Jan. 14, 1958 A. J. MEYER, JR 2,819,869

MOUNTING ARRANGEMENT FOR TURBINE OR COMPRESSOR BLADING

Filed May 2, 1950 3 Sheets-Sheet 1

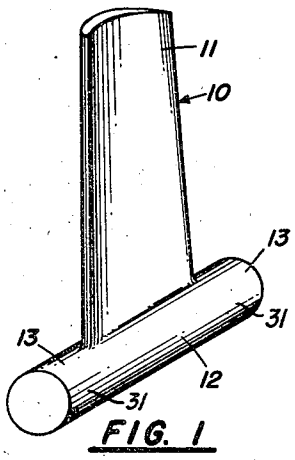


FIG. 1

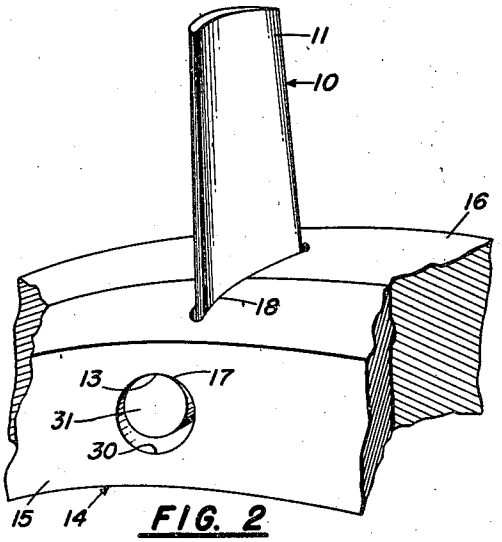


FIG. 2

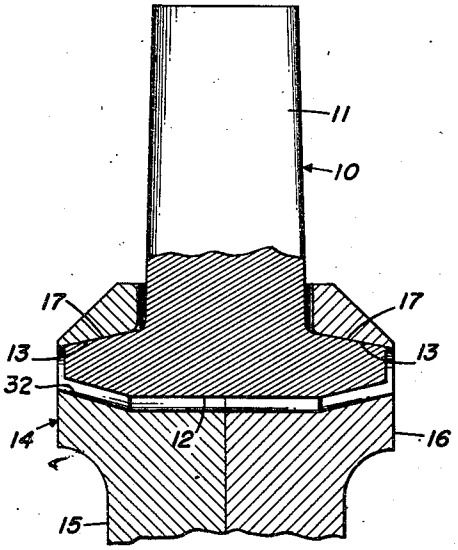


FIG. 4

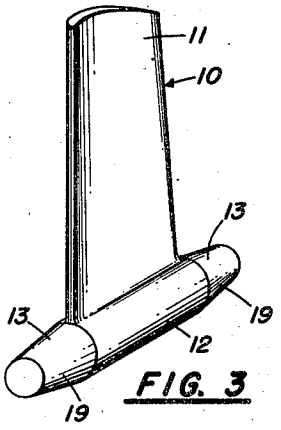


FIG. 3

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MOUNTING ARRANGEMENT FOR TURBINE OR COMPRESSOR BLADING

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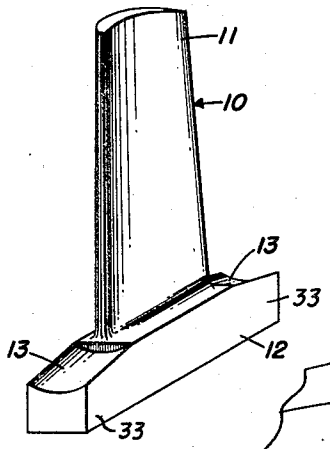


FIG. 5

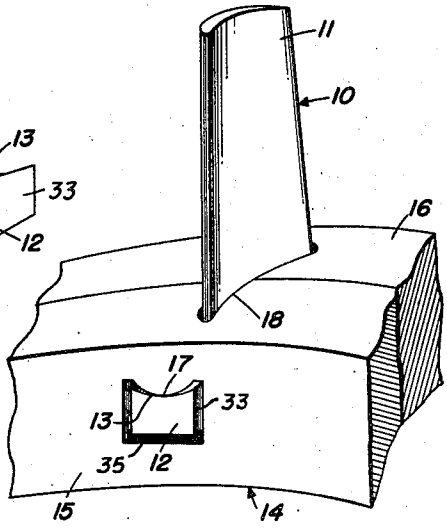


FIG. 6

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MOUNTING ARRANGEMENT FOR TURBINE OR COMPRESSOR BLADING

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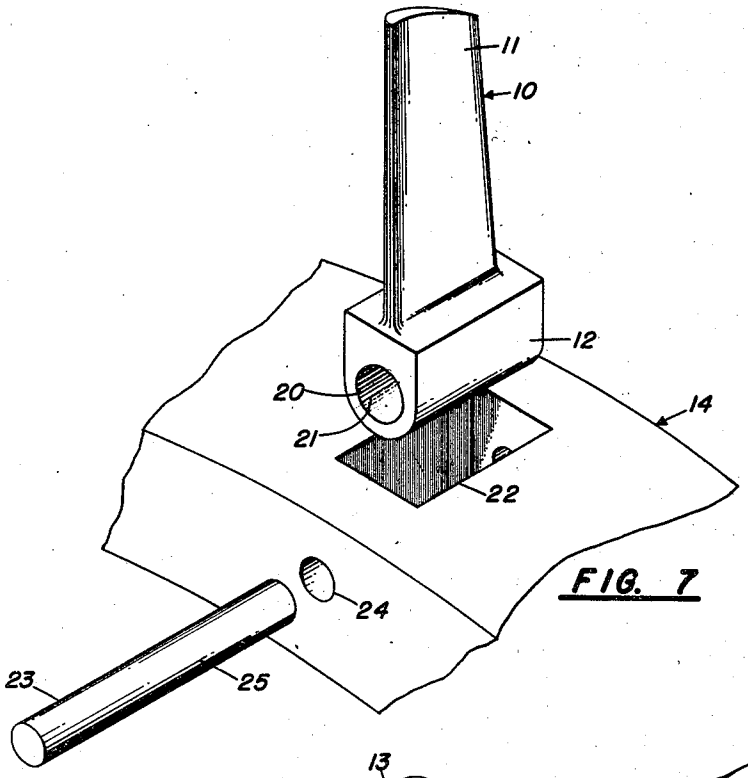


FIG. 7

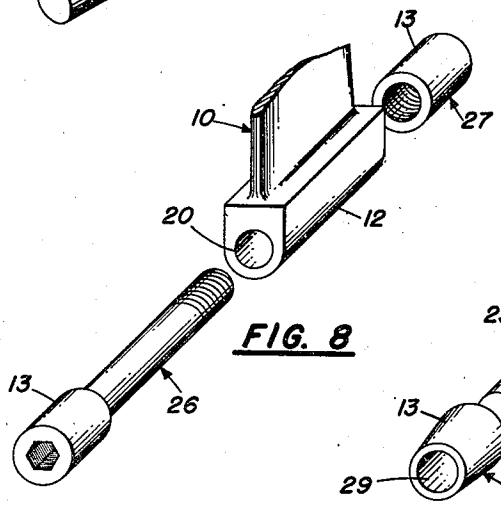


FIG. 8

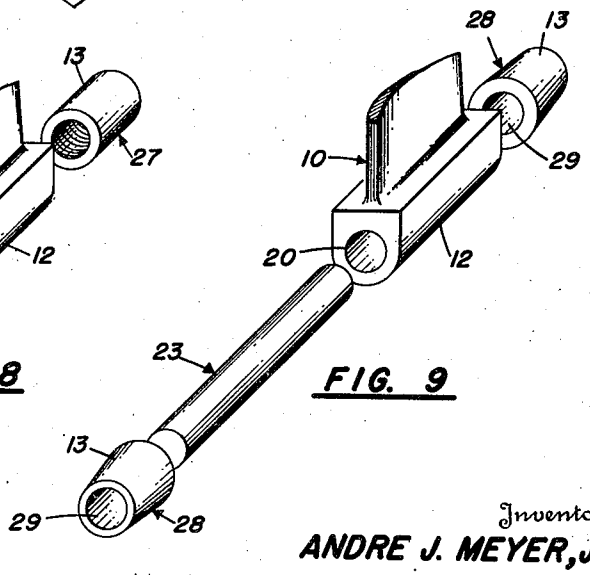


FIG. 9

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MOUNTING ARRANGEMENT FOR TURBINE OR COMPRESSOR BLADING

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Application May 2, 1950, Serial No. 159,565

15 Claims. (Cl. 253—77)

(Granted under Title 35, U. S. Code (1952), sec. 266)

This invention relates to turbine and compressor blades and in particular to an improved blade mounting which permits free positioning of the blade under operating conditions and thus reduces or eliminates vibratory stresses in the blade.

The invention comprises blade-root extensions with cylindrical or conical contact surfaces which fit into openings in the rim of a turbine or compressor disk, said openings having curved contact surfaces of substantially larger radii of curvature than contact surface radii of the root extensions.

In the steam turbine industry and more particularly in the recent gas-turbine and jet-propulsion air-compressor fields, vibration problems in the blading have caused great concern. Many blades have broken because of the vibratory stresses superimposed upon high centrifugal stresses and many complete units have been destroyed as a result of blade failures. Some means, therefore, that can reduce blade vibrations and thus prevent blade failures is urgently needed. From basic theory we know that a hinged cantilever beam cannot vibrate in a mode similar to the first-bending mode of vibration for a fixed cantilever. The first-bending mode is the form of vibration which most frequently causes trouble. The invention described herein provides a means for permitting a blade to have hinged freedom when the disk is rotating at operating speeds even though high centrifugal forces are being imposed on the blade. The proposed blade mounting does not restrain the blade root except in the radial direction. Consequently, even if the blade vibrates in a higher bending mode the vibratory stresses in the blade and root will be greatly reduced. Thus, it is evident that the loose blade mounting will help to eliminate blade failure by reducing vibratory stresses.

Also the means of mounting turbine blades provide a very effective way of attaching ceramic blades to metal disks. The difference in coefficients of expansion for ceramics and metals will not introduce additional stresses in the parts if the clearances possible with the proposed design are made large enough. In addition, disk distortion of two-piece wheels caused by centrifugal forces, an important consideration in most proposed ceramic-blade assemblies, can be neglected when the loose mount is used.

The general object of this invention is to increase the life of turbine and compressor impeller blades by reducing the vibratory stresses in the blades.

An additional object is to permit the attachment of blades to a wheel of a material that has a different coefficient of expansion than the blade material.

A still further object is to permit the attachment of blades to a wheel that distorts during operation as a result of centrifugal forces and/or thermal strains without imposing any additional stresses in the blade root.

These objectives may be achieved by the design and construction of the rotor blade as hereinafter described and shown in the accompanying drawings which are merely illustrative of preferred embodiments of said blade

construction and are not otherwise limitative thereto and in which the same reference numerals refer to the same elements throughout the different figures.

In the drawings:

Fig. 1 is a perspective view of one form of blade unit having cylindrical root extensions for hingedly mounting the blade in accordance with this invention,

Fig. 2 is a perspective view of the blade unit shown by Fig. 1, mounted in portions of a two-piece wheel,

Fig. 3 is a perspective view of another form of blade unit which has frusto-conical root extensions for hingedly mounting the blade,

Fig. 4 is a sectional elevational view showing the blade unit of Fig. 3 mounted in portions of a two-piece wheel,

Fig. 5 is a perspective view of still another form of blade unit which has a different type of root extensions for hingedly mounting the blade,

Fig. 6 is a perspective view showing the blade unit of Fig. 5 mounted in portions of a two-piece wheel,

Fig. 7 is an exploded perspective view showing a type of mounting which may be used in a one-piece wheel.

Figs. 8 and 9 are also exploded perspective views illustrating other constructions which would permit the use of a one-piece wheel.

As shown in the various figures of the drawings, the compressor or turbine blades are loosely attached by the blade roots to the rotating disk so that the blade roots are not restrained, except in the radial direction, although high centrifugal forces are acting on the blades due to the rotative speed. When a blade is thus mounted, it will not vibrate in a mode similar to the first bending mode of a vibrating fixed cantilever beam and the blade root cannot be compressed by surrounding disk material as a result of thermal strains.

The wheel 14, as indicated in Fig. 2, consists of two mating wheel sections 15 and 16 having plane peripheral adjoining surfaces which, at intervals around the wheel, are pierced radially inward of the periphery of the rim by lateral, aligned openings, recesses or bores 30, forming continuous bearing surfaces 17 for the blade root extensions as described below. Radially, on the wheel periphery, above the bores 30 and within the wheel rim edges, the rim sections are transversely slotted, as at 18, Fig. 2, to receive the blade, which extends therethrough.

The blade unit 10 includes the blade 11 and the blade root 12, the blade being a streamlined airfoil section adapted to extend radially from the wheel rim through the transverse slot 18, the width of the blade at the slot axially of the rim being less than the slot length and the thickness of the blade at the slot circumferentially of the rim being less than the corresponding slot dimensions, and the blade root 12 being a cylindrical member attached centrally along its length to the base of blade 11 and thus terminating in projecting end pieces or extensions 31 provided with bearing surfaces 13 adapted to seat in the rim openings 30. When the assembly is turning, the centrifugal force acting on the blade pulls it radially outward so that contact surfaces 13 of the blade bear against surfaces 17 of the disk portions. The radii of curvature of surface 17 is larger than the radii of curvature of surface 13 resulting in a single-line contact thus permitting the blade-root section to roll in the disk openings regardless of the magnitude of the centrifugal force. Slot 18 is machined in portions 15 and 16 with sufficient oversize to allow blade deflections that would be experienced in operation.

The blade-root extensions 19 and the corresponding bore openings 32 shown in Figs. 3 and 4 are frusto-conically shaped so that the blade will align itself in the direction parallel to the root axis when the blade is subjected to a centrifugal load. All other components of

the construction are the same and serve the same purpose as those in Figure 1.

An alternative structure is indicated in Figure 5. Here the blade root is generally rectangular instead of cylindrical and the outer surface of the ends or extensions 33 of the root are inclined outwardly from the blade toward the root ends and cylindrically hollowed to develop a line center of curvature lying in the blade plane. The bearing surface 13 of this root curvature is adapted to engage a bearing surface 17 on the outer surface of a generally squared bore 35 formed in transverse alignment through the two wheel sections 15 and 16 in the wheel rim. In this form, the radii of curvature of the contact surfaces are reversed, surface 13 having larger radii of curvature than contact surface 17 of the disk portions 15 and 16.

Still another construction that accomplishes the same purpose is illustrated in Figure 7. The blade 10 is lowered into the rectangular socket or opening 22 in the turbine or compressor wheel 14 until the upper surface of the blade root 12 is flush with the periphery of wheel 14. Pin 23 is then pressed into hole 24 and through opening 20 in the blade root. Opening 20 is of larger diameter than the diameter of pin 23 and consequently when the assembly is revolving, there will be single-line contact between surface 21 in the blade-root opening 20 and surface 25 on the under side of the pin. Socket 22 is large enough and deep enough to permit normal blade and root movement under operating speeds such as might be caused by high modes of vibration.

Bolt 26 shown in Figure 8 permits a construction that makes it possible to hold a blade removably in a one-piece rotor. After the blade root 12 is inserted in an opening in the rotor periphery, bolt 26 is passed through the opening in the side of the rotor disk, through the blade hole 20, and nut 27 is tightened on the threaded end of said bolt in the opening in the other side of the disk. Thus the bolt is rigidly secured to the blade 10 and contact surfaces 13 make single line contact in the slightly larger disk holes.

Figure 9 illustrates a structure similar to that sketched in Figure 8 but conical rolls 28 replace the bolt head and nut, thus aligning the blade axially as well as radially. The assembly is placed in the turbine or compressor wheel sockets and pin 23 is inserted and retained in the wheel by any known means.

It is impractical to illustrate and describe all the possible variations of blade mounting that will achieve the objectives of this invention; however, it is obvious to those skilled in the art that the shapes and sizes of the component parts of the proposed blade mounting can be widely varied without departing from the spirit or the scope of the invention, both of which are defined in the herewith appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rimmed rotor and for prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor materials comprising a plurality of blades, root extensions on said blades, said extensions having arcuate bearing surfaces thereon, and a rotor having a rim divided medially in the plane of rotation and provided with a plurality of spaced, transverse, peripheral slots through each of which a blade is adapted to extend, the slot width being greater than the slot thickness, and pairs of aligned bores having axes parallel to the rotor axis, said bores being radially inward of the periphery of said rim, each pair of said aligned bores having continuous bearing surfaces adapted to receive the blade root extensions of a single blade along said bearing surfaces and to engage the arcuate surfaces of said extensions along a single pivot line, the curvature of the bores at the surfaces of contact with the arcuate area of the blade root extensions being less than the curvature of the blade root extensions at this area.

2. Apparatus as defined in claim 1 wherein said root extensions and rotor bores are cylindrical in contour.

3. Apparatus as defined in claim 1 wherein said root extensions are frusto-conical in shape and said bores are frusto-conical in shape complementary to the frusto-conical shape of said root extensions but of greater radius of curvature than that of said root extensions.

4. Apparatus as defined in claim 1 wherein said root extensions are substantially rectangular in cross section, the bearing surfaces thereof being concavely arcuate and said bores are substantially rectangular in cross section, of greater transverse dimensions, than those of said root extensions to provide clearance therearound and of which the bearing surface is convexly arcuate but of smaller radius of curvature than that of the concave bearing surfaces on said root extensions.

5. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rotor and for the prevention of stresses therein due to differences in thermal coefficients of extension between the blade and root material comprising a two-piece rotor, a plurality of radially extending slots symmetrically positioned in the circumference of each rotor piece, the slots in one rotor piece being in matched relationship to a slot in the other rotor piece to form a unitary slot, a plurality of substantially rectangular openings in the lateral faces of said rotor pieces near the periphery thereof and extending therethrough in radial alignment with said slots, the upper or outermost surface of said openings being convexly arcuate and a plurality of impeller blades extending freely through said circumferential slots, root extensions of substantially rectangular cross section on said blades extending into said openings, the bearing faces of said root extensions being concavely arcuate and adapted to contact said convexly arcuate surfaces of said openings, the radius of curvature of said convexly arcuate surfaces being smaller than that of said concavely arcuate faces whereby the contact therebetween is linear and said blades are freely rollable in said openings within the limits of said slots.

6. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rotor and for the prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor material comprising a one-piece rotor, a plurality of sockets, rectangular in cross section, symmetrically spaced around the circumference and extending radially of said rotor, an arcuate opening extending from each lateral face of said rotor in alignment with and into each one of said sockets, impeller blades provided with roots adapted to fit freely within said sockets, the blades projecting radially beyond said sockets and rim, a cylindrical bore extending longitudinally through each one of said roots and adapted to be in axial alignment with said arcuate openings, and a cylindrical pin extending through each of said blade root bores and aligned rotor openings and fixed to said rotor, the diameter of the bore being greater than that of the pin whereby said blades are freely rotatable on said pin within the limits of said sockets.

7. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rotor and for the prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor material comprising a one-piece rotor, a plurality of sockets symmetrically spaced around the circumference and with sides extending radially of said rotor, an arcuate opening extending from each lateral face of said rotor into each one of said sockets, said openings being in alignment with said socket and each other form-

ing pairs of openings in the rotor faces, impeller blades provided with roots adapted to fit freely within said sockets, the blades projecting radially beyond said sockets and rim, a cylindrical bore extending longitudinally through each one of said roots and adapted to be in axial alignment with said arcuate openings, a cylindrical pin threaded at each end adapted to extend through each pair of said openings and said bore and to fit snugly and fixedly in said bore, and interiorly threaded cylindrical bushings adapted to engage the threaded ends of said pins to lock said pins with respect to the roots of said blades and to fit within said openings, the exterior diameter of said bushings being less than the internal diameter of said openings whereby a single line contact is provided between the interior arcuate surface of said openings and the exterior surface of said bushings and said blades are freely rotatable within the limits of said sockets.

8. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rotor and for the prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor material comprising a one-piece rotor, a plurality of sockets, rectangular in cross section, symmetrically spaced around the circumference and extending radially of said rotor, a frusto-conically shaped opening extending from each lateral face of said rotor to form a pair of openings in alignment with and into each one of said sockets, impeller blades provided with roots adapted to fit freely within said sockets, the blades projecting beyond said sockets and rim, a cylindrical bore extending longitudinally through each one of said roots and adapted to be in axial alignment with said frusto-conically shaped openings, a cylindrical pin adapted to extend through each pair of said openings and said bore and fixedly attached to said bore, and frusto-conically shaped bushings adapted for attachment to the ends of said pins and to fit within said openings, said openings being of greater diameter than that of the bushings extending therethrough whereby a single line contact is provided between the surfaces of said openings and said bushings and said blades are freely rotatable within the limits of said sockets.

9. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rimmed rotor and for prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor materials comprising a plurality of blades, root extensions on each edge of said blades with arcuate bearing surfaces thereon, a rotor provided with a plurality of lateral continuously and arcuately surfaced bores through the rotor parallel to the rotor axis and near the rim thereof, and a plurality of radially positioned transverse slots on the rotor periphery connecting with said bores, said blade root extensions being pivotally mounted in said lateral bores and said blades extending through said radial slots, said bore arcuate surfaces having a curvature less than that of the arcuate surfaces on said extensions and forming single line bearing surfaces for said root extensions which extend thereinto and are freely rollable therein.

10. Apparatus as defined in claim 9 wherein said root extensions and rotor bores are cylindrical in contour.

11. Apparatus as defined in claim 9 wherein said root extensions are frusto-conical in shape and said bore openings are frusto-conical in shape complementary to the frusto-conical shape of said root extensions but of greater radius of curvature than that of said root extensions.

12. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rimmed rotor and for prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor materials comprising a plurality of blades, root extensions on said blades, said extensions having arcuate surfaces thereon, a rotor provided with a plurality of lateral bores near the rim thereof

extending through said rotor and having arcuate surfaces thereon, and transverse radial slots formed in the rotor rim each communicating with two of said lateral bores and having dimensions greater than the transverse dimensions of said blade to provide clearance therearound, said root extensions being substantially rectangular in cross section with bearing surfaces concavely arcuate, and said bores being substantially rectangular in cross section and of greater dimensions than those of said root extensions to provide clearance therearound, the arcuate surfaces of said bores being convex and having smaller radii of curvature than those of the concave bearing surfaces on said root extensions, each of said blade roots being normally positioned in one of said radial slots with the arcuate bearing surfaces of said root extensions in bearing engagement with the arcuate surfaces of said bores and the blade extending radially from said blade root through one of said rim slots beyond the rotor rim.

13. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rimmed rotor and for the prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor materials comprising a plurality of blades, a root extension on each edge of said blades with arcuate bearing surfaces thereon, and a rotor having a rim provided with a plurality of spaced transverse radial slots, and side openings through said rotor at points spaced radially inward from said rim slots and communicating therewith, said openings having continuous arcuate bearing surfaces, said blade root extensions protruding into said rotor side openings with the arcuate surfaces thereof in bearing contact with the side opening arcuate surfaces along a single pivot line, and the blades extending radially from said rim through said slots, the width of said slots being greater than the blade thickness in the slot area to permit limited pivotal blade movement in said slots, the curvature of the blade root extension arcuate surfaces being greater than that of the co-engaging side opening arcuate surfaces, whereby a free rolling contact between the surfaces is obtained.

14. Apparatus for the elimination of vibratory stresses inherent in impeller blades attached to a high speed rimmed rotor for the prevention of stresses therein due to differences in thermal coefficients of expansion between the blade and rotor materials comprising a plurality of blades, root extensions on said blades, said extensions having arcuate surfaces thereon, and a rotor having continuous arcuate bearing surfaces at points displaced radially inward from the periphery of said rotor rim adapted to engage said root extension arcuate surfaces for pivotal blade movement, said rotor along its rim periphery, and adjacent said rim bearing surfaces, having spaced transverse radial slots through each of which a blade extends, the width of said slots being greater than the blade thickness in the slot area.

15. Apparatus for the elimination of vibratory stresses inherent in impeller blades mounted on a rotor, comprising a plurality of blades, a root extension on each of said blades forming one connecting member between said blade and rotor, said extension being provided with a continuous arcuate bearing surface, a rotor having a rim forming another connecting member between said blade and rotor provided with a transverse bore parallel to the rotor axis and displaced radially inward of the rim periphery, said bore having a continuous arcuate bearing surface thereon and said root extension protruding into said bore with the respective arcuate surfaces in rolling contact with each other, the curvature of one arcuate surface being greater than that of the other arcuate surface and the axes of curvature for the point of curvature contact of said arcuate surfaces being parallel to each other and at right angles to the plane of rim rotation, said rim having spaced peripheral transverse slots therein through which the blade extends, the width of these slots being greater than the blade thickness in the slot area

whereby limited blade movement on said bearing surfaces is permitted.

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