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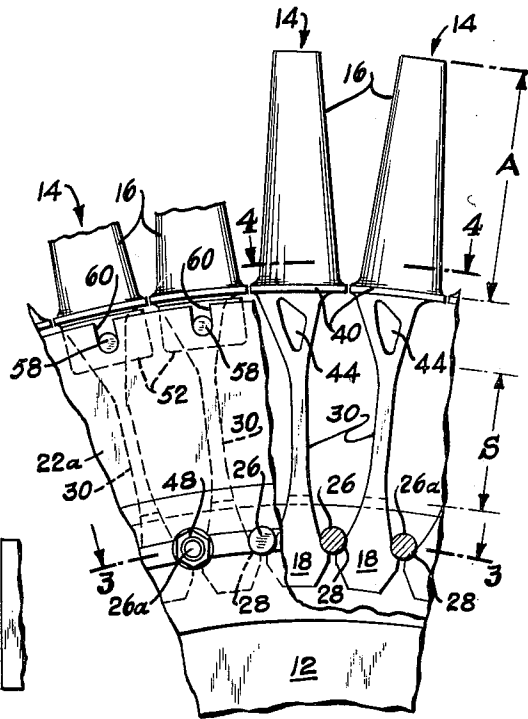
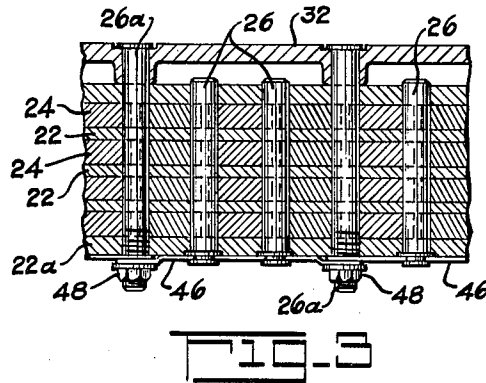
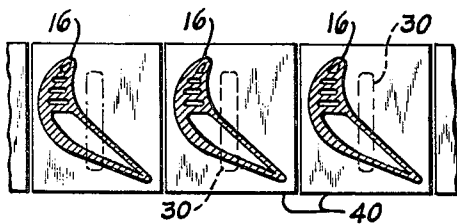
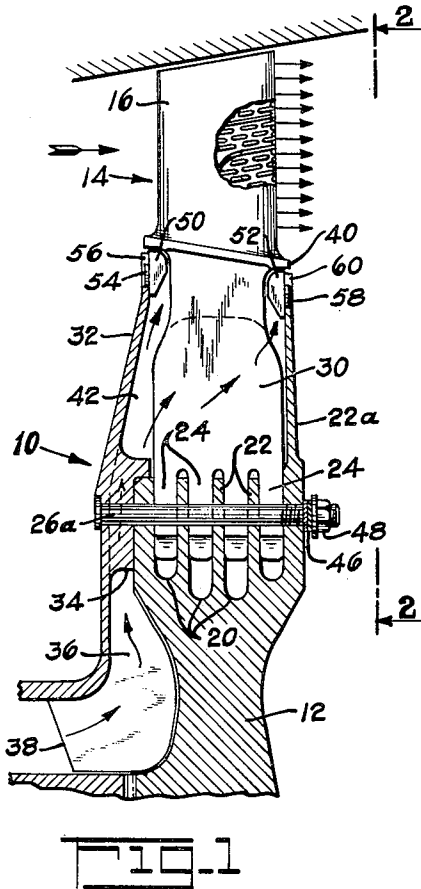
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2,999,668

SELF-BALANCED ROTOR BLADE

Filed Aug. 28, 1958

2 Sheets-Sheet 1



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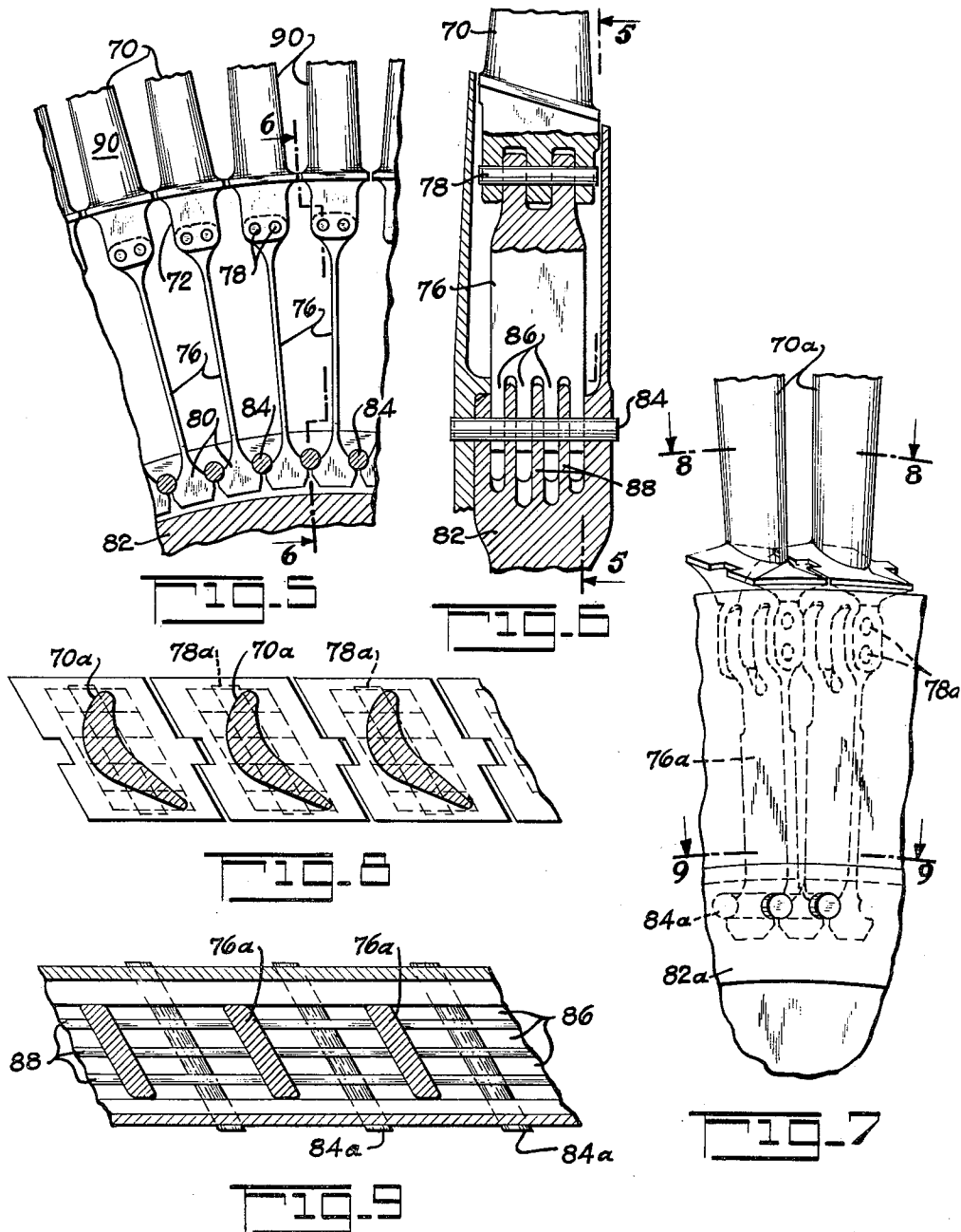
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SELF-BALANCED ROTOR BLADE

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2 Sheets-Sheet 2



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1

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SELF-BALANCED ROTOR BLADE

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11 Claims. (Cl. 253—39.15)

This invention relates to rotor blades for compressors, turbines and like apparatus and is particularly directed to the supporting structure for such blades.

An object of the present invention comprises the provision of a novel and simple arrangement for attaching rotor blades to their supporting rotor discs such that a reduction in weight and stress concentration is effected over prior rotor blade attaching means.

A further object of the invention comprises the provision of a flexible shank between the blade airfoil portion and its root end so that the blade can deflect under the gas loads acting thereon. This construction minimizes bending stresses which would otherwise be imposed on the airfoil portion of the blade. This feature is particularly important in the case of turbine blades because of the high gas temperature to which such blades are subjected.

Other objects of the invention will become apparent upon reading the annexed detailed description along with the drawing in which:

FIG. 1 is an axial sectional view thru a bladed turbine rotor embodying the invention;

FIG. 2 is an end view taken along line 2—2 of FIG. 1 but partly broken away to more clearly show the blade shank structure.

FIGS. 3 and 4 are sectional views taken along lines 3—3 and 4—4 of FIG. 2;

FIG. 5 is a view similar to FIG. 2 but illustrating a modified construction, FIG. 5 being taken along line 5—5 of FIG. 6;

FIG. 6 is a sectional view taken along line 6—6 of FIG. 5;

FIG. 7 is a view similar to FIG. 5 but illustrating a further modified construction; and

FIGS. 8 and 9 are views taken along lines 8—8 and 9—9 respectively, of FIG. 7.

Referring first to FIGS. 1—4 of the drawing, reference numeral 10 designates an axial-flow turbine rotor, for example for a gas turbine engine.

The rotor 10 includes a rotor disc 12 and a plurality of circumferentially-spaced blades 14 are secured to the rotor disc at its periphery. Each rotor blade includes an airfoil section 16 extending radially outwardly from the rotor disc and a root end 18 for securing said blade to the rotor disc.

For the purpose of securing the rotor blades to the rotor disc, said disc has a plurality of annular grooves 20 about its periphery leaving a plurality of annular radially-outwardly extending ribs 22. Also the root end 18 of each rotor blade is slotted so as to form fingers or tangs 24 arranged to be received between the rotor disc ribs 18.

The rotor blades 14 are attached or anchored to the rotor disc 12 by a plurality of circumferentially-spaced pins 26, there being one pin 26 disposed between each pair of blades. Each pin 26 is disposed generally parallel to the axis of its rotor and extends across and thru the rotor disc ribs 22.

Each slotted blade root end 18 has an approximately quarter round groove 28 on each side of and extending axially across its fingers 24 for engagement with the adjacent pin 26. As illustrated the surface portion of each pin 26 engaged by a blade root-end groove 28 subtends an angle slightly less than 90° about the pin axis on the ad-

2

jacent half of the radially inner side of said pin such that the total surface portion of a pin 26 engaged by the grooves 28 of the two blade root ends between which said pin is disposed subtends an angle slightly less than 180° about the pin axis on the radially inner side of said pin. Obviously, however, the portion of each pin 26 engaged by a blade root end groove 28 could be substantially different from 90°. For ease of fabrication the pins 26 preferably have a circular cross-section, as illustrated.

With this construction each blade 14 is secured to the rotor disc 12 by the two pins 26, one on each side of said blade. Also each pin 26 serves as one of the pins securing each of the two adjacent blades. The pins 26 secure the rotor blades 14 in position by supporting said blades against radially outward movement in response to the centrifugal forces acting thereon during rotor rotation.

This mode of blade attachment results in a material savings in weight of the rotor as compared to prior modes of blade attachment. Also this mode of blade attachment permits more blades to be attached to a rotor periphery per unit circumferential length of said periphery. As a result, the shanks of the blades can be made elongate to bring the point of blade attachment well radially inwardly of the blade airfoil section notwithstanding the smaller rotor circumferential periphery at this smaller radius. Hence, the aforedescribed mode of blade attachment facilitates providing each blade with an elongate flexible shank. For this purpose each rotor blade 14 preferably includes a shank having an elongate flexible shank section 30 between its root end 18 and airfoil section 16. Each blade shank flexible section is of generally rectangular cross-section with the long dimension of said cross-section being parallel to the rotor axis as shown in FIG. 4 and with said rectangular cross-section being relatively thin in a circumferential direction. With each rotor blade having this elongate flexible shank the gas loads on each blade will serve, by bending of its shank, to deflect the blade to a position in which the centrifugal force acting on the blade and the bending stresses in the blade shank balance said gas loads. This construction thereby minimizes the bending stresses which would otherwise exist in the airfoil section of each blade.

As used herein a blade having an elongate flexible shank is one in which the flexible section 30 of the blade shank has a length S which is at least equal to one-third the length A of the blade airfoil section.

The turbine rotor disc 12 also has an annular shroud member 32 secured to its upstream side. For this purpose certain of the pins 26 are made longer and also function to secure the member shroud 28 to the rotor disc 12, these long pins being designated by reference numeral 26a and actually are clamping bolts. The shroud member 32 has a plurality of circumferentially-spaced bosses 34 to provide a space 36 between said shroud member 32 and the rotor disc proper for supplying cooling air radially outwardly therethru. The shroud member 32 may have a plurality of circumferentially-spaced vanes 38 extending across the space 36 to help provide some pumping action to produce radially-outwardly flow of said cooling air thru the space 36 between the rotor disc 12 and its shroud member 32. In the case of a gas turbine engine this cooling air may be bled off from the engine compressor for example as disclosed in copending application Serial No. 557,051, filed January 3, 1956, now Patent No. 2,951,340.

The annular shroud member 32 extends radially outwardly to the blade shelves 40. Likewise, of the rotor ribs 22, the rib (designated 22a) on the side of the rotor member remote from its shroud member 32 also extends radially outwardly to said blade shelves 40. With this arrangement the annular shroud 32 and rotor disc rib 22a form an annular space 42 within which the blade

shanks 30 extend whereby said blade shanks are supplied with cooling air by the vanes 38. Also the blade airfoil sections 16 may be hollow for cooling air flow therethru. For this purpose openings 44 may be provided in each blade shank directly under the blade shelf 40 and at both the upstream and downstream sides of the blade for air flow therein. The interior of each hollow airfoil section may be similar to that disclosed in copending application Serial No. 623,943, filed November 23, 1956. Thus the cooling air supplied by the vanes 38 flows out around the blade shanks 30 and out thru the hollow airfoil section 16 of the blades.

As previously described, the bending stresses resulting from the gas loads on the rotor blades 16 are produced in the flexible blade shanks rather than in the airfoil section of the blades which are exposed to the hot turbine gases. Furthermore, the blade shanks are air cooled, as described, by the cooling air flow around said shanks and therefore the operating temperature of the blade shanks is much lower than that of the blade airfoil sections. Accordingly, the blade shanks are better able to withstand said bending stresses than the hotter airfoil sections.

As best seen in FIG. 3, locking plates 46 are held in position by the nuts 48 for the pin bolts 26a. Each locking plate engages in an annular groove in adjacent pins 26 to hold said pins in position. As illustrated in FIG. 4 there are two pins 26 between adjacent bolts 26a so that each locking plate 46 engages two pins 26 to hold said pins in position. As will appear, however, any number of pins 26 may be provided between each pair of bolts 26a.

The structure described makes it possible to readily remove and replace blades 16 simply by providing access to the downstream side of the rotor 12. Thus by removing only the nuts 48 of two adjacent bolts 26a, the locking plate 46 held by said nuts with its two pins 26 can be removed whereupon any or all of the three blades 14 between said bolts 26a can readily be removed radially from the rotor periphery. Likewise the blades 14 can be readily replaced by reversing this procedure. No removal of the bolts 26a is necessary to permit removal or replacement of any of the blades 14.

It should be noted that if only one pin 26 is provided between each pair of bolts 26a then the circumferential clearance between the blade root ends 18 must be such as to provide for sufficient lateral displacement of an adjacent blade 14 upon removal of a pin 26 to permit removal of said blade.

Because each blade 14 has a flexible shank section 30, its amplitude of vibration may become excessive at a resonant condition. Particularly for this reason each blade is provided with a pair of weight members 50 and 52 frictionally engageable with the underside of the blade shelf 31. Each weight member 50 has a short cylindrical projection 54 which is received within a radial slot 56 at the radially outer portion of the shroud member 32, said projection maintaining the weight member 50 between and at the radially outer portion of said shroud member and the shank 30 of the associated blade. Similarly, each weight member 52 has a short cylindrical projection 58 which is received within a radial slot 60 at the radially outer periphery of the rotor disc rib 22a, said projection 58 maintaining the weight member 52 between and at the radially outer portion of the rib 22a and the shank 30 of the associated blade. Each weight member 50 and 52 is urged outwardly by the centrifugal force acting thereon during rotor rotation into frictional engagement with the underside of the associated blade itself. In this way vibrations of any blade relative to the rotor disc are frictionally damped by its associated weight members 50 and 52. Obviously, if desired a wear plate of suitable material may be secured to the underside of each blade shelf for frictional engagement with the weight members 50 and 52.

Because of the differences in stress and temperature of the airfoil section and shank section of each blade, it may be desirable to make said sections of each blade of different material. Such a modification is illustrated in FIGS. 5-6.

As illustrated in FIGS. 5-6, each blade 70 has a stub projection 72 on the underside of the blade shelf 74 and to which an elongate flexible shank 76 is attached by pins 78. The radially inner portion of each blade shank 76 terminates in a slotted root end 80 which is secured to the rotor disc 82 by pins 84 as in the structure of FIG. 1. Thus the fingers or tangs 86 formed by the slotted root end 80 of each blade 70 are received between annular ribs 88 around the periphery of the rotor disc 82. The pins 84 extend thru the rotor disc ribs 88 and engage grooves in the sides of the adjacent fingers 86 to hold the blades in place.

With this arrangement of FIGS. 5-6 the shank section 76 of each blade may be made of different material from that of its airfoil section 90. For example, each blade shank may be made of a suitable steel while each airfoil section is made of titanium or a titanium alloy. Except for the separate shank and airfoil section of each blade 70 the rotor structure of FIGS. 5-6 preferably is like that of FIGS. 1-4.

In FIGS. 1-4 the long dimension of the cross-section of each blade shank 30 is parallel to the rotor axis and the pins 26 are parallel to said axis. Likewise in FIGS. 5-6 this long dimension of the cross-section of each blade shank 76 is parallel to the rotor axis and the pins 78 and 84 are parallel to said axis. With this construction each rotor blade shank is flexible only as to circumferential vibrations of the blades. More complete flexibility of the blade can be achieved by making the long dimension of the cross-section of each blade shank substantially parallel to the chord of the blade airfoil section adjacent to the blade shelf. Such a construction is illustrated in FIGS. 7-9.

The modification of FIGS. 7-9 is generally similar to that of FIGS. 5-6 in that the shank of each blade can be made of different material from that of the blade airfoil section. For ease of understanding, the parts of FIGS. 7-9 corresponding to the parts of FIGS. 5-6 have been designated by the same reference numerals, but with a subscript *a* added thereto, as the reference numerals of said corresponding part.

As illustrated in FIGS. 7-9, the long dimension of the cross-section of each blade shank 76a is substantially parallel to the chord of the blade airfoil section adjacent to the blade itself. Likewise, the pins 78a connecting each blade shank section 76a to its airfoil section 86a and the pins 84a securing the blades to the rotor disc 82a are all parallel to said blade chord. The construction of FIGS. 7-9 is otherwise like that of FIGS. 5-6. Obviously, the construction of FIGS. 1-4 may be similarly modified.

The construction of FIGS. 7-9 has the advantage of providing the blade with flexibility in the direction of the gas loads on the blades instead of only in a circumferential direction as in FIGS. 1-6. However, fabrication of the structure of FIGS. 7-9 is obviously more difficult and because the blade shanks can now flex in a direction inclined to the axial direction the problem of providing an adequate seal between the shelves of adjacent blades is made more difficult.

The modifications of FIGS. 5-6 and FIGS. 7-9 do not show the air cooling feature and the blade vibration damping feature of FIGS. 1-4 for simplicity of illustration. Obviously, however, these features may also be provided in FIGS. 5-6 and FIGS. 7-9. The air cooling feature probably would not be required by compressor blades because of their lower operating temperatures compared to that of turbine blades and the blade vibration damping feature probably would have less advantage in the case of relatively short blades.

5

While we have described our invention in detail in its present preferred embodiment, it will be obvious to those skilled in the art, after understanding our invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. We aim in the appended claims to cover all such modifications.

We claim as our invention:

1. A rotor for compressors, turbines or the like comprising a rotor member; a plurality of circumferentially-spaced blades extending radially outwardly from the periphery of said rotor member, each of said blades having a circumferentially-enlarged root end portion with the remaining portion of each blade extending radially outwardly from the radially-outer end of the blade root end portion; and a plurality of circumferentially-spaced pins disposed about the periphery of and extending through said rotor member between the root ends of said blades with each pin engaging a groove in the side of and at the radially outer end of each of the enlarged root ends of the two adjacent blades for supporting the blades against radially outward movement, each blade decreasing in circumferential width radially outwardly of its supporting pins such that the portion of the circumference of each pin surrounded by the root end grooves of the two adjacent blades is substantially less than 360° and a substantial portion of the radially outer side of each pin is free of contact with the two blades supported thereby.

2. A rotor structure as recited in claim 1 in which the portion of each said pin engaged by each of its said associated blade root end grooves subtends an angle of less than 90° about the pin axis and is disposed on the radially inner side of said pin.

3. A rotor structure as recited in claim 1 in which each blade includes an airfoil section and a flexible shank section interconnecting its said airfoil section and its said root end.

4. A rotor structure as recited in claim 3 and including passage means in the rotor for supplying a cooling medium to the flexible shank section of each blade for flow thereover.

5. A rotor structure as recited in claim 3 in which the airfoil section of each blade is made of different material from that of its flexible shank section.

6. A rotor structure as recited in claim 3 in which said rotor member has a plurality of weight members, one for each of said blades, each of said weight members being carried by said rotor member for frictional engagement with a portion of its associated blade, adjacent to the radially outer portion of the shank section of said blade, in response to centrifugal force acting on said weight member during rotor rotation for damping blade vibrations.

7. A rotor structure as recited in claim 1 in which said rotor member includes a plurality of annular elements and in which only certain of said pins comprise bolts clamping said elements together such that the remainder of said pins are removable to permit removal of any of said blades without removal of said bolts.

8. A rotor structure as recited in claim 1 in which the

6

shank section of each blade has a rectangular cross-section the long dimension of which is substantially parallel to the chord of the airfoil section of said blade adjacent to the blade shank.

9. A rotor structure as recited in claim 1 in which the shank section of each blade has a rectangular cross-section the long dimension of which and the supporting pins for said blade are all generally parallel to the chord of the airfoil section of said blade adjacent to the blade shank.

10. A rotor structure for compressors, turbines or the like comprising a rotor member; a plurality of circumferentially-spaced blades each including an airfoil section extending radially-outwardly from said rotor member, a root end section secured to said rotor member and a flexible shank section interconnecting its said airfoil and root end sections; and means for frictionally engaging each blade adjacent the junction of its shank and airfoil sections for damping blade vibrations, said frictional damping means including a plurality of weight members, one for each of said blades, each of said weight members being carried by said rotor member for frictional engagement with a portion of its associated blade in response to centrifugal force acting on said weight member during rotor rotation for damping blade vibrations.

11. A rotor structure for compressors, turbines or the like comprising a rotor member having a plurality of radially-outwardly extending annular ribs about its periphery; a plurality of circumferentially-spaced blades extending radially outwardly from the periphery of said rotor member, each of said blades having a circumferentially-enlarged slotted root end forming tangs interfitted between said rotor member ribs with the remaining portion of each blade extending radially outwardly from the radially-outer end of the blade root end portion; and a plurality of circumferentially-spaced pins extending through said ribs and between the root ends of said blades with each pin engaging a groove in the side of and at the radially-outer end of each of the enlarged root ends of the two adjacent blades for supporting the blades against radially outward movement, each blade decreasing in circumferential width radially outwardly of its supporting pins such that the portion of the circumference of each pin surrounded by the root end grooves of the two adjacent blades is less than 360° and a substantial portion of the radially outer side of each pin is free of contact with the two blades supported thereby.

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