

[54] UNSHROUDED INTERNALLY COOLED
TURBINE BLADES

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416/97; 416/228

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[58] **Field of Search** 415/116, 110, 115, 80,
415/81, 82, 172, 173; 416/97, 92, 228, 232,
96

[56] **References Cited**

UNITED STATES PATENTS		
2,647,368	8/1953	Triebnigg..... 416/97
3,011,762	12/1961	Poult..... 415/172
3,164,367	1/1965	Lynch..... 416/97
3,446,482	5/1969	Kydd..... 416/232
3,533,712	10/1970	Kercher..... 415/116
3,730,640	5/1973	Rice..... 415/172

FOREIGN PATENTS OR APPLICATIONS

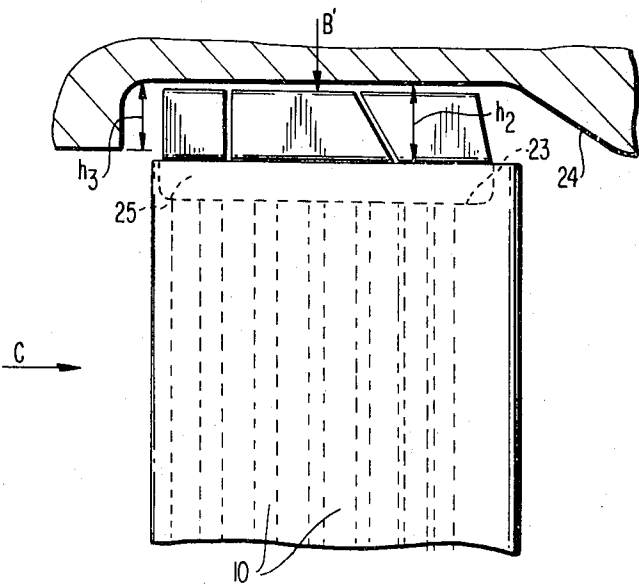
611,650 11/1948 United Kingdom..... 416/92
858,335 10/1952 Germany 415/80

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[57] **ABSTRACT**

An unshrouded turbine rotor blade having internal cooling flow cavities opening into a tip well at the radial outer end of the blade. The tip well is formed by a bottom part and radially extending walls which terminate in rubbing crown surfaces for accommodating rubbing engagement of the blade tip against a surrounding turbine casing. The walls forming the tip well and rubbing crown surfaces are configured to deflect the flow of cooling medium out of the tip well in a direction such that the outflow of the cooling medium imparts reactive forces against said blade in the direction of blade rotation. In one preferred embodiment, a slot over only a part of the wall forming the pressure side of the blade is provided for the flow deflection. In another preferred embodiment, a slot is formed over the entire pressure side of the blade between bent over wall members at the suction side and the wall at the pressure side.

5 Claims, 6 Drawing Figures



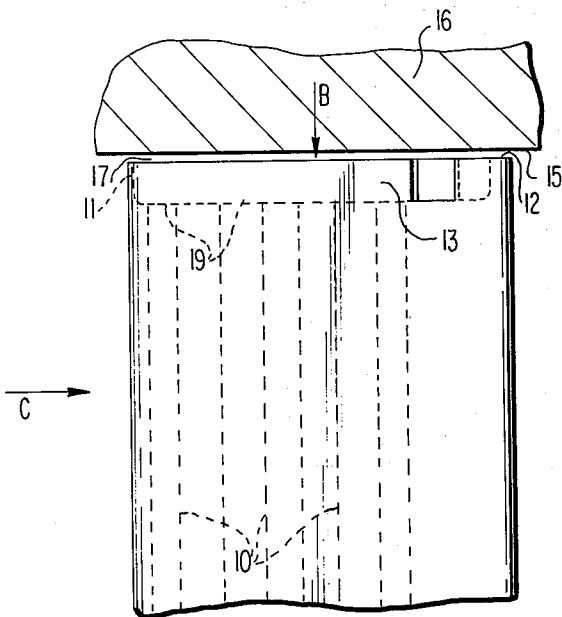


FIG. 1

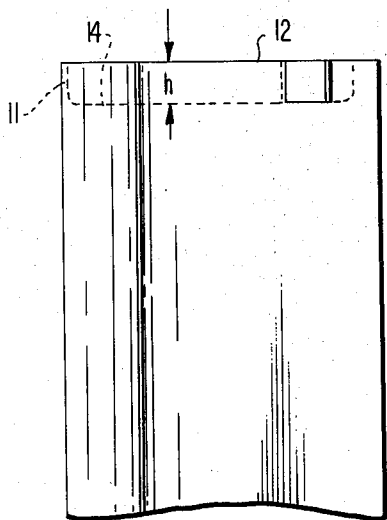


FIG. 3

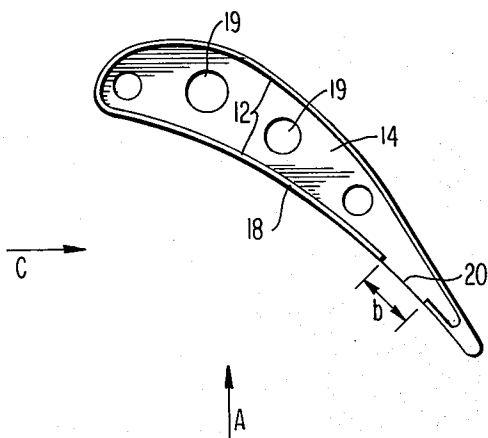


FIG. 2

FIG. 4

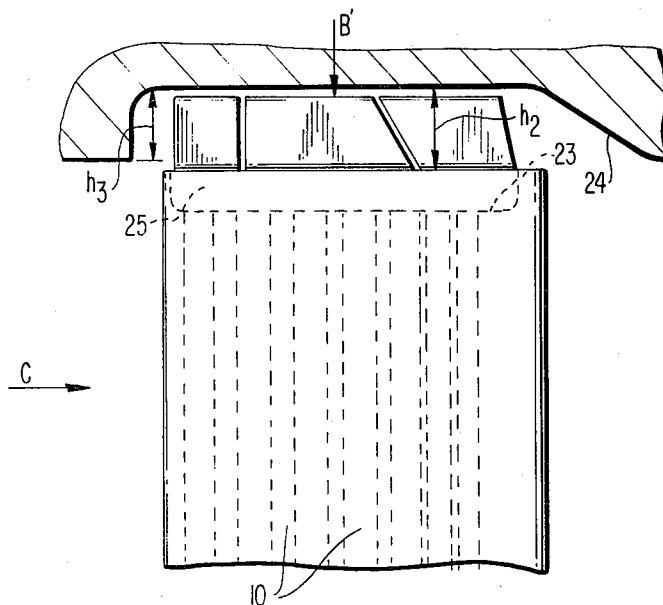


FIG. 6

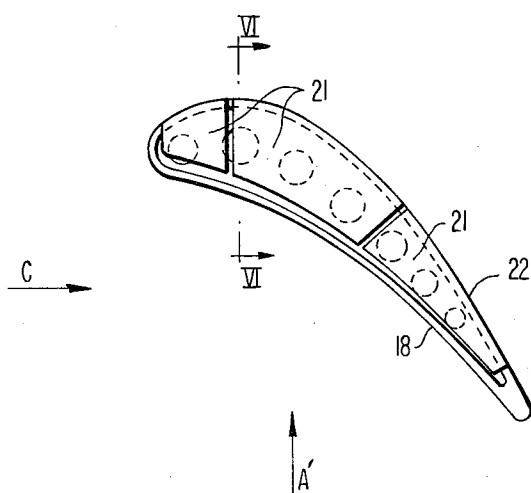
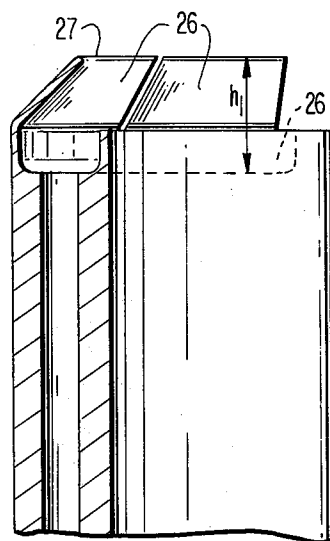


FIG. 5

UNSHROUDED INTERNALLY COOLED TURBINE BLADES

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to an unshrouded turbine rotor blade having a cavity for the flow of a cooling medium. More particularly, this invention relates to a rotor blade for use in gas turbines and the like, where the flow cavity may be a single duct or the like, or may comprise several ducts or a system of ducts.

It has been contemplated to provide an unshrouded rotor blade for use in axial-flow turbines which has a rubbing crown at its tip with a well formed inside said rubbing crown. The radial sealing clearance of the rotor blade in the turbine is formed by a rubbing edge on the radially outer end of the crown and by the turbine casing. When this edge rubs against the turbine casing, no damage will result to the blade or otherwise in that the rubbing edge is merely ground back or bent over. The blade crown may be fashioned, e.g., by electrical discharge machining or electrochemical machining using contoured electrodes.

The present invention contemplates providing a blade construction having means for utilizing the cooling medium, after it has cooled the unshrouded turbine rotor blade, for augmenting the torque in the turbine shaft. The present invention also contemplates simultaneously fitting such blade with a rubbing crown.

This invention further contemplates providing a rotor blade in which the cooling flow cavity has an exit for the cooling medium to flow to the tip well inside the blade crown and in which the crown is shaped to deflect the cooling medium for reactive impetus to blade rotation. In this manner a portion of the energy of the cooling flow is utilized in service in the form of added torque. In service, heated cooling medium issues from the flow cavity exit and enters the tip well, and a portion of this cooling flow is deflected by the specially shaped crown which at its radially outer end is enclosed by the turbine casing. Viewing the rotor axially, this deflection is exactly, approximately or quasi counterdirectional to the rotation of said bladed rotor. Simultaneously, this portion of the cooling flow is expelled from the blade crown or tip well into the adjacent gap between blades of this rotor. The remaining portion of the cooling flow reaches this gap through the blade sealing clearance.

According to preferred embodiments of the present invention, on the pressure side of the blade, the crown is open across at least part of the width of the blade. The deflected cooling medium is therefore expelled from the crown or tip well through a gap or vent open across part of the blade width, or in another embodiment, through an opening which extends across the entire width of blade. This wide-open design is employed particularly where the cooling air flow is relatively voluminous. In a preferred embodiment of this wide-open design, the suction side walls of the crown are bent towards the pressure side.

The present invention further contemplates a rotor blade in a turbine casing, especially a blade having a rubbing crown of the wideopen design, where the crown projects into an annular slot in the turbine casing, the width of the slot being approximately equal to the height of the crown opening.

The above discussed and further features, objects, and advantages of the present invention will become more obvious from the following description when taken in conjunction with the accompanying drawings, which show, for purposes of illustration only, several embodiments in accordance with the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial circumferential schematic side view taken in the direction of arrow A of FIG. 2 of a first embodiment of a rotor blade and casing constructed in accordance with the present invention;

FIG. 2 is a radial end view taken in the direction of arrow B of FIG. 1;

FIG. 3 is a partial schematic view taken in the direction of arrow C (direction of turbine centerline) of FIG. 1;

FIG. 4 is a partial circumferential schematic side view taken in the direction of arrow A' of FIG. 5 of a second embodiment of a rotor blade and casing constructed in accordance with the present invention;

FIG. 5 is a radial end view taken in the direction of arrow B' of FIG. 4; and

FIG. 6 is a section of the blade of FIGS. 4 and 5 taken along section VI—VI in direction C of FIG. 5.

DETAILED DESCRIPTION OF THE DRAWINGS

In FIGS. 1 to 6 the flow cavity for air as a cooling medium includes the sum of ducts 10, which all extend radially as do the blades and which each have an outlet port 19.

In the embodiment of FIGS. 1 to 3, the blade has a rubbing crown at its tip. The blade crown has a crown wall 11 of relatively thin wall thickness and a contour similar to that of the unrestrained or open end of the blade. The crown wall 11 of the crown has a rubbing edge 12.

The rubbing edge 12 has the same contour as the crown and the blade and is as long as the circumference of the contour. A tip well 13 is formed in the crown bounded by wall 11 and has a well bottom 14. An inner wall 15 of the turbine casing 16 and the rubbing edge 12 together form a radial blade sealing clearance 17. The radial height of the tip well 13 from bottom 14 to the rubbing edge 12, is relatively small.

On the pressure side 18 of the blade, the tip crown exhibits a gap 20 having a width b . The cooling air issues radially from the exit ports 19 in bottom 14, flows into the tip well 13 which at its radially outer side is covered by the inner wall 15, is deflected in the tip well 13 towards the gap 20, and leaves the tip well through the gap 20 in a direction approximately opposite to that of the circumferential direction A, which is also the direction of rotation of the turbine rotor. The flow area $b \times h$ of the gap 20 bears a certain relation to the total exit area of the ducts 10, allowing for the fact that a certain share of the radial sealing gap 17, which has a flow area of "circumference of contour times width of radial gap," can be considered additional cooling flow area.

According to the embodiment of FIGS. 4 to 6, the crown is open on the pressure side 18 of the blade across approximately the entire width of blade. The height h_1 of the tip well 26 is considerably larger than height of tip well 13 shown in FIGS. 1 to 3. There are more ducts 10 than on the embodiment FIGS. 1 to 3,

and their total exit area is greater than on the embodiment FIGS. 1 to 3.

In constructing the blade of FIGS. 4 to 6, first, a relatively deep starting well of a radial drop or height h_1 is made which is then worked or cut off on the pressure side 18 of the blade over approximately the entire width of blade but not down to the well bottom 23, leaving a crown wall 25 along the pressure side 18. On the suction side 22 of the blade, the wall of the tip well which is now radially longer than the wall 25 at the pressure side 18, is then cut in a wedge-shaped pattern (See FIG. 5) and the so-produced wall portions are bent at an angle (See FIG. 6) towards pressure side 18 of the blade, and the crown wall 21 results. As best seen in FIG. 5, wall 21 covers a majority of the well in the outward direction. This crown wall 21 has a rubbing edge 27. Since wall 25 is radially shorter, no rubbing edge is formed thereon. This open crown gap between walls 21 and 25 for the exit of the cooling air from the tip well 26 has a height h_2 which is less than h_1 by the height of wall 25.

The crown or blade tip projects into an annular slot formed in the turbine casing. The depth h_3 of this casing slot is approximately equal to the height h_2 of the open crown gap between walls 21 and 25. The casing slot wall 24 which in the direction of axial turbine flow lies aft is chamfered in that direction.

While I have shown and described only several embodiments in connection with the present invention, it is understood that the same is not limited thereto, but is susceptible to numerous changes and modifications as would be known to those skilled in the art given the present disclosure of the invention, and we therefore do not wish to be limited to the details shown and described herein only schematically but intend to cover all such changes and modifications.

What is claimed is:

1. An unshrouded turbine rotor blade of the type which in use is rotatable about a rotor axis and has radially inner and outer ends with respect to said axis; said blade comprising:
 - a tip well formed adjacent the radially outer end of the blade,
 - cooling flow cavity means in said blade which terminate in cooling medium exit means opening into said tip well such that cooling medium flows through said cavity means into said tip well during rotation of said blade,
 - cooling flow deflecting means for deflecting the flow of cooling medium out of said tip well, said cooling flow cavity means, said cooling medium exit means and said cooling flow deflecting means being relatively configured in such a manner that outflows of said cooling medium from said tip well impart reactive forces against said blade in the direction of blade rotation,
 - blade rubbing crown means at the radially outer end of the blade for accommodating rubbing engagement of the blade against a turbine casing means which surrounds the blade in use,
 - and turbine casing means for accommodating the outer end of said blade,
 - wherein said tip well is formed by wall means which extend radially outwardly of a bottom of said tip well and circumferentially surround the contour of the outer end of said blade,

wherein said cooling flow deflecting means includes opening means in said wall means which extend over at least a portion of one side of the blade, wherein said blade has a suction side which faces in the general direction of rotation of the blade and a pressure side which faces in the general direction opposite the direction of rotation of the blade,

wherein said one side is said pressure side, wherein said wall means includes suction side wall member means which have the radially outer ends thereof bent toward the pressure side of the blade, said opening means being formed between said radially outer ends of said suction side wall member means and respective radial outer ends of pressure side wall member means forming part of said wall means, and

wherein said turbine casing means for accommodating the outer end of said blade includes an annular slot which has a radial depth which is approximately equal to the radial extent of said opening means formed between said suction side wall members and pressure side wall members.

2. A blade according to claim 1, wherein said rubbing crown means are formed at the radially outermost portions of said suction side wall members.

3. An unshrouded turbine rotor blade of the type which in use is rotatable about a rotor axis and has radially inner and outer ends with respect to said axis; said blade comprising:

- a tip well formed adjacent the radially outer end of the blade,
- cooling flow cavity means in said blade which terminate in cooling medium exit means opening into said tip well such that cooling medium flows through said cavity means into said tip well during rotation of said blade,
- cooling flow deflecting means for deflecting the flow of cooling medium out of said tip well, said cooling flow cavity means, said cooling medium exit means and said cooling flow deflecting means being relatively configured in such a manner that outflows of said cooling medium from said tip well impart reactive forces against said blade in the direction of blade rotation,

and turbine casing means for accommodating the outer end of said blade,

wherein said blade has a suction side which faces in the general direction of rotation of the blade and a pressure side which faces in the general direction opposite the direction of rotation of the blade, said cooling flow deflecting means being formed by suction side wall member means which have radially outer ends thereof bent toward the pressure side of the blade so as to define a pressure side cooling medium discharge opening,

and wherein said turbine casing means includes an annular slot which has a radial depth which is approximately equal to the radial extent of said pressure side cooling medium discharge opening.

4. A blade according to claim 3, wherein said annular slot is beveled on the downstream side of the blade as seen in the flow direction of turbine driving medium, said slot being beveled in the downstream direction.

5. A blade according to claim 3, wherein said blade extends into said annular slot a distance equal to the radial extent of said pressure side cooling medium discharge opening.

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