

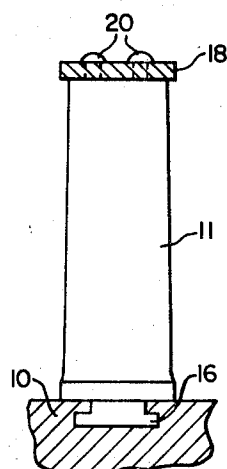
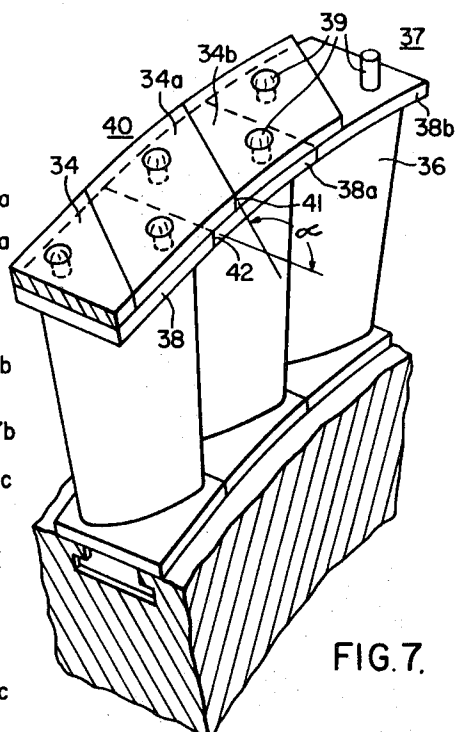
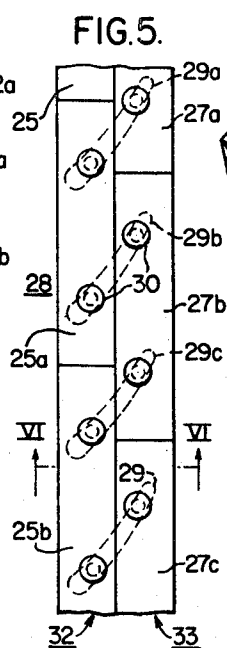
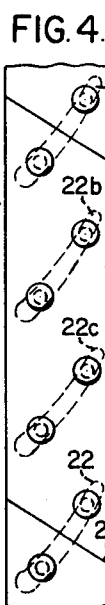
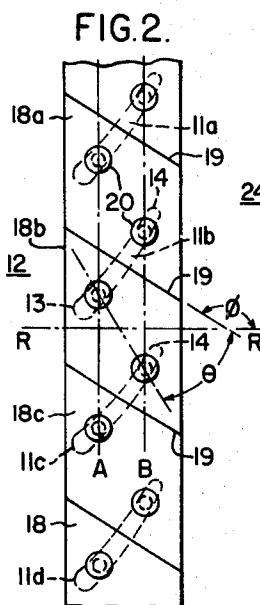
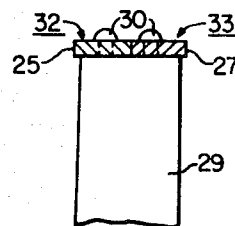
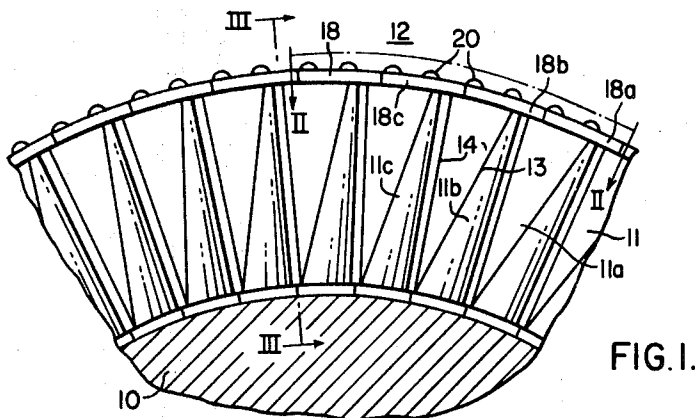
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3,606,578

CONTINUOUS SHROUDING-RIVETED CONSTRUCTION

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WITNESSES

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3,606,578 CONTINUOUS SHROUDING-RIVETED CONSTRUCTION

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5 Claims

ABSTRACT OF THE DISCLOSURE

A circular shrouded rotor blade structure for an elastic fluid axial flow turbine or compressor comprising an annular row of blades and an annular series of arcuate segments associated with the blades and arranged in end-to-end relationship to form a continuous 360° shroud, wherein each pair of neighboring shroud segments is firmly riveted to a blade common to both with each segment being riveted to at least two blades. There may be more than one row of arcuate segments forming the shroud.

BACKGROUND OF THE INVENTION

This invention relates, generally, to an elastic fluid axial flow turbine or compressor and, more particularly, to a shrouded rotor blade structure.

The primary advantage of providing shrouding on the tips of rotor blades is to minimize vibrational forces, thereby minimizing vibrational stresses in the blades, as well known in the art. The shrouding, however, may subject the blades to additional thermal bending stresses.

Turbine blades which are fastened to the same shroud segment have several different material vibrational modes. The tangential mode vibration is the in-phase vibration in the plane of maximum flexibility, perpendicular to the rotational axis of the rotor. The axial mode vibration is the in-phase vibration in the direction of the axis.

The invention minimizes the tangential and axial vibrational modes and minimizes the thermal bending stresses. Furthermore, this rotor blade structure is inexpensive to manufacture and can be easily and economically repaired.

Earlier inventions of this type are disclosed in A. J. Partington Pat. 3,367,629 and P. D. Saunders Pat. 3,367,630 both issued on Feb. 6, 1968 and both assigned to the same assignee as this invention.

SUMMARY

This invention relates, generally, to an elastic fluid axial flow turbine or compressor and, more particularly to a shrouded rotor blade structure.

The structure comprises an annular row of blades and an annular series of arcuate segments arranged in end-to-end relationship to form a continuous 360° shroud. Each pair of neighboring segments is connected to a blade common to both and each segment is connected to at least two blades. There may be more than one row of segments forming the shroud and there may be more than one layer of shroud segments.

Four embodiments are illustrated in the drawings. The first embodiment comprises a single row of segments of parallelogram shape in plan where each segment is riveted to two blades and each pair of neighboring segments is riveted to a blade common to both. The second embodiment is similar to the first except the shroud segment is riveted to more than two blades and at least one blade is solely riveted to the shroud segment. The third embodiment is similar to the first embodiment except that there are two rows of segments in side-by-side relationship and

each blade is riveted to a side-by-side segment with one rivet in each row. The fourth embodiment is similar to the first except that the outermost tip of the blade is arcuately shaped and conforms to the arcuate shroud segment.

Elastic fluid flows through the turbine at high temperature and pressure, turning the rotor. As the shroud expands due to the centrifugal and thermal forces, the segments rotate slightly around the rivets so that the segments are in sliding, frictional abutment with their adjacent segments creating frictional damping and thus minimizing the stresses due to the centrifugal forces and the thermal strains.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial section of a rotor with a shrouded blade structure in elevation formed in accordance with the present invention;

FIG. 2 is a developed view, on a larger scale, of the shroud structure taken along line II—II of FIG. 1 showing a plan view of the shroud;

FIG. 3 is a view on the same scale as FIG. 2, partly in elevation and partly in section, taken along line III—III in FIG. 1;

FIG. 4 is a view similar to FIG. 2, but showing another embodiment of the invention;

FIG. 5 is a view similar to FIG. 2, but showing a further embodiment of the invention;

FIG. 6 is a fragmentary view taken along line VI—VI of FIG. 5; and

FIG. 7 is a fragmentary view in perspective of a still further modification of the shroud.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings in detail and particularly to FIG. 1, there is shown a portion of a rotor 10 having a transverse annular row of blades 11 substantially identical to each other and further identified by alphabetical suffixes 11a, 11b, 11c, etc. signifying their relationship to each other, and a shroud 12, surrounding the outermost tips of the blades 11. As indicated in FIG. 2, the blades 11 are of the usual airfoil contour as well known in the art with a leading edge 13 and a trailing edge 14.

As shown more clearly in FIG. 3, the blades 11 are provided with suitable root portions 16 which are disposed in a suitable peripheral groove in the rotor 10. The blades 11 extend radially outward relative to the axis of rotation of the rotor 10, indicated by the dot-dash line R—R, and they may constitute one stage of a multi-stage axial flow turbine (not shown). On the radially outermost tip portion of the blade 11 are two tenons 20, which, as illustrated, are integral with the blade.

The shroud 12 comprises an annular series of arcuate segments 18 substantially identical to each other and further identified by alphabetical suffixes 18a, 18b, 18c, etc. signifying their end-to-end relation to each other. The segments 18 form a continuous 360° shroud. Referring to FIG. 2, the segment 18a is securely connected to the two blades 11a, 11b by the tenons 20. In a similar manner, segment 18b is securely fastened to the two blades 11b and 11c by the tenons 20 and segment 18c is securely fastened to the two blades 11c and 11d. The remaining segments proceed in the manner described above.

As shown in FIG. 2, the segment 18b is a segment of an arc and is of parallelogram shape in plan and the end portion 19 of the segment 18b lies in a plane which forms an oblique angle ϕ with the axis of rotation of the rotor R—R. The segment 18b has two apertures through which the tenons 20 project. A line connecting the adjacent

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tenon on the leading edge 13 of the blade 11b and the tenon on the trailing edge 14 of the blade 11c lies in a plane which forms an acute angle θ with the axis of rotation of the rotor. The tenons 20 are deformed such as by riveting to tightly connect the segment 18b to the blades 11b and 11c. A similar analysis can be made for the remaining segments, blades and tenons.

The neighboring segments 18a and 18b are riveted to the blade 11b common to both segments and correspondingly, the remaining segments are fastened in a similar arrangement.

The tenons are arranged in two circular rows indicated by the dot-dash lines A—A, B—B conforming to the curvature of the shroud 12, and which rows lie in planes perpendicular to the axis of rotation of the rotor R—R.

The shroud 12 comprises a single layer and a single row of segments 18.

As previously explained, as the shroud segments 18 expand and the adjacent segments 18a and 18b tend to frictionally engage each other, the stresses build up in the segments, but no frictional damping occurs unless the segments slide on each other. The blade 11b is connected by one tenon 20, to segment 18a, and by a second tenon 20, to the adjacent segment 18b. As the stresses continue to increase, the segment 18b minutely pivots or rotates around the tenon 20 causing a slight movement along the edge portion 19 of the segments 18a and 18c. There will be a corresponding movement of the segments 18a and 18c along the end portions 19 of the segment 18b so that the segments frictionally slide along the adjacent end portions 19 and produce frictional damping by dissipating the stresses and minimizing thermal distortion. A similar analysis can be made for the remaining segments which cooperate with each other in a like manner.

DESCRIPTION OF THE SECOND EMBODIMENT

The second embodiment, as shown in FIG. 4, is similar to the shrouded rotor blade structure in FIGS. 1, 2 and 3 but differs in the following manners. The shroud 24 comprises an annular series of arcuate segments 21 substantially identical to each other and further identified by alphabetical suffixes 21a, 21b, etc. characterizing their end-to-end relationship with each other. The shroud segment 21b is firmly connected to more than two blades for example, blades 22a, 22b, 22c and 22d. Each pair of neighboring segments 21a and 21b is firmly connected to the blade 22a common to both and the remaining blades 22b and 22c are entirely connected to the shroud segment 21b. A similar analysis can be made for the remaining segments.

The primary advantage of this embodiment is economy; the fewer the number of shroud segments to manufacture and assemble, the less expensive it is to produce the rotor structure. However, as the number of segments 21 approaches the lower limit of two segments, in which all the blades 22 except for two are entirely connected to the shroud segments, frictional damping is virtually eliminated and there is a corresponding increase in thermal distortion. On the other hand, as the number of shroud segments increases, approaching the configuration of the first embodiment 12, where each segment 18 is connected to only two blades, there is a corresponding increase in frictional damping and a reduction of thermal distortion.

DESCRIPTION OF THE THIRD EMBODIMENT

The third embodiment shown in FIGS. 5 and 6 is substantially similar to the first embodiment but differs in the following. The shroud 28 comprises a left row 32 of segments 25a, 25b, 25c, etc. and a right row 33 of segments 27a, 27b, 27c, etc. which are substantially the same size and shape, the alphabetical suffixes characterizing their end-to-end relationship with each other. The rows 32, 33 are arranged in side-by-side relation with each other and the segments 25a and 27a, 25b and 27b, 25c and 27c, etc. are staggered relative to each other. There

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are two tenons 30 integral with the blade 29a and each tenon is connected to a side-by-side segment 25 and 27a with one tenon in each row 32, 33. Similarly, two tenons 30 are integral with the blade 29b and each tenon is connected to a side-by-side segment 25a and 27b with one tenon in each row 32, 33. Each pair of adjacent blades 29a and 29b joins three segments 25a, 27a and 27b with one segment 25a common to two blades 29a and 29b. A similar relationship exists among segments 25b and 27b, blades 29c, and 29, and tenons 30 and the remaining segments, blades, and tenons.

The advantage of this embodiment is that any motion will produce additional frictional damping because of the increased area of contact between the segments 25a and 27a, 25b and 27b, and the cooperating remaining segments of the shroud 28.

DESCRIPTION OF THE FOURTH EMBODIMENT

The fourth embodiment shown in FIG. 7 is substantially similar to the first embodiment except for the differences which follow. The outer shroud 40 comprises an annular series of arcuate segments 34 substantially identical to each other and further identified by alphabetical suffixes 34a, 34b, etc. characterizing their end-to-end relationship with each other. The segments 34 are similar in size and shape and, as illustrated, are of parallelogram shape in plan.

Each blade 36 has an outermost tip forming an integral blade cover 38 of arcuate segmental shape substantially identical to each other and further identified by alphabetical suffixes 38a, 38b, etc. indicating their end-to-end relationship. The blade covers 38, 38a, 38b, etc. form a continuous 360° inner shroud 37 which shroud conforms to and cooperates with the outer shroud 40. As indicated, the arcuate segments or blade covers 38 are rectangular in plan.

Two tenons 39 are integral with and extend radially outwardly from the blade cover 38 and the shroud segments 34 and 34b are fastened to the blade cover 338 by deformation of the tenons 39 as previously described. Similarly, two tenons 39 are integral with the blade cover 38a and the shroud segments 34a and 34b are fastened in a like manner to the blade cover 38a. A similar analysis can be made for the remaining segments.

The segments 34 of the outer shroud 40 are disposed in staggered relation on the blade covers 38 of the inner shroud 37. The edge portion 41 of the segment 34a forms an oblique angle α with the edge portion 42 of the blade cover 38a and a similar relation exists among the remaining edge portions. In this manner, better sealing against leakage of motive fluid by the shroud is obtained since there is no direct opening through the two shrouds. Another advantage to this embodiment is that the inner shroud 37 offers better tip contour whereby better fastening to the outer shroud 40 from the blades 36 can be secured.

Although more than one embodiment has been shown, it is intended that all the matter contained in the foregoing description or shown in the accompanying drawing shall be interpreted as illustrative and not in the limiting sense.

What is claimed is:

1. In an elastic fluid utilizing apparatus, a rotor having a transverse annular row of blades, a continuous shroud surrounding the radially outermost tips of the blades, said shroud comprising at least two rows of arcuate segments arranged in end-to-end relation with each other, means connecting each segment securely to at least two blades, and each pair of neighboring segments being firmly connected to a blade common to both.
2. The structure defined in claim 1, wherein the rows are arranged in side-by-side relation with each other.

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3. The structure defined in claim 1, wherein the segments in the adjacent rows are staggered.

4. The structure defined in claim 1, wherein at least two rows of segments are arranged in side-by-side relation with each other, the segments being staggered and substantially the same size and shape. 5

5. The structure defined in claim 1, wherein each blade has two tenons, and each tenon is connected to a side-by-side segment with one tenon in each row.

6**References Cited****UNITED STATES PATENTS**

1,371,328	3/1921	Schneider	-----	416—191
3,070,350	12/1962	Stewart	-----	416—191

EVERETTE A. POWELL, JR., Primary Examiner

U.S. Cl. X.R.

416—195