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[54] **AXIAL SUPERSONIC COMPRESSOR**

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[30] **Foreign Application Priority Data**

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[58] **Field of Search**........................415/181, 210, 207

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[57] **ABSTRACT**

An axial supersonic fluid compressor has ducts incorporating both mobile and fixed blades that are designed to receive essentially normal shock waves. This is accomplished by having the angles of incidence upstream from the fixed and mobile blades relatively small; the passage cross sections of the ducts between the blades of the mobile wheel convergent; the passage cross sections of the ducts between the fixed blades divergent, and the profile of the leading edges of the fixed and mobile blades rounded off with a small radius of curvature.

9 Claims, 3 Drawing Figures

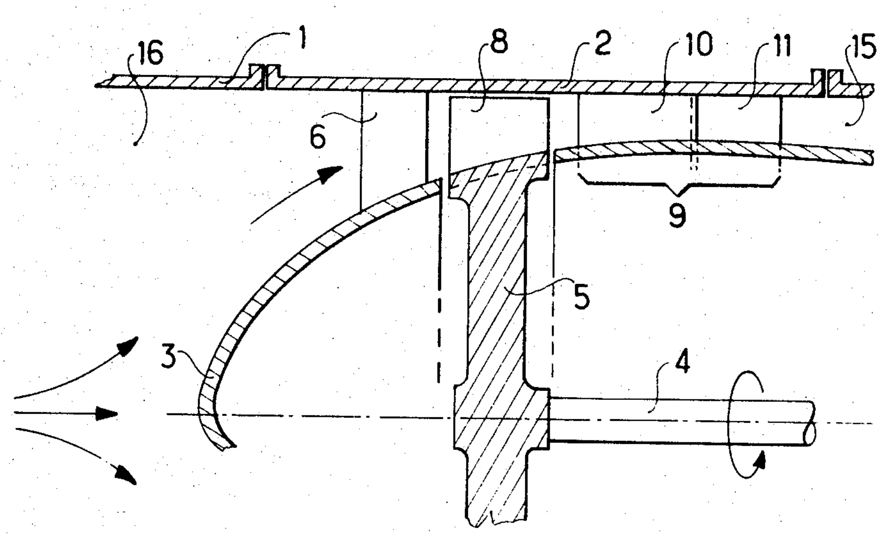


FIG.1

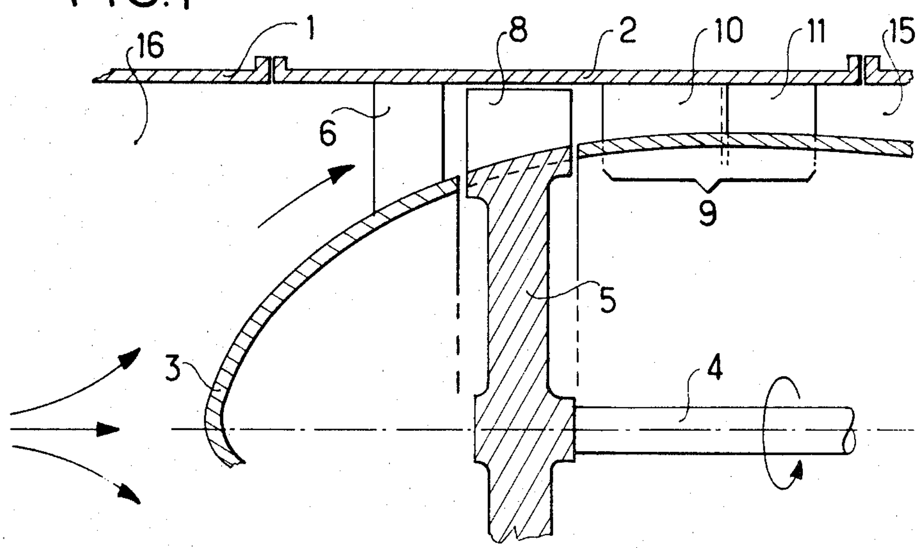


FIG. 2

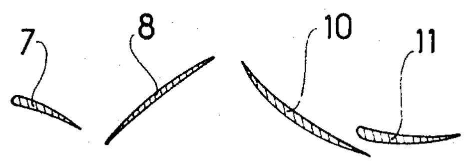
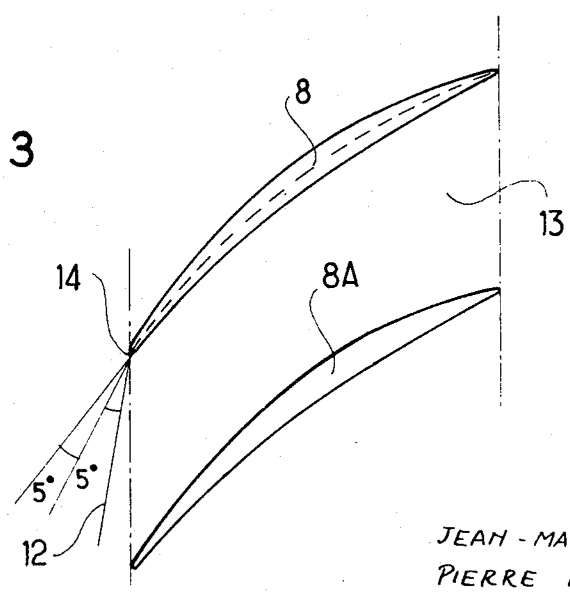


FIG. 3



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AXIAL SUPERSONIC COMPRESSOR

BACKGROUND OF THE INVENTION

Present invention relates to an axial supersonic fluid compressor subject to shock waves. In particular, it relates to air compressors for aircraft turbine engines and to compressors for gas intended to be subjected to physical or chemical treatment.

DESCRIPTION OF THE PRIOR ART

It has been previously proposed to make fluid compressors that produce oblique shock waves which, theoretically, for the same rate of compression as a straight normal shock wave at right angles to the flow passage between adjacent blades, offer smaller energy losses and thus offer a higher yield. I have found, however, that this form of fluid compressor involves certain inconveniences. In particular, it is difficult to exactly predict the configuration of a flow with multiple oblique shocks. This is linked very closely to the angle of incidence of the vanes and the shape of their leading edge, which means practically that one must provide this flow configuration either only in the stator or impulse rotor or only in the rotor or shock rotor in the same compression stage. The problem of boundary layer breakaway exists either in the places where the oblique shock waves are reflected or along the profiles which produce even small deviations in the direction of flow. As a result, supersonic axial compressors with multiple oblique shock waves do not offer the high yield that would be expected theoretically.

It has also been proposed to build supersonic axial compressors to produce a high fluid speed, either by giving the blades positions that will guarantee a high flow deflection angle or by very heavily reducing the passage cross section between the blades from the inlet to the outlet. In the first case, it is necessary to correct the direction of fluid flow with respect to the axis which produces losses due to friction and breakaway and these losses are added on top of those due to the deviation of the fluid jet at the entry of the blades. In the second case, the blades must present thick trailing edges which brings about major losses due to large slippage.

SUMMARY OF THE INVENTION

The present invention is directed to an axial supersonic fluid compressor that includes a fluid inlet opening followed by a cylindrical or conical divergent body portion extending downstream from the opening. A centrally positioned cap is arranged in the inlet opening and is symmetrical with respect to the axis of the compressor and with the cylindrical or conical body, defines a ring-shaped conduit. At least one mobile wheel with thin deflecting blades is mounted on an axial engine shaft. The blades are attached downstream from the output of the mobile wheel in order partially to transform the kinetic energy of the pressurized fluid. The channels or ducts of the mobile or fixed blades receive essentially normal shock waves at right angles to the flow passages between adjacent blades. A supersonic axial compressor receiving normal shock waves will give high compression rates with a reduced number of stages while still presenting an excellent power yield.

The supersonic axial compressor of the present invention is characterized by the fact that the angles of incidence upstream from the fixed and mobile blades have a relatively small height. Further, the passage cross section of the ducts between the blades of the mobile wheel are convergent while the ducts between the fixed blades are divergent. The profile leading edges of the fixed and mobile blades are rounded off with a small radius of curvature. The angle of incidence between the fixed and mobile blades and the direction of fluid flow remains relatively small.

During the course of experiments, it was found that three conditions are necessary in order to obtain a high yield. These conditions must occur simultaneously as follows;

a. the angle of an incidence between the fixed and mobile blades and the direction of fluid flow remains relatively small;

b. The passage cross sections of the ducts between the blades are divergent with respect to to the fixed blades and are convergent with respect to the mobile blades;

c. The leading profile of both the fixed and mobile blades is rounded off with a small radius of curvature. Experiments have shown that when only two of the above three conditions are present, it is not possible to obtain the high yield.

In a modification of the supersonic axial compressor, the ducts between the fixed blades are sufficiently short and divergent so that essentially straight shock waves will appear.

According to another variation, the ducts between the fixed blades have essentially slightly divergent passage cross sections with sufficient length so that a progressive flow transformation will be assured.

In another modification, the ducts between the blades of the mobile wheel are sufficiently short and convergent so that essentially normal shock waves will occur.

According to another variation, the ducts between the blades of the mobile wheel have an essentially slightly convergent passage cross section and sufficient length so that progressive flow transformation will be realized.

By following the present invention, it is possible to divide the shocks between the rotor and the stator and have the shock waves or the progressive equivalent transformation have the same effect as a normal shock wave both in the stator and in the rotor.

According to a preferred form of implementation of the present invention, the curvature radius of the profile of the leading edges of the fixed and the mobile blades is about 0.5 percent of the chord of the blade. This condition facilitates the obtaining of a stable shock wave with minimum losses.

According to another preferred version, the angles of the successive profiles of the blades have a reference direction, such that the product of the ratios of the relative fluid speed with respect to the blades at the critical speed of sound in the fluid, at the input and output of each stage of blades, will be unity. This condition tends to guarantee maximum power output. According to another preferred form, the compressor contains a final slow down stage, having fixed blades subjected to fluid at sub-sonic or supersonic speed. The duct between the fixed blades has a straight cross section from the upstream toward the downstream direction so as to slow down the fluid to a moderate speed, for example, on the order of 0.25 Mach.

Finally, with respect to a modification, the compressor can incorporate in the final stage means for straightening the direction of the fluid where the means involves blades with staggered profiles which permit strong deviations with small losses in supersonic flow.

A supersonic axial compressor of the present invention can be advantageously used in a turbine engine, especially in an aircraft turbojet. In light turbojets, it can advantageously be followed by a likewise supersonic centrifugal compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 discloses a schematic representation of the cross section of the compressor of the present invention;

FIG. 2 discloses the profiles of the blades of the distributor, the wheel and the compressor straightener.

FIG. 3 discloses in detail two neighboring blades of the mobile wheel.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the above Figures, a single stage air compressor according to the present invention with essentially normal shock waves at right angles to the flow passage between adjacent blades in the stator and rotor will now be explained. The compressor disclosed in FIGS. 1 and 2 has a low sectional height comprising about 15 percent of the average radius. It includes a cylindrical inlet sleeve 1 and the cylindrical casing 2. In modified versions of the present invention, these envelopes may have a conical form. An axial cap 3, with the inlet sleeve 1 and the casing 2 limits the conduit offered for the air to be compressed. A shaft 4, connected to a motor or engine (not shown) drives the wheel 5. At the inlet end of the cylindrical casing, a distributor 6 with fixed blades 7, diverts the flow of air into the direction of the rotation of the wheel so as to keep within reasonable limits (on the order of Mach 1.5) the relative supersonic speed of the fluid with respect to the mobile blades 8 of wheel 5. The fixed blades 10 and 11 of the straightener 9, are intended to reduce the speed of the compressed air to a value on the order of Mach 0.25.

Referring to FIG. 3, the blades 8 and 8*a* of wheel 5 have an inner surface which makes an angle of 10° with the direction of incidence 12 of the inlet flow of air. Between the blades 8 and 8*a* a conduit or duct 13 is presented with a decreasing passage area cross section. The leading edge 14 of blade will have a small radius of curvature, for example, 0.3mm for a blade whose chord is 65 mm.

In an axial compressor having a peripheral speed of the mobile wheel amounting to 530 meters per second, the air penetrates between the blades of the wheel at a relative speed of Mach 1.35. The deflection of the air, as it traverses the wheel is about 30°. The relative speed of the air at the output of the wheel is Mach 0.75. The speed of the air where it approaches the fixed diffuser, which follows the output of the wheel, will reach Mach 1.22. The overall compression rate, defined as the ratios of static pressure measured at a speed of Mach 0.25 in the downstream conduit 15 and the upstream conduit 16 of the compressor is 2.5. The adiabatic yield of the complete stage, at this compression rate, is in excess of 0.85. By way of comparison, a sub-sonic compressor with a single stage would only give a compression rate of less than 1.5 for a similar yield.

It should be understood that various modifications can be made in the supersonic axial compressor of the present invention without going beyond the framework of the present invention and accordingly, the scope of the present invention should be measured solely from its claims. In particular, the number of stages can be selected as a function of the final compression rate desired. Also it is possible to mix, into the gas flow coming from one stage, a secondary gas flow recycled at the same pressure and introduced by a tangential 13 inlet opening.

What is claimed is:

1. A supersonic axial flow fluid compressor comprising means defining a fluid inlet opening, including a cylindrical sleeve and an internally-mounted cap diverging in the downstream flow direction; a compressor housing; a mobile wheel rotatably mounted in said compressor housing, said mobile wheel having relatively thin pumping blades mounted thereon, said thin pumping blades having a leading and a trailing edge; means for rotatably driving the mobile wheel; distributing means including a plurality of fixed blades mounted in the fluid inlet opening upstream of the mobile wheel, said fixed blades having a leading edge and a trailing edge; a plurality of first fixed blades mounted downstream of the mobile wheel, each of said first fixed blades mounted downstream of said wheel having a leading edge and a trailing edge, the angles of incidence of the fixed blades upstream and downstream of the mobile wheel and the blades of the mobile wheel with the direction of flow of fluid being relatively small within the range of 0°–10°, the cross-sectional thickness of the blades on the mobile wheel increasing in the direction of the trailing edges to cause the cross-sectional flow area between the blades of the mobile wheel to be convergent in the direction of the trailing edges, the cross-sectional thickness of the fixed blades of both sets decreasing toward the trailing edges thereof to cause the cross-sectional flow area between the fixed blades to be divergent toward the trailing edges thereof, the profile of the leading edges of the fixed and mobile blades being rounded off with a small radius of curvature, whereby essentially normal shock waves at right angles to the direction of fluid flow are produced with a minimum of boundary flow separation.

2. A compressor as in claim 1 where the fluid inlet opening is a ring-shaped conduit and the angle of the mobile blades at their leading edge is about 10° with the fluid flow.

3. A compressor as in claim 2 where the fixed blades are short, the cross-sectional flow area between the fixed blades being divergent toward the trailing edges thereof so that essentially normal shock waves are produced.

4. A compressor as in claim 2 where the cross-sectional flow area between the fixed blades has a slightly divergent passage cross section in the direction of the trailing edges thereof, the lengths of the blades between

the leading and trailing edges being of sufficient length so that a progressive flow transformation is produced.

5. A compressor as in claim **2** where the radius of curvature of the profile of the leading edges of the first fixed blades and mobile blades is about 0.5 percent of the chord of the blades.

6. A compressor as in claim **2**, wherein the surface profile of each of said blades of said rotating wheel between said leading and trailing edges thereof is defined by an infinite number of points where the successive angles formed between the tangent at each point on the profile of the blades and a common reference direction are such that the product of the ratios of the relative input speed of the fluid with respect to the blades at a critical speed of sound in the fluid at the input and at the output of each stage of blades is near unity.

7. A compressor as in claim **6** further including means to slow the speed of the fluid including a second set of fixed blades mounted downstream of the first fixed blades.

8. A compressor as in claim **7** where the first fixed blades and the second set of fixed blades have staggered profiles with respect to each other to straighten the direction of the fluid flow.

9. A compressor as in claim **8**, further including a supersonic centrifugal compressor connected in the air flow stream downstream of the second set of fixed blades.

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