TURBOMACHINERY BLADE STRUCTURE

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ABSTRACT

An economically fabricated turbomachinery blade structure with good and predictable high temperature characteristics having a hollow integrally cast member defining the blade portion, the platform portion, a transition shank portion defining an opening to the blade chamber and a pair of juxtaposed rails extending therefrom. A hollow insert, formed with a plurality of nozzles in the side walls thereof, is secured within the cast member chamber so as to direct coolant fluid against the inner surfaces of the blade portion. To provide means enabling attachment of the blade to a supporting rotor, in one form, the juxtaposed rails are formed into abutting contact at their free ends and bonded. In another form, a root insert is provided which is secured to the inner surface of shank rails. Suitable passages are provided to direct coolant fluid into the insert chamber and to discharge the coolant fluid through the trailing edge and the end closure of the blade. Means may be provided to automatically space the insert nozzles from the blade side walls. A plurality of posts may be provided in the trailing edge portion of the blade to increase the effective convection cooling area. All bonds subjected to structural loading are spaced from the blade portion and positioned to be bathed in coolant fluid so as to reduce their operating temperature environment.

5 Claims, 8 Drawing Figures
TURBOMACHINERY BLADE STRUCTURE

This invention relates to gas turbine engines and more particularly to an improved fluid cooled turbomachinery blade structure for use in high temperature gas turbines.

It is well known that significant increases in gas turbine engine performance, in terms of thrust or work output per unit of fluid input, can be obtained by increasing the turbine inlet temperature of the motive fluid or hot gas stream. It is also recognized that one major limitation on turbine inlet temperature is that which is imposed by the turbine blade temperature capability. In an effort to extend turbine blade capability, numerous complex turbomachinery blade structures have been proposed which employ one or more modes of cooling using fluid usually extracted from the compressor.

In such blades, if a large percentage of the blade cooling is to be derived from a cooling mode, such as film or transpiration cooling, which is affected by the flow patterns of the hot gas stream over the blade or by manufacturing tolerances, cooling effectiveness is difficult to predict.

Such prior blade structures have usually been complex in nature and require sophisticated and expensive machining and assembly techniques in their fabrication. In addition, many such prior blade structures employ one or more brazed, welded, or similarly bonded joints in the portion of the blade structure exposed to the hot gas stream. As will be understood, such bonds may impose a severe limitation on the operating temperature capacity of the blade and such limitation will be greatly enhanced if such bond is operative to transmit blade loading.

This invention, then, is concerned with a fluid cooled, high temperature blade structure which overcomes the above mentioned problems.

Accordingly, a primary object of this invention is a relatively low cost, high temperature blade structure having all bonds spaced from the portion of the blade structure in contact with the hot gas stream.

Another object of this invention is a turbine blade structure having predictable high temperature characteristics.

Other objects and advantages of the invention will become apparent on reading the following description of the preferred embodiment.

Briefly stated, the turbomachinery blade structure of this invention comprises a cast member, means for mounting the cast member to a supporting rotor, a insert for the cast member formed with a chamber therein, and means for cooling said blade structure by impingement of a cooling fluid on the inner surfaces of the blade portion of the cast member. The cooling fluid is discharged into the hot gas stream through trailing passages. All structural bonds between the cast member, insert, and mounting means are spaced from the hot gas stream.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of this invention, it is believed the invention will be better understood from the following description of the preferred embodiments taken in connection with the accompanying drawings wherein:

FIG. 1 is a partial cross-sectional view diagrammatically showing one installation of the blade structure of this invention;

FIG. 2 is an exploded perspective view, in partial section, showing one embodiment of the blade structure of this invention;

FIG. 3 is a cross-sectional view taken along line 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 2;

FIG. 5 is a partial cross-sectional view taken along line 5—5 of FIG. 2;

FIG. 6 is a cross-sectional view, like that of FIG. 3, of another embodiment of the blade structure of this invention;

FIG. 7 is a cross-sectional view taken along line 7—7 of FIG. 6; and

FIG. 8 is a cross-sectional view taken along line 8—8 of FIG. 6.

Like reference numerals will be used to refer to like parts and features throughout the following description of the preferred embodiment.

Referring now to the drawings and particularly to FIG. 1, the turbine portion of a gas turbine engine has been shown diagrammatically in partial section as comprising a rotor 10 having a plurality of blades 12 extending radially therefrom around its periphery. The blades 12 extend into a passage 14 through which a motive fluid or hot gas stream (indicated by flow arrows in FIG. 1) is directed and are adapted to extract energy from the motive fluid and impart rotary motion to the rotor 10 in a well known manner. To enable internal cooling of each blade 12, suitable means shown generally at 16, may be provided to direct a coolant fluid (indicated generally by the broken flow arrows in FIG. 1) through the rotor 10 to each blade 12.

Turning now to FIGS. 2 through 5, one embodiment of the improved blade structure of this invention has been shown as including a hollow cast member 20, means 22 for engaging and securing the blade to the supporting rotor 10, and an insert 24 for directing coolant fluid within a blade portion 26 of the cast member 20.

The cast member 20 has been shown as including a platform portion 28, a blade portion 26 extending or projecting from the platform portion 28, and a transition shank portion 30 extending from the platform portion 28, generally oppositely to the blade portion 26, and defining an opening or passage 32 to a chamber 34 within the blade portion 26.

As best shown in FIGS. 2 and 4, the blade portion 26 is formed with a leading edge 36, a trailing edge 38 and airfoil shaped side walls 40 extending therebetween which are suitably formed and adapted to extract energy from the motive fluid flowing thereacross, as in FIG. 1, through the mechanism of either action or reaction fluid dynamics and impart rotary motion to the supporting rotor 10. The chamber 34 is defined by blade side wall inner surfaces 42 and an integrally cast end closure wall 44.

The cast member chamber 34 includes a raking edge portion 46 having a plurality of posts 48 extending thereacross and connecting opposed side walls 40. A plurality of passages 50 are provided in trailing edge 38 to enable efflux of coolant fluid from chamber 34 as will be hereinafter discussed. Additional efflux passages 52 may be formed in end closure 44 to provide cooling to that area of the blade.
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The platform portion 28 has been shown as having a top surface 54 which is adapted to define, in part, the passage 14 into which the blade portion 26 extends and through which the motive fluid or hot gas stream is directed. The platform portion, as will be understood, may be variously shaped to perform interlocking or dampering functions between adjacent blades when arranged and mounted in a circumferential row around the supporting rotor 10 as in FIG. 1.

As previously indicated, the case member Shank portion 30 is integrally cast with and extends from platform portion 28, generally oppositely of the blade portion 26, and defines the opening or passage 32 communicating with cast member chamber 34.

In the embodiment of FIGS. 2 through 5 the means 22 for attaching the blade to the rotor 10 has been shown as comprising juxtaposed shank rails 56, integrally cast with member 20, which extend from the shank 30 generally oppositely to blade portion 26. The rails 56 are suitably formed into abutting contact and suitably bonded together as at 58. The outer surfaces of the joined shank rails 56 are suitably formed in a “fit tree,” dovetail, or like configuration, as shown generally at 60, so as to enable attachment of the blade structure to the supporting rotor 10 in a well known manner. A plurality of passages 62 are provided through the rail abutment to enable influx of a coolant fluid to the blade structure as will be hereinafter discussed.

The insert 24 has been shown as being a thin walled shell having side walls 64 generally conforming to the contour of the blade side walls 40 and formed with a plurality of nozzles or apertures 66 which are disposed in spaced relationship to the inner surfaces 42 of the blade portion 26 by suitable spacing means 68. As viewed in FIG. 2, the insert 24 is closed at one end 70 and defines a chamber 72 therein which is open at end 74 to receive coolant fluid.

Suitable means as at 76 are provided to secure the insert 24 to the cast member 20 in a manner enabling passage of coolant fluid into chamber 72. In the embodiment of FIGS. 2 through 5 such means also function to close passage 32 and comprise a collar 78 formed with a passage 80 and a surrounding flange 82. The collar 78 is bonded to the open end 74 of insert 24 with passage 80 communicating with chamber 72 and the flange 82 abuts and is suitably bonded to a lower rim 84 of the transition shank 30 in a manner securing the insert 24 to the cast member 20 and closing passage 32.

In order to direct coolant fluid from passages 62 to collar passage 80 and, hence, into the insert chamber 72, suitable means such as seal plates 86 are provided. As best shown in FIGS. 2 and 3, one seal plate extends between rail leading edges 88 in overlapping relationship with shank 30 and the rail abutment while the other seal plate similarly extends between rail trailing edges 90.

Although the spacing means 68 has been shown as a plurality of dimples, projections or the like, integrally formed with insert side walls 64 and abutting inner surfaces 42 of the blade side walls 40, it should be understood that such projections may be carried by the cast member 20.

Referring now to the embodiment of FIGS. 6 through 8, the blade attachment means 22 has been shown as comprising a root insert 92 which abuts and is suitably bonded to the opposed inner shank rail surfaces 94 and 96. The insert 24 is secured at its open end 74 with chamber 72 communicating with passages 62. Like the mounting means 22 of FIG. 2, the root insert 92 is suitably formed with a “fit tree” or other suitable configuration, as at 60 and passages 62 are provided through the mounting means for delivery of coolant fluid into the blade structure. In order to close passage 32, means such as the seal plates 86 may be provided as in the embodiment of FIG. 2.

As previously mentioned, a primary advantage of the turbomachinery blade structure of this invention is the economical manner in which it may be fabricated. For example, in the embodiment of FIGS. 2 through 5, the cast member 20, which includes the blade portion 26, platform portion 28, transition shank 30 and rails 56, is formed as a relatively non complex integral casting. The lower ends of shank rails 56 are cast in a spaced apart, flared out position, as at 98 in FIG. 5, so as to allow insertion therebetween of the thin walled insert 24. With the insert 24 bonded to the collar 78, this assembly is simply inserted into cast member chamber 34, with means 68 automatically establishing the proper spacing between the insert nozzles 66 and the blade inner surface 42. After the collar flange 82 is bonded to the shank rim 84, the ends of the shank rails 56 are suitably formed from their flared out position 98 into abutting contact. The shank rails are then bonded at 58 and the proper external contour, as at 60, is machined. The passages 62 are preferably cast but may be machined after bonding.

The insert 24 may be economically formed of any suitable metallic material by a deep drawing, stamping or like suitable process, with the closed end 70 being either integrally formed with side walls 64 or bonded closed.

The embodiment of FIGS. 2 through 5 is also extremely advantageous from the structural standpoint in that in transmitting either centrifugal or aerodynamic loading to the support rotor 10 it is not necessary to transmit force through a bonded joint. It should also be noted that no bond is directly exposed to the high temperature environment of the motive fluid and that all bonds are arranged so as to be continually bathed in coolant fluid.

In the embodiment of FIGS. 6 through 8, the cast member 20 is formed as an integral casting and is conveniently assembled with the insert 24, after the latter has been secured to root insert 92, by simply sliding insert 24 within the chamber 34 and bonding the root insert 92 to inner rail surfaces 94 and 96. While enjoying the structural advantages and fabrication economies of the embodiment of FIGS. 2 through 5, the embodiment of FIG. 6 enables the material selection of the blade portion 26 and the mounting means 22 to be tailored to their respective environments, it being understood that the stress loading and temperature environment of the blade portion 26 is somewhat different from the temperature environment and structural loading of the mounting means 22.

In operation, the blade structure of this invention is mounted as one of a circumferential row of blades in a
well known manner to the supporting rotor 10 by engaging the mounting means 22 with a correspondingly contoured groove (not shown) in the rotor 10. The blade portion 26 extends generally radially from the supporting rotor and projects into the annular passage 14 through which the motive fluid is directed. The blade portion 26, through the well known mechanics of action and/or reaction fluid dynamics, extracts energy from the hot gas stream and imparts rotary motion to the supporting rotor 10. In performing this function, it is well known that the efficiency, in terms of thrust or useful work output per unit of fuel input, is greatly increased by increasing the turbine inlet temperature of the motive fluid. To enable the blade structure of this invention to operate in such a high temperature environment and hence increase the efficiency of the turbomachinery apparatus in which it is used, suitable means 16 are provided to direct coolant fluid to inlet passage 62. From inlet passages 62, the coolant fluid enters insert chamber 72 and is then impinged against the blade wall inner surfaces 42 by nozzles 66. As will be understood, the number, location and size of the nozzles 66 may be varied so as to achieve a generally uniform side wall temperature around the periphery of the blade.

From chamber 34, the coolant fluid is exhausted into the hot gas stream through end closure passages 52 and trailing edge passages 50.

Posts 48 are provided in chamber portion 46 to increase the convection heat transfer to the fluid passing into the hot gas stream through trailing edge passages 50.

By exhausting the coolant fluid through passages 50 and 52, disturbances to the flow of motive fluid and efficiency losses due thereto are minimized. Further, by eliminating all blade side wall passages, such as are common in film cooled blades, the structural integrity of the blade is not jeopardized by high stress concentrations due to mechanical voids and high localized temperature gradients.

Since the blade structure of this invention does not rely on transpiration, film or other like modes of cooling which may be affected by the flow patterns of the motive fluid around the blade, cooling effectiveness and, therefore, the temperature capability of the blade is highly predictable.

Accordingly, from the foregoing it will be appreciated that the present invention provides an economically fabricated, non complex cooled blade structure which possesses good and predictable high temperature characteristics.

What is claimed is:

1. A turbomachinery blade structure comprising:
   a hollow, integrally cast member including a platform portion adapted to define, in part, an inner boundary of a motive fluid passage, a blade portion projecting from said platform portion, a transition shank projecting from said platform portion generally oppositely to said blade portion and defining an opening to said hollow cast member, and a pair of juxtaposed shank rails projecting from said transition shank;
   a hollow insert slideably received within said hollow cast member blade portion in spaced relationship thereto, said insert formed with an open inner end for receiving a coolant fluid, a closed outer end and a plurality of apertures for impinging said coolant fluid against said cast member blade portion;
   means for discharging said coolant fluid from said hollow cast member blade portion;
   a mounting collar formed with a passage therethrough, the open end of said insert secured to said collar in flow communication with said collar passage, said collar including a flange secured to said tubular shank in closing relationship to said shank opening;
   means enabling attachment of said blade structure to a supporting rotor with said blade portion extending generally radially therefrom, said attachment means comprising abutting, bonded together radially inner ends of said shank rails;
   at least one passage formed through said abutting, bonded together ends of said shank rails; and
   means extending between said shank rails adjacent the leading and trailing edges thereof for closing the openings defined between such edges and directing fluid from said shank rail passage to said collar passage.

2. The structure of claim 1 further characterized in that said blade portion includes a leading edge, a trailing edge, generally airfoil shaped sidewalls extending therebetween, and an end closure wall, said means for discharging coolant fluid from said cast member chamber comprising a plurality of passages formed through said trailing edge and said end closure wall.

3. The structure of claim 2 further characterized in that the portion of said cast member chamber adjacent said trailing edge passages contains a plurality of posts extending thereacross and joining said blade side walls to thereby increase convective heat transfer.

4. The structure of claim 1 further characterized in that said insert includes means, integrally formed therewith, for automatically establishing said spaced relationship between said nozzles and said cast member.

5. A turbomachinery blade structure comprising:
   a hollow, integrally cast member including a platform portion adapted to define, in part, an inner boundary of a motive fluid passage, a blade portion projecting from said platform portion, a transition shank portion projecting from said platform portion generally oppositely to said blade portion and defining an opening to said hollow cast member, and a pair of juxtaposed shank rails projecting from said transition shank;
   a hollow insert slideably received within said hollow cast member blade portion in spaced relationship thereto, said insert formed with an open inner end for receiving a coolant fluid, a closed outer end and a plurality of apertures for impinging said coolant fluid against said cast member blade portion;
   means for discharging said coolant fluid from said hollow cast member blade portion;
   a mounting collar formed with a passage therethrough, the open end of said insert secured to said collar in flow communication with said collar passage, said collar including a flange secured to said tubular shank in closing relationship to said shank opening;
   means enabling attachment of said blade structure to a supporting rotor with said blade portion extending generally radially therefrom, said attachment means comprising a root insert extending between and bonded to said shank rails, and said root insert formed with at least one radially extending passage therethrough, said hollow insert secured to said
root insert with said hollow insert open end in flow communication with said root insert passage; and means extending between said rails for closing said shank opening.