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(54) Leading edge cooling of a gas turbine component using staggered turbulator strips

(57) A turbine engine component has an airfoil portion (32) having a leading edge, a suction side (46), a pressure side (42) and a radial flow leading edge cavity (34) through which a cooling fluid flows for cooling the leading edge. The turbine engine component further has a staggered arrangement of trip strips (40; 44) for generating a vortex (49) in the leading edge cavity (34) which impinges on a nose portion (36) of the leading edge cavity (34).

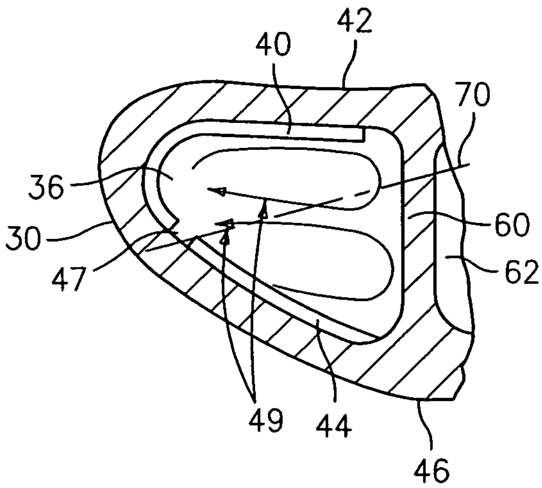

FIG. 7

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Description

BACKGROUND

(1) Field of the Invention

[0001] The present invention relates to enhanced cooling of the leading edge of airfoil portions of turbine engine components using trip strips that are preferably staggered and wrapped around the nose of the leading edge cavity.

(2) Prior Art

[0002] Due to the extreme environment in which they are used, some turbine engine components, such as blades and vanes, are cooled. A variety of different cooling techniques have been employed. One such scheme is illustrated in FIG. 1 where there is shown an airfoil portion 10 of a turbine engine component 12. As can be seen from the figure, a radial flow leading edge cavity 14 is used to effect cooling of the leading edge region.

[0003] Despite the existence of such a cooling scheme, there remains a need for improving the cooling of the leading edge of the airfoil portions of turbine engine components.

SUMMARY OF THE INVENTION

[0004] Accordingly, it is an aim of the present invention to provide enhanced cooling for the leading edge of airfoil portions of turbine engine components.

[0005] In accordance with the present invention, a turbine engine component broadly comprises an airfoil portion having a leading edge, a suction side, and a pressure side, a radial flow leading edge cavity through which a cooling fluid flows for cooling the leading edge, and means for generating a vortex in the leading edge cavity which impinges on a nose portion of the leading edge cavity. The vortex generating means preferably comprises a first set of trip strips which wrap around the nose portion of the leading edge cavity and a second set of trip strips. The first set of trip strips is preferably staggered relative to the second set of trip strips.

[0006] Other details of the leading edge cooling using staggered trip strips of the present invention, as well as other advantages attendant thereto, are set forth in the following detailed description and the accompanying drawings wherein like reference numerals depict like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 illustrates a prior art turbine engine component having a radial flow leading edge cavity;
FIG. 2 illustrates a cross-section of a leading edge portion of an airfoil used in a turbine engine component having staggered and wrapped trip strips;
FIG. 3 illustrates the trip strips on the suction side of the leading edge portion;
FIG. 4 illustrates the trip strips on the pressure side of the leading edge portion;
FIG. 5 illustrates the placement of the leading edge of the staggered trip strips;
FIG. 6 is a three dimensional view of the leading edge trip strips; and
FIG. 7 illustrates the vortex generated in the leading edge cavity.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0008] Referring now to the drawings, FIG. 2 illustrates the leading edge 30 of an airfoil portion 32 of a turbine engine component. As can be seen from this figure, the leading edge 30 has a leading edge cavity 34 in which a cooling fluid, such as engine bleed air, flows in a radial direction. The leading edge 30 also has a nose portion 36 and an external stagnation region 38.

[0009] It has been found that trip strips are desirable to provide adequate cooling of the leading edge, especially at the nose portion 36 of the airfoil portion 32 adjacent to the external stagnation region 38. The trip strip arrangement which will be discussed hereinafter provides high heat transfer to the leading edge 30 of the airfoil portion 32.

[0010] As shown in FIGS. 2, 5 and 6, a plurality of trip strips 40 are positioned on the pressure side 42 of the airfoil portion 32, while, as shown in FIGS. 2, 3, and 6, a plurality of trip strips 44 are placed on the suction side 46 of the airfoil portion 32. Referring now to FIGS. 2 and 6, the trip strips 40 on the pressure side 42 are wrapped around the leading edge nose portion 36. As the pressure side trip strips 40 wrap around the leading edge, the curvature of the leading edge nose portion 36 causes the trip strips 40 to be oriented more or less normal to the direction of flow 48 (see FIG. 6). As cooling air passes over the thus oriented trip strips 40, the flow is tripped and generates a large vortex 49 at the leading edge (see FIG. 7). This large vortex generates very high heat transfer coefficients at the leading edge nose 36.

[0011] Referring now to FIGS. 4 and 6, it can be seen that the trip strips 40 and the trip strips 44 are preferably staggered approximately one half pitch apart between the suction side 46 and the pressure side 42 of the airfoil portion 32. As shown in FIGS. 2 and 7, there is also a gap 47 between adjacent ones of the trip strips 40 and the trip strips 44. Each gap 47 is preferably located along a parting line 70 of the airfoil portion 32.

[0012] The orientation of the trip strips 40 and 44 in the cavity 34 also increases heat transfer at the leading edge 30 of the airfoil portion 32. If desired, the trip strips 40 and 44 may be oriented at an angle α of approximately 45 degrees relative to the flow direction 48. The leading edges 54 and 56 of the trip strips 40 and 44 are positioned in the region of highest heat load, in this case the leading edge nose 36. This trip strip orientation permits the creation of a turbulent vortex 49 in the cavity 34. The cooling fluid initially hits the leading edges 54 and 56 of the trip strip and separates from the airfoil surface. The flow then re-attaches downstream of the trip strip leading edges 54 and 56 and moves toward the divider rib 60 between the leading edge cavity 34 and the adjacent cavity 62. As the flow approaches the divider rib 60, it is forced toward the opposite airfoil wall. The flow is directed perpendicular to the pressure side and suction side walls 42 and 46, and meets at the center of the cavity 34. The flow is now forced back towards the leading edge 30 of the airfoil portion 32. The result of this flow migration causes a large vortex 49 that drives flow into the leading edge of the cavity, acting as an impingement jet which also enhances heat transfer at the leading edge nose 36.

[0013] Using the trip strip configuration of the present invention, radial flowing leading edge cavities of turbine engine components will see an increase in convective heat transfer at the leading edge nose of the cavity.

[0014] The particular orientation of the trip strip configuration allows for cooling flow to impinge on the leading edge nose 36, further enhancing heat transfer. The leading edge of the trip strips 40 and 44 is located near the nose 36 of the leading edge cavity 34.

[0015] The trip strips 40, although skewed at an angle α with respect to the direction of flow 48 along the pressure-side wall 42, become normal to the direction of flow 48 as they wrap around the nose 36 of the leading edge cavity 34, increasing the turbulent vortex 49 generated by the trip strips 40 and 44, and subsequently increasing the heat transfer coefficient.

[0016] The trip strips 40 and 44 may overlap with the trip strip 40 extending underneath the trip strip 44, and vice-versa.

[0017] While the trip strips 40 have been described as being on the pressure side wall 42 of the airfoil portion, they could instead be mounted to the suction side wall 46 if desired. In such a situation, the trip strips 44 would be mounted to the pressure side wall 42.

[0018] Away from the leading edge nose 36, the staggered and 45 degree angled trip strips generate a vortex that impinges flow onto the nose 36 of the leading edge cavity.

[0019] The trip strip configuration of the present invention maintains a P/E ratio between 3 and 25 where P is the radial pitch in between trip strips and E is trip strip height. Further, the trip strip configuration described herein maintains an E/H ratio of between 0.15 and 1.50 where E is trip strip height and H is the height of the cavity 34.

[0020] Airflow testing has shown that the heat transfer coefficients at the leading edge of the airfoil adjacent to the external stagnation region when using the staggered trip strips of the present invention are enhanced by approximately two times, greatly increasing airfoil oxidation and thermo-mechanical fatigue cracking life.

Claims

1. A turbine engine component comprising:

    an airfoil portion (32) having a leading edge, a suction side (46), and a pressure side (42);
    a radial flow leading edge cavity (34) through which a cooling fluid flows for cooling said leading edge; and
    means for generating a vortex (49) in said leading edge cavity (34) which impinges on a nose portion (36) of said leading edge cavity (34).

2. The turbine engine component according to claim 1, wherein said vortex generating means comprises a plurality of first trip strips (40; 44) wrapped around said nose portion (36) of said leading edge cavity (34).

3. The turbine engine component according to claim 2, wherein said first trip strips (40) are mounted to the suction side (46) of said airfoil portion (32).

4. The turbine engine component according to claim 2, wherein said first trip strips (44) are mounted to the pressure side (42) of said airfoil portion (32).

5. The turbine engine component according to claim 2, wherein said vortex generating means further comprises a plurality of second trip strips (44; 40) and a plurality of gaps (47) between said first trip strips (40; 44) and said second trip strips (44; 40).

6. The turbine engine component according to claim 5, wherein said second trip strips (44; 40) are mounted on said pressure side (42) of said airfoil portion (32).

7. The turbine engine component according to claim 5, wherein said second trip strips (44; 40) are mounted on said suction side (46) of said airfoil portion (32).

8. The turbine engine component according to claim 5, wherein said first trip strips (40; 44) and said second trip strips (44; 40) are staggered.

9. The turbine engine component according to any of claims 5 to 8, wherein said plurality of gaps (47) are located along a parting line (70) of said airfoil portion (32).

10. The turbine engine component according to any of claims 5 to 9, wherein said first trip strips (40; 44) and second trip strips (44; 40) are positioned along a direction of flow (48) of said cooling fluid.

11. The turbine engine component according to claim 10, wherein the first trip strips (40; 44) are oriented substantially normal to the direction of flow so as to generate said vortex (49) at said leading edge.

12. The turbine engine component according to claim 10, wherein said first and second trip strips (40; 44) are each oriented at an angle of 45 degrees relative to the direction of flow of said cooling fluid.

13. The turbine engine component according to claim 10, wherein each of said first and second trip strips (40; 44) has a leading edge and said leading edge of each of said trip strips is positioned in a region of highest heat load.

14. The turbine engine component according to claim 13, wherein said leading edge of said first trip (40; 44) strips overlap said leading edge of said second trip strips (44; 40).

15. The turbine engine component according to claim 13, wherein said leading edge of said second trip strips (44; 40) overlap said leading edge of said first trip strips (40; 44).

16. The turbine engine component according to any of claims 10 to 15, wherein said trip strips (40; 44) have a P/E ratio in the range of from 3 to 25 where P is a radial pitch between trip strips and E is trip strip height.

17. The turbine engine component according to any of claims 10 to 16, wherein said trip strips (40; 44) have an E/H ratio between 0.15 and 1.50 where E is trip strip height and H is height of the cavity.

18. The turbine engine component according to any of claims 10 to 17, wherein said first trip strips (40; 44) and said second trip strips (44; 40) are staggered approximately one half pitch apart.

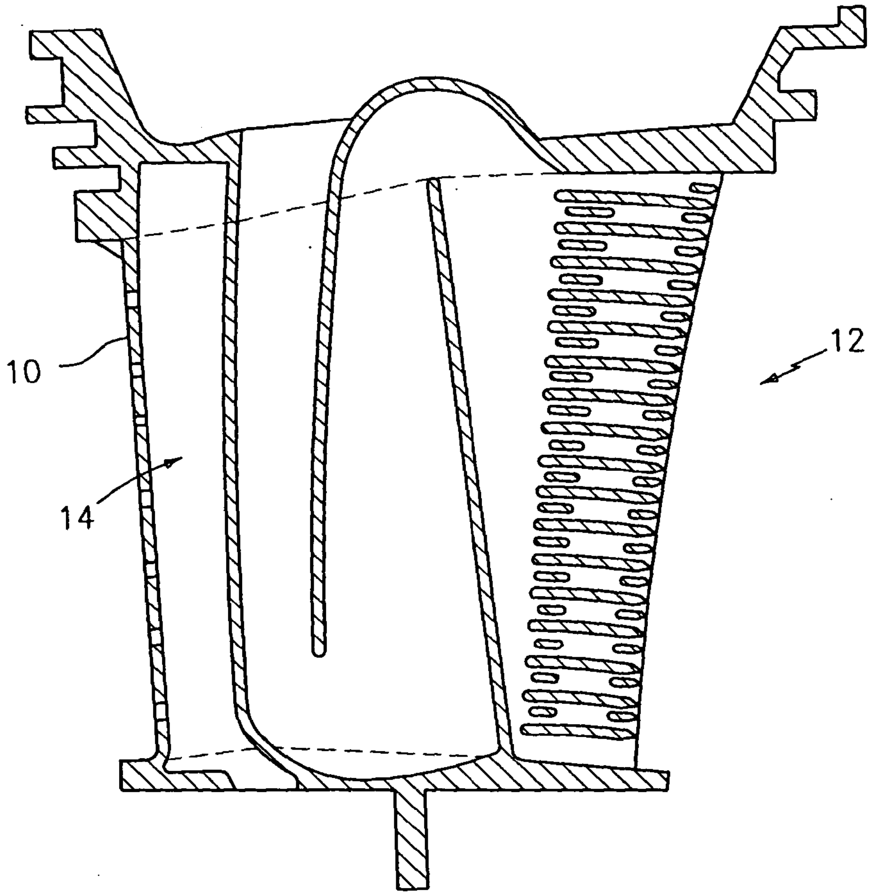

FIG. 1
(PRIOR ART)

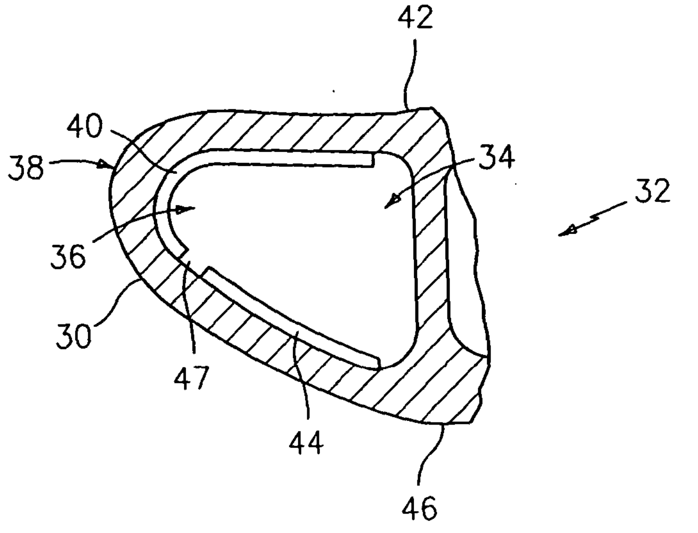

FIG. 2

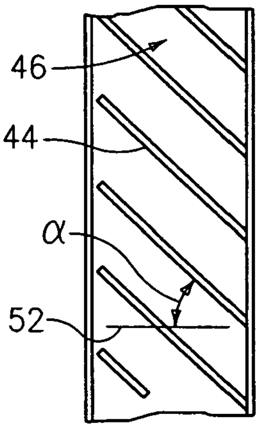

FIG. 3

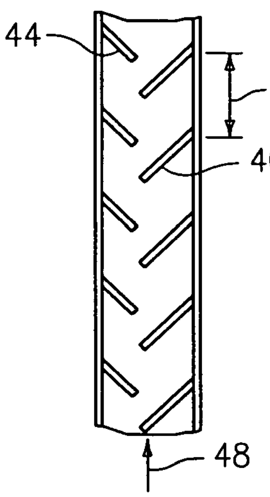

FIG. 4

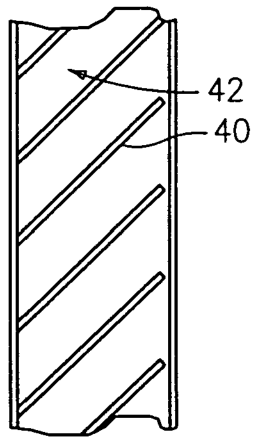

FIG. 5

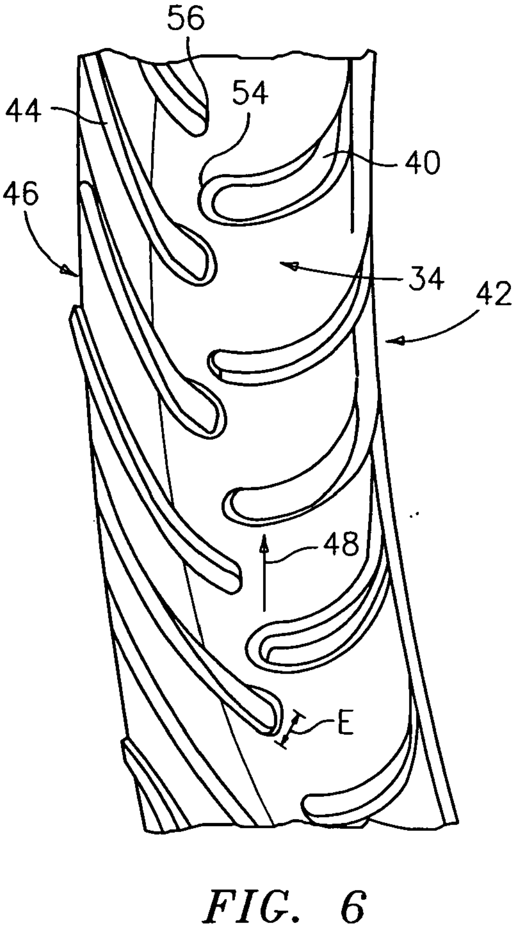

FIG. 6

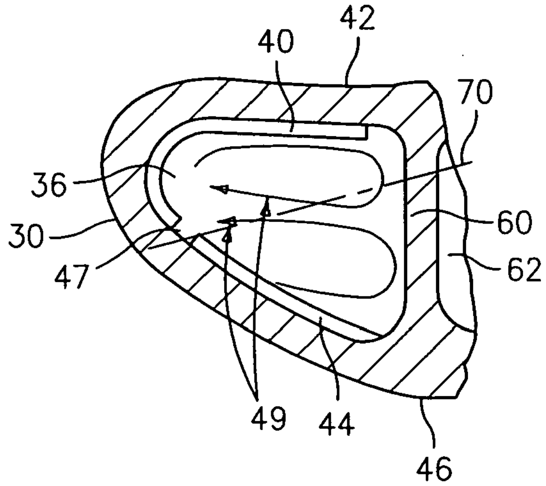

FIG. 7