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(54) Turbine airfoil and corresponding method of cooling

(57) A turbine airfoil includes a blade (10) having a leading (16) and trailing (18) edges and an internal cooling circuit (20), and a plurality of film holes (22) extending between the internal cooling circuit (20) and an exterior of the blade (10). The plurality of film holes (22) are shaped to generate a swirling flow exiting the film holes (22) adjacent the leading edge (16) to thereby enhance local convection and provide an insulating barrier to gas-path flow. A corresponding of film cooling a turbine airfoil is also provided.

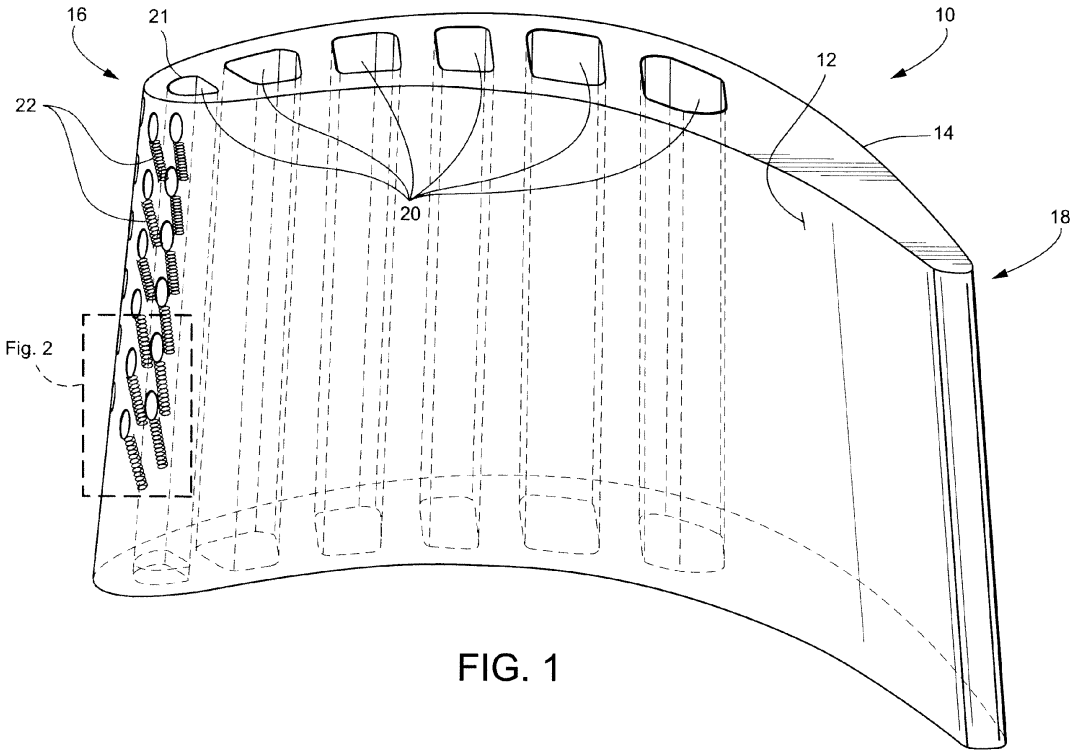

FIG. 1

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Description

BACKGROUND OF THE INVENTION

[0001] This application relates generally to gas turbine engines and, more particularly, to methods and apparatus for film cooling airfoils used within gas turbine engines.

[0002] Gas turbine engines typically include a compressor, a combustor, and a turbine. Airflow entering the compressor is compressed and directed to the combustor where it is mixed with fuel and ignited, producing hot combustion gases used to drive the turbine. Blades and vanes used in the turbine section of a gas turbine engine each have an airfoil section that extends radially across an engine flowpath. During engine operation, the turbine blades and vanes are exposed to elevated temperatures that can lead to mechanical failure and corrosion. Therefore, it is common practice to make the blades and vanes from a temperature tolerant alloy and to apply corrosion resistant and thermally insulating coatings to the airfoil and other flowpath exposed surfaces. It is also widespread practice to cool the airfoils by flowing a coolant through the interior of the airfoils.

[0003] For example, a turbine vane or rotor blade typically includes a hollow airfoil, the outside of which is exposed to the hot combustion gases, and the inside of which is supplied with cooling fluid, which is typically compressed air. The airfoil includes leading and trailing edges, a pressure side, and a suction side. The pressure and suction sides connect at the airfoil leading and trailing edges, and span radially between an airfoil root and an airfoil tip. Film cooling holes extend between an internal cooling circuit defined within the airfoil and an outer surface of the airfoil. The film cooling holes route cooling fluid from the internal cooling circuit to the outside of the airfoil for film cooling the airfoil.

[0004] Helical ribs in cooling holes have been used to generate a secondary flow pair of longitudinal vortices in the same direction as the turn of the rib. It may be desirable to utilize this known behavior in film holes to improve film cooling, increase coverage for film cooling and augment cooling efficiency.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In a first aspect, the invention resides in a turbine airfoil includes a blade with a pressure sidewall and a suction sidewall joined together at chordally opposite leading and trailing edges, and at least one cooling hole disposed between the pressure sidewall and the suction sidewall adjacent the leading edge. A plurality of curved film holes extend between the at least one cooling hole and an exterior of the blade.

[0006] In another aspect, the invention resides a turbine airfoil includes a blade having a leading and trailing edges and an internal cooling circuit, and a plurality of film holes extending between the internal cooling circuit and an exterior of the blade. The plurality of film holes are shaped to generate a swirling flow exiting the film holes adjacent the leading edge to thereby enhance local convection and provide an insulating barrier to gaspath flow.

[0007] In yet another aspect, the invention resides in a method of film cooling a turbine airfoil includes the steps of delivering cooling air to the internal cooling circuit, and flowing the cooling air from the internal cooling circuit through a plurality of film holes extending between the internal cooling circuit and an exterior of the blade. The flowing step comprises swirling the cooling air in the film holes and thereby providing an insulating barrier to gaspath flow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 is a perspective view of a blade portion of a turbine airfoil;

FIG. 2 shows an exemplary arrangement of helical film holes; and

FIG. 3 shows a double helical film hole.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Film-cooling holes or film holes are widely used in modem gas turbines to cool the turbine airfoils that are exposed to hot combustion gases during operation of the turbine. The film-cooling holes provide cooling of the airfoil in several ways. Firstly, they provide film-cooling of the airfoil surface. Film-cooling is the cooling of a body or surface by maintaining a thin fluid layer over the affected area of a fluid that has a lower temperature than the operating environment. The fluid film insulates the film-cooled surface from the external operating environment, thereby reducing convective heat transfer from the external operating environment into the airfoil. Further, the film of the cooling fluid also removes heat from the airfoil surface. Secondly, film-cooling also provides convective heat transfer from and cooling of the airfoil sidewall surrounding the film-cooling hole as the cooling air flows through it along the length of the hole. Thirdly, the film-cooling holes remove heat by providing an exhaust path for the cooling air that has been heated as it in turn cools the airfoil by passage through the airfoil cooling circuit.

[0010] FIG. 1 shows a blade section 10 of a turbine airfoil. The blade includes a pressure sidewall 12 and a suction sidewall 14 joined together at chordally opposite leading 16 and trailing 18 edges. A cooling circuit is defined by a plurality of cooling passages or holes 20 that are disposed between the pressure sidewall 12 and the

suction sidewall 14. At least one cooling hole 21 is positioned adjacent the leading edge 16.

[0011] Film holes or film cooling holes are known that extend from one or more of the cooling holes 20 to an exterior of the blade. The film cooling holes are typically straight and direct cooling air from the cooling holes 20 to the blade exterior. With continued reference to FIG. 1, and with reference to FIG. 2, the airfoil according to preferred embodiments includes a plurality of curved film holes 22 that extend between the cooling hole 21 and the exterior of the blade 10. That is, a passage between the cooling hole 21 and the exterior of the blade 10 comprises a curved or twisted groove or the like such that air flowing through and exiting the film holes 22 is turning. An exemplary shape for the film holes may be helical, although other shapes may be contemplated, and the invention is not necessarily meant to be limited to the arrangement shown in the drawings. With the helical or other curved or twisted shaped film holes 22, the film flow coming out of the holes no longer has a direct path, but rather exits in a swirling pattern, resulting in enhanced local convection with the holes as well as providing an insulating barrier to the gas path flow.

[0012] Preferably, the helical film holes 22 are oriented in both clockwise and counter-clockwise directions. Adjacent ones of the plurality of helical film holes 22 may thus be oriented in opposite directions. As a consequence of such structure, the exiting flow swirls in opposite vortices, further enhancing the advantageous effects of the design. As shown in FIG. 2, in an exemplary embodiment, a first group 24 of the helical film holes 22 may be oriented in one direction, while a second group 26 is oriented in an opposite direction. As shown, the first groups 24 and second groups 26 may alternate along a length of the blade 10. In the embodiment shown in FIG. 2, each of the first and second groups 24, 26 comprises three helical film holes 22.

[0013] In yet another exemplary construction, with reference to FIG. 3, at least one of the helical film holes may comprise a double helical film hole 220. That is, the film hole 220 may comprise two (or more) interlaced helical grooves or passageways through which cooling air is passed.

[0014] The cooling circuit with helical film holes serves to improve film cooling, increase coverage for film cooling and generally augment cooling efficiency. The swirling flow provides for enhanced local convection within the holes and also provides an insulating barrier to the gas-path flow.

[0015] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

Claims

1. A turbine airfoil comprising:

a blade (10) including a pressure sidewall (12) and a suction sidewall (14) joined together at chordally opposite leading (16) and trailing (18) edges;
at least one cooling hole (20) disposed between the pressure sidewall (12) and the suction sidewall (14) adjacent the leading edge (16); and
a plurality of curved film holes (22) extending between the at least one cooling hole (20) and an exterior of the blade (10).

2. A turbine airfoil according to claim 1, wherein the curved film holes (22) are helical.

3. A turbine airfoil according to claim 2, wherein the plurality of helical film holes (22) are oriented in clockwise and counter-clockwise directions.

4. A turbine airfoil according to claim 2 or 3, wherein adjacent ones of the plurality of helical film holes (22) are oriented in opposite directions.

5. A turbine airfoil according to claim 2 or 3, wherein first groups (24) of the helical film holes (22) are oriented in one direction and second groups (26) of the helical film holes (22) are oriented in an opposite direction.

6. A turbine airfoil according to claim 5, wherein the first groups (24) and second groups (28) alternate along a length of the blade (10).

7. A turbine airfoil according to claim 5 or 6, wherein each of the first (24) and second (26) groups comprises three helical film holes (22).

8. A turbine airfoil according to any of claims 2 to 7, wherein at least one of the plurality of helical film holes (22) comprises a double helical film hole (220).

9. A turbine airfoil according to any preceding claim comprising:

wherein the plurality of film holes (22) being shaped to generate a swirling flow exiting the film holes (22) adjacent the leading edge (16) to thereby enhance local convection and provide an insulating barrier to gaspath flow.

10. A method of film cooling a turbine airfoil including a blade (10) with a leading edge (16) and a trailing edge (18) and having an internal cooling circuit (20), the method comprising:

delivering cooling air to the internal cooling circuit (20); and

flowing the cooling air from the internal cooling circuit (20) through a plurality of film holes (22) extending between the internal cooling circuit (20) and an exterior of the blade (10), the flowing step comprising swirling the cooling air in the film holes (22) and thereby providing an insulating barrier to gaspath flow.

11. A method according to claim 10, wherein the plurality of film holes comprise helical film holes (22), and wherein the flowing step is practiced by flowing the cooling air from the internal cooling circuit (20) through the helical film holes (22).

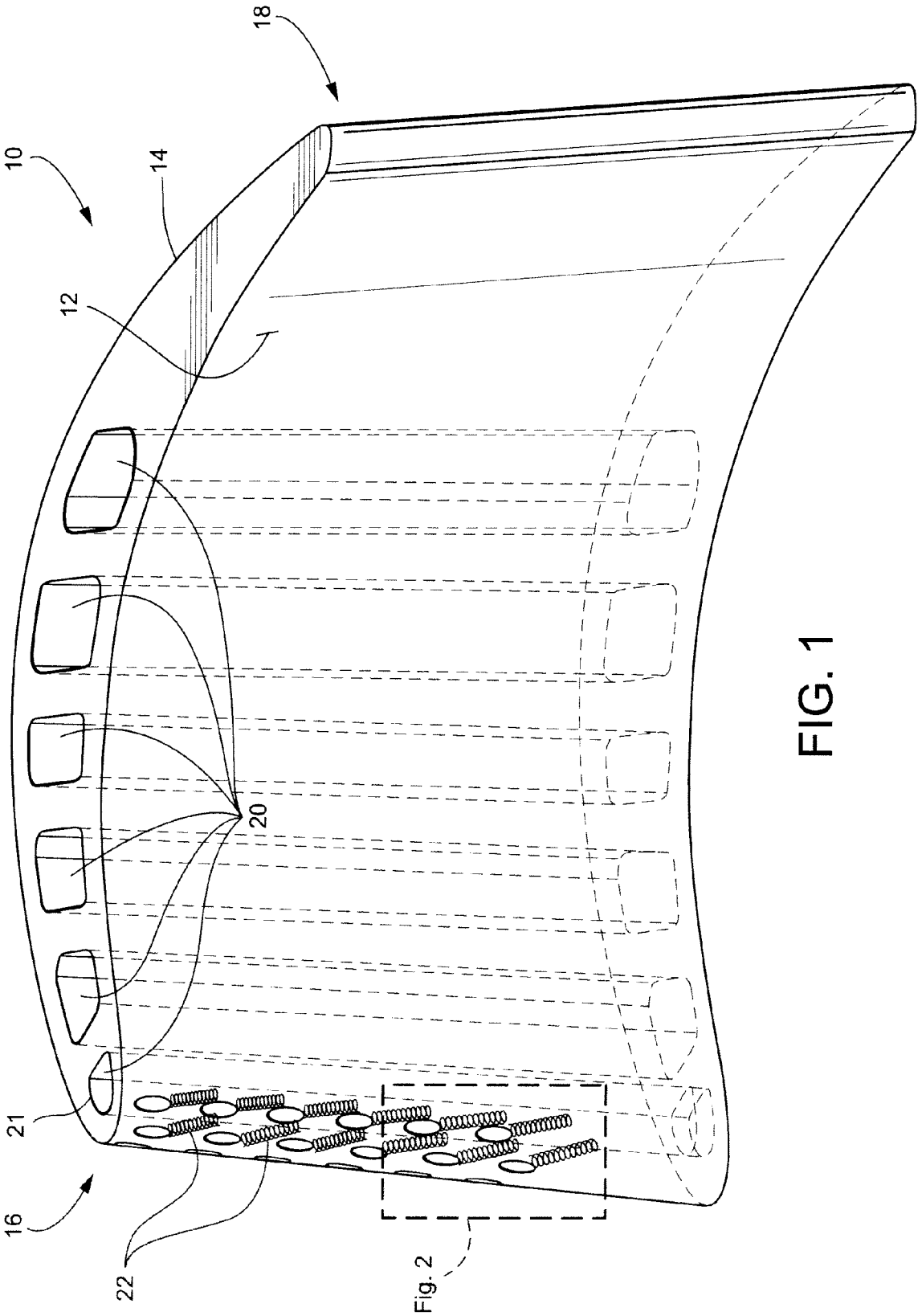


FIG. 1

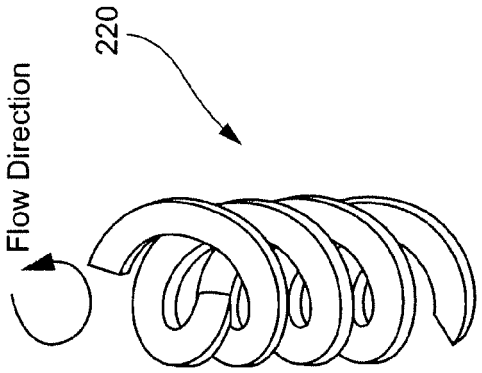
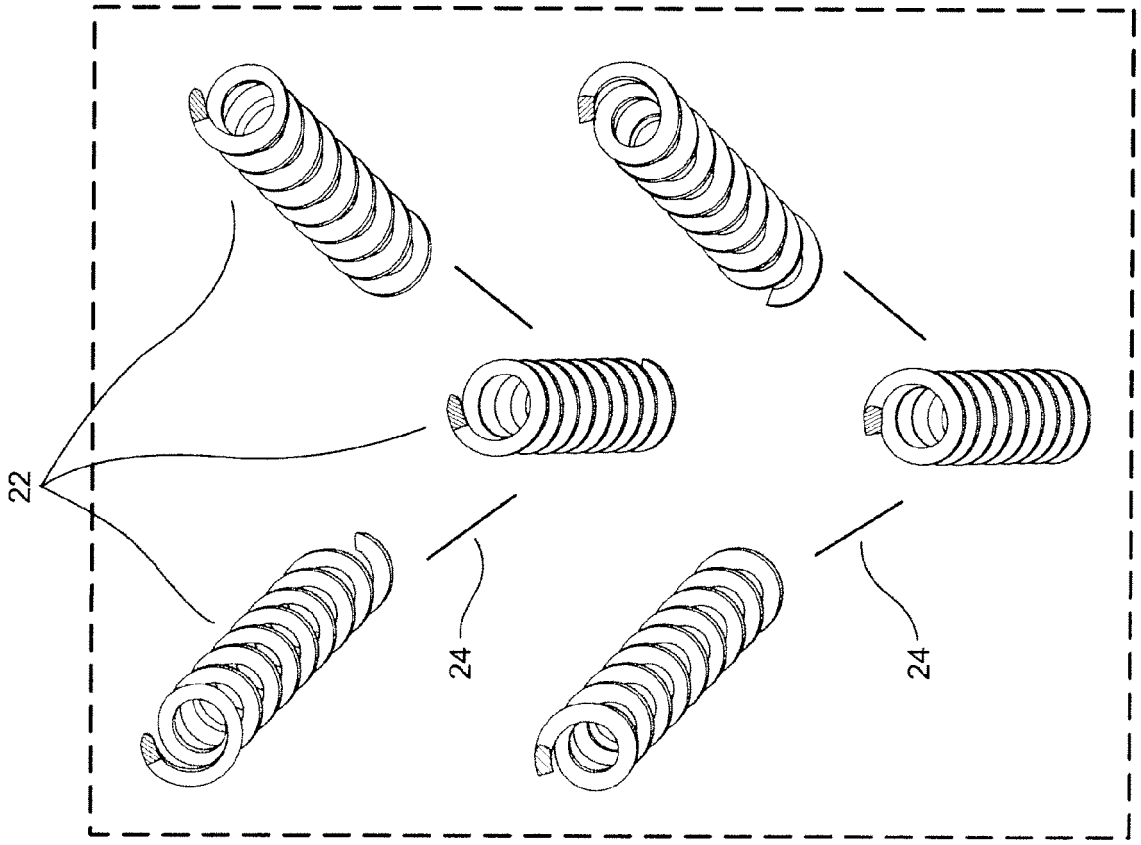


FIG. 3

FIG. 2



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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	28 March 2013	Raspo, Fabrice

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