

EUROPEAN PATENT APPLICATION

Application number: 86630032.0

Int. Cl.⁴: **F 01 D 11/08**
F 01 D 5/20

Date of filing: 06.03.86

Priority: 11.03.85 US 710270

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Date of publication of application:
17.09.86 Bulletin 86/38

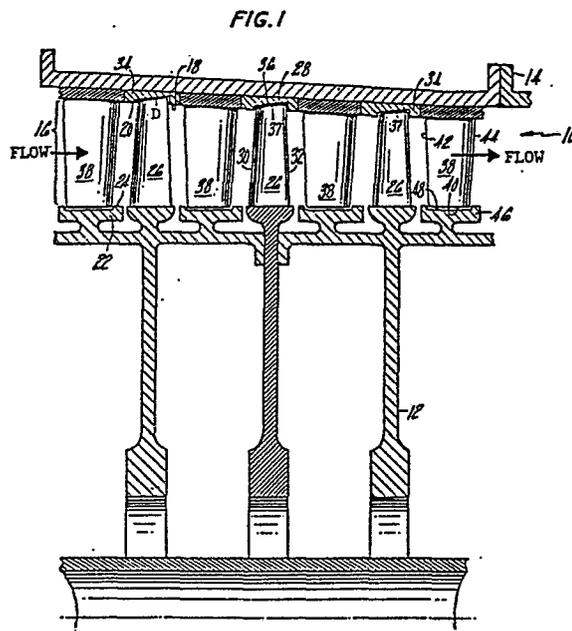
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DE FR GB SE

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Compressor blade tip seal.

The trench inner wall surrounding the tips (28) of axial flow fan/compressor blades (26) in a turbine type power plant is angularly disposed relative to the gas path wall (20) to allow deeper penetration into the trench and minimize leakage around the tips (28). Gap closure between the inner wall (37) of the trench and tip (28) is contemplated by the contour of the blade/trench.



Description

Compressor Blade Tip Seal

Technical Field

This invention relates to axial flow
5 fans/compressors of gas turbine engines and parti-
cularly to the relationship of the tips of the blades
to the adjacent shroud or rub strip.

Background Art

U.S. Patent No. 4,239,452 granted to
10 Frank Roberts, Jr. on December 16, 1980 entitled Blade
Tip Shroud for a Compressor Stage of a Gas Turbine
Engine and U.S. Patent No. 4,238,170 granted to
Brian A. Robideau and Juri Niiler on December 9, 1980
15 entitled Blade Tip Seal for an Axial Flow Rotary, both
of which were assigned to United Technologies Corpor-
ation, the assignee common to the present patent
application disclose shrouds that include trenches
adjacent the tips of the blades.

As disclosed in U.S. Patent No. 4,238,170 supra,
20 for example, the tips of the compressor blades extend
adjacent the surrounding shroud or rub strip that is
trenched or recessed to the dimension complimentary to
the outer station and tip of the blade. In some
instances, say at the low pressure stages where soft
25 abradable materials such as a synthetic rubber can be
utilized, the blades which move radially outward
during engine acceleration, machine the groove.
Obviously, this technique assures a close fit of the
mating parts and helps in avoiding leakage around the
30 tips of the blade.

The problem constantly plaguing the engine technical people is how to maintain this leakage to a minimum, if not prevent it. While the designs disclosed in the above mentioned patents help toward this
5 end, leakage is still prevalent.

Other techniques for minimizing tip leakage is discussed in the above-mentioned patents. Suffice it to say that the present invention is an improvement over the techniques taught in these patents, supra,
10 and serve to improve engine operating efficiencies over and above that attainable by the heretofore known designs.

Disclosure of Invention

A feature of the invention is to provide a
15 slanted trench in the rub strip, shroud, or the engine case of a gas turbine engine adjacent the tips of the blades of the fan and/or compressor. The contour of the blade and the inner wall as seen by the cross section of the trench is angularly disposed relative
20 to the flow path wall.

This invention contemplates that the angular contour is designed to effectuate a closure in the gap between the inner wall of the trench and the tip of the blade upon displacement of the compressor and/or
25 fan blade arising out of the growth of the materials resulting from stable speed and temperature operating conditions. Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodi-
30 ment of the invention.

Brief Description of Drawings

Fig. 1 is a partial view in section of a compressor section of a gas turbine engine schematically showing the slanted trench of the casing wall or rub strip of this invention.

Fig. 2 is an enlarged view of a non-slanted trench adjacent the tip station of a compressor blade of the prior art design.

Fig. 3 is an enlarged view of one of the blades and the attendant slanted trench in the engine casing, and

Fig. 4 is a partial view of the tip stations and trench illustrating another embodiment of this invention.

Best Mode for Carrying Out the Invention

The invention in its preferred embodiment is illustrated for use in the lower temperature stations of a gas turbine engine and particularly in the compressor section where a soft material circumscribes the engine's inner diameter of the engine case and is abradable so as to be susceptible of being machined by the operation of the rotating blades. Thus, as disclosed in the U.S. Patent No. 4,238,170, supra, the blades at zero rotational speeds are spaced from the inner diameter of the rub strip and when accelerated to its highest operating speed, cut into the rub strip to define the trench. It is, however, to be understood and as will be obvious to one skilled in this art, the trench shape can be machined out prior to engine operation. What is considered the improvement by the teachings of this invention is the particular contour of the tips of the blades and its cooperating trench.

- 4 -

A portion of a compression section 10 of an axial flow compressor of a gas turbine engine is illustrated in Fig. 1. A flow path 16 for working medium gases extends axially through the compression section. An
5 - outer wall 18 having an inwardly facing surface 20 and an inner wall 22 having an outwardly facing surface 24 form the flow path. A plurality of axially spaced rows of rotor blades as represented by the single
10 blades 26 extend outwardly from the rotor across the flow path into proximity with the outer wall. Each blade has an unshrouded tip 28 and is contoured to an airfoil cross section. Accordingly, each blade has a pressure side and a suction side and, as illustrated, has an upstream end 30 and a downstream end 32. Extend-
15 ing over the tips of each row of rotor blades is a stator seal land 34. Each land has a circumferentially extending groove 36 formed therein to a depth D at an inwardly facing surface 37 thereof.

A plurality of rows of stator vanes represented
20 by the single vanes 38 are cantilevered inwardly from the stator across the flow path into proximity with the inner wall. Each vane, which in this illustration has an unshrouded tip 40, is contoured to an airfoil section. Accordingly, each vane has a pressure side
25 and a suction side and, as illustrated, has an upstream end 42 and a downstream end 44. Extending over the tips of each row of stator vanes is a rotor seal land 46. Each land has a circumferentially
extending groove 48 formed therein.

30 In the nonoperating condition the blade tips 26 are spaced from the inwardly facing surface 20. The gap between tips and surface enables assembly of the

- 5 -

components. In response to centrifugally and thermally generated forces as the machine is accelerated to high operating speeds the rotor tips grow radially outward machining the groove 36 in the stator seal land 34. The point of closest proximity of the blades to the bottom of the groove is referred to as the "pinch point" and normally occurs during a transient engine operating to a maximum speed or power condition. As the engine reaches thermal stability at a given operating speed the outer wall including the land, moves both axially and radially relative to the blade tips to a position at which the blade tips and inner surface 37 define a gap.

A problem with the heretofore design as illustrated in Fig. 2 which is a prior art design is that the blade 50 penetration into the trench increases with operating speed and causes pumping of air against the trench vertical wall 53 which creates turbulence. The turbulence as shown by arrow A, essentially becomes a blockage in the flow path of the gas engine's working medium and adversely affects performance. The maximum depth of blade tip penetration must be controlled to avoid unreasonable turbulence losses at the maximum operating speed. At low speed operating the blade will not penetrate into the trench and leakage can readily occur between the flow path outer wall and the blade tip.

Ideally, it is desirable to match the pressure gradient across the tip which tends to leak air from the high pressure side to the low pressure side by the pressure created by the tip pumping action. In the heretofore shown embodiment the full width of the

blade works on the air and has the tendency of over pressurizing this air and hence, creates the undesirable turbulence.

5 According to this invention the tip of the blade is contoured to be angularly disposed relative to the gas path wall. This is best seen in Fig. 3. As the trench is machined as described above, the trench is formed to define the contour of the inner surface 37. Looking at the cross section of the trench it is
10 apparent that the axial extension of surface 37 relative to the flow path defined by wall 20 forms angle alpha α . By virtue of this contour, two important features are realized:

(1) The full width of the blade pumped against
15 the vertical trench wall in the situation of the heretofore design as soon as any portion of the blade tip penetrated into the trench. Thus the blade penetration is minimal prior to creating undesirable turbulence. Only the aft portion of the blade tip
20 pumps against the trench vertical wall in Figure 2 when the speed is attained to cause the blade tip to penetrate into the trench. Thus the blade tip can penetrate deeper into the trench prior to creating the limiting condition of turbulence. At lower operating
25 speed conditions the revised tip design will permit penetration whereas the heretofore design did not permit penetration. (2) By slanting the trench in the proper direction, the gap will be reduced by the relative axial motion between the blade tip and trench
30 outer wall as these engine parts achieve thermal stability at any given engine speed condition. Thus knowing the axial growth direction of the case, say in

- 7 -

the direction of the arrow B relative to the blade's axial motion, it is apparent that gap D tends to become smaller.

5 Fig. 4 exemplifies another configuration on how the tip can be contoured to combat the leakage problem alluded to in the above. As noted the tip of blade 70 is contoured in a sawtooth fashion providing a plurality of parallel channels 72. In each channel the inner surface 74 is angularly disposed to the gas path
10 wall providing similar benefits as was described above.

The preferred embodiment described in connection with Fig. 3 has proven to be particularly efficacious resulting in perhaps a 0.1 or 0.2% improvement in
15 specific fuel consumption as evidenced on the PW2037 engine manufactured by Pratt & Whitney Aircraft of United Technologies Corporation, the assignee of this patent application.

20 It should be understood that the invention is not limited to the particular embodiments shown and described herein, but that various changes and modifications may be made without departing from the spirit and scope of this novel concept as defined by the following claims.

Claims

1. For a gas turbine engine with high and low power operating conditions having an engine case, a rotor with a plurality of radially extending blades
5 rotatably supported in said engine case, a portion of said engine case having a circumferentially extending trench having an inner surface and a vertical wall, the inner surface facing the tips of said blades and having a contour complimenting the contour of the tips
10 of said blades, the inner wall of said engine case and the outer surface of said rotor defining a flow path for said engine's working medium, said inner surface of said trench being angularly contoured relative to said inner wall of the engine case, whereby a portion
15 of said tips of said blades is positioned into said trench when in the lower power operating condition so as to provide a pumping action of the air against said side wall of said trench so as to prevent said working medium from migrating from the high pressure side of
20 said blades to the low pressure side of said blades.

2. An engine as claimed in claim 1 wherein said blades include a leading edge at the lower pressure side of said working medium and a trailing edge at the higher pressure side of said working medium, the tip
25 of the blade slanting from a given diameter at the leading edge to a higher diameter at the trailing edge, whereby said higher diameter portion of said tip penetrating said trench when said power plant is operating at said lower power.

3. An engine as claimed in claim 2 wherein said engine casing has a particular direction of growth and the direction of said slant is selected to be in the direction to minimize the gap between the tip of said blade and the inner surface of said trench upon growth of said engine casing.

4. An engine as in claim 1 including an abradable material lining said inner wall adjacent the tips of said blades and said trench being machined into said abradable material by accelerating said engine to said high power operating condition whereby said blades expand radially.

5. In combination, a gas turbine engine operable over a power range, having an engine case, a plurality of axially spaced rotors having a plurality of radially extending blades forming stages of compression in the compression section of said engine rotatably supported in said engine case, an inner wall on said engine case and an outer surface on said rotor defining a gas path for the engine's working medium, said inner wall of said engine case being made from an abradable material so that the tips of said blades move radially outward to machine a trench overlying said tips when said engine is accelerated to the high power of said range, each of said tips of said blades slanting in an axial direction from a smaller diameter from the leading edge to a larger diameter at the trailing edge, the inner surface of said trench having a corresponding slant, whereby when said engine is operating to a lower power of said range said blades

- 10 -

retreat from said inner surface of said trench so that only the larger diameter of said blades penetrate said trench whereby said portion of said blade penetrating said trench pumps the engine's working medium adjacent
5 said tips to minimize the flow of said working medium from the high to the lower pressure around said tips.

