

June 19, 1962

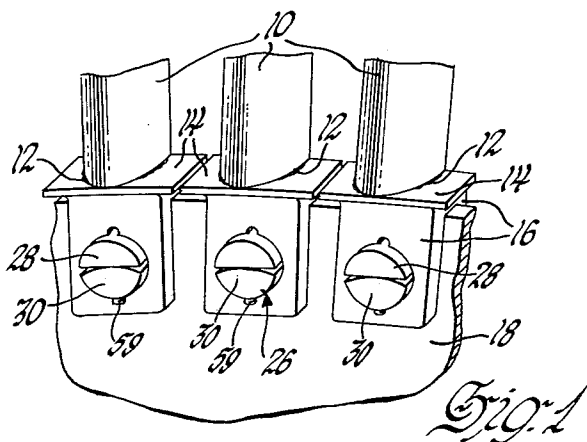
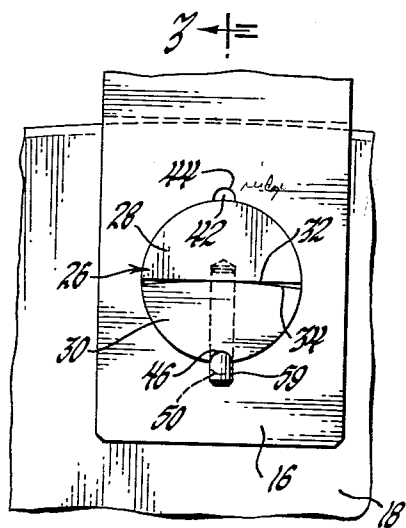
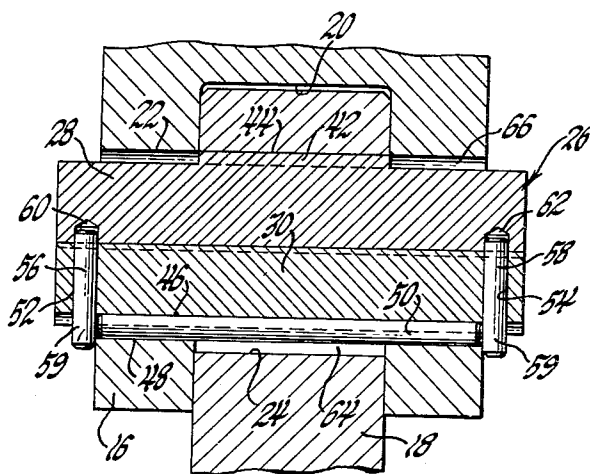
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BLADE RETENTION MEANS

Filed Aug. 13, 1958

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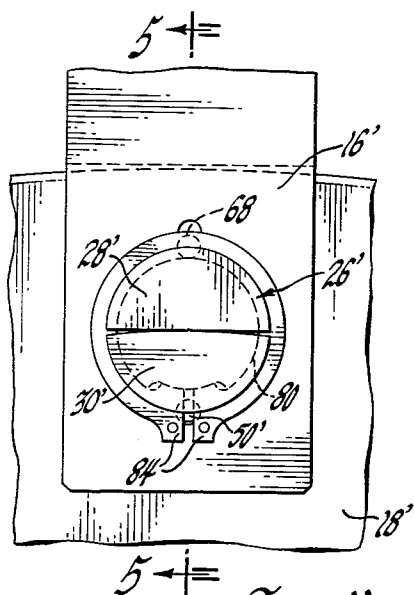


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BLADE RETENTION MEANS

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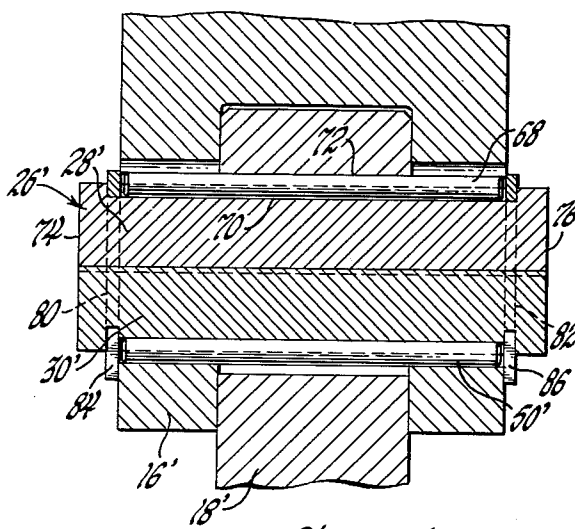
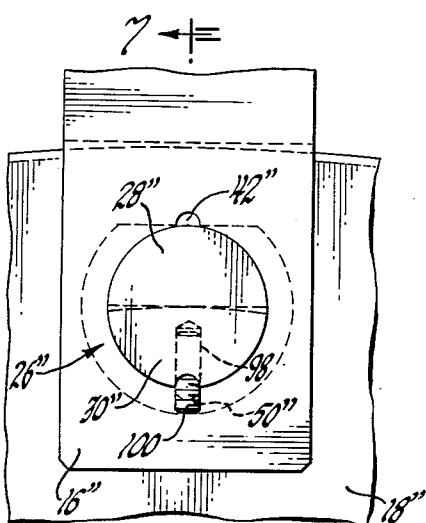
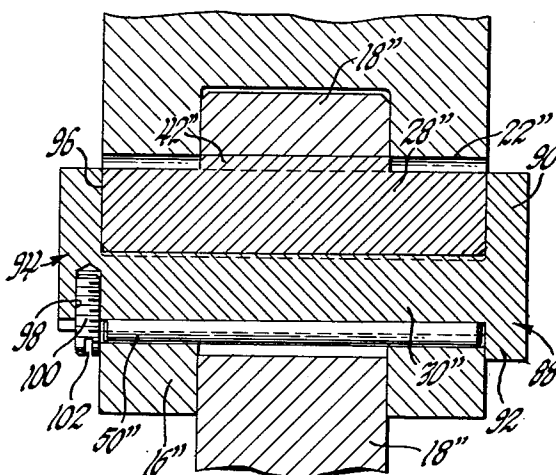


Fig: 5



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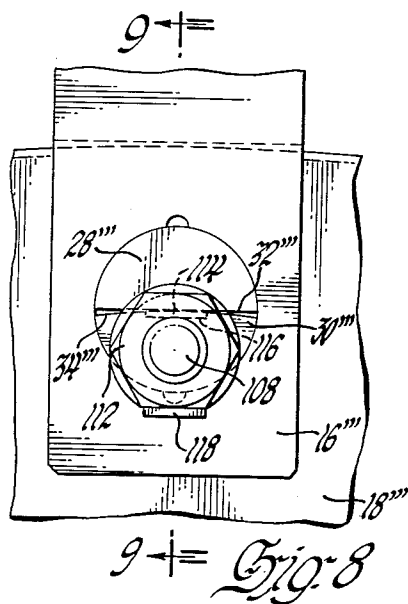
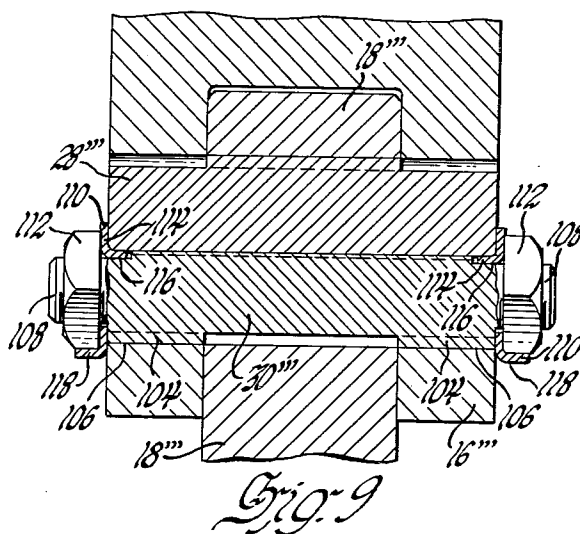
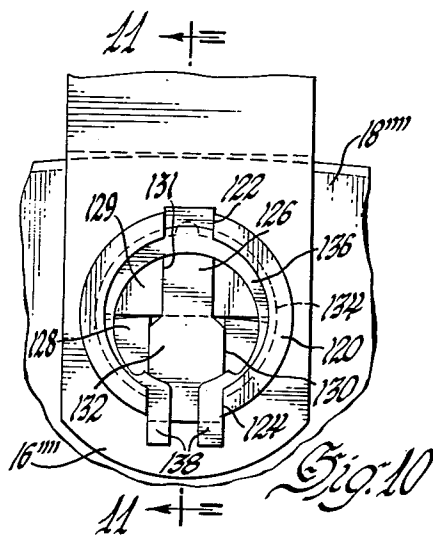
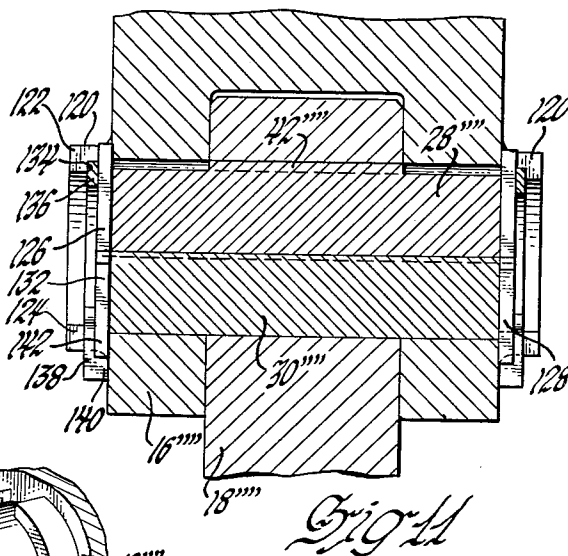
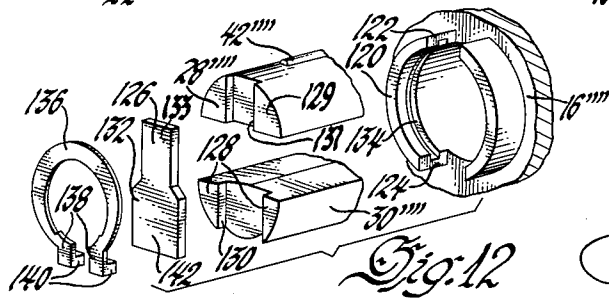
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3,039,738

BLADE RETENTION MEANS

Filed Aug. 13, 1958

3 Sheets-Sheet 3



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BLADE RETENTION MEANS

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Filed Aug. 13, 1958, Ser. No. 757,440
18 Claims. (Cl. 253-77)

This invention relates to a pinned connection between the rotor blades of a compressor and the rotor wheel.

In the conventional gas turbine engine, the compressor section is made up of a number of blade stages, each stage comprising a rotor blade row connected to a rotating disk or drum secured to the drive shaft, and a stationary or stator blade row secured to the compressor case. Each rotor blade is cast or forged integrally with or may be brazed to a platform having a plurality of depending tangs for straddling the rotor wheel hub, and a connection, such as a pin for example, is inserted through suitable holes in the tangs and the disk to secure the two together. The rotor blade is generally mounted in the gas stream in the compressor section with its chord skewed with respect to the axes of the pin and the rotor. With this type of mounting, the force of the gas striking the blade will exert a bending moment attempting to bend the blade about the blade base, while centrifugal force acting on the blade upon rotation of the rotor wheel will exert a force in the radial direction. The advantageous feature of a pinned blade is that it reduces, or essentially eliminates, restraint at the point of attachment to the rotor. The pin permits the blade to seek an equilibrium position balancing the gas bending forces and the centrifugal forces. However, it is essential that the design be such that there is no sliding friction in the joint. If sliding is permitted between the pin connection and the tangs and rotor wheel, the pins and holes will wear, and friction will produce an end restraint which may increase the blade stress and result in undesirable vibrational frequencies that can lead to fatigue failures.

This invention eliminates the above objections by providing a pinned connection between the blade tangs and the rotor wheel that prevents sliding of the rotor blade tangs with respect to the wheel while permitting a rolling action therebetween. The invention accomplishes this by providing a split pin mounting means consisting of two substantially semi-cylindrical pin portions having abutting faces, each face of which is a segment of a surface of a large diameter cylinder, i.e., large with respect to the radius of each of the pin portions, with a controlled difference in the radii of the two faces. One surface may be flat with the abutting surface convex, or one surface concave with the other surface convex. The outer pin portion is fixed to the wheel and the inner portion to the blade. With such a construction, the blade may tilt about the rotor axis by the rolling of one pin section upon the other. Since the centrifugal force acting on the blade is very high compared to the gas bending force, the amount of tilt necessary to balance the centrifugal moment against the gas bending moment is very small. In fact, the blade may be constructed with a slightly offset mass center so that it balances the gas bending moment under average or normal conditions with no tilt or lean. Slight clearances are provided in the wheel and blade root portions to permit the rolling action, but the clearance does not permit any substantial displacement of the blade root with respect to the wheel.

This invention, therefore, relates to a split pin blade-to-rotor connecting means for permitting a rolling action of the blade with respect to the rotor wheel, while eliminating sliding relative thereto.

This invention also relates to a novel tuning feature to prevent undesirable vibrational frequencies.

This invention also relates to a means of attaching the different portions of the split pin to the wheel and blade tangs, and to means for preventing axial movement of the pin with respect to the blade and disk.

Other features, advantages and objects will become apparent by reference to the detailed description of the invention and to the drawings wherein:

FIGURE 1 is a perspective partial view of a blade mounting means embodying this invention,

FIGURE 2 shows one form of the coupling means of FIGURE 1,

FIGURE 3 is a cross-sectional view taken on the plane indicated by the line 3-3 of FIGURE 2,

FIGURE 4 is a partial end view of a second form of the coupling shown in FIGURE 1,

FIGURE 5 is a cross-sectional view taken on the line indicated by the line 5-5 of FIGURE 4,

FIGURE 6 is a partial end view of a third form of the coupling of FIGURE 1,

FIGURE 7 is a cross-sectional view taken on the plane indicated by the line 7-7 of FIGURE 6,

FIGURE 8 is a partial end view showing a fourth form of the coupling of FIGURE 1,

FIGURE 9 is a cross-sectional view taken on the plane indicated by the line 9-9 of FIGURE 8,

FIGURE 10 is a partial end view of a fifth form of the coupling of FIGURE 1,

FIGURE 11 is a cross-sectional view taken on the plane indicated by the line 11-11 of FIGURE 1, and

FIGURE 12 is a perspective partial view of the coupling of FIGURES 10 and 11.

Referring now to the drawings and more particularly to FIGURE 1, there is shown therein a number of compressor rotor blades 10 each brazed at 12 to a platform 14 having two radially projecting tangs or leg portions 16 adapted to straddle the rim of a rotor wheel 18, the platform having a small radial clearance from the rim at 20. Both the blade tangs 16 and the wheel rim 18 are provided with suitable holes or apertures 22 and 24, respectively, for the insertion of a suitable connecting means, which in this case is a split pin 26.

The design of pinned blades for highly loaded rotating members involves several problems. One concerns contact stresses while another concerns the angle at which the forces are applied.

In a conventional pinned blade connection, if the difference between the pin and rotor hole diameters is large, i.e., the pin diameter is small, the contact stress will be quite high since the contact stress varies as a function of the differences in diameters divided by the product of the two. However, the contact angle at which the forces are applied is favorable in this case since tilting of the blade and therefore the small diametered pin about the relatively large rotor hole causes only a small planetation of the pin about the rotor drum hole. If the differential in the diameters of the pin and rotor hole is decreased to decrease the contact stress, then upon tilting of the blade, unfavorable angles are obtained at which the forces are supplied resulting in sliding of the pin instead of rolling. Therefore, to maintain the contact stress low without encountering unfavorable contact angles and therefore sliding, the rolling surfaces of the pin and hole must have radii of large circles and the radii must differ by only a small amount.

This controlled radii construction also solves an objectionable vibrational problem. The frequency of vibration of the blades varies as a function of the r.p.m. of the engine and the radial distance between the mass center of gravity of the blades and the focal or pivot point of the C.G. about the rotor hole. In a conventional pinned blade connection, with a small diametered

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pin having a relatively fixed focal point, there is practically no control over the location of the focal point and the radial distance to the C.G., as a result, it often occurs that the blades are tuned to an exciting engine order of vibration.

However, the controlled radii feature of this invention eliminates this problem by controlling the focal or pivot about which the C.G. rotates, thus controlling the frequency of vibration since, as stated above, the frequency varies as a function of the radial distance between the focal point and the C.G. By a proper selection of the large radii and therefore the curvature of the abutting surfaces, which roll upon each other, the frequency of vibration can be controlled so that it is maintained within an unobjectionable range at normal engine running speeds.

Such a design is illustrated in FIGURES 1 through 11 forming the subject of this invention wherein the pin 26 is a two-piece split pin, the abutting surfaces or faces of each piece having radii of very large circles and the two radii differing by only a small amount. A numerical illustration will help serve to clarify the values of these large radii. For example, where a hole diameter of only one-half inch is permitted in the blade, it is possible to design rolling radii of very high values, say 10 to 20 inches, with the rolling radii differing by only .05 inch. This large radius reduces greatly the contact stress and is quite important to providing long life to such non-lubricated members.

As seen in FIGURES 2 and 3 illustrating one form of the coupling, the pin 26 comprises two substantially semi-circular sections 28 and 30 facing each other and having abutting concave and convex surfaces 32 and 34, respectively. Surfaces 32 and 34 are each a segment of a cylinder of large radius, i.e., a radius that is large with respect to the radius of the holes in the tangs 16 and rotor 18. The controlled difference in radii of the two abutting surfaces 32 and 34 is small to permit the limited rolling action of the sections 28 and 30 upon each other as already described.

Referring now more in detail to FIGURES 2 to 12, the manner in which the split pin sections are connected to the wheel rim, the blade tangs and to each other so as to connect the wheel and blades for a rolling action while preventing axial movement of the pin and rotation of the pin portions in the blade or rim to which they are connected will now be described.

In these FIGURES 2 to 12, corresponding elements will be identified by corresponding numbers, however, with the addition of one or more primes to indicate different modifications.

In FIGURES 2 and 3, the split pin section 28 is provided intermediate of its ends with a rounded ridge or key portion 42 adapted to engage in a mating slot or keyway 44 machined in the wheel rim 18 to prevent relative rotation of the two. Pin section 30 is provided with a machined portion or groove 46 cooperating with a similar machined portion 48 in the blade tangs 16 for receiving a locking pin 50 locking section 30 against rotation in the blade tangs 16. To prevent axial movement of the pin sections with respect to the tangs 16 and wheel rim 18, two holes 52 and 54 are drilled in each end of both sections 28 and 30 of the pin 26 for the insertion therein of locking pins 56 and 58, the locking pins having portions 59 overlapping and bearing against the blade tangs 16. Since a rolling action is desired between sections 28 and 30, these sections must move independently of each other. Therefore, a clearance 60 is provided between the retaining pin 56 and section 28, with a clearance 62 provided between the retaining pin 58 and section 28. The retaining pins 56 and 58 are press fitted within section 30 and loosely fitted into section 28. Clearances 64 and 66 are also provided between the wheel rim 18 and section 30, and tangs 16 and section 28, respectively.

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As will thus be seen, the split pin connects both the wheel rim and the tangs with a secure coupling, while permitting rolling movement of the blade tangs with respect to the wheel rim. At the same time, the split pin sections are coupled to each other and are prevented from moving axially of the blade tangs.

Referring now to FIGURES 4 and 5, there is shown therein a modification of the split pin mounting means shown in FIGURES 2 and 3 wherein the ridge 42 of section 28 in FIGURE 3 is replaced by a retaining pin 68 identical to the retaining pin 50. Section 28' is machined at 70 to receive half of the retaining pin 68, the other half being received within the machined wheel rim portion 72. In this modification, the end portions 74 and 76 of both sections of the pin 25' are provided with grooves 80 and 82 for contracting split rings 84 and 86 for preventing axial movement of the pin sections 28' and 30' and the pins 68 and 50'.

FIGURES 6 and 7 show a third form of the coupling of FIGURE 1. In these figures, it will be seen that section 28'' with its ridge 42'' engaging the wheel rim 18'' remain the same as in FIGURES 2 and 3, while the section 30'' is changed. Section 30'' has one end 88 larger in diameter than the diameter of the hole 22'' provided in the blade tangs 16'', one portion 90 of the end 88 overlapping section 28'' with the other portion 92 overlapping and abutting the blade tang 16''. The other end 94 of section 30'' has a diameter smaller than the diameter of the hole 22'' but of a diameter large enough to overlap section 28'' at 96. To secure the pin sections 28'' and 30'' from axial movement, a bore 98 is machined in section 30'' for the insertion of a suitable retaining pin 100 which upon insertion has an end portion 102 abutting against tang 16'' and the pin 50'', thereby securely positioning the split pin 26''.

Referring now to FIGURES 8 and 9, the split pin sections 28''' and 30''' are shown as having the same abutting arcuate surfaces 32''' and 34''', while the means for preventing axial movement of the pin is modified from that of FIGURES 2 and 3. In these figures, the pin 50 of FIGURES 2 and 3 is replaced by two ridges 104 formed on the pin section 30''' and mating with similarly formed slots or keyways 106 in the blade tangs 16'''. Also, section 30''', as seen in FIGURE 9, has formed on each end threaded projections 108 adapted to receive locking tab washers 110 and nuts 112 thereon. The tab 114 of the washer 110 is bent into a slot 116 machined in the section 30''', with the other portions 118 bent over the nut 112 to prevent rotation of the same.

Still another form of coupling similar to that of FIGURES 2 and 3 is shown in FIGURES 10 and 12, wherein the ridge or keyway 42'''' is retained, but the axial pin 50 of FIGURE 3 is eliminated. Instead, suitable hollow annular bosses 120 are provided on the outside of each of the tangs 16'''' for securing the tangs, wheel rim 18''', and sections 28'''' and 30'''' together. The bosses 120 are slotted at 122 and 124 for reception of a slideable key 126 therein. Furthermore, both pin sections 28'''' and 30'''' are extended at their ends 128 and 129, respectively, and provided therein with recessed or slotted portions 130 and 131 for slideably receiving the mating portions 132 and 133 of the key 126. A suitable clearance is provided between the recessed portion 131 and the mating portion of the key to permit the rolling action. The bosses 120 are annularly recessed or grooved at 134 to receive expanding split ring members 136 having extended lower portions 138 with axial projections 140 overlying the bottom portion 142 of the keys 126 to prevent radial movement of the same when assembled.

The operation of the several forms of coupling will be clear from the figures described, and therefore only a brief resume will be given. In all of the modifications shown in FIGURES 2 to 11, the blade tangs 16 are telescoped over the rotor wheel rim 18 and the split pin 26 is inserted through the appropriate apertures in the tangs

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and wheel rim. Depending on the particular modifications, the keys, bolts, split rings, or nuts are then positioned for connecting the two sections 28 and 30 together and to the tang portions 16 and wheel rim 18. Because of the abutting faces 32 and 34 differing in radii by a controlled amount, and because the split pin 26 is of a diameter only slightly less than the diameter of the apertures in the tangs and wheel rim, a relatively tight rolling fit is provided between the pin and tangs and wheel rim.

Therefore, upon firing of the engine, the gas bending force exerted upon the blades 10 will cause the blades and tangs 16 to tilt about the rotor section by sections 28 and 30 rolling on one another until the gas bending moment is balanced by the moment created by the centrifugal force acting on the blades, the roll pins and ridge and keyway connections between the tangs, wheel rim and sections permitting such tilting action. Thus, the stresses on the blades are balanced with respect to each other, sliding of the pin with respect to the holes is prevented and no end restraint is placed on the blade. At the same time, with the several forms of coupling shown in FIGURES 2 to 11, the split pin is axially located and a secure coupling is effected.

From the foregoing it will be seen that this invention provides a split pin blade mounting means that is very effective in reducing the stresses on the rotor blades and eliminating the objectionable vibrational frequencies at running speeds of the engine, thereby reducing the fatigue and increasing the service record. It will also be seen that this invention provides a mounting wherein a rolling action is permitted, while sliding, which produces wear and end restraint, is eliminated. It will be understood that the invention can be modified beyond the illustrated embodiments, and therefore, any limitations to be imposed are those set forth in the following claims.

We claim:

1. A gas turbomachine comprising a plurality of rotatable blade members, a rotatable wheel disk, said members and disk having apertures therein, and means connecting each of said members and said wheel disk, said means comprising a pin longitudinally split into a plurality of arcuate sections having abutting faces and insertable through said apertures, said faces constituting arcs of different diameter circles, the radii of said arcs being controlled with respect to each other to differ by a controlled minute amount, said abutting faces being free to roll on each other, said sections being positioned with one radially outwardly of the other, means connecting one of said sections to said blade member and another of said sections to said disk, said blade members being subjected to a force in one direction by the gas passing through said engine, said blade members being subjected to centrifugal force in another direction upon rotation of said wheel disk, the rolling action of said faces balancing the action of said forces to reduce wear between said pin, disk and said members.

2. A turbomachine comprising a rotatable disk, a rotatable blade member, and means connecting said blade member and said disk, said blade member and said disk having apertures therein, said connecting means comprising pin means longitudinally split into a plurality of sections and insertable through said apertures, each of said sections being arcuate and adapted to roll on each other, means connecting one of said sections to said disk and another of said sections to said blade member, said arcuate sections being positioned one radially outwardly of the other permitting rolling action of said blade member with respect to said disk, and means preventing axial movement of said sections with respect to the axis of said wheel.

3. A turbomachine as in claim 2, wherein said means for preventing axial movement of said sections comprises a plurality of locking pins each engaging said sections and a portion of said blade member.

4. A turbomachine as in claim 2, wherein said means

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to prevent axial movement of said pin means comprises split rings each engaging said sections and a portion of said blade member, said split rings being positioned on opposite ends of said pin means.

5. A turbomachine as in claim 2, wherein said means preventing axial movement of said pin means includes means formed on one of said sections adapted to overlap another of said sections and a portion of said blade member at one end of said pin means, and means connected to said one section and abutting another portion of said blade member at the opposite end of said pin means.

6. A turbomachine as in claim 2, wherein said means for preventing axial movement of said pin means includes one of said sections having formed thereon projections extending axially thereof at opposite ends of said pin means, and adjustable fastening means for connecting with said projections, said fastening means overlapping said sections and a portion of said blade member at each end of said pin means.

7. A turbomachine as in claim 2, wherein said means for preventing axial movement of said pin means includes bosses projecting from portions of said blade members, said bosses being provided with slots therein, key members slideable in said slots, and split rings engageable with said bosses and said key members.

8. A gas turbomachine comprising a plurality of rotatable blade members subject to vibration upon operation of said turbomachine, a rotatable disk, and movable pin means connecting said disk and said blade members, said blade members being subjected to the force of the gases passing through said gas turbomachine, said blade members being also subjected to centrifugal force upon rotation of said disk, said pin means connecting said blade members and said disk for a relative rotational movement therebetween establishing a balance between said forces, said pin means being longitudinally split and comprising a plurality of elements including a first element and having an arcuate surface thereon and being connected to said disk, a second element connected to said blade members and having an arcuate surface thereon abutting the arcuate surface of said first element, the radii of curvature of said arcuate surfaces being greater than the radius of said pin means and being controlled with respect to each other to differ by a controlled minute amount, the action of said forces effecting rotation of said blade members relative to said disk rolling said second element upon said first element, the control of said radii preventing a sliding relative movement between said surfaces and controlling the frequency of vibration of said blade members.

9. A gas turbomachine comprising a rotatable disk, a plurality of rotatable blade members subject to vibration upon operation of said turbomachine, and pin means connecting said disk and said members, said disk and blade members being provided with apertures therein, said pin means being insertable through said apertures for providing a movable connection between said blade members and said disk, said blade members being subjected to the force of the gases passing through said gas turbomachine, said blade members being also subjected to centrifugal force upon rotation of said disk, said pin means having a movement establishing a balance between said forces, said pin means being longitudinally split and comprising a plurality of arcuate sections having abutting faces, said faces constituting arcs of different diameter circles, said abutting faces being free to roll on each other, means connecting one of said sections to said blade members, means connecting another of said sections to said disk, the radii of said arcs being controlled with respect to each other to differ by a controlled minute amount, the radii of said arcs being greater than the radii of said apertures, the action of said forces effecting rotation of said blade members relative to said disk rolling one of said arcuate sections upon another of said arcuate sec-

tions, the controlled difference in radii of said arcs preventing a sliding movement between said sections and controlling the frequency of vibrations of said blade members.

10. A gas turbomachine comprising a plurality of rotatable blade members, a rotatable disk, said members and disk having apertures therein, and movable longitudinally split pin means insertable through said apertures for connecting said disk and said blade members, said blade members being subjected to the force of the gases passing through said gas turbomachine, said blade members being also subjected to centrifugal force upon rotation of said disk, said split pin means having a movement establishing a balance between said forces, said split pin means including a plurality of arcuate sections having abutting face portions, the abutting face portions of one of said sections being an arc of a circle having a diameter substantially greater than the diameter of the circle defining said arcuate sections.

11. A rotatable bladed device comprising a rotor, a blade member, said rotor and member having apertures therein adapted to be aligned with each other, and movable pin means insertable through said apertures upon alignment thereof for connecting said member and rotor together for a relative pivotal movement therebetween, said pin means comprising a pin split longitudinally into a plurality of substantially semi-cylindrical segments abutting and facing each other forming a pin as a whole, the facing portions of said segments each constituting an arc of a circle the radius of which is substantially greater than the radius of curvature of any of said segments, the radii of said arcs differing by an amount minute in comparison to either of the radii of said arcs, said one and another segments being positioned one radially outwardly of the other with respect to the axis of rotation of said rotor so the said facing portions are rollable upon one another upon relative pivotal movement of said blade member with respect to said rotor.

12. A rotor assembly comprising a rotatable wheel, a blade member, and connecting means pivotally connecting said wheel and said blade member, said blade member and said wheel each being provided with a suitable arcuate aperture therein, said connecting means comprising longitudinally extending means longitudinally split into a plurality of abutting portions having their abutting surfaces rollable on each other, said portions together being insertable through the blade member and wheel apertures, and means connecting one of said portions to said blade member and a second of said portions to said wheel, the abutting surfaces of said portions each constituting the arc of a circle having a radius substantially larger than the radius of each of the apertures into which the portions are insertable to effect the rolling of said portion surfaces on each other about their longitudinal axes upon relative pivotal movement of said blade member and wheel.

13. A rotor assembly comprising a rotatable wheel, a blade member, and connecting means pivotally connecting said wheel and said blade member, said blade member and said wheel each being provided with a suitable arcuate aperture therein, said connecting means comprising longitudinally extending pin means longitudinally split into a plurality of abutting portions together insertable through the blade member and wheel apertures and having their abutting surfaces rollable upon each other, and means connecting one of said portions to said blade member and a second of said portions to said wheel, one of said surfaces being flat and the other surface constituting the arc of a large circle having a radius substantially larger than the radius of each of the said apertures into which the portions are insertable to effect rolling of said surfaces upon each other about their longitudinal axes upon relative pivotal movement of said blade member and wheel.

14. A rotor assembly comprising a rotatable wheel, a

blade member, and connecting means pivotally connecting said wheel and said blade member, said blade member and said wheel each being provided with a suitable aperture therein, said connecting means comprising longitudinally extending means longitudinally split into a plurality of portions of substantially similar size together insertable through said blade member and wheel apertures, said portions having abutting arcuate surfaces rollable upon each other, means connecting one of said portions to said blade member and another of said portions to said wheel, said one and another surfaces each having a radius controlled with respect to the radius of the other to differ therefrom by a controlled minute amount effecting rolling of said surfaces upon each other about their longitudinal axes upon relative pivotal movement of said blade member and wheel.

15. A rotor assembly comprising a rotatable wheel, a blade member, and connecting means pivotally connecting said wheel and said blade member, said blade member and said wheel each being provided with a suitable arcuate aperture therein, said connecting means comprising longitudinally extending means longitudinally split into a plurality of portions together insertable through said blade member and wheel apertures, said portions having abutting arcuate surfaces rollable upon each other, means connecting one of said portions to said blade member and a second of said portions to said wheel, said surfaces each having a radius controlled with respect to the radius of the other to differ therefrom by a controlled minute amount effecting rolling of said surfaces upon each other about their longitudinal axes upon relative pivotal movement of said blade member and wheel, the radius of each of said surfaces being substantially greater than the radius of each of the apertures into which the portions are insertable.

16. A rotor assembly comprising a rotatable wheel, a blade member, and connecting means pivotally connecting said wheel and said blade member, said blade member and said wheel each being provided with a suitable arcuate aperture therein, said connecting means comprising longitudinally extending pin means longitudinally split into a plurality of portions together insertable through said blade member and wheel apertures, said portions having abutting arcuate surfaces rollable upon each other, means connecting one of said portions to said blade member and a second of said portions to said wheel, said surfaces each having a radius controlled with respect to the radius of the other to differ therefrom by a controlled minute amount effecting rolling of said surfaces upon each other about their longitudinal axes upon relative pivotal movement of said blade member and wheel, the radius of each of said surfaces being substantially greater than the diameter of each of the blade member and wheel apertures into which the portions are insertable.

17. A rotor assembly comprising a rotatable wheel, a blade member and connecting means pivotally connecting said wheel and said blade member, said blade member and said wheel each being provided with a suitable aperture therein, said connecting means comprising longitudinally extending pin means longitudinally split into a plurality of substantially semi-cylindrical portions facing each other and together insertable through said blade member and wheel apertures, said portions having their facing surfaces abutting and rollable upon each other, and means connecting one of said portions to said blade member and a second of said portions to said wheel.

18. A pivotal assembly comprising a plurality of members pivotally connected to each other at adjacent portions, each of said members having an arcuate opening therein adapted to be aligned with the other openings upon assembly of said members, the pivotal connection of said members including a pin insertable through all of said member openings when aligned and fixedly secured to some of said members while slidably and rotatably engag-

ing the remaining of said members, the circumferential curvature of said pin and each of the member arcuate openings being similar and defined by a plurality of joined arcs of different diameter circles, the radius of the arc of one portion of each of said openings and said pin being substantially greater than the radius of each of the remaining of said plurality of arcs, the one pin portion and member opening portions abutting each other, the radius of the one pin portion arc differing from the radius of the arc of the portion of each of the remaining members which it abuts by a controlled minute amount to effect rolling of said pin and remaining members portions

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upon each other upon relative pivotal movement of said members.

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