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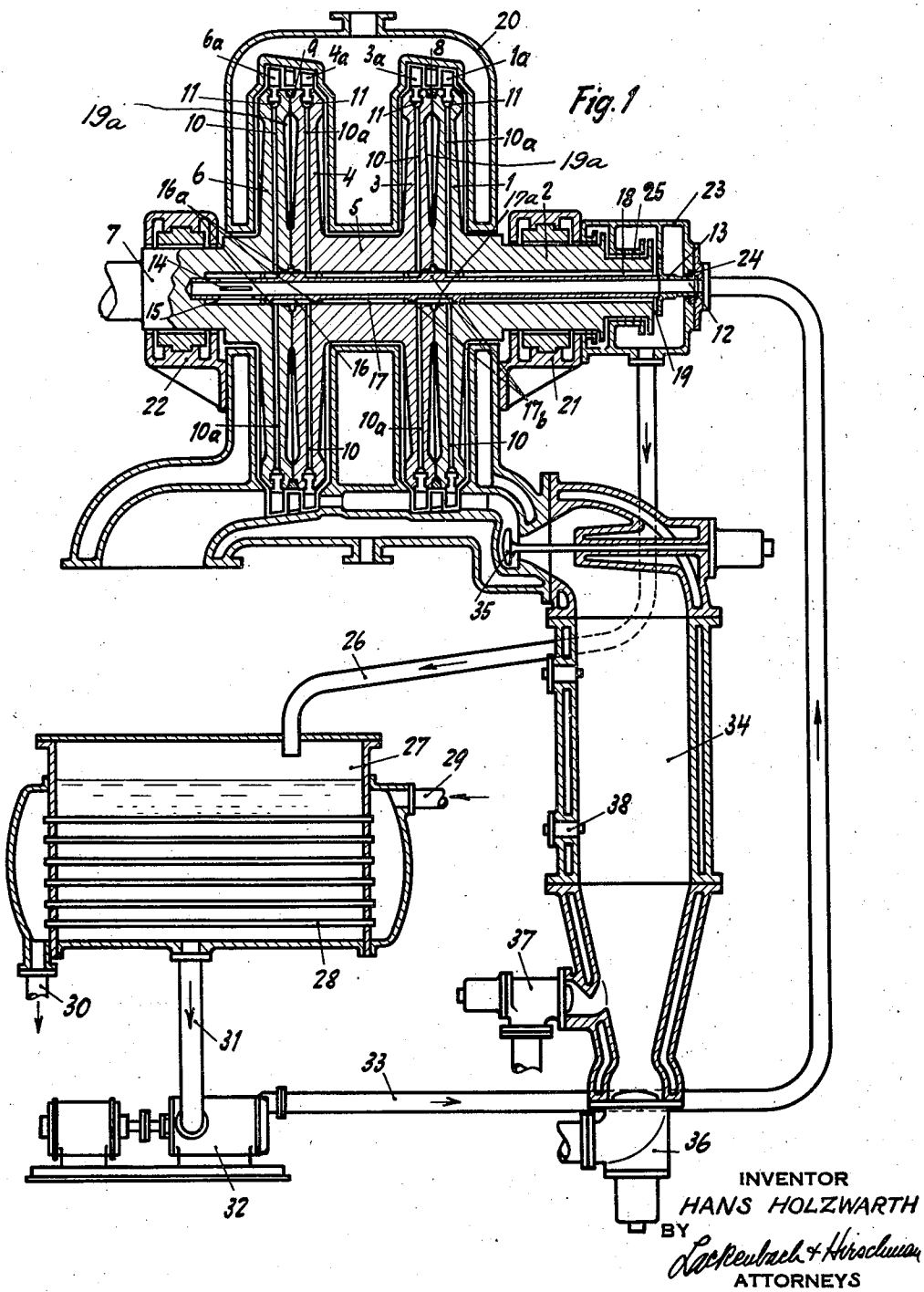
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LIQUID COOLED MULTIRINGED TURBINE ROTOR

Filed Sept. 15, 1938

2 Sheets-Sheet 1



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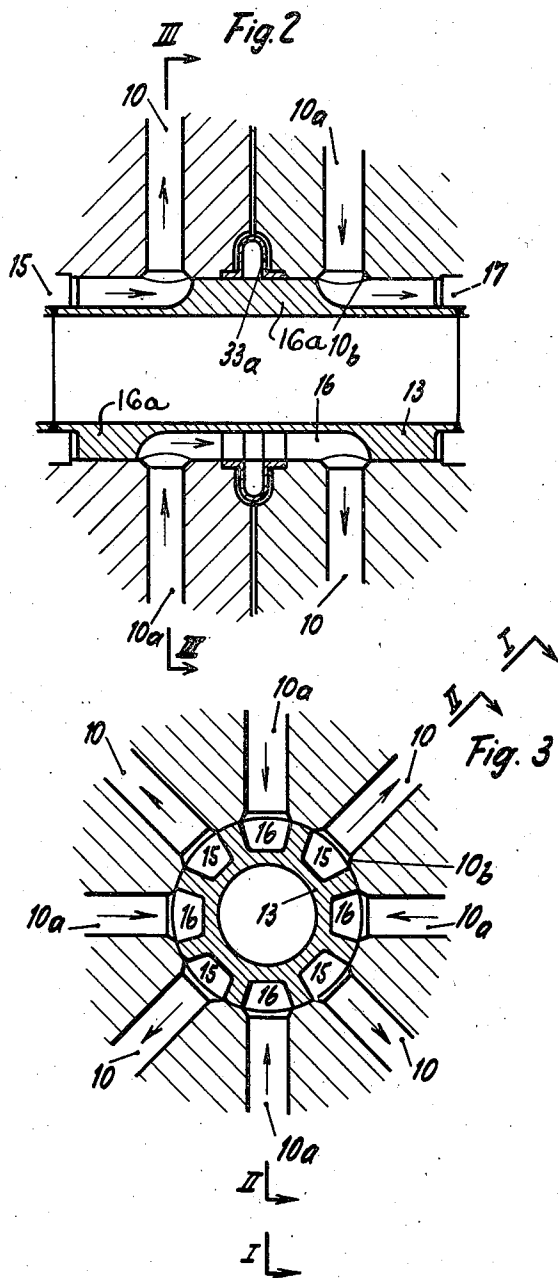
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LIQUID COOLED, MULTIRINGED TURBINE ROTOR

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10 Claims. (Cl. 60—41)

The present invention relates to the cooling of turbine rotors, and more particularly of rotors driven by combustion gases, such as gases generated by explosion of fuel and air under constant volume.

The attempt to cool turbine blades and rotors, particularly of combustion turbines, has been pursued for a long time. I have found from experience that, on the one hand, it is best to employ liquid cooling agents to obtain an adequate heat-withdrawal and, from the standpoint of heat economy, it is desirable to withdraw the heated cooling agent from the turbine and re-cool it for re-use rather than discharge it into the combustion gases; and on the other hand, it is important to expose as small an area as possible to the cooling agent in the supply and discharge channels in the turbine rotor in view of the high pressures (up to 200 atmospheres and above) that the cooling agent attains in the rotor, which pressures would act disruptively on the adjacent surfaces of parts of a composite rotor, which were screwed, riveted or welded to each other.

Radial bores through the rotor body have proved to be the only means suitable for the supplying of the cooling agent to and its withdrawal from the rotor crown or the blades, such bores connecting distributing channels, directed for example at the feet of the blades along the blade-ring, with the hollow hub of the turbine rotor. The cooling agent can flow outwardly through one or several radial bores to the just-mentioned distributing channels and can be withdrawn through other bores inwardly toward the wheel hub. This arrangement, wherein radial bores connect supply and withdrawal channels in the wheel hub with the distributing channels in the blade ring, has been found to be quite satisfactory with rotors having only a single blade ring, so long as provision was made for a sufficient flow of cooling agent.

In view of the high gas velocities which arise during the impingement of the blades in consequence of the high combustion gas temperatures and pressures, it has proved to be advantageous to employ, instead of single-ringed rotors, multi-ringed rotors and especially Curtis wheels, at least in the first stage. To retain in the simplest manner the liquid cooling with radial bores of relatively small diameter, it was obvious to construct the multi-ringed rotor in known manner as a simple disc with thickened crown. The radial bores required for supplying and withdrawing the cooling liquid were then, as with single-ringed

rotors, led through the central plane of the wheel disc, closed at the outer crown by plugs or by welding and connected with two distributing or collecting channels, one for each ring of blades, by transverse bores running parallel to the axis of the wheel, the channels extending along the feet of the blades in the blade rings. This arrangement of the cooling agent conduits appeared very simple and appropriate and corresponded to the satisfactory cooling provisions of the single-ringed wheels.

However, in the operation of multi-ringed rotors constructed as just described, unexpected difficulties arose. It was observed that even though the bore diameters and cooling agent pressure were sufficiently large to insure adequate cooling, the blades suffered from overheating in a short time. This result I found was due to sharp deflections in the direction of flow which the arrangement of transverse bores running perpendicularly to the radial bores necessarily involved. These bends or branchings caused especially strong deposition of impurities unavoidably contained in every cooling liquid, and especially the separation of salts when water was used. The flow of the cooling liquid was in this way throttled so greatly that finally evaporation of the cooling liquid occurred, which favored still more strongly the deposition of impurities. Finally the heat withdrawal from the wheel and blades reached such small values that damage to the blades resulted.

The present invention accordingly is based upon the discovery that all branching of the conduits for the cooling agent, leading to the formation of dead spaces with reduced flow velocities, must be avoided, and that in the case of multi-ringed rotors, in spite of the increased expenditure of material and of manufacturing cost, straight bores through the body of the rotor, which are free from bends and branches, must run from each of the distributing or collecting channels in the rotor crown to the rotor hub. Consequently, liquid-cooled, multi-ringed turbine rotors, especially for explosion turbines, are characterized in accordance with the invention by the feature that the rotor is constructed of a plurality of individual rotor elements or discs, each having a crown sufficiently wide for only one ring of blades, the cooling agent conduits which connect the channels associated with each blade ring in the circumferential direction of the wheel and distribute the cooling agent to the individual blades, with the hollow hub of the wheel being constructed as uninterrupted, straight and

tubular passageways continuously from the cooled blade surfaces to the point of discharge into the hollow hub, such passageways for the different blade rings lying in separate planes transverse to the shaft axis and intersecting the enlarged body of the rotor.

The drawings show, by way of example, a constructional embodiment of the invention illustrating this feature and also additional novel features which will be described below. In said drawings,

Fig. 1 illustrates a longitudinal section through the central axis of a rotor constructed in accordance with the invention, the section being taken generally along the line I—I of Fig. 3.

Fig. 2 shows that part of the rotor, on an enlarged scale, at which the radial cooling agent conduits open into the hollow hub, and is a section along the line II—II of Fig. 3; while

Fig. 3 shows on the scale of Fig. 2 a vertical cross-section through the rotor along the line III—III of Fig. 2.

The rotating body or rotor shown in Fig. 1 is composed of three individual parts, namely of the rotor element 1 with the stub shaft 2 joined thereto by forging, the rotor elements 3 and 4 made of one piece with the shaft section 5 connecting them, and the rotor element 6 with the stub shaft 7, forged thereto, the rotor elements 1, 3, 4 and 6 carrying respectively the rings of blades 1a, 3a, 4a and 6a. The individual rotors 1 and 3, and likewise 4 and 6, are connected by welding at their circumferences at the places indicated at 8 and 9, so that a closed, unitary rotating body is provided. The rotor elements are preferably of the Laval type of wheels of uniform strength and thus are of reduced thickness below the crowns, but the solid body or web of the elements underlies each ring of blades down to the hub. By this construction, in which an individual wheel disc is provided for each ring of blades and in which the discs are united into a single rotating body by welding, there results inherently the possibility of arranging straight radial bores 10 and 10a, free from bends and branches, for connecting the collecting channels 11, each of which may run along the feet of a number of blades, with the cooling agent supply and discharge in the common hub. In this way there is for the first time created a practicable cooling arrangement for multi-ringed turbine rotors since all of the channels are free from bends and branches and thereby the danger of clogging of the channels is completely avoided.

In this connection it is immaterial whether the distributing or collecting channels 11 lie only in the crown of the wheel, whether they lie against the blade rings, or whether still other bores lead out from these distributing channels into the blades. It has, however, been found that channels in the blades very rapidly become clogged and therefore are advantageously avoided from the beginning.

As will be seen from Figs. 1 and 2, a series of channels and collecting spaces at the rotor hub are associated with the rotor sections 6, 4, 3 and 1 in such manner that a series flow of the cooling agent is obtained from the left end of the supply pipe 13 toward the right end thereof, as viewed in Fig. 1. In the construction illustrated by way of example in the drawings, a more or less arcuate distributing channel is arranged at the foot or at the base of a number of adjacent blades in each blade ring, the ends of such chan-

nel being connected with the supply and discharge, more or less radial bores 10 and 10a.

The cooling agent enters at 12 into the cooling tube 13, arranged within a bore in the shaft of larger diameter than the tube, and passes through the slits 14 into the annular space 15 which surrounds the other end of the tube 13. From this point the cooling agent reaches the distributing or collecting channels 11 of the rotor 6 through the radial bores 10, and is discharged from such channels through the radial bores 10a whence it passes into the channels 16. The latter run parallel to the axis of the shaft and are spaced circumferentially about the tube 13.

These channels 16 are formed by axially parallel and axially transverse ridges or ribs 16a, there being a channel 16 for each discharge bore 10a of the rotor section 6. The other end of each of the channels 16 communicates with an inlet bore 10 of the rotor section 4, the discharge bores 10a of such rotor section leading from the distributing channels 11 thereof and opening into the annular space 17 between the pipe 13 and the walls of the shaft bore. From the other end of the space 17 run the supply bores 10 for the distributing channels 11 of the rotor section 3, the discharge bores 10a in such section emptying into separate, circumferentially spaced axially parallel channels 17a formed by the axially parallel and axially transverse ridges or ribs 17b. From the latter channels the cooling agent flows into the supply bores 10 of the rotor section 1 and returns through the discharge bores 10a into the annular space 18, from which it discharges through passage 19 into the pipe 26. It will be understood that while the illustrated construction is designed to incorporate four distributing channels for each ring of blades, more or fewer of such channels can be employed.

It will be seen from the foregoing that the present invention solves in a very simple manner the problem of providing a rotor having a plurality of rings of blades, with straight, unbranched supply and discharge bores for the cooling agent distributing channels at the base of the blades despite the fact that the actual axial wall thickness of the web of the rotor inwardly of the crown is less than the axial thickness of the crown and in fact may be no greater than the distance between the center lines of the leftmost and rightmost rows of blades. Where the web of reduced thickness is solidly constructed, broken or branched supply and discharge conduits 10, 10a are unavoidable. By the construction of the present invention, an annular space 19a is provided between each two rotor sections, so that despite the reduced web thickness, web material exists continuously from each blade ring radially to the hub.

By constructing the rotor as a composite member by welding together, at their peripheries, several individual rotors, the provision of the radial supply and discharge conduits and also the distributing channels in the crown or crowns of the rotor is greatly facilitated as these passageways can be formed in the individual rotor sections before they are united. A construction of this kind leads to further advantages by reason of the fact that the wall thicknesses of the individual rotor sections turn out smaller than the wall thickness of a wheel carrying a plurality of blade rings; in this way distortions of the rotors under the heat stresses are effectively avoided. Also, the dimensions of the rotor hubs remain within tolerable limits, in particular sud-

den thickenings can be dispensed with. On the other hand, important simplifications occur in providing the rotor with blades. It has proved to be expedient, especially in gas turbine bladings, to weld the individual blades in fixed position in the rotor and to arrange the anchor consisting throughout of welding material between the blades. If a number of blade rings are arranged on one and the same rotor, then one of the blade rings acts interferingly in these welding operations when the other is to be welded. In rotors constructed in accordance with the invention, the blades can first of all be welded into the individual rotors and the rotors, after the blading has been completed, can be welded together. In this way the mounting of the blading is made easier to an important degree. Finally, it has proved to be necessary, in order to avoid an unnecessary pressure drop of the cooling agent, to form the mouths of the radial cooling agent conduits extremely carefully at the hollow hub, especially well rounded off, as shown at 10b, in order that at these points throttling, and likewise banking up of the cooling agent giving rise to depositions, may be completely avoided. Such a construction of the mouth can, however, not be obtained with known tools when the rotors carrying the blade rings consist of a single piece. Here, also, the division of the body of the rotor and the subsequent welding affords the advantage that the place to be worked remains easily accessible, so that the mouth can be given the requisite shape.

The rotor is surrounded by the housing 20 and is held in the latter by the bearing blocks 21 and 22. The cooling water supply and withdrawal take place in the housing 23; the stuffing box 24 here seals the interior against the entering cooling water and the packing 25 against the outflowing water; the cooling water flows out of the housing 23 through the conduit 26 into the water tank 27, where it is re-cooled by the cooling tubes 28, into which cooling water flows by way of the tubular conduit 29, and from which the cooling water flows off through the conduit 30. The re-cooled cooling water of the rotor is sucked by the pump 32 through the conduit 31 and is again conducted by way of pipes 33 and 13, to the rotor. The spaces between the latter, opposing faces of the rotor section may be sealed by the rings 33a.

The rotor is impinged in known manner by combustion gases which are generated in the explosion chamber 34 and flow out through the nozzle valve 35 to the rotor. The explosion chamber 34 is charged with air through the valve 36 and with gas or other fuel through the valve 37; the mixture is then ignited by the spark plugs 38. The nozzle valve then is opened under the control of a suitable timing device and discharges the hot gases at high pressures into an expansion nozzle which directs them against the blades.

Certain of the novel features hereinabove disclosed may be utilized without others and variations may be resorted to within the scope of the appended claims without departing from the spirit of the invention.

I claim:

1. A liquid-cooled, combustion gas turbine rotor, comprising a plurality of rotor elements of uniform strength circumferentially united at the crown, each having a crown sufficiently wide to receive only a single ring of blades, said elements being of reduced thickness immediately inside of said crown, whereby an annular space

is formed between adjoining elements, the web extending radially continuously from the blade feet to the hub, channels for a liquid cooling agent located in each rotor element adjacent to the feet of blades in each ring, and running in the circumferential direction and distributing the cooling agent to the individual blades, and straight bores running directly from the channels in each rotor element through the web of the element and connecting the channels separately with the hollow hub of the rotor.

2. A liquid-cooled combustion gas turbine rotor comprising a plurality of circumferentially united individual rotor elements of uniform strength, a hollow hub connected to the rotor, each rotor element having a crown sufficiently wide to receive only a single ring of blades and being of reduced thickness immediately inside of the said crown, whereby an annular space is formed between adjoining elements, the web extending radially continuously from the blade feet to the hub, separate distributing channels for a liquid cooling agent associated with the individual rings of blades and located in the crown of the respective rotor elements, substantially straight, unbranched supply and discharge bores running through the web of the respective rotor element from each of said channels to the hub of the rotor, the bores for the different blade rings thus lying in different axially transverse planes, and supply and discharge channels for the cooling agent connected with said bores at the hub of the rotor and both opening at the same side of the hub.

3. A liquid-cooled combustion gas turbine rotor having a plurality of axially traversed rings of blades thereon, a hollow hub forming part of the rotor, separate distributing channels for a liquid cooling agent associated with the individual rings of blades and located in the rotor, substantially straight, unbranched supply and discharge bores running through the body of the rotor between each of said channels and the hub of the rotor, the bores for the different blade rings lying in different axially transverse planes, and connecting channels located at the rotor hub and arranged to connect the distributing channels of the successive blade rings in series by way of said supply and discharge bores.

4. A liquid-cooled combustion gas turbine rotor having a plurality of axially traversed rings of blades thereon, a hollow hub connected with the rotor, separate distributing channels for a liquid cooling agent associated with the individual rings of blades and located in the rotor, substantially straight, unbranched supply and discharge bores running through the body of the rotor from said channels to the hub of the rotor, a supply pipe for the cooling liquid extending into said hub but spaced from the walls of the bore thereof, and ridges between the pipe and said bore walls dividing the annular space between the pipe and hub into channels arranged to connect the distributing channels of the successive blade rings in series by way of said supply and discharge bores.

5. A liquid-cooled combustion gas turbine rotor having a plurality of axially traversed rings of blades thereon, a hollow hub connected with the rotor, separate distributing channels for a liquid cooling agent associated with the individual rings of blades and located in the rotor, substantially straight, unbranched supply and discharge bores running through the body of the rotor from said channels to the hub of the rotor,

and connecting channels located at the rotor hub and arranged to connect the distributing channels of the successive blade rings in series by way of said supply and discharge bores, the supply bore of the distributing channel of one blade ring being in axial alignment with the discharge bore of the distributing channel of the adjoining blade ring, said bores being joined by a connecting channel at the hub.

6. A liquid-cooled, combustion gas turbine rotor having a plurality of rings of blades thereon upon the same, axially continuous crown, a separate channel for a liquid cooling agent located in the rotor adjacent to the feet of blades in each ring and running in the circumferential direction and distributing the cooling agent to the individual blades of the associated ring, a hollow hub forming part of the rotor, the body of the rotor being of reduced axial thickness inwardly of the crown and being divided into as many sections as there are rows of blades by the interposition of annular spaces between the sections, whereby solid web material extends radially continuously from said channels to the rotor hub, a pipe for cooling agent arranged within the hub in spaced relation to the walls thereof and forming a surrounding, reverse path for the cooling agent, and straight conduits passing through the rotor and connecting the channels separately with the hollow hub of the rotor, the inlet and discharge ends of the conduits at the hub being rounded off.

7. A liquid-cooled combustion gas turbine rotor comprising two end sections each having a single rotor element and a single blade ring thereon, and a stub shaft projecting from each element, and a central section consisting of two spaced rotor elements joined by an intermediate shaft section and united to the aforementioned elements at the outer peripheries of said elements, the adjacent elements being of approximately the same outer diameter; said rotor elements each having a crown sufficiently wide to receive only a single ring of blades, and being of reduced thickness immediately inside of said crown, channels for a liquid cooling agent located in each rotor element adjacent to the feet of blades in each ring, and running in the circumferential direction and distributing the cooling agent to the individual blades, a hollow hub connected with the rotor and adapted to receive a cooling fluid, and straight bores running directly from the channels in each rotor element through the body of the element and connecting the channels separately with the hollow hub of the rotor.

8. A liquid-cooled, combustion gas turbine rotor having a hollow hub forming part thereof, a plurality of rings of blades on the crown of the rotor, channels for a liquid cooling agent located in the rotor adjacent to the feet of the blades in said rings of blades, the body of the rotor being of reduced actual thickness inwardly of the crown and being divided into as many sections as

there are rows of blades by the interposition of annular spaces between the sections, whereby solid web material extends radially continuously from said channels to the rotor hub, straight bores lying in such axially spaced web sections and connecting the channels with the interior of the hub, means within the hub forming axial channels between the bores associated with the channels of different blade rings, and means for supplying a cooling agent to and withdrawing the same from the hub at the same side of the hub.

9. A liquid-cooled, combustion gas turbine rotor having a hollow hub forming part thereof, a plurality of rings of blades on the crown of the rotor, channels for a liquid cooling agent located in the rotor adjacent to the feet of the blades in said rings of blades, the body of the rotor providing a continuous mass of metal from the feet of the blades of each of said rings radially to the rotor hub, straight, unbranched bores connecting the channels with the interior of the hub, means within the hub forming axial channels between the bores associated with the channels of different blade rings, means for supplying a cooling agent to and withdrawing the same from the hub, a plurality of channels being associated with each blade ring and the supply and discharge bores for each ring being arranged in alternation in a substantially radial plane and likewise in substantially axial planes from blade ring to blade ring, the cooling channels, axial channels and bores being so interconnected that a supply bore runs from the hub outwardly to one end of a cooling channel at the foot of a ring of blades, while a discharge bore extends from the other end of such channel inwardly to an axial channel at the hub, such latter channel charging into a bore associated with the adjoining ring of blades, which latter bore runs into one end of a cooling channel associated with said adjoining ring of blades, a discharge bore connecting the last-mentioned cooling channel with the hub.

10. A liquid-cooled, combustion gas turbine rotor having a hollow hub forming part thereof, a plurality of rings of blades on the crown of the rotor, channels for a liquid cooling agent located in the rotor adjacent to the feet of the blades in said rings of blades, the body of the rotor being of reduced actual thickness inwardly of the crown and being divided into as many sections as there are rows of blades by the interposition of annular spaces between the sections, whereby solid web material extends radially continuously from said channels to the rotor hub, straight bores lying in such axially spaced web sections and connecting the channels with the interior of the hub, and means for supplying a cooling agent to and withdrawing the same from the hub.

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