A rotor blade (14) is provided having a hollow airfoil (22) and a root (20). The hollow airfoil (22) has a cavity defined by a suction side wall (38), a pressure side wall (36), a leading edge (32), a trailing edge (34), a base (28), and a tip (30). An internal passage configuration (40) is disposed within the cavity. The configuration includes a first radial passage (48), a second radial passage (50), and a rib (53) disposed between and separating the first radial passage (48) and second radial passage (50). A plurality of crossover apertures (52) are disposed within the rib (53). A portion of the plurality of crossover apertures (52) are oblong having a length (70) extending through the rib (53), and a height (74) and a width (72). The height (74) of each oblong aperture (52) is greater than the width (72). In some embodiments, the oblong crossover apertures (52) are aligned heightwise along the rib (53). The root (20) includes a conduit (42) that is operable to permit airflow through the root (20) and into the first radial passage (48).
Description

BACKGROUND OF THE INVENTION

1. Technical Field

[0001] This invention applies to gas turbine rotor blades in general, and to cooled gas turbine rotor blades in particular.

2. Background Information

[0002] Turbine sections within an axial flow turbine engine include rotor assemblies that include a rotating disc and a number of rotor blades circumferentially disposed around the disk. Rotor blades include an airfoil portion for positioning within the gas path through the engine. Because the temperature within the gas path very often negatively affects the durability of the airfoil, it is known to cool an airfoil by passing cooling air through the airfoil. The cooled air helps decrease the temperature of the airfoil material and thereby increase its durability.

[0003] Prior art cooled rotor blades very often utilize internal passage configurations that include a first radial passage extending contiguous with the leading edge, a second radial passage, and a rib disposed between and separating the passages. A plurality of crossover apertures is disposed within the rib, typically oriented perpendicular to the airfoil wall along the leading edge. A pressure difference across the rib causes a portion of the cooling air traveling within the second radial passage to pass through the crossover apertures and impinge on the leading edge wall.

[0004] Prior art leading edge impingement configurations typically employed circular crossover apertures uniformly spaced along the rib. The cooling air impinging from each circular crossover aperture creates a region of relatively high heat transfer, albeit a small one. Collectively, the circular crossover apertures create a line of discrete regions of high heat transfer separated by larger areas of relatively low heat transfer. The variations in heat transfer make the leading edge increase the possibility of undesirable fatigue, distress, oxidation, etc. within the leading edge wall.

[0005] What is needed is an airfoil having improved impingement cooling that increases the uniformity of impingement cooling, particularly along the leading edge of the blade.

DISCLOSURE OF THE INVENTION

[0006] According to the present invention, a rotor blade is provided having a hollow airfoil and a root. The hollow airfoil has a cavity defined by a suction side wall, a pressure side wall, a leading edge, a trailing edge, a base, and a tip. An internal passage configuration is disposed within the cavity. The configuration includes a first radial passage, a second radial passage, and a rib disposed between and separating the first radial passage and second radial passage. A plurality of crossover apertures are disposed within the rib. A portion of the plurality of crossover apertures are oblong having a length extending through the rib, and a height and a width. The height of each oblong aperture is greater than the width. In some embodiments, the oblong crossover apertures are aligned heightwise along the rib. The root includes a conduit that is operable to permit airflow through the root and into the first passage.

[0007] One of the advantages of the present rotor blade and method is that airflow pressure losses within the airfoil are decreased relative to prior art airfoils having impingement cooling of which we are aware.

[0008] These and other features and advantages of the present invention will become apparent in light of the detailed description of a preferred embodiment thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a diagrammatic perspective view of the rotor assembly section. FIG. 2 is a diagrammatic sectional view of a rotor blade having an embodiment of the internal passage configuration. FIG. 3 is a diagrammatic sectional view of a portion of a rotor blade having an embodiment of the internal passage configuration. FIG. 4 is a diagrammatic partial view of a rib with oblong crossover apertures disposed therein.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Referring to FIG. 1, a rotor blade assembly 10 for a gas turbine engine is provided having a disk 12 and a plurality of rotor blades 14. The disk 12 includes a plurality of recesses 16 circumferentially disposed around the disk 12 and a rotational centerline 18 about which the disk 12 may rotate. Each blade 14 includes a root 20, an airfoil 22, a platform 24, and a radial centerline 25. The root 20 includes a geometry (e.g., a fir tree configuration) that mates with that of one of the recesses 16 within the disk 12. As can be seen in FIG. 2, the root 20 further includes conduits 26 through which cooling air may enter the root 20 and pass through into the airfoil 22.

[0011] Referring to FIGS. 2 - 4, the airfoil 22 includes a base 28, a tip 30, a leading edge 32, a trailing edge 34, a pressure side wall 36 (see FIG. 1), and a suction side wall 38 (see FIG. 1), and an internal passage configuration 40. FIG. 2 diagrammatically illustrates an airfoil 22 sectioned between the leading edge 32 and the trailing edge 34. The pressure side wall 36 and the suction side wall 38 extend between the base 28 and the...
tip 30 and meet at the leading edge 32 and the trailing edge 34.

[0012] The internal passage configuration includes a first conduit 42, a second conduit 44, and a third conduit 46 extending through the root 20 into the airfoil 22. Fewer or more conduits may be used alternatively. The first conduit 42 is in fluid communication with a first radial passage 48. A second radial passage 50 is disposed forward of the first radial passage 48, contiguous with the leading edge 32, and is connected to the first radial passage 48 by a plurality of crossover apertures 52. The crossover apertures 52 are disposed in a rib 53 that extends between and separates the first radial passage 48 and the second radial passage 50. The second radial passage 50 is connected to the exterior of the airfoil 22 by a plurality of cooling apertures 54 disposed along the leading edge 32. In some embodiments, the second radial passage 50 may be disposed in one or more cavities. In other embodiments, the second radial passage 50 may be in direct fluid communication with the first conduit 42. At the outer radial end of the first radial passage 48 (i.e., the end of the first radial passage 48 opposite the first conduit 42), the first radial passage 48 is connected to an axially extending passage 56 that extends to the trailing edge 34 of the airfoil 22, adjacent the tip 30 of the airfoil 22.

[0013] A portion of the crossover apertures 52 disposed in the rib 53 are oblong, each having a length 70, width 72, and height 74. In a preferred embodiment, substantially all of the crossover apertures 52 are oblong. The length 70 of each crossover aperture 52 extends through the rib 53. The height 74 and width 72 are substantially perpendicular to each other and to the length 70. The height 74 of each oblong crossover aperture 52 is greater than the width 72. In a preferred embodiment, the height 74 is approximately twice the width 72 in magnitude. The oblong crossover apertures 52 are aligned heightwise along the rib 53, such that the heights 74 of the oblong crossover apertures 52 are substantially collinear. In the embodiment shown in FIGS. 3 and 4, the oblong crossover apertures 52 are shown as having a constant width 72 and circular ends. The oblong crossover apertures 52 are not limited to this embodiment.

[0014] The rib 53 is separated from the interior surface of the leading edge wall 78 by a distance "L". The oblong crossover apertures 52 may be described as having a hydraulic diameter "D". In a preferred embodiment, the separation of the rib 53 from the leading edge wall 78, and the size of the oblong crossover apertures 53 are such that the ratio of L/D is on average in the approximate range of 2.8 to 3.0. It is our experience that an L/D in this approximate range provides desirable impingement cooling.

[0015] The first radial passage 48 includes a plurality of trip strips 58 attached to the interior surface of one or both of the pressure side wall 36 and the suction side wall 38. The trip strips 58 are disposed within the passage 48 at an angle α that is skewed relative to the cooling airflow direction 60 within passage 48; i.e., at an angle between perpendicular and parallel to the airflow direction 60. Preferably, the trip strips 58 are oriented at an angle of approximately 45° to the cooling airflow direction 60. The orientation of each trip strip 58 within the passage 48 is such that the trip strip 58 converges toward the rib 53 containing the crossover apertures 52, when viewed in the airflow direction 60. Each of the trip strips 58 has an end disposed adjacent the rib 53 (i.e., a "rib end"). At least a portion of the trip strips 58 have a rib end radially located between a pair of crossover apertures 52, preferably approximately midway between the pair of crossover apertures 52.

[0016] Referring to FIG. 2, the second conduit 44 is in fluid communication with a serpentine passage 64 disposed immediately aft of the first and second radial passages 50, 48, in the mid-body region of the airfoil 22. The serpentine passage 64 has an odd number of radial segments 66, which number is greater than one; e.g., 3, 5, etc. The odd number of radial segments 66 ensures that the last radial segment in the serpentine 64 ends adjacent the axially extending passage 56. Passage configurations other than the aforesaid serpentine passage 64 may be used within the mid-body region alternatively.

[0017] The third conduit 46 is in fluid communication with one or more passages 68 disposed between the serpentine passage 64 and the trailing edge 34 of the airfoil 22.

[0018] In the operation of the invention, the rotor blade airfoil 22 is disposed within the core gas path of the turbine engine. The airfoil 22 is subject to high temperature core gas passing by the airfoil 22. Cooling air, that is substantially lower in temperature than the core gas, is fed into the airfoil 22 through the conduits 42, 44, 46 disposed in the root 20.

[0019] Cooling air traveling through the first conduit 42 passes directly into the first radial passage 48, and subsequently into the axially extending passage 56 adjacent the tip 30 of the airfoil 22. A portion of the cooling air traveling within the first radial passage 48 encounters the trip strips 58 disposed within the passage 48. The trip strips 58 converging toward the rib 53 direct the portion of cooling airflow toward the rib 53. The position of the trip strips 58 relative to the crossover apertures 52 are such that the portion of cooling airflow directed toward the rib 53 is also directed toward the crossover apertures 52. The portion of cooling airflow travels through the crossover apertures 52 and into the second radial passage 50. The cooling air subsequently exits the second radial passage 50 via the cooling apertures 52 disposed in the leading edge 32 and impinges on the interior surface of the leading edge wall.

[0020] As stated above, prior art circular crossover apertures typically create a line of discrete regions of high heat transfer separated by larger areas of relatively low heat transfer. The oblong crossover apertures 52 of
the present invention provide a more uniform radial heat transfer profile along the leading edge 32 that the aforesaid prior art. The regions of desirable relatively high heat transfer are larger, and the regions of undesirable relatively low heat transfer are smaller. In addition, the heat transfer within the regions of relatively low heat transfer appears to be increased by cooling air showering radially outward from the oblong crossover apertures 52.

[0021] Although this invention has been shown and described with respect to the detailed embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the scope of the invention.

Claims

1. A rotor blade (14), comprising:

   a hollow airfoil (22) having a cavity defined by a suction side wall (38), a pressure side wall (36), a leading edge (32), a trailing edge (34), a base (28), and a tip (30);

   an internal passage configuration (40) disposed within the cavity, which configuration includes a first radial passage (48), a second radial passage (50), a rib (53) disposed between and separating the first radial passage (48) and second radial passage (50), and a plurality of crossover apertures (52) disposed within the rib (53), wherein a portion of the plurality of crossover apertures (52) are oblong having a length (70) extending through the rib (53), and a height (74) and a width (72), and wherein the height (74) of each oblong crossover aperture (52) is greater than the width (72);

   a root having a conduit (42) that is operable to permit airflow through the root and into the first radial passage (48).

2. The rotor blade of claim 1, wherein substantially all of the crossover apertures (52) are oblong.

3. The rotor blade of claim 2, wherein the height (74) of each crossover aperture (52) is approximately twice the magnitude of the width (72) of that crossover aperture (52).

4. The rotor blade of any preceding claim, wherein the oblong crossover apertures (52) are aligned heightwise along the rib (53).

5. The rotor blade of any preceding claim, wherein the second radial passage (50) is contiguous with the leading edge (32).

6. The rotor blade of any preceding claim, wherein the rib (53) is separated from the leading edge (32) by a distance "L", and the oblong crossover apertures (52) have a hydraulic diameter "D", and the ratio of L/D is on average in the approximate range of 2.8 to 3.0.