is mounted at a distance from an axis of rotation of the cups such that the axis of rotation is positioned facing the suction face of the variable-pitch blade and substantially closer to the trailing edge than the leading edge of the variable-pitch blade.

10. A radial turbine nozzle according to claim 9, wherein the leading edge of each variable-pitch blade is located substantially in a wake of a fixed blade so as to guide the gas flows radially towards a central axis of rotation of the turbine.

11. A radial turbine nozzle according to claim 9, wherein the leading edge of each variable-pitch blade has a thickness substantially greater than that of the trailing edge and an aerodynamic curved shape optimized for absorption of a wake of air generated by a fixed blade of the fixed array facing it.

12. A radial turbine nozzle according to claim 9, wherein an average thickness of a portion of a variable-pitch blade between the mounting cups is substantially less than a thickness of a remainder of the variable-pitch blade located on a leading edge side.

13. A radial turbine nozzle according to claim 9, wherein the variable-pitch blades are configured to pivot between two extreme positions about a reference position corresponding to 100% of an aerodynamic flow area, a closed position cutting off air flow, corresponding to 0% of the reference flow area, and an open position of maximum air-flow opening, corresponding to 150% of the reference flow area.

14. A radial turbine nozzle according to claim 9, wherein the fixed-pitch blades are thick enough to ensure passage of structural loads.

15. A radial turbine nozzle according to claim 9, wherein the radial turbine is one of a turboshaft engine turbine, an auxiliary power source of an aircraft, or a turbocharger.

16. A radial turbine nozzle according to claim 9, wherein the radial turbine is fitted with a volute, a diameter of which decreases between its inlet and its end at vanes.

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