

[54] **COOLED AIRFOIL**

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[51] Int. Cl. **F01d 5/18**

[58] Field of Search **416/92, 96, 97, 95;**
415/115

[56] **References Cited**

UNITED STATES PATENTS

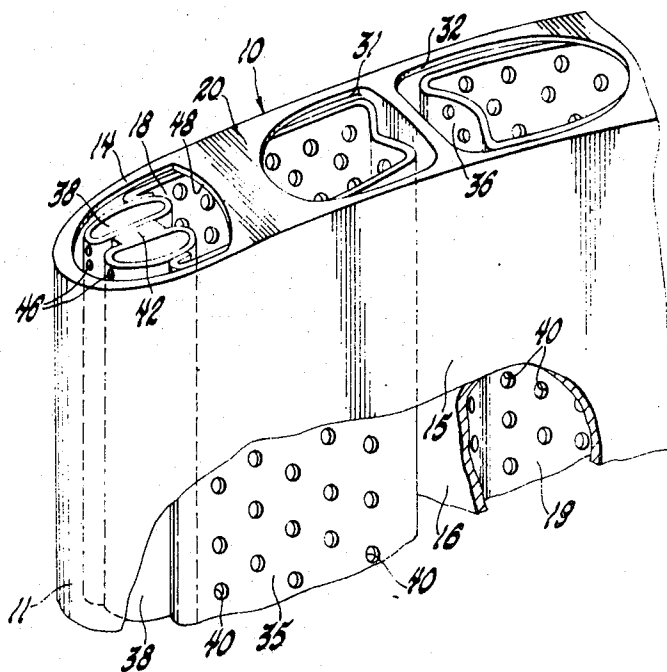
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Primary Examiner—Everette A. Powell, Jr.
Attorney—Paul Fitzpatrick et al.

[57] **ABSTRACT**

A hollow air-cooled turbine blade or vane includes a liner for bringing cooling air into the blade and discharging it through two cooling air exhaust tubes disposed near the interior of the leading edge and extending spanwise of the blade. These tubes define between them a slot nozzle for discharge of air from the liner for impingement cooling of the leading edge. The exhaust tubes have air entrance holes adjacent the leading edge. The pressure drop to cause the circulation of the air out through the tubes is caused by centrifugal force or pressure drop across the stage or both.

4 Claims, 4 Drawing Figures



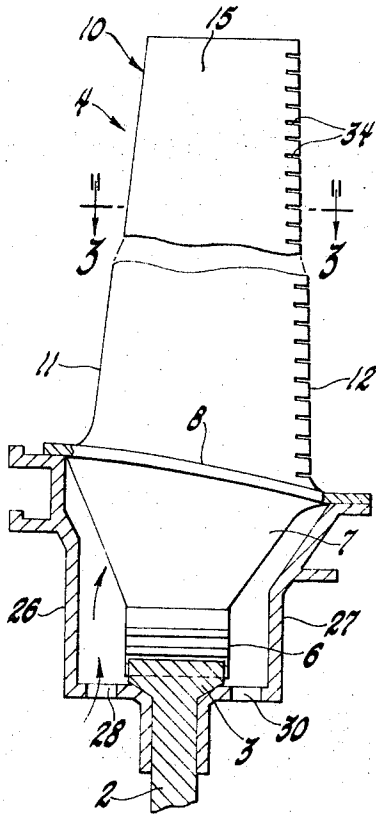


Fig. 1

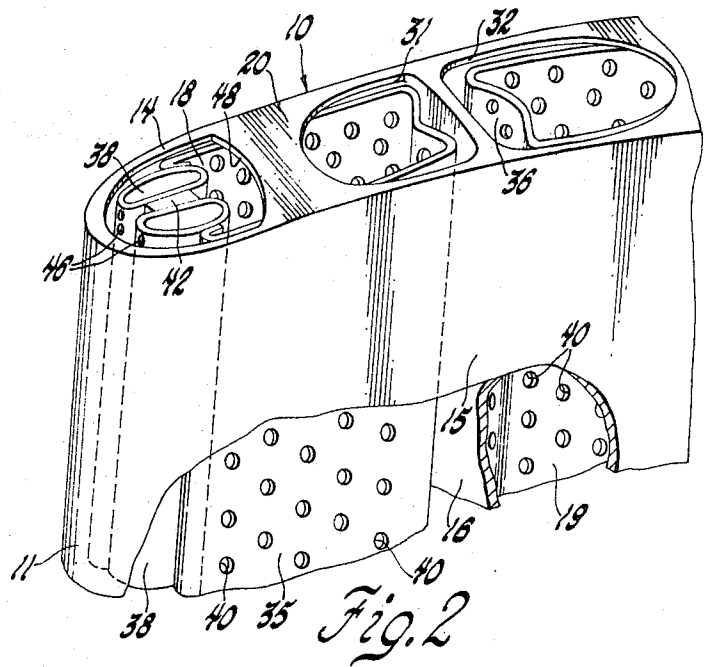


Fig. 2

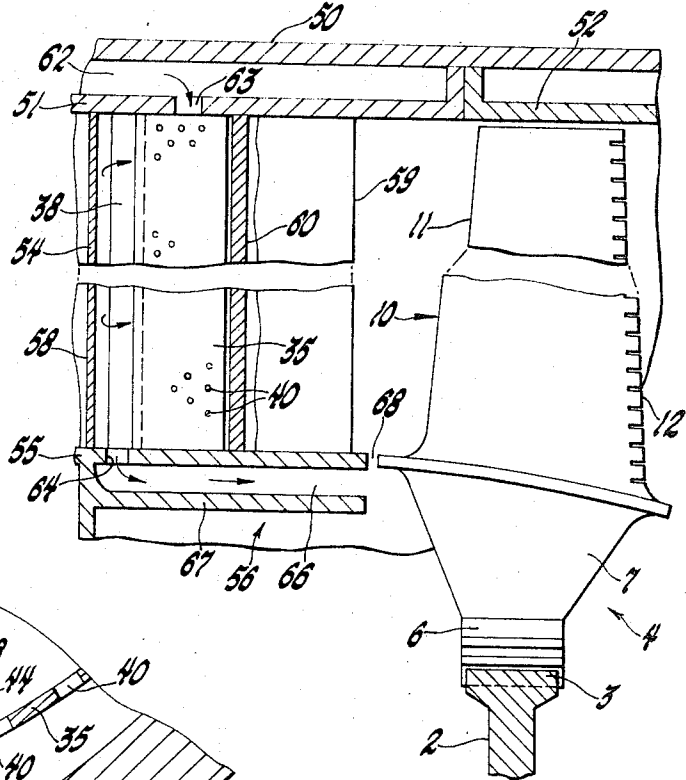


Fig. 4

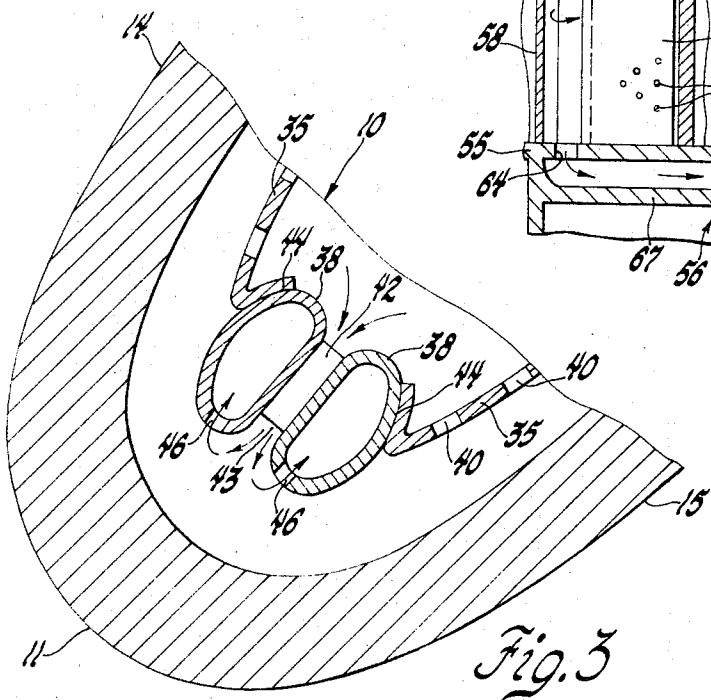


Fig. 3

COOLED AIRFOIL

My invention is directed to improved cooled turbine blades and the like and is particularly directed to improved structures employing the principles of convection and impingement cooling. As used here, the term convection cooling refers to the transfer of heat from the interior of a blade wall to a cooling medium flowing along the wall. Impingement cooling is a variation of convection cooling in which the cooling medium is directed as a sheet or jet toward the wall to be cooled, thereby improving the efficiency of the heat transfer or providing for increased heat transfer in particular localities such, for example, as the leading edge of a blade. The invention is particularly concerned with improvements in the cooling of the blade leading edge and with improved structure of a blade liner for this purpose.

Convection cooling of a blade wall, as distinguished from impingement cooling, is described in Zimmerman U.S. Pat. No. 2,859,011, Nov. 4, 1958, and Emerson et al. U.S. Pat. No. 3,446,480, May 27, 1969. Impingement cooling by air spouting from blade liners against the wall of a blade is described in Weise et al. U.S. Pat. No. 2,873,944, Feb. 17, 1959. A blade including a liner with special provisions for jetting air to the leading edge of the blade for impingement cooling is disclosed in Giesman et al. U.S. Pat. No. 3,635,587, Jan. 18, 1972.

According to my invention, impingement cooling of the leading edge of a blade is accomplished by jetting air from a slot nozzle which is defined by two tubes which serve to discharge at least a considerable part of the leading edge impingement cooling air from the blade so that this air does not flow past other portions of the blade wall, which are cooled by other means, and interfere with such cooling.

The principal object of my invention is to improve the cooling of gas turbine airfoils such as blades and vanes and to provide structure which is readily fabricated and is particularly suitable for such a purpose.

The nature of my invention and its advantages will be apparent to those skilled in the art from the succeeding detailed description and accompanying drawings of preferred embodiments of the invention.

FIG. 1 is a fragmentary sectional view of a turbine wheel with a blade mounted thereon.

FIG. 2 is a fragmentary enlarged axonometric view of the tip of the blade with parts cut away.

FIG. 3 is an enlarged transverse sectional view of the leading edge of the blade taken on the plane indicated by the line 3—3 in FIG. 1.

FIG. 4 is a sectional view of a turbine showing application of the invention to turbine nozzle vanes.

Referring first to FIGS. 1 and 2, there is illustrated a turbine wheel 2 having a rim 3 on which are mounted a ring of fluid-reacting members or blading members 4, commonly known as blades. Each blade comprises a dovetail root 6, a stalk 7, a platform 8, and a blade proper or airfoil 10. The airfoil is hollow and has a leading edge at 11, a trailing edge at 12, a convex face or wall 14, and a concave face or wall 15, these faces extending from one edge to the other. A web 16 adjacent the maximum thickness zone of the blade joins the two faces or walls to define with the blade wall a chamber 18 extending from the leading edge to the web 16 and a chamber 19 extending from the web 16 to the trailing edge. These chambers extend spanwise of the blade through the platform and to the tip of the blade, which

is partially closed by a tip closure 20. The blade stalk provides a structure into which air may be admitted from adjacent the blade stalk and flow into the chambers in the airfoil 10.

The blade root 6 is mounted in suitably serrated slots in the wheel rim 3. The blade is retained and flow of fluid between the wheel rim and platforms is prevented by two cover plates or rings of cover plates 26 and 27. These cover plates may be unitary or segmented. The details are immaterial to the invention. Such plates are shown in U.S. Pat. No. 3,446,480 referred to above, and in White U.S. Pat. No. 3,034,298, May 15, 1962, for example. Holes 28 in the plate 26 and 30 in the plate 27 provide for entry of cooling air or other medium from a suitable source (not illustrated) into the space between the cover plates and the blade stalk, from which the fluid flows into the blade stalk and thus into the passages 18 and 19. The fluid ultimately exhausts through openings 31 and 32 in the blade tip closure 20 forward and rearward of the web 16, respectively. Also, preferably, the trailing edge of the blade is formed with outlets such as slots 34 for exhaust of cooling air at this point.

The structure so far described may be considered as state of the art. To indicate generally the scale of the drawings, the specific blade shown has a chord of about two inches.

To provide for air impingement and better flow of the cooling air along the interior of the surface of the blade wall, blade liners 35 and 36 are provided extending spanwise of the blade in chambers 18 and 19, respectively. These liners are open at the platform end of the blade and closed at the 32, of the blade, and are made of very thin flexible heat resisting sheet metal, preferably about three to five thousandths inch thick. The liners are preferably spaced about twenty-five thousandths inch from the blade wall. Each liner has numerous small holes or perforations distributed over its surface as indicated generally at 40 in FIGS. 2, 4, and 5. These perforations may be about seven thousandths inch in diameter. Air which flows from the liner through these holes impinges against the inner surface of the blade wall and flows between the blade wall and liner to the outlets at 31, 32 and 34.

The structure of the liner as so far described may be the same as that shown and described in greater detail in my companion application Docket No. A-15,161. The details of the liner so far described are not a significant part of the subject invention.

My present invention is concerned with the structure of the liner 35 adjacent the leading edge of the airfoil to provide improved impingement cooling at this point. Referring to FIGS. 2 and 3, liner 35 includes two parallel generally oval tubes 38 which extend spanwise of the blade from one end to the other. These tubes are fixed to each other by spaced sheet metal spacers 42 which are thin in the spanwise direction of the blade so that, effectively, the opening between the two tubes 38 defines a slot nozzle 43. The walls of the liner 35 are bonded to the tubes as indicated at 44. The bonding in this case, as with the bond between the two tubes, may be a brazed or other joint.

The sheet of gas issuing from the slot nozzle 43 impinges on the blade leading edge 11 and then is withdrawn through a row of holes 46 in the forward edges of tubes 38 into these tubes for discharge from the airfoil. As shown in FIG. 2, the tubes extend to the tip of

the blade where the gas is discharged through the corresponding opening or pair of openings 48 in the blade closure 20 which register with the ends of tubes 38. In the case of a rotating stage such as the rotor stage shown in FIG. 1, the centrifugal force caused by rotation of the rotor and the normally lower external pressure at the blade tip tends to eject the gas from the tubes 38 and thus provide a draft for drawing the warmed impingement cooling air into the holes 46.

The point of this structure is that the air heated by the leading edge of the blade, which has a high rate of heat transfer from the turbine motive fluid, does not flow rearwardly or radially in the leading edge passage interior of the blade wall, in which case it would tend to interfere with the impingement heat transfer coefficient. Impingement effects are reduced in the presence of cross flow and the cross flow removal through the tubes 38 is of basic importance.

FIG. 4 illustrates the application of the invention to a turbine nozzle vane, the principal difference from the embodiment previously described being that the structure is stationary and that the suction to draw the heated leading edge cooling air into the exhaust tubes is developed by the pressure drop across the nozzle. FIG. 4 discloses in schematic or conventional fashion known turbine structure which may include a turbine outer case 50 in which is mounted a nozzle outer shroud 51 and the rotor shroud 52. The nozzle includes vanes or airfoils 54 extending from the outer shroud 51 to an inner shroud 55. The shroud 51, vanes 54, and shroud 55 define an annular cascade or turbine nozzle 56 from which the motive fluid is discharged to a turbine rotor comprising blades 10 mounted on wheel 2 which rotor structure may be as described above or may be of any suitable nature.

The nozzle vanes have a leading edge 58 and a trailing edge 59 and the usual concave and convex faces joining these. Also, preferably, the nozzle vanes include a transverse web 60 adjacent the midchord of the vane. In general, the structure may be much the same as that described with respect to the blades 10 above except, of course, for the difference in the mounting of the airfoil structure. A line 35, which may correspond to the liner 35 previously described, is mounted in the chamber ahead of the web 60 and is associated with discharge tubes 38 as previously described. FIG. 3 may be considered to depict a section of the forward edge portion of the vane 54.

In the case of the nozzle installation, cooling air, which may be compressor discharge air, is fed into a space 62 between the turbine case and outer shroud 51 from which it flows through a hole 63 into each vane liner 35. The air is ejected from the slot nozzle 43 and, after cooling the leading edge, is withdrawn into the exhaust tubes 38 which communicate with an outlet 64 in the inner shroud 55. Air thus discharged flows into a space 66 between the inner shroud and an annular wall 67 which is blocked from compressor discharge pressure but is open to pressure downstream of the turbine nozzle through the gap 68 between the nozzle and the turbine rotor. The leading edge impingement cooling air thus is circulated by virtue of the pressure drop across the turbine nozzle through the circuit just described. Impingement cooling from openings 40 in the liner may also occur as previously described. The air used for this impingement cooling may be discharged

through any suitably located outlet in the surface or end of the vane.

It should be apparent to those skilled in the art that I have devised an improved arrangement for impingement cooling of the leading edge of a heated airfoil which minimizes interference by this impingement cooling air with other cooling air, and provides for vigorous circulation of the leading edge impingement cooling air.

The detailed description of preferred embodiments of the invention for the purpose of explaining the principles thereof is not to be considered as limiting or restricting the invention, since many modifications may be made by the exercise of skill in the art.

I claim:

1. A cooled fluid-directing element for a turbomachine comprising, in combination, a wall defining a hollow airfoil having two faces and a leading edge joining the faces, means for conducting a cooling gas into the airfoil, two cooling gas exhaust tubes disposed adjacent the interior of the leading edge and extending spanwise of the airfoil to an outlet at one end of the airfoil, the exhaust tubes defining between them a slot nozzle for discharge of the cooling gas from the conducting means toward the interior of the leading edge, and the exhaust tubes defining means for entry of the cooling gas into the tubes from near the leading edge.

2. A cooled fluid-directing rotor blade element for a turbomachine comprising, in combination, a wall defining a hollow airfoil having two faces and a leading edge joining the faces, the airfoil having a base adapted for connection to a rotor and having a tip remote from the base, means for conducting a cooling gas into the airfoil, two cooling gas exhaust tubes disposed adjacent the interior of the leading edge and extending spanwise of the airfoil to an outlet at the tip end of the airfoil, the exhaust tubes defining between them a slot nozzle for discharge of the cooling gas from the conducting means toward the interior of the leading edge, and the exhaust tubes defining means for entry of the cooling gas into the tubes from near the leading edge.

3. A cooled fluid-directing nozzle vane installation for a turbomachine comprising, in combination, a wall defining a hollow nozzle vane airfoil having two faces and a leading edge joining the faces, means for conducting a cooling gas into the airfoil, two cooling gas exhaust tubes disposed adjacent the interior of the leading edge and extending spanwise of the airfoil to an outlet at one end of the airfoil, the exhaust tubes defining between them a slot nozzle for discharge of the cooling gas from the conducting means toward the interior of the leading edge, and the exhaust tubes defining means for entry of the cooling gas into the tubes from near the leading edge, the means for conducting the cooling gas into the element being subjected to pressure upstream of the nozzle vane and the exhaust tube outlet being subjected to pressure downstream of the nozzle vane.

4. A cooled fluid-directing element for a turbomachine comprising, in combination, a wall defining a hollow airfoil having two faces and a leading edge joining the faces, means including a blade liner for conducting a cooling gas into the airfoil, two cooling gas exhaust tubes disposed adjacent the interior of the leading edge and extending spanwise of the airfoil to an outlet at one end of the airfoil, the exhaust tubes defining the leading edge portion of the blade liner and defining between them a slot nozzle for discharge of the cooling gas from the liner toward the interior of the leading edge, and the exhaust tubes having ports distributed along the tubes for entry of the cooling gas into the tubes from near the leading edge.

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