

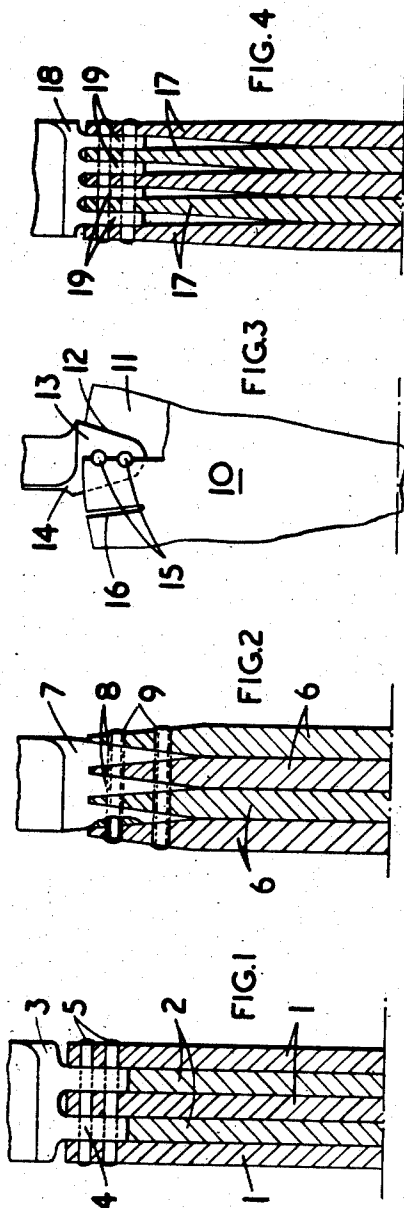
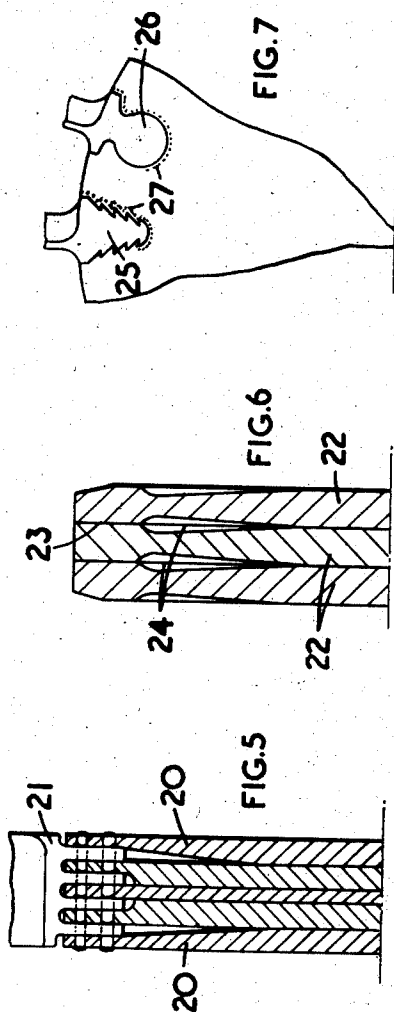
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J. ATKINSON
TURBINE OR LIKE ROTOR

2,657,008

Filed July 29, 1948

3 Sheets-Sheet 1



Inventor
By *Joseph Atkinson*
Steven Davis Miller & Maher
Attorneys

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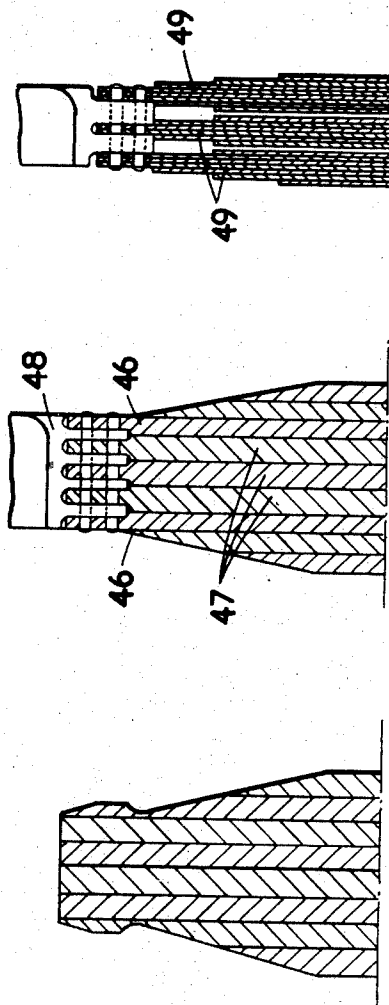
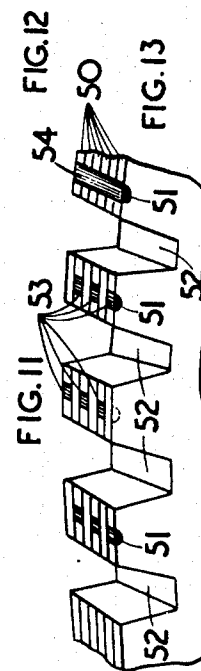


FIG. 10

FIG. 12

FIG. 11

FIG. 13

Inventor
By *Joseph Atkinson*
Stevens Davis Miller & Maher
Attorneys

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TURBINE OR LIKE ROTOR

Joseph Atkinson, London, England

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9 Claims. (Cl. 253—39.15)

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This invention relates to rotors of axial flow turbines operating at high temperatures which are made from a plurality of co-axial disc-like elements having the blades separately fabricated and attached thereto. It is well known to make rotors of the kind indicated from one or more relatively massive discs or wheels of which not more than two carry any one row of blades and which are usually substantial one-piece forgings, castings, or similar bodies. This method of manufacture has a number of disadvantages, particularly in the case of forgings, which may be mitigated by the use of a laminar construction of rotor and the present invention has for its object in general to assist in rendering practicable, more especially under the working conditions of a high temperature gas turbine, of a rotor of laminar construction, by which is meant herein, a construction in which each blade element is carried by at least three disc-like elements so that support therefor is afforded by any one such disc-like element independently of support afforded by any other.

In the manufacture of a laminar rotor, one difficulty that arises is in ensuring that all the laminae will remain in their correct relative radial positions during operation. This problem may become particularly acute in the case of gas turbine rotors in respect of which difficult operating conditions may arise due to high working temperatures combined with high running speeds and stresses. In these circumstances a small displacement of the laminae may give rise to serious unbalancing of the rotor and a maldistribution of stress in the anchorages of attached blades, possibly resulting in pulling out of the blades. It is an object of the invention in one of its aspects to mitigate these difficulties.

Accordingly, in one aspect, the invention provides a bladed rotor for an axial flow gas turbine operating at high temperatures comprising at least three disc-like laminae integrated to form a laminated rotor body having recessed peripheral seatings for the reception of blade roots, at least some of said laminae being united by a bonded joint extending over a substantial area of the opposed faces of the laminae, and separately fabricated blades having root portions of an overall width in the axial direction substantially greater than the thickness of a single lamina, each blade having its root portion engaged in said seating and being attached to at least three of said laminae so that support for the blade is afforded by any one such lamina independently of support afforded by any other.

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It is thought that by this means the possibility of differential distortion between adjacent discs due to rotational stresses in operation will be materially reduced; furthermore, in the case of a rotor operating in uneven thermal conditions, by using a bonding medium having good thermal properties, such as, for example, a metallic bonding like brazing metal or solder, so that the thermal gradient between adjacent discs is reduced, the thermal distortion occurring will be similarly reduced.

When brazing or soldering provides the bonding between rotor discs the abutting surfaces could be plated with the bonding material prior to assembly or a thin sheet of the material (such as copper foil) inserted between abutting surfaces during assembly. The heat necessary to fuse the bonding material could be applied by means of a furnace, a torch, or by the high frequency induction method.

It is contemplated that bonding may be used to supplement more conventional means of attaching blades to a rotor. Thus, in the case of a blade engaging axial or circumferential recesses in the rotor periphery, the blades may be bonded into the slots. This may be achieved by plating the blade root with bonding material before its insertion and subsequently heating it, or by introducing molten bonding material between the blade root and its seat by capillary action.

A further difficulty in any high temperature turbine rotor is to insure adequate cooling of the rotor body. Accordingly the invention provides a bladed rotor for an axial flow gas turbine operating at high temperatures comprising at least three disc-like laminae integrated to form a laminated rotor body and separately fabricated blades mounted peripherally on said body, each blade being attached to at least three of said laminae so that support therefor against radial displacement is directly afforded by any one such lamina independently of support afforded by any other, wherein at least one lamina is adapted to provide coolant space within the body by being of reduced thickness at increasing radii over a substantial proportion of its radial dimension, wherein said laminae are apertured to form a passage communicating with said coolant space and wherein the rotor body is provided with opening means near the hub thereof for the entry of coolant into said passage and further opening means nearer the rim thereof for the outlet from said passage of coolant

after it has passed through said coolant space and cooled said body.

Various other advantages arising from the invention will be revealed in the ensuing descriptions of the particular embodiments of the various aspects of the invention illustrated diagrammatically in the accompanying drawings. In the drawings Figures 1, 2, 4, 5, 6, 8, 10, 11 and 12 represent part cross-sections in an axial plane through various rotors intended primarily for use in an axial flow gas turbine and thus for operation at high rotational speeds and stresses combined with high working temperatures at the blades; Figures 3, 7, 9 and 13 represent part elevations of certain of these rotors. The constructions described are, however, in some respects applicable to rotors generally.

Figure 1 shows a rotor comprising a number of plane discs 1, alternate discs 1 being of a greater diameter than the disc 2 between them, so providing a number of circumferentially extending grooves in the assembled rotor. Each of the radially extending blades attached to the rotor has a root 3 comprising a number of tongues 4 extending radially inward into and complementarily to, the grooves in the rotor; the blades are held by pins 5 extending in the axial direction through the blade root and rotor discs. The abutting surfaces of adjacent rotor discs and/or the blade roots are bonded by brazing or soldering, or by other means, to promote stress distribution. Figure 2 shows a rotor similar in construction to that shown in Figure 1, but in this case each of the discs 6 whilst being substantially plane is bevelled on each side at its periphery so that circumferential grooves of tapered section are formed in the rotor. The blade roots have tongues 8 of tapered shape to correspond with the grooves in the rotor. The bonding between the blade root and rotor discs may thus extend over a greater surface area than in the previous case. Pins 9 are again used to hold the blades and they may, where necessary, be hollow to provide a passage for a coolant fluid. Figure 3 shows a fragmentary elevation, partly sectioned, of a rotor similar to that shown in Figure 1 but in this case two similar plane discs, of which the outer one 10 is partly shown, abut on either side of an intervening plane disc 11 of similar diameter to the disc 10. The rim of the disc 11 has a plurality of recesses 12 cut into it, each being shaped to accommodate a tongue 13 on a blade root 14. Thus, when assembled, the three discs present abutting surfaces for bonding to the tongue 13 over the whole of its axially and circumferentially extending surfaces; pins 15 again supplement the bonding for blade attachment. A slot 16 may be made between each blade root in the discs having continuous rims to permit distortion and relieve stresses in the rim at high temperatures; this provision may be included in the other embodiments described. Figure 4 shows a part section of a rotor comprising a number of discs 17 graded in the radial direction in respect of their thickness, so conforming with the requirements of stress distribution. The blade roots 18 are provided with tongues 19 which are complementary to the circumferentially extending grooves formed between the assembled discs and are secured by bonding and pins as in the previous example. In this case the discs 17 are reduced in thickness from hub to rim by a half so that the tongues and grooves of the blade attachment are of equal width, but

this relationship may, of course, be modified where required. Figure 5 shows a rotor comprising a combination of graded and plane discs, the reduction in cross-section required for strength distribution being limited to the outer two discs 20 only, each of which is reduced on its inner side; by this means centrifugal loads are developed in operation which tend to close the outer discs on to the blade roots. The remaining discs are selected for thickness, or are reduced in thickness at their peripheries, to accommodate tongued and grooved blade roots 21. In each of the constructions shown in Figures 4 and 5 it is preferred that axially abutting surfaces of the discs and of the blade roots shall be bonded in a suitable manner. Figure 6 represents a rotor designed for blade attachment by means of blade roots which engage axial slots formed in the periphery of the rotor; the discs vary in thickness over their radius but are provided with axially abutting annuli 23 at their rims. By suitably bonding adjacent discs at hub and rim, the spaces 24 between the discs are totally enclosed and may contain a conductive or convective cooling medium, for example, a sodium salt. Figure 7 represents an end elevation of a rotor, such as that in Figure 6 in which the blade roots engage complementary axial slots in the rotor periphery. Two typical root forms are shown, namely a "fir-tree" root, 25, and a "key-hole" root, 26; blade attachments are effected primarily by the interlocking surfaces of the blade and groove, but with these surfaces bonded additional security results; as applied to the blade attachments in a rotor for high temperature operation, only part of the surfaces of the root is bonded, as indicated by the broken lines 27, so permitting deformation of the rotor rim in operation. The bonding also locates the blade when cold, thereby obviating the necessity for peening the rotor at the blade root. Figure 8 shows a section of a rotor constructed in a manner similar to that in Figure 6 but provided with passages through the rotor for a current of cooling air. The discs are of varying thickness to conform with the requirements for stress distribution and abut axially at hub and rim; adjacent discs are provided with a complementary spigot and recess attachment 28 at the hub to permit their concentric location. Axially abutting surfaces of the discs are bonded and the assembly is secured to a hollow stub shaft 29, also located by a spigot and recess engagement 30, and secured by a number of axially extending bolts. Air passes from the hollow shaft 29 through a hole 31 in the first disc 32 and a recess 33 in the face of the second disc 34, which is shown in elevation in Figure 9, and out toward the rim of the rotor, where it passes through channels 35 in the abutting rims of the discs. These channels 35 are each connected by holes 36 bored through the second disc to similar channels 35 in the abutting rims of the second and third discs 34 and 37 respectively, by which the air passes into the cavity 38 between the latter. The air path is continued, by the provision of holes 39, 40, 41 and channels 35 in appropriate discs through the rotor, from inlet to outlet, in a radially outward direction so that a centrifugal pumping action takes place on the air within the rotor, and its flow thereby maintained. This is further ensured by providing radially extending impeller blades, 42, on the last disc 43 of the rotor from which the air is finally discharged in an axial direction through

holes 44 in the last disc 43. This disc forms part of the rotor assembly and includes a balance ring 45 on which adjustments effecting the dynamic balance of the rotor may be made. This cooling arrangement ensures an adequate dissipation of heat from the vicinity of the root of each blade on the rotor and maintains the temperatures of all bonded joints within permissible limits.

The requirements for stress distribution in a rotor in accordance with the invention may be satisfied by an alternative method of construction as already described; in this case the rotor comprises a number of discs of varying diameter. Some particular examples of such an embodiment will now be described with appropriate references to the accompanying drawings.

Figure 10 shows a rotor comprising a number of plane discs of varying diameters bonded together so that the composite body conforms to the requirements of stress distribution. If necessary, surplus material may be removed from the rotor after bonding to arrive at the finished sizes. This rotor is intended for blade attachments by means of axial grooves in the periphery of the rotor. Figure 11 shows a rotor constructed in a similar manner to that in Figure 10 but designed for blade root attachments of the tongue and groove type, when the blades would also be bonded. The discs 46 have one, and the intermediate discs 47 both sides of their rims thinned to accommodate the blade roots 48.

A rotor may be constructed in a manner which incorporates both types of construction described generally in the foregoing. For instance, Figure 12 shows a rotor having the graded disc construction (similar to that in Figure 4), but in this case each disc 49 is fabricated from a number of discs of varying diameters; all abutting surfaces are bonded.

In the embodiments illustrated by Figures 10 to 12 cooling passages may be formed in the rotor by perforating certain discs prior to assembly. As has already been indicated, the discs of a rotor may be bonded by welding their adjoining surfaces. Figure 13 shows a fragmentary projection of a rotor, comprising discs which abut at their rims, and having axially extending blade seat recesses in its periphery, in which each of the discs 50 has welding grooves 51 cut at spaced points on its periphery. These are arranged, in the assembled rotor, to come between the positions of the respective blade seat recesses 52, and may coincide on alternate discs as at 53, or may extend across the rotor width as at 54. When the grooves 51 are filled with welding material, the discs are united and may be handled as a solid body. Similar grooves and welds may be provided at the hub bore of a rotor.

A metal rotor disc might have its mechanical properties improved by work hardening additional to that incurred in its manufacture. For this purpose the disc may be subjected to shot peening or a process having similar effects before assembly. In each of the particular embodiments of the invention described, the discs may be concentrically located, and their attachment to a shaft effected, by boring each disc at its centre and assembling the rotor on its shaft, to which each element may be bonded. Under these circumstances, axially adjacent components of the rotor would preferably be provided with abutting surfaces round the rotor bore which could be bonded.

I claim:

1. A bladed rotor for an axial flow gas turbine operating at high temperatures comprising at least three disc-like laminae integrated to form a laminated rotor body having recessed peripheral seatings for the reception of blade roots, at least some of said laminae being united by a bonded joint extending over a substantial area of the opposed faces of the laminae, and separately fabricated blades having root portions of an overall width in the axial direction substantially greater than the thickness of a single lamina, each blade having its root portion engaged in said seating and being attached to at least three of said laminae so that support for the blade is afforded by any one such lamina independently of support afforded by any other.

2. A bladed rotor according to claim 1, wherein at least one of said lamina is provided around its rim with recesses providing in part at least said recessed peripheral seating, and each blade root has a tongue accommodated in one of said recesses and secured therein against radial displacement.

3. A bladed rotor according to claim 2, wherein alternate laminae are provided with the said recesses, and each blade root has tongues corresponding with the number of recessed laminae.

4. A bladed rotor according to claim 1, wherein there is a bonded union between the blade roots and the said seatings.

5. A bladed rotor according to claim 4, wherein the said bonded union extends only over a part of the abutting surfaces of the blade root and the seating, in such manner that in the turbine operating conditions relative thermal deformation is permitted between blade root and seating.

6. A bladed rotor according to claim 1, comprising a number of said disc-like laminae of which a group of similar diameter are mounted co-axially and in axial abutment, and further pairs of which laminae abut co-axially on either side of the group, each successive pair of laminae being of progressively diminishing diameter, to form a laminar rotor body of an effective axial cross-section diminishing in the direction from hub to rim in the sense of conforming to the requirements of stress distribution.

7. A blade carrier body for an axial flow gas turbine rotor designed for operation at high temperatures comprising at least three integrated disc-like laminae, at least some of which are united by a bonded joint extending over a substantial area of the opposed faces of the laminae, the laminae providing recessed peripheral seatings for the reception of the roots of separately fabricated blades, and being so individually dimensioned that the laminar body formed thereby is of diminishing thickness of material in the direction from hub to rim in the sense of conforming to the requirements of stress distribution.

8. A bladed rotor for an axial flow gas turbine operating at high temperatures comprising at least three disc-like laminae integrated to form a laminated rotor body and separately fabricated blades mounted peripherally on said body, each blade being attached to at least three of said laminae so that support therefor against radial displacement is directly afforded by any one such lamina independently of support afforded by any other, wherein at least one lamina is adapted to provide coolant space within the body by being of reduced thickness at increasing radii over a

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substantial proportion of its radial dimension, wherein said laminae are apertured to form a passage communicating with said coolant space and wherein the rotor body is provided with opening means near the hub thereof for the entry of coolant into said passage and further opening means nearer the rim thereof for the outlet from said passage of coolant after it has passed through said coolant space and cooled said body.

9. A bladed rotor according to claim 8 wherein adjacent said outlet opening means impeller blading is provided which in the turbine operating conditions assists in maintaining a continuous current of coolant through said passage and space.

JOSEPH ATKINSON.

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