United States Patent [19]

Hueber

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[54] **INTEGRAL TURBINE WHEEL WITH AXIAL THROUGH-OPENINGS AT THE OUTER RIM AND WITH CONTROLLED RIM CRACKS**

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[73] Assignee: **Motoren-Und Turbinen-Union,** Munich, Germany

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[52] **U.S. Cl.** **416/244,** 416/95

[51] **Int. Cl.** **F01d 5/08**

[58] **Field of Search** ..... 416/244, 244 A, 95–97, 416/213

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Primary Examiner—Everette A. Powell, Jr.

Attorney, Agent, or Firm—Craig and Antonelli

[57] **ABSTRACT**

A turbine wheel in which the rim and the blades are made in one piece; intended breaking places for radial heat cracks are provided at the ends of radial slots and through-openings are provided which extend through the rim portions of the turbine wheel substantially in the axial direction and thereby prevent the continuation of the heat cracks in a radially inward direction; the through-openings interconnect the high pressure side and the low pressure side of the turbine wheel while the intended breaking places are located between the slots and the through-openings.

25 Claims, 12 Drawing Figures

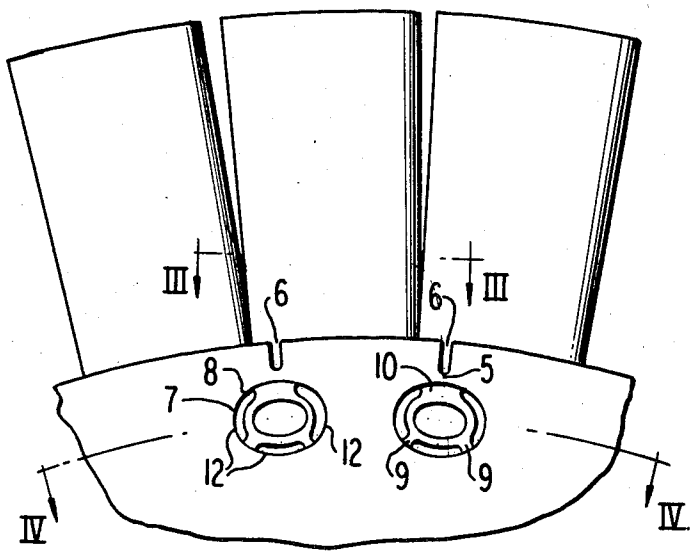


FIG.1

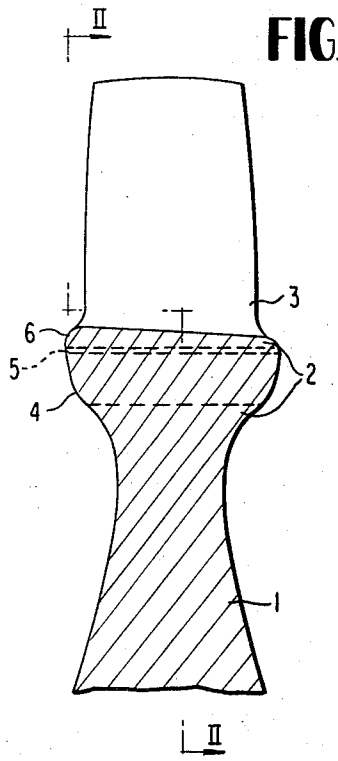


FIG.2

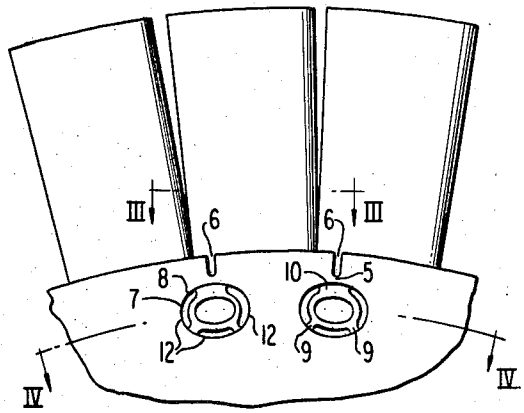


FIG.3

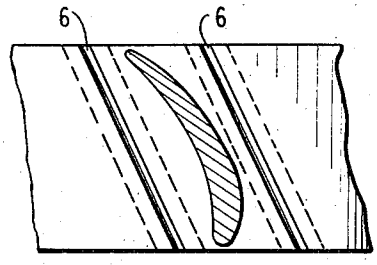


FIG.5

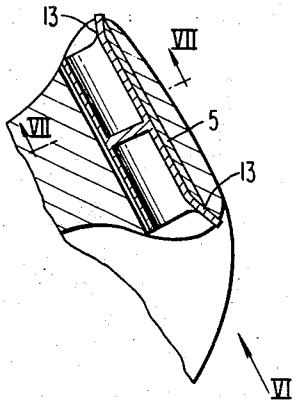


FIG.4

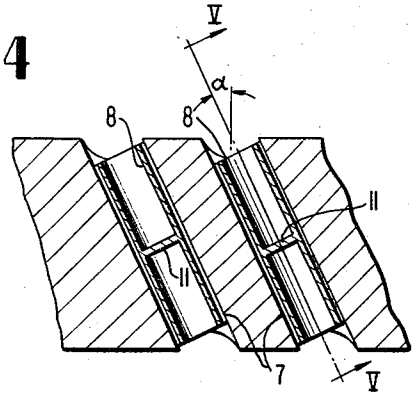


FIG.6

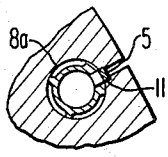


FIG.7

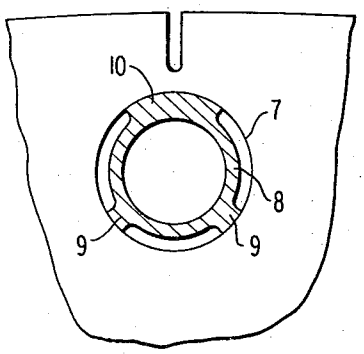


FIG.9

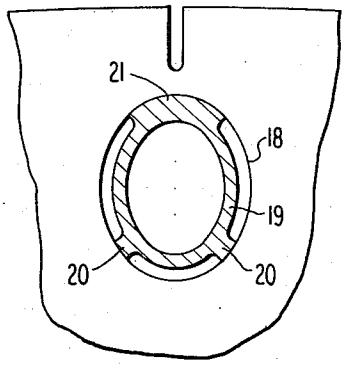


FIG.8

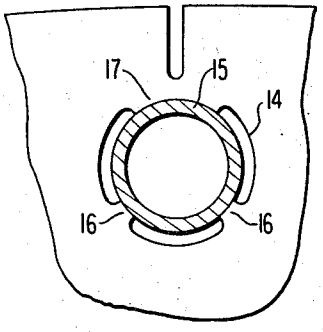


FIG.10

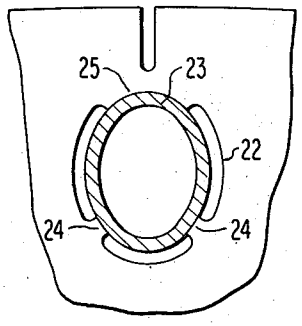


FIG.11

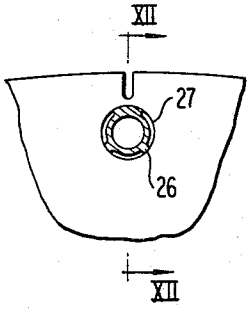
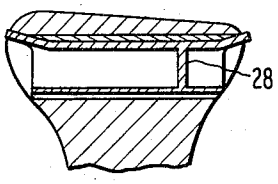


FIG.12



INTEGRAL TURBINE WHEEL WITH AXIAL THROUGH-OPENINGS AT THE OUTER RIM AND WITH CONTROLLED RIM CRACKS

The present invention relates to a turbine wheel in which the rim and blades are made of one piece, which is provided at the outer rim portion with intended or predetermined breaking places for radial heat cracks at the ends of radial slots, and additionally with through-openings or apertures which extend through the rim portions in the axial direction and thereby prevent the heat cracks in their further radial inwardly direction continuation or development.

With known wheels or rotors of this type, the through-openings or apertures are subsequently again closed at the narrowest places. As a result thereof, the disk and turbine rim cannot be cooled sufficiently, whence these turbine wheels are not suited for high turbine inlet temperatures. Additionally, the through-openings, as partially also the rim cracks and/or slots have to be sealed off involving special expenditures in order to prevent the penetration and through-flow of hot gases and therewith a further overheating.

It is the object of the present invention to provide a turbine wheel which, with the use of an intensive internal cooling of the rim, enables higher process or operating temperatures and simultaneously therewith by the introduction of controlled rim cracks, a greater flexibility in the load or power control whereby radial through-slots together with their leakage losses and the necessity of special separate seals between the high pressure side and the low pressure side of the turbine wheel are avoided. A further aim of the present invention is to dampen the blade vibrations with suitable means.

As solution to the underlying problems, the present invention essentially consists in that the through-openings or apertures connect with each other the high pressure and low pressure side and in that the intended or predetermined breaking places are located between the slots and the through-openings. Consequently, whereas in the prior art, the bores were subsequently closed, they remain open in the solution according to the present invention.

The essentially axially extending through-openings or apertures arranged according to the present invention combine in an advantageous manner the intensive internal cooling of the turbine wheel-outer rim with the interception or stoppage of the controlled rim cracks whose location they additionally determine in conjunction with the radial slots. As a result thereof, they enable higher process or operating temperatures and reduce the danger of wheel breakages or fractures. Therebeyond, the rim cracks contribute toward the improvement of the temperature-alternate stress strength or temperature fatigue strength and to the damping of blade vibrations. Additionally, the expenditures required in the prior art wheels for sealing off the through-openings are saved by the connection of the high pressure side and low pressure side.

According to a further feature of the present invention, the axial through-openings are constructed prism-shaped in a particularly appropriate manner. They extend at slight distances in parallel underneath the radial slots whereby the narrow remaining web represents the intended or predetermined breaking place. Small tubular members or pipes are inserted into the through-openings whose internal cross section is closed at one place by a partition wall. Additionally, the small pipes are so dimensioned that a sufficient gap remains between the through-opening and the small pipes in order to permit the passage of a sufficient amount of cooling air. The through-openings or apertures can be hollowed out already during the casting or can be produced also subsequently by boring or electro-chemical or electro-erosive removal processes of conventional type. The slots can be produced in a similar manner.

In this embodiment, a further increase of the turbine inlet temperature is made possible by the concentrated guidance of cooling air close to the inner cooling surfaces of the wheel rim together with a simple manufacture. The narrow intended breaking place suppresses also after the breakage, the penetration of hot gases from the outside, in which task it is additionally supported by the abutment surface of the small pipe.

According to a further feature of the present invention, the through-openings and small pipes have a circular cross section. In that case, the through-openings can be bored and the small pipes can be constructed as rod stock whereby the manufacturing costs are considerably decreased.

According to a further embodiment of a turbine wheel according to the present invention, the through-openings have an oval, possibly an eliptical profile whereby the major axis is disposed radially to the wheel axis. This shape enables a better stress distribution in the transition between blade base and solid disk. The manufacture takes place appropriately by casting, but may also take place by other processes, for example, by the erosion process of conventional type. The inserted small pipes may have an oval or any other suitable base cross section.

According to a still further feature of the present invention, the small pipes are profiled on the outside thereof and more particularly in such a manner that three or more webs run along the outer surface thereof which serve for the maintenance of the desired radial distance between the small tubular member and the bore. The channels for the cooling air are located in the circumferential direction between the webs. The cooling air is thereby guided very close along the surface to be cooled which makes possible a good cooling with economically metered cooling air. The manufacture then takes place, for example, by milling or remaing out the cooling channels between the webs. However, it is also possible to make the small pipes from a simple pipe or tubular stock with constant wall thickness, for example, with the aid of a drawing nozzle. In that case, the webs can be readily formed-in, and also base cross sections deviating from the round or oval shape can be readily manufactured for optimizing the cooling air channel cross section.

According to a still further feature of the present invention, the through-openings and small pipes may be so constructed that the webs serving for the maintenance of the radial gaps are not disposed at the pipes but at the inner contour of the through-openings. In case that in the manufacturing costs of the through-openings, the shape or form thereof plays no decisive role, at least the manufacture of the small pipes can thus be simplified.

According to still another embodiment of the present invention, in each through-opening, one of the webs is somewhat wider than the other webs and is so arranged

that it is located at the place disposed farthest radially outwardly in relation to the turbine wheel axis, and more particularly at the place where the intended breaking place terminates in the through-opening. Even though the intended breaking places already assure a good shielding of the cooling channels against hot gases entering from the outside by reason of their small dimensions and also by reason of the labyrinth effect of their breaking surfaces, as compared to machined-in continuous slots, it is additionally achieved by the aforementioned measure that the small pipe thereby comes to lie at the termination of the rim cracks and thereby still better seals the same. It is thereby of no importance whether the web belongs to the outer contour or to the small pipe; however, in the former case, the web must be so wide that the crack extends therethrough radially.

According to another feature of the present invention, the small pipes are provided at both ends with one tab or lug each, which after the insertion of the small pipes into the through-openings are bent up approximately in the radially outward direction and thereby come to lie in grooves provided therefor on the side of the rim. As a result thereof, the small tubular members are secured against axial displacement and possibly also against rotation. These lugs or tabs, like the already mentioned wider webs, are also arranged radially outwardly so that the abutment of the webs and therewith their fixation is assisted during the operation by the centrifugal forces.

According to a further feature of the present invention, the cooling is to be improved by turbulence enhancement in the cooling air channels. For that reason, the small pipes are provided with bores outside of the web areas through which the cooling air is blown out of the inside of the pipe directly against the bore walls (impingement cooling). In order to enlarge this zone of improved cooling, the partition wall may be displaced within the small pipe, if so desired, up to the end of the small pipe on the low pressure side.

These and further objects, features and advantages of the present invention will become more apparent from the following description when taken in connection with the accompanying drawing which shows, for purposes of illustration only, several embodiments in accordance with the present invention, and wherein:

FIG. 1 is a cross-sectional view of an intergral turbine wheel according to the present invention whereby the intended breaking place and through-opening are indicated only in dash line for purposes of simplification of the drawing;

FIG. 2 is a cross-sectional view through the turbine wheel of FIG. 1, taken along line II—II of FIG. 1;

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

FIG. 4 is a cross-sectional view taken along the IV—IV of FIG. 1, unwound in the plane of the drawing;

FIG. 5 is a cross-sectional view, taken along line V—V of FIG. 4, of a through-opening according to the present invention with inserted small pipes;

FIG. 6 is a partial elevational view of the end face of the through-opening and small pipe, taken in the direction of arrow VI in FIG. 5;

FIGS. 7–10 are cross-sectional views through four embodiments of through-openings with inserted pipes and with different configurations of the through-openings;

FIG. 11 is a partial elevational view of a modified embodiment in accordance with the present invention representing an improved cooling system; and

FIG. 12 is a cross-sectional view taken along line XII—XII of FIG. 1, illustrating the through-opening and inserted pipe in accordance with the present invention.

Referring now to the drawing wherein like reference numerals are used throughout the various views to designate like parts, the turbine wheel illustrated in cross section in FIG. 1 consists essentially of the disk 1, of the rim 2 and of the blades 3. A through-opening or aperture 4 according to the present invention which is constructed in this embodiment as bore, an intended breaking place 5 and a radial slot 6 are illustrated in FIG. 1 only in dash lines for the sake of simplicity. The inserted small tube or pipe was omitted for the sake of simplicity.

The cross section of FIG. 2, taken along line II—II of FIG. 1, which lies in the disk plane, illustrates two through-openings or apertures 7 with the associated intentional breaking places 5 and the radial slots 6. By reason of the fact that the through-openings 7 do not extend parallel to the turbine axis, they appear oval in this figure. Two narrow webs 9 and a wider web 10 are made in one piece with the small pipe 8. The cooling channels 12 are thereby disposed—as viewed in the circumferential direction—between the webs.

The common direction of the radial slots 6 (according to the cross section III—III of FIG. 2) and of the through-openings 7 (cross section IV—IV in FIG. 2) which deviates from the direction parallel to the turbine axis, are illustrated in FIGS. 3 and 4. Additionally, the arrangement of one through-opening 7 each between two adjacent blade bases can be recognized in FIG. 3. The inserted small tubular members or small pipes are provided with partition walls 11 as shown in FIG. 4. A cross section according to line V—V of FIG. 4 illustrates in FIG. 5 the same small pipe with the lugs or tabs 13 for fixing the same in the installed position. The end face of the small pipe equipped with a securing lug 13 is illustrated in FIG. 6 representing a partial elevational view taken in the direction of arrow VI of FIG. 5.

Four different embodiments for the through-openings and small pipes are illustrated in FIGS. 7, 8, 9 and 10. The plane of cross section in each case thereby is to be considered as extending along the line VII—VII of FIG. 5.

FIGS. 7 and 9 thereby illustrate through-openings 7 and 14 and small pipes 8 and 15 having a circular base shape whereas FIGS. 9 and 10 illustrate similar through-openings 18 and 22 and small pipes 19 and 23 having an eliptical base shape.

However, in FIGS. 7 and 9, the webs 9, 10 and 20, 21 are made in one piece with the small pipes 8 and 19, respectively, whereas in the embodiments of FIGS. 8 and 10, the webs 16, 17 and 24, 25 are made in one piece with the rim, for example, by hollowing out during the casting.

A further improvement of the cooling results from the provision of the small pipes with bores 27 as can be seen in FIG. 11. These bores 27 extend through the pipe walls intermediate the webs 26 in the part of the pipes near the pressure side as delimited by the parti-

tion walls **28**. In order not to restrict unnecessarily thereby the area of an intensive cooling, the partition wall **28** may be displaced somewhat toward the low pressure side.

While I have shown and described several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to those skilled in the art, and I therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

I claim:

1. A turbine wheel having rim means and blade means made in one piece, said rim means including an outer rim portion, comprising: radial slot means provided at said outer rim portion, means forming intentional breaking places for radial heat cracks provided at the ends of said radial slot means, aperture means disposed in said rim portion in a generally axially direction for preventing said radial heat cracks from continuing in a radially inward direction, said aperture means including means for communicating the high pressure side with the low pressure side of the turbine wheel, said intentional breaking places being disposed between said slot means and said aperture means.

2. A turbine wheel according to claim **1**, wherein said aperture means include prism-shaped apertures and said communicating means includes small pipe means disposed in said apertures, said pipe means being provided with a partition wall means in the inner cross section thereof for substantially completely closing off said cross section, said small pipe means being disposed in said aperture means to permit a radial play therein.

3. A turbine wheel according to claim **2**, wherein said apertures and said small pipe means have a substantially circular cross section.

4. A turbine wheel according to claim **3**, wherein said apertures are of oval shape with the major axis of said oval shape being directed radially in relation to the turbine wheel axis, and wherein said small pipe means have an oval cross section.

5. A turbine wheel according to claim **4**, wherein said apertures and said small pipe means have an eliptical cross section.

6. A turbine wheel according to claim **1**, wherein the outer contour of said small pipe means is profiled and is provided with web means extending in the axial direction for the support of said small pipe means in the said aperture means, said web means forming therebetween channel means for the guidance of cooling air through the turbine wheel.

7. A turbine wheel according to claim **6**, wherein said apertures and said small pipe means have a substantially circular cross section.

8. A turbine wheel according to claim **6**, wherein said apertures are of oval shape with the major axis of said oval shape being directed radially in relation to the turbine wheel axis, and wherein said small pipe means have an oval cross section.

9. A turbine wheel according to claim **8**, wherein said apertures and said small pipe means have an eliptical cross section.

10. A turbine wheel according to claim **6**, wherein said aperture means include prism-shaped apertures and said communicating means includes small pipe means disposed in said apertures, said pipe means being provided with a partition wall means in the inner cross section thereof for substantially completely closing off said cross section, said small pipe means being disposed in said aperture means to permit a radial play therein.

11. A turbine wheel according to claim **2**, wherein said small pipe means is provided with a smooth outer contour, and wherein the inner walls of said apertures are provided with substantially axially extending ribs forming webs.

12. A turbine wheel according to claim **11**, wherein said apertures and said small pipe means have a substantially circular cross section.

13. A turbine wheel according to claim **11**, wherein said apertures are of oval shape with the major axis of said oval shape being directed radially in relation to the turbine wheel axis, and wherein said small pipe means have an oval cross section.

14. A turbine wheel according to claim **12**, wherein said apertures and said small pipe means have an eliptical cross section.

15. A turbine wheel according to claim **11**, wherein said aperture means include prism-shaped apertures and said communicating means includes small pipe means disposed in said apertures, said pipe means being provided with a partition wall means in the inner cross section thereof for substantially completely closing off said cross section, said small pipe means being disposed in said aperture means to permit a radial play therein.

16. A turbine wheel according to claim **6**, wherein one of said web means is somewhat wider than the remaining web means, said wider web means being arranged radially outwardly in relation to the turbine wheel axis.

17. A turbine wheel according to claim **11**, wherein one of said web means is somewhat wider than the remaining web means, said wider web means being arranged radially outwardly in relation to the turbine wheel axis.

18. A turbine wheel according to claim **2**, a lug is provided at each end of said pipe means and the turbine wheel being provided with grooves engageable with said lugs, said grooves being disposed on the radially outwardly directed side of the apertures in relation to the turbine wheel axis.

19. A turbine wheel according to claim **6**, wherein said pipe means are provided with bores outside the area of said web means.

20. A turbine wheel according to claim **19**, wherein said bores are substantially radial bores in relation to the axis of said pipe means.

21. A turbine wheel according to claim **20**, wherein a lug is provided at each end of said pipe means and the turbine wheel is provided with grooves engageable with said lugs, said grooves being disposed on the radially outwardly directed side of the apertures in relation to the turbine wheel axis.

22. A turbine wheel according to claim **11**, wherein said pipe means are provided with bores outside the area of said web means.

23. A turbine wheel according to claim **22**, wherein said bores are substantially radial bores in relation to the axis of said pipe means.

24. A turbine wheel according to claim **2**, wherein said pipe means are provided with web means and bores disposed between said web means, said bores being disposed on the side of said partition wall means near the pressure side of the turbine wheel.

25. A turbine wheel according to claim **24**, wherein said bores are substantially radial bores in relation to the axis of the pipe means.

* * * * *