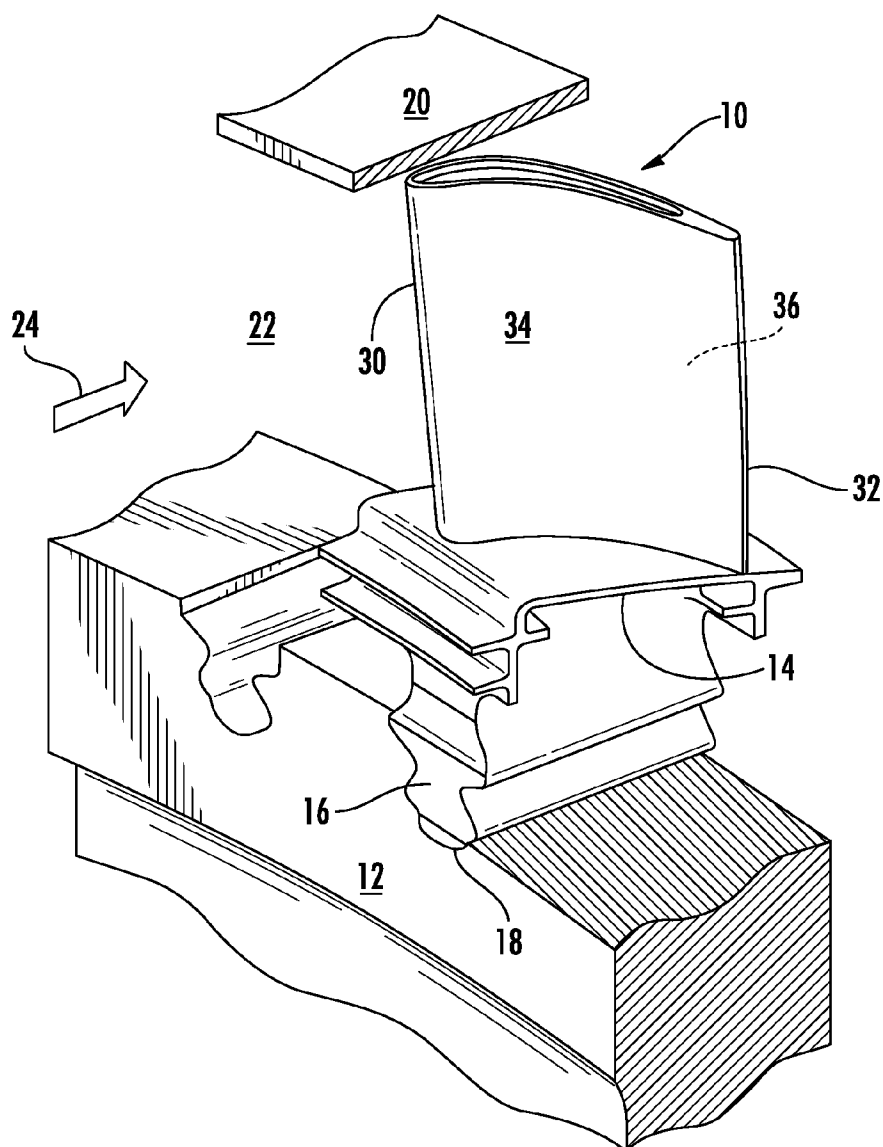




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(19) **United States**(12) **Patent Application Publication**
Giglio et al.(10) **Pub. No.: US 2014/0044557 A1**(43) **Pub. Date: Feb. 13, 2014**(54) **TURBINE BLADE AND METHOD FOR
COOLING THE TURBINE BLADE**(22) Filed: **Aug. 9, 2012****Publication Classification**(75) Inventors: **Anthony Louis Giglio**, Simpsonville,
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Greer, SC (US)(51) **Int. Cl.**
F01D 5/18 (2006.01)
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(52) **U.S. Cl.**
USPC **416/97 R; 416/236 R**(73) Assignee: **GENERAL ELECTRIC COMPANY**,
Schenectady, NY (US)(57) **ABSTRACT**

A turbine blade includes an outer surface, and a rim surrounds at least a portion of the outer surface. A trench in the rim extends around at least a portion of the outer surface.

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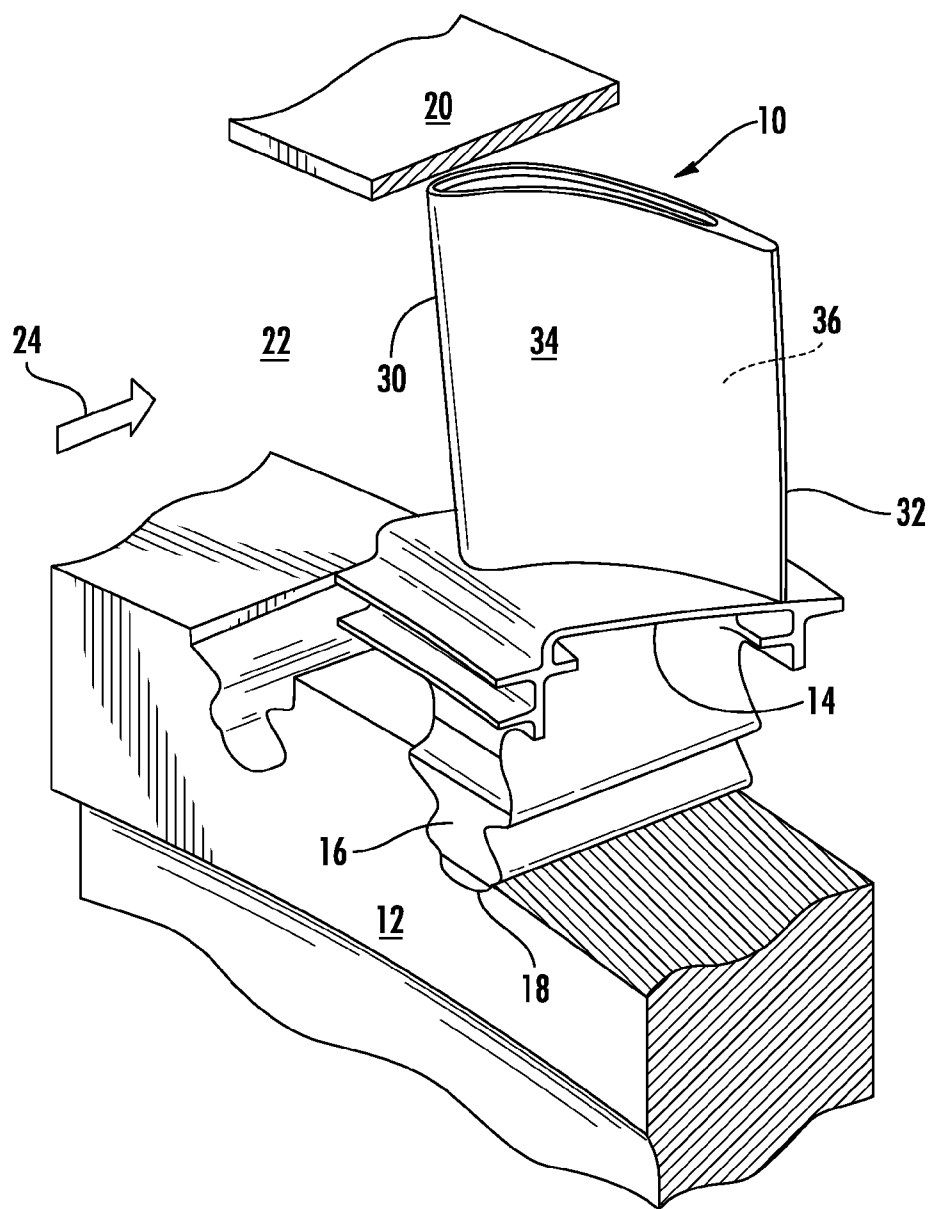
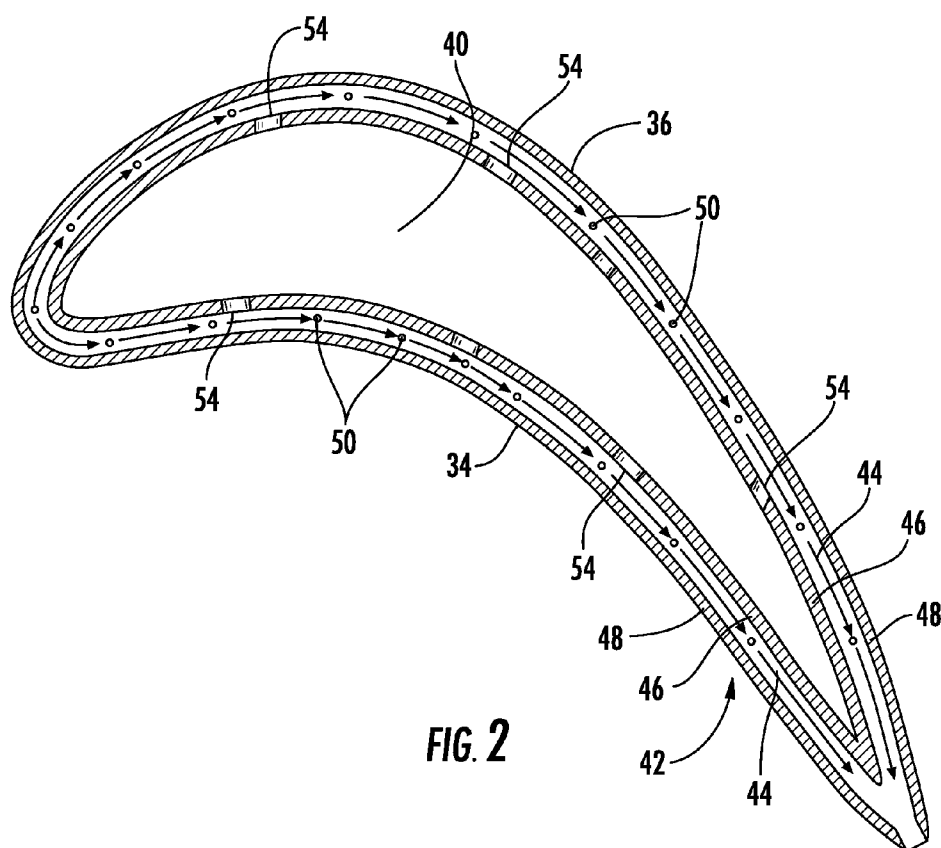


FIG. 1



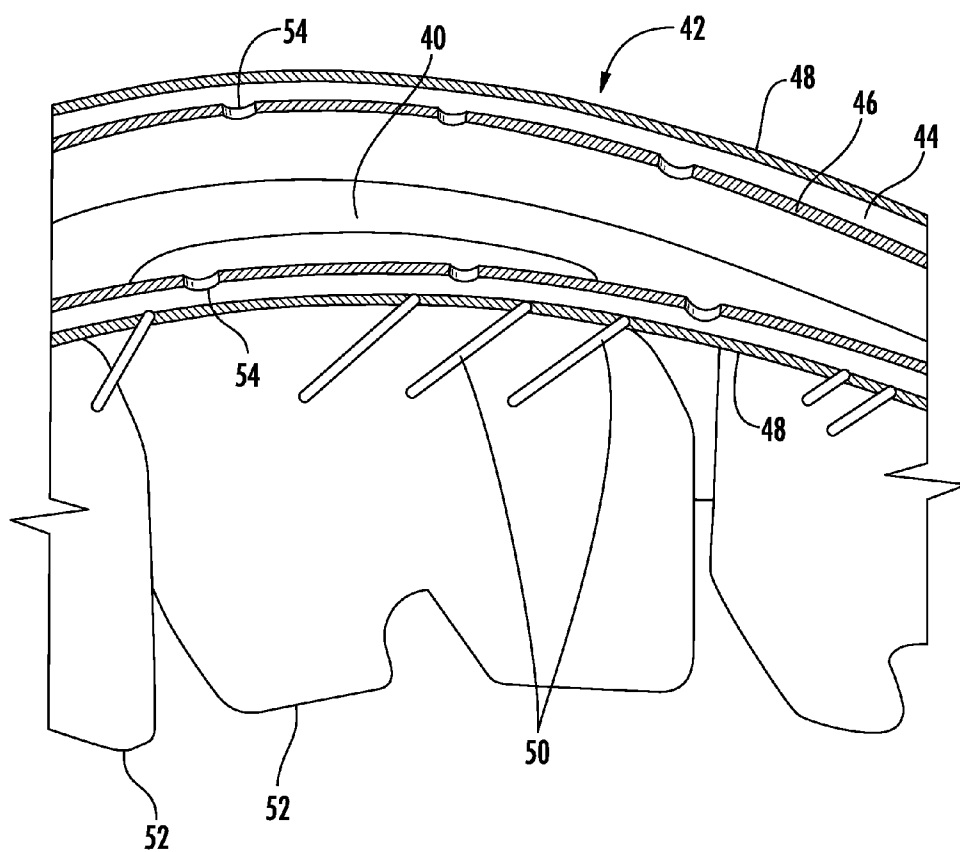


FIG. 3

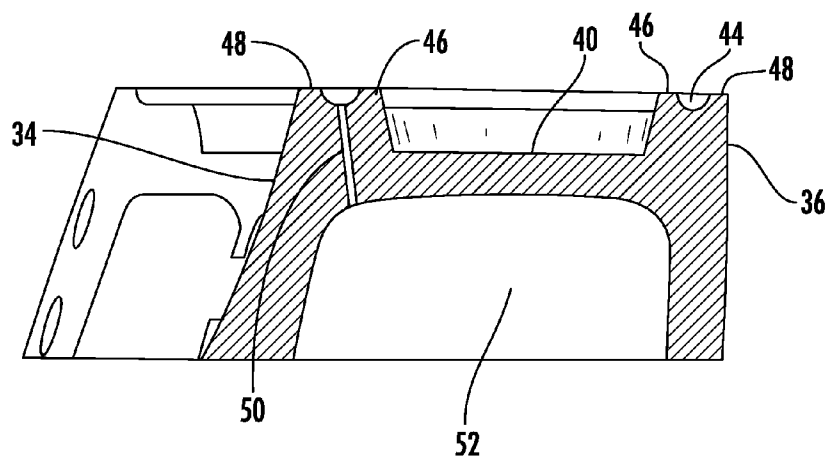


FIG. 4

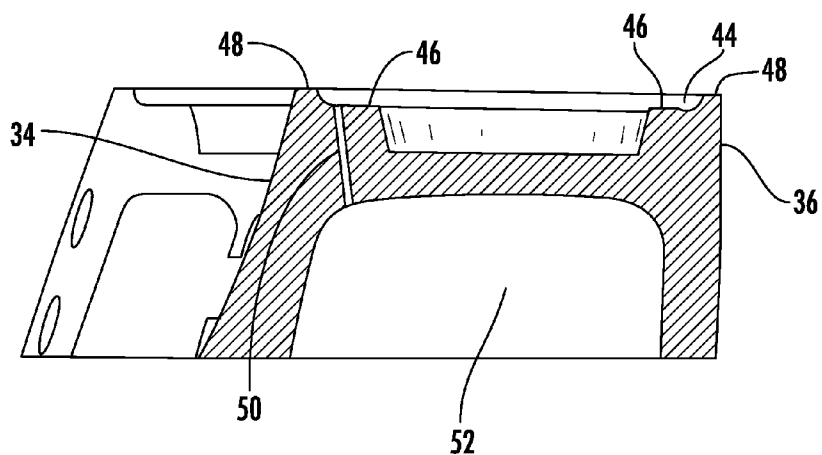


FIG. 5

TURBINE BLADE AND METHOD FOR COOLING THE TURBINE BLADE

FIELD OF THE INVENTION

[0001] The present invention generally involves a turbine blade and a method for cooling the turbine blade.

BACKGROUND OF THE INVENTION

[0002] Turbines are widely used in industrial and commercial operations. A typical commercial steam or gas turbine used to generate electrical power includes alternating stages of stationary and rotating airfoils or blades. For example, stationary vanes may be attached to a stationary component such as a casing that surrounds the turbine, and rotating blades may be attached to a rotor located along an axial centerline of the turbine. A compressed working fluid, such as but not limited to steam, combustion gases, or air, flows through the turbine, and the stationary vanes accelerate and direct the compressed working fluid onto the subsequent stage of rotating blades to impart motion to the rotating blades, thus turning the rotor and performing work.

[0003] Compressed working fluid that leaks around or bypasses the turbine blades reduces the efficiency of the turbine. To reduce the amount of compressed working fluid that bypasses the rotating blades, the casing may include stationary shroud segments that surround each stage of rotating blades, and each rotating blade may include a tip cap at an outer radial tip that reduces the clearance between the shroud segments and the rotating blade. Although effective at reducing or preventing leakage around the rotating blades, the interaction between the shroud segments and the tip caps may result in elevated local temperatures that may reduce the low cycle fatigue limits and/or lead to increased creep at the tip caps. As a result, a cooling media may be supplied to flow inside each rotating blade before flowing through cooling passages to provide film cooling over the tip caps of the rotating blades.

[0004] In particular designs, each tip cap may include an outer surface that is at least partially surrounded by a rim. The rim and the outer surface may at least partially define a tip cavity, also known as a squealer tip cavity, between the rim, the outer surface, and the surrounding shroud segments. In the manner, the cooling media may be supplied to the tip cavity to remove heat from the tip cap before flowing over the rim and out of the tip cavity. However, cooling media that flows over the suction side of the rotating blade may disrupt the flow of the compressed working fluid over the rotating blades and/or reduce the operating efficiency of the rotating blades. As a result, an improved turbine blade and a method for cooling the turbine blade would be useful.

BRIEF DESCRIPTION OF THE INVENTION

[0005] Aspects and advantages of the invention are set forth below in the following description, or may be obvious from the description, or may be learned through practice of the invention.

[0006] One embodiment of the present invention is a turbine blade that includes an outer surface, and a rim surrounds at least a portion of the outer surface. A trench in the rim extends around at least a portion of the outer surface.

[0007] Another embodiment of the present invention is a turbine blade that includes an outer surface. A pressure side wall extends from a leading edge to a trailing edge along a first

portion of the outer surface. A suction side wall opposed to the pressure side wall extends from the leading edge to the trailing edge along a second portion of the outer surface. A groove in at least one of the pressure side wall or the suction side wall extends around at least a portion of the outer surface.

[0008] The present invention may also include a turbine blade that includes an outer surface. A first wall surrounds at least a portion of the outer surface. A second wall surrounds at least a portion of the first wall to define a trench between the first and second walls, and the trench extends around at least a portion of the outer surface.

[0009] Those of ordinary skill in the art will better appreciate the features and aspects of such embodiments, and others, upon review of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A full and enabling disclosure of the present invention, including the best mode thereof to one skilled in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

[0011] FIG. 1 is a perspective view of an exemplary turbine stage within the scope of the present invention;

[0012] FIG. 2 is a top plan view of the turbine blade shown in FIG. 1 according to one embodiment of the present invention;

[0013] FIG. 3 is a top perspective view of the turbine blade shown in FIG. 1 according to one embodiment of the present invention;

[0014] FIG. 4 is a radial cross-section view of the turbine blade shown in FIG. 1 according to one embodiment of the present invention; and

[0015] FIG. 5 is a radial cross-section view of the turbine blade shown in FIG. 1 according to an alternate embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention. As used herein, the terms “first”, “second”, and “third” may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. In addition, the terms “upstream” and “downstream” refer to the relative location of components in a fluid pathway. For example, component A is upstream from component B if a fluid flows from component A to component B. Conversely, component B is downstream from component A if component B receives a fluid flow from component A.

[0017] Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that modifications and variations can be made in the present invention without departing from the scope or spirit thereof. For instance, features illustrated or described as part of one embodiment may be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0018] Various embodiments of the present invention include a turbine blade and a method for cooling the turbine blade. The turbine blade generally includes a tip cap having a squealer tip or cavity at least partially surrounded by a rim. A groove or trench in the rim runs along at least a portion of the rim. In particular embodiments, the rim may include outer and inner walls that define the groove or trench, and the outer wall may be higher than the inner wall. In other particular embodiments, the inner wall may include one or more notches that provide fluid communication from the groove or trench to the cavity. In still further embodiments, the groove or trench may include one or more cooling passages or holes drilled into the trench to provide fluid communication from an internal cavity through the tip cap to supply film cooling to the groove or trench. Although exemplary embodiments of the present invention will be described generally in the context of a turbine blade incorporated into a gas turbine, one of ordinary skill in the art will readily appreciate from the teachings herein that embodiments of the present invention are not limited to a gas turbine unless specifically recited in the claims.

[0019] Referring now to the drawings, wherein identical numerals indicate the same elements throughout the figures, FIG. 1 provides a perspective view of an exemplary turbine stage within the scope of the present invention. As shown, the turbine stage generally includes multiple turbine blades 10 that extend radially from a rotor wheel 12. Each turbine blade 10 may be connected to a platform 14 having a dovetail root 16. The dovetail root 16 may axially slide into a complementary dovetail slot 18 in the rotor wheel 12 to hold the platform 14 and turbine blade 10 radially in place. An annular shroud 20 or plurality of shroud segments may circumferentially surround the turbine blades 10 so that the rotor wheel 12 and annular shroud 20 at least partially define a hot gas path 22 through which combustion gases or another compressed working fluid 24 may flow.

[0020] Each turbine blade 10 generally has an airfoil shape with a leading edge 30 and a trailing edge 32 downstream from the leading edge 30. A concave surface or pressure side wall 34 extends between the leading and trailing edges 30, 32 on one side of the turbine blade 10, and a convex surface or suction side wall 36 extends between the leading and trailing edges 30, 32 on the other side of the turbine blade 10. The pressure and suction side walls 34, 36 generally extend radially in the hot gas path 22 from the platform 14 to the annular shroud 20 to form the airfoil shape of the turbine blade 10.

[0021] FIG. 2 provides a top plan view, FIG. 3 provides a top perspective view, and FIG. 4 provides a radial cross-section view of the of the turbine blade 10 shown in FIG. 1 according to one embodiment of the present invention. As shown in FIGS. 2-4, each turbine blade 10 includes an outer surface 40 proximate to the annular shroud 20. The pressure and suction side walls 34, 36 may extend radially beyond the outer surface 40 to form a rim 42 that surrounds at least a portion of the outer surface 40. In this manner, the rim 42 and the outer surface 40 at least partially define a cavity, also known as a squealer cavity, in the radially outer portion of the turbine blade 10 adjacent to the annular shroud 20.

[0022] One or more cooling apertures (not shown) through the outer surface 40 may deliver a cooling media from cavities within the turbine blade 10 to the squealer tip cavity. The cooling media may remove heat from the outer surface 40 while also partially insulating the outer surface 40 from the extreme temperatures of the surrounding flow of working

fluid 24. In this manner, the tip of the turbine blade 10 may be maintained at an acceptable temperature during operation. As one of ordinary skill in the art will appreciate, the tip of the turbine blade 10 is a difficult area to cool and, thus, generally requires a high level of cooling media flow through the squealer tip cavity. In particular, the trailing edge 32 of the turbine blade 10 is difficult to cool in conventional systems because most of the cooling media is swept over the suction side wall 36 before reaching the trailing edge 32 of the turbine blade 10. Cooling media that flows over the suction side wall 36 has a negative effect on turbine engine aerodynamic efficiency, and minimizing this flow path thus improves engine performance.

[0023] As shown most clearly in FIGS. 2-4, the rim 42 may include a groove or trench 44 that extends around at least a portion of the outer surface 40. For example, the rim 42 may include an inner wall 46 that surrounds at least a portion of the outer surface 40 and an outer wall 48 that surrounds at least a portion of the inner wall 46 to define the groove or trench 44 between the inner and outer walls 46, 48. The cross-sectional profile, depth, and width of the groove or trench 44 may vary according to the particular application and location on the turbine blade 10. For example, the groove or trench 44 may have an arcuate, square, triangular or other cross-sectional profile with a depth and width that gradually decreases from the leading edge 30 to the trailing edge 32. In particular embodiments, for example, the depth of the groove or trench 44 may be between approximately 10% and 75% of the depth of the squealer tip cavity. However, one of ordinary skill in the art will readily appreciate from the teachings herein that the present invention is not limited to any particular cross-section, depth, or width for the groove or trench 44 unless specifically recited in the claims.

[0024] In particular embodiments, the groove or trench 44 may extend continuously in the rim 42 around the entire outer surface 40, as shown in FIGS. 2-4. Alternately or in addition, the groove or trench 44 may include a plurality of cooling passages 50 that provide fluid communication for a cooling media to flow into the groove or trench 44 from one or more cavities 52 inside the turbine blade 10. As shown most clearly in FIG. 3, the cavities 52 inside of the turbine blade 10 may have any configuration including, for example, serpentine flow channels with various turbulators therein for enhancing cooling media effectiveness. In addition, the cooling passages 50 may be angled toward the trailing edge 32 of the turbine blade 10 to enhance cooling media flow and heat removal in the trench 44. In this manner, the cooling media may flow from the cavities 52, through the cooling passages 50, and into the groove or trench 44 to remove heat and/or protect the surface of the rim 42 from excessive temperatures associated with the working fluid 24 in the hot gas path 22.

[0025] In the particular embodiment shown in FIGS. 2-4, the inner wall 46 of the trench 44 may include one or more notches 54 that provide fluid communication from the groove or trench 44 to the outer surface 40 in the squealer tip cavity. This additional flow path may increase the volume of cooling media supplied to the outer surface 40 in the squealer tip cavity while also reducing the amount of cooling media that leaks over the outer wall 48 of the rim 42. Alternately or in addition, the outer wall 48 of the rim 42 may be slightly higher than the inner wall 46 to similarly enhancing cooling media flow into the squealer tip cavity while also reducing the

amount of cooling media that leaks over the outer wall 48 of the rim 42, as shown in the particular embodiment illustrated in FIG. 5.

[0026] One of ordinary skill in the art will readily appreciate from the teachings herein that the turbine blades 10 shown and described with respect to FIGS. 1-5 may also provide one or more methods for cooling the turbine blade 10. The methods may include, for example, flowing the cooling media from cavities 52 inside the turbine blade 10, through cooling passages 50, and into the groove or trench 44. In particular embodiments, the method may further include flowing the cooling media through the groove or trench 44 in the rim 42 around the entire circumference of the outer surface 40. In other particular embodiments, the method may include flowing the cooling media through notches 54 in the inner wall 46 of the groove or trench 44 and/or over the inner wall 46 and across the outer surface 40.

[0027] It is anticipated that the various embodiments shown and described in FIGS. 1-5 will enhance cooling to the rim 42 while also reducing the amount of cooling media that flows over the rim 42 and into the hot gas path 22. As a result, the embodiments described herein will reduce the temperatures of the turbine blade 10, especially around the outer radial portion, thereby improving the low cycle fatigue limits for these components and reducing localized creep due to excessive temperatures.

[0028] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A turbine blade, comprising:
 - a. an outer surface;
 - b. a rim that surrounds at least a portion of the outer surface; and
 - c. a trench in the rim, wherein the trench extends around at least a portion of the outer surface.
2. The turbine blade as in claim 1, wherein the trench extends continuously in the rim around the entire outer surface.
3. The turbine blade as in claim 1, wherein the rim includes an outer wall that defines an outer portion of the trench and an inner wall that defines an inner portion of the trench, and the outer wall is higher than the inner wall.
4. The turbine blade as in claim 1, wherein the rim includes an outer wall that defines an outer portion of the trench and an inner wall that defines an inner portion of the trench, and the inner wall includes one or more notches that provide fluid communication from the trench to the outer surface.

5. The turbine blade as in claim 1, further comprising a plurality of cooling passages in the trench that provide fluid communication from inside the turbine blade.

6. The turbine blade as in claim 5, wherein the plurality of cooling passages in the trench are angled toward a trailing edge of the turbine blade.

7. A turbine blade, comprising:

- a. an outer surface;
- b. a pressure side wall that extends from a leading edge to a trailing edge along a first portion of the outer surface;
- c. a suction side wall opposed to the pressure side wall, wherein the suction side wall extends from the leading edge to the trailing edge along a second portion of the outer surface; and
- d. a groove in at least one of the pressure side wall or the suction side wall, wherein the groove extends around at least a portion of the outer surface.

8. The turbine blade as in claim 7, wherein the groove extends continuously in the pressure side wall and the suction side wall around the entire outer surface.

9. The turbine blade as in claim 7, wherein the pressure side wall includes an outer wall that defines an outer portion of the groove and an inner wall that defines an inner portion of the groove, and the outer wall is higher than the inner wall.

10. The turbine blade as in claim 7, wherein the pressure side wall includes an outer wall that defines an outer portion of the groove and an inner wall that defines an inner portion of the groove, and the inner wall includes one or more notches that provide fluid communication from the groove to the outer surface.

11. The turbine blade as in claim 7, further comprising a plurality of cooling passages in the groove that provide fluid communication from inside the turbine blade.

12. The turbine blade as in claim 11, wherein the plurality of cooling passages in the trench are angled toward a trailing edge of the turbine blade.

13. A turbine blade, comprising:

- a. an outer surface;
- b. a first wall that surrounds at least a portion of the outer surface; and
- c. a second wall that surrounds at least a portion of the first wall to define a trench between the first and second walls, wherein the trench extends around at least a portion of the outer surface.

14. The turbine blade as in claim 13, wherein the trench extends continuously around the entire outer surface.

15. The turbine blade as in claim 13, wherein the first wall is shorter than the second wall.

16. The turbine blade as in claim 13, wherein the first wall includes one or more notches that provide fluid communication from the trench to the outer surface.

17. The turbine blade as in claim 13, further comprising a plurality of cooling passages in the trench that provide fluid communication from inside the turbine blade.

18. The turbine blade as in claim 17, wherein the plurality of cooling passages in the trench are angled toward a trailing edge of the turbine blade.

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