Nov. 9, 1965 R. H. BOSTOCK, JR 3,216,700

ROTOR BLADE LOCKING MEANS

Filed Oct. 24, 1963

Fig 1

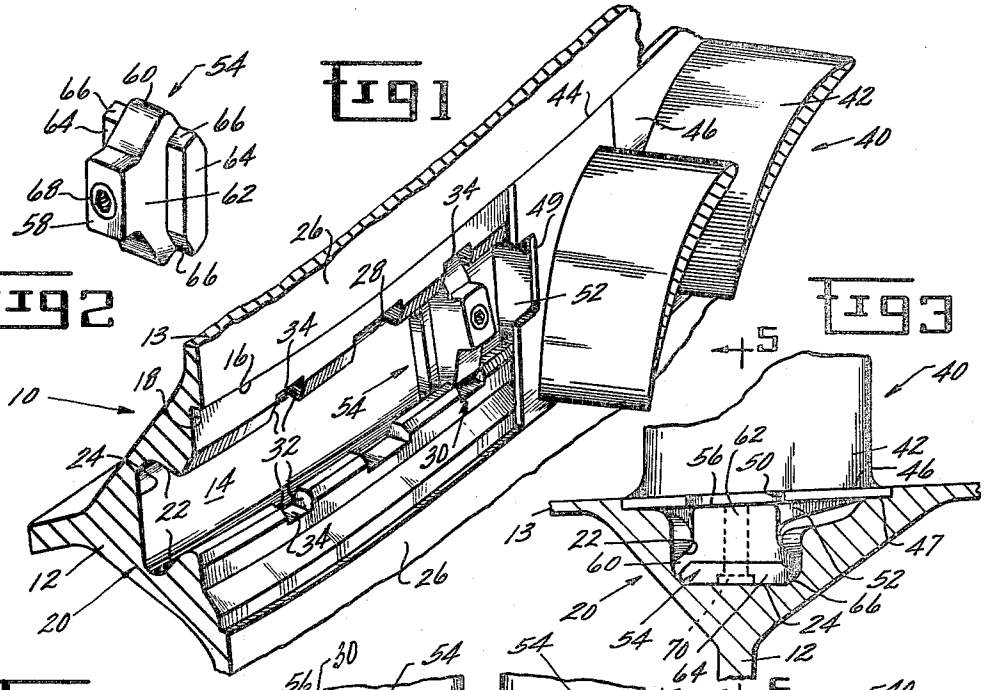


Fig 2



Fig 3



Fig 5

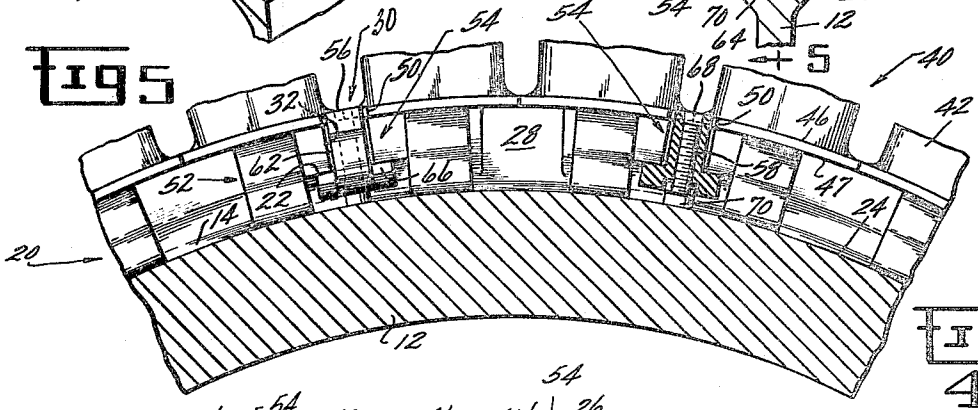


Fig 4

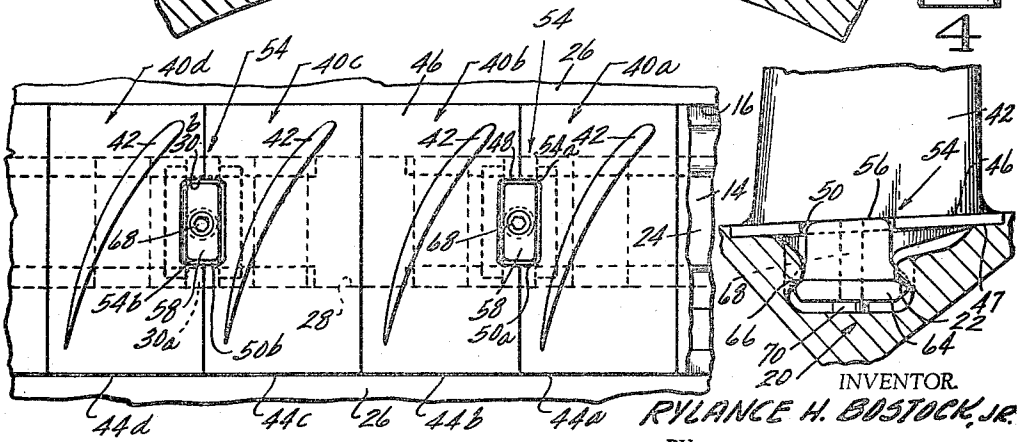


Fig 6

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# ROTOR BLADE LOCKING MEANS

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The present invention relates to bladed rotors for axial flow turbomachinery and the like and, more specifically, to a blade locking arrangement particularly suitable for use in relatively small, lightweight rotor assemblies utilizing thin-walled, relatively high-stressed rotor body or drum structures supporting airfoil members, such as rows of individual compressor or turbine blades disposed in circumferentially-extending slots or grooves in a rotor drum, wherein particular attention must be paid to the reduction or elimination of areas of stress concentration.

With increased usage of improved, lightweight, high-strength construction materials, such as titanium and other alloys having similar properties, in the construction of turbomachinery, e.g., aircraft gas turbine engine components, some design problems have arisen. For example, while it is advantageous to use lightweight, thin-walled relatively small diameter drum type rotor body structures having individual removable airfoil members in axial flow compressors, for example, avoidance of stress concentration points has become increasingly important. Heretofore, it has been possible to lock the airfoil members or blades in position by use of staking or screw means threadably engaged with the rotor drum and located in or adjacent to the circumferential groove or slot in which the blades are retained against the action of centrifugal force during rotor operation. The staking acts to prevent relative circumferential movement of the blades in the slot, as is more fully described in the patent to Lechthaler et al. 2,931,625, of common assignment. However, this solution gives rise to an associated stress concentration at the area of the hole in the lightweight, highly-stressed rim or outer diameter of the main rotor body or drum. In addition, with this arrangement the locking means or set screw engaged in the drum is placed in shear. Frequently, with modern high speed turbomachinery the shear stresses became too great for the screw or stake and the reliability of the blade locking system was substantially reduced. Other solutions to the stated problem have involved the use of a blade locking device wherein the means actuated to achieve locking, while not threadably engaged with the rotor drum, nevertheless imposes undesirable loads on portions of the individual blade members. Specifically, one known means for locking compressor blades, for example, involves the use of a locking block having an actuating member threadably engaged therewith for moving the block from an initial unlocked position outwardly to a final locked position in the groove wherein the locking blade loads the underside of a portion of the blade base. These blade base portions or platforms typically comprise, in cooperation with the outer surface of the drum, the inner part of the aerodynamic flow path in the turbomachine. With use of modern lightweight, highly-stressed materials, such as the aforementioned titanium and similar alloys, in the case of the relatively small turbomachines, in particular, the imposition of additional stresses on the blade platforms by such a locking arrangement cannot be tolerated. Furthermore, in relatively small turbomachines operated at extremely high rotational speeds, it is possible for the outer diameter or rim area of the main



rotor drum to deform slightly, but neverthless enough to allow partial movement of the blades in the circumferential retaining groove. Moreover, in such rotor configurations the bladed members are usually inserted through a so-called loading slot cut transversely of the groove, the complete blade row being rotated slightly before locking so that no one blade is opposite the slot. Therefore, it becomes important that the blades are not permitted to move even partially into the loading slot during rotor operation. Since it is also undesirable to rely solely on friction to lock these blades, some other solution than that disclosed in the prior known devices must be utilized.

In summary, therefore, in the case of lightweight, highly-stressed, thin-walled rotor structures it is particularly important to avoid undue stress concentrations and in the small diameter rotors having small blade root means or dovetails retained in similarly shaped grooves the blades must be blocked from the loading slot with a positive locking action without unduly loading the blades, i.e., the platforms. Further, it is desirable not to rely on friction to lock the blades while at the same time avoiding the increased stress concentration in the rotor drum associated with "staking" or threadably-engaged screw type locking actuation means, if such is employed.

It is, therefore, a general object of the present invention to devise a new and improved rotor blade locking means for a lightweight, highly-stressed, rotor assembly utilizing thin-walled elements.

A more specific object of the present invention is a new and improved rotor blade locking means for use in a drum-type rotor having a circumferential groove into which blade members may be individually inserted and removed, wherein the blade locking member is self-supporting and does not impose any undue additional loads on the blade members.

A further object of the present invention is to provide an improved rotor blade locking means whereby undue stress concentrations are avoided in the main rotor supporting structure comprised of a lightweight, initially highly-stressed alloy material.

A further more specific object of the present invention is to provide for use in a rotor assembly of the drum-type having circumferentially extending slots into which individual blade members are insertable and removable, a self-supporting locking device wherein stress concentrations are minimized both in the main rotor structure and the individual blade members and, particularly in the case of relatively small diameter rotor assemblies, blade member separation and rotor rim deformation is not detrimental to achieving a positive locking action.

Briefly in one embodiment, the invention comprises, in a thin-walled, highly-stressed, turbomachine rotor body member of the drum-type having at least one circumferentially-extending groove and a plurality of bladed members inserted therein through means of a transverse loading slot for retention in the groove against the action of centrifugal force, an improved locking means for the bladed members comprising at least one locking slot extending transversely of the groove and radially inward to the bottom wall thereof, and at least one locking device in the form of a lug including an upper portion having oppositely-directed side walls, a lower portion having spaced end wall load bearing surfaces, and a threaded hole therethrough. The locking lug is adapted to be inserted in the loading slot and moved to a position directly under, i.e., radially-inward of the locking slot. A pair of the bladed members have platform portions contain-

ing cutouts which, when the members are assembled in the groove and placed in abutting relationship, form an opening. With the opening thus formed positioned over the locking slot, the locking lug is moved radially outward by means of a screw threadably engaged with the hole to a position wherein the locking lug is loaded against the walls of the groove and the upper portion thereof extends out into the opening formed by the platform cutouts. The upper portion of the locking lug prevents circumferential movement of the bladed members in the groove without any additional stress imposed on the members since the locking lug is self-supported in the groove.

Other objects and advantages of the present invention will be more readily apparent as the same become better understood with reference to the following description and the appended claims, including the accompanying drawings all of which describe and show by way of illustration only and without limitation what is considered to be a preferred embodiment of the invention. The drawings consist of the following:

FIG. 1 is a pictorial view of a segment of a drum-type rotor body illustrating the circumferentially-extending bladed member groove, including the loading and locking slots, with a portion of the members of the row inserted therein together with a locking device;

FIG. 2 is a pictorial enlargement of the locking device or lug for use with the rotor assembly of FIG. 1;

FIG. 3 is a cross-sectional view of the rotor assembly with the locking lug in the initial position in the locking slot preparatory to initiation of the locking action;

FIG. 4 is a cross-sectional illustration of the components of FIG. 3 with locking lug in the final locking position;

FIG. 5 is a view taken along lines 5—5 of FIG. 3; and

FIG. 6 is a plan view of a segment of a completed rotor assembly with the bladed members in the locked position.

Referring now to the drawings and specifically FIG. 1, shown therein is a configuration useful in both steam and gas turbine machinery, although the illustration is more typical of a lightweight aircraft gas turbine engine. Indicated generally by numeral **10** is a segment of a main rotor type body of the drum type. The rotor body includes a number of enlarged peripheral or rim areas, one of which is indicated at **12**, spaced axially of the turbomachine rotor body and joined by a relatively thin-walled shell structure **13**. Each enlarged rim portion **12** of the rotor drum includes a groove, indicated generally at **14**, extending circumferentially of the drum in a plane perpendicular to the axis thereof. In this instance, the groove **14** includes an outer channel portion **16** having a bottom wall **18**. The bottom wall **18** of the groove **14** opens into a base portion, indicated generally at **20**, having a pair of divergent walls **22—22** that act as load surfaces and extending further inwardly into the enlarged rim area, and a bottom wall **24**. It will be obvious to those skilled in the art that the configuration of the bottom portion conforms to the so-called "dovetail" arrangement widely used for retaining complementary-shaped bladed members in rotors. The groove **14** thus appears in the outer surface **26** of the rotor drum as a two-step, circumferentially-extending opening. Circumferentially spaced about the groove **14** are three cutouts. In this embodiment, the first cutout comprises a loading slot, indicated at **28**, which extends radially inward and is intermediate and equally spaced from a pair of similar extending locking slots **30—30**. Each locking slot comprises a pair of circumferentially-spaced side walls **32—32** and axially-spaced end walls **34—34**.

In the case of either gas or steam turbines, airfoil members must also be provided to react against the motive fluid moving through the turbomachine to produce power. As shown in the drawings, the airfoil members or blades **40** typically include an airfoil or blade portion **42**, and the aforementioned platform portion **44**, having outer surface and inner surfaces **46** and **47**, respectively. With the platform portions located in the channel **16**, the outer surfaces **26** and **46** of the rotor drum and platforms, respectively, are at the same radial plane so as to cooperate in forming the inner wall of the aerodynamic flow-path through the turbomachine. As shown in the described embodiment, and perhaps best seen in FIGS. 1 and 6, the platforms of the blade members are in abutment when located in the groove with a pair of left and righthand cutouts **48** and **49**, respectively, provided in two adjacent pairs of platforms (platforms **44***a*–**44***b* and **44***c*–**44***d*, in FIG. 6) forming rectangular-shaped openings **50—50**. In the embodiment illustrated two of these openings are provided, i.e., the number of openings is the same as the number of locking slots **30—30**. In addition to the platform, each blade base also includes a root portion **52** which is a dovetail-shaped member adapted to be received in the groove **14** by being inserted through the loading slot **28**. The shape and size of the root or dovetail portion **52** of the blade is such that it will slide circumferentially in close abutment with the walls **22—22** of the similarly shaped base portion **20** of the groove **14**. Thus, as shown in FIG. 1, the blades **40** already assembled in the rotor have been loaded in the slot **28** and moved circumferentially to a position slightly beyond one of the locking slots **30**.

As depicted in more detail in FIG. 2, an improved locking member in the form of the lug, generally indicated at **54**, is provided. In this embodiment, the lug includes a projecting generally rectangular upper portion **56** having a threaded hole **58** therein which extends completely through hte locking lug, i.e., into and through an enlarged lower portion **60**. The upper and lower portions are bounded by a pair of continuous oppositely-disposed load bearing side surfaces or walls **62—62** to locate the lug against peripheral movement as will become apparent. Extending laterally from the lower portion **60** of the locking lug are a pair of ears **64—64** having oppositely-disposed, i.e., axially spaced, divergent pressure or load bearing end wall surfaces **66—66** of a generally complementary shaped dovetailed configuration. These surfaces provide for the lugs to be self-supporting in the locking slot. As depicted in the drawings, threadably engaged with the locking lug is an actuating member in the form of a jacking screw **68**. As best seen in FIG. 5, the jacking screw includes an enlarged base portion **70**.

Turning now to FIG. 3, the locking lug is there illustrated resting on the bottom wall **24** of the base portion **20** of the groove **14** preparatory to initiation of the locking action. FIG. 4 on the other hand, illustrates the position of the locking lug **54** when it has been moved radially outward in the groove by reaction of the jacking screw **68** on the bottom wall **24** of the groove. In the latter position, the side walls **62—62** of the lug bear against the side walls **32—32** of the locking slot in cooperating engagement therewith which prevents movement of the locking lug in the circumferential direction. Since the upper portion **56** of the lug projects upwardly into the rectangular hole **50** formed by the abutting cutouts **48** and **49**, as best seen in FIG. 6, it will be obvious that circumferential movement within the rotor groove **14** of the individual blades **40** is prevented. Further, and more importantly, with the improved arrangement of my invention when the locking lug **54** is in the position shown in FIGS. 4 and 5, the load surfaces **66—66** of the lugs are loaded against the divergent walls **22—22** of the base portion **20** in the groove **14** in substantial abutment therewith. Thus, contrary to the known locking arrangements, no outward loading on the blade platforms is required to lock the blades against the action of centrifugal force. This eliminates the stress concentrations normally imposed on the thin-walled platform members by the conventional blade locking devices.

For a more complete understanding of the invention, the steps required in assembling and locking of the rotor blades **40** in the drum member **10** will now be described. It will be understood that initially all but a few of the

blades of a row are inserted into the loading slot at **28** and rotated circumferentially about the axis of the rotor body **10** until the row is substantially complete. Turning now to FIG. 6, for illustrative purposes only the remaining blade or airfoil members to be inserted, and other components, will be referred to by letter designations, e.g., bladed members **40***a*–**40***b*–**40***c* and **40***d*. Thus, member **40***a* may first be inserted into the loading slot and moved to a position slightly to the right of a locking slot, i.e., slot **30***a*. A locking lug **54***a* is then inserted in the loading slot and moved to a position radially inward of the locking slot **30***a*. At this point, it should be understood that the locking lug is in the position shown in FIG. 3, wherein the upper portion **56** is *not* projecting above the level of the inner surface **47** of the platforms, i.e., into the rectangular hole **50**. Thus, there is no interference between the locking lug and the platform portion **44***a*. Next an airfoil member, which may be referred to by the numeral **40***d*, is inserted in the loading slot **28** and moved to the left—in the drawing—to a point slightly beyond the locking slot **30***b*. Next a locking lug **54***b* is inserted in the loading slot and moved to position radially inward of the locking slot **30***b*, i.e., the same position as occupied by the first mentioned locking lug **54***a*. Next airfoil member **40***c* (or **40***b*) is inserted and moved to the left (or to the right) until the platform portion is in abutment with the adjacent bladed member **40***a* (or **40***d*) to form the rectangular shaped hole **50**. At this point it will be obvious that it will be impossible to insert the final blade member in the loading slot unless the entire row of blades—and lugs—is shifted circumferentially in the groove either to the right or to the left depending on which airfoil member remains to be inserted. Thus, the entire row may be moved right to a position which will allow the final airfoil member, say member **40***c*, to be inserted in the loading slot. With all the blades in the groove **14**, the entire row is again shifted to line up the rectangular shaped holes **50***a* and **50***b* with the locking slots (lugs) **30***a* and **30***b*. Suitable means, such as an Allen wrench, is then engaged with the jacking screw actuating means **68** of each locking lug in turn and the lugs are moved radially outward in the locking slots to the position shown in FIGS. 4 and 5. With the enlarged portion **70** bearing against the bottom wall **24** of the base portion **20** of the groove and the load surfaces **66**—**66** of the lugs locked against the divergent walls **22**—**22** of the grooves, it will be clear that the locking lugs do not load the bladed members. Further, since the screw **68** is not threadably engaged in a hole in the rotor drum, as is the case with the above-described conventional "staked" arrangement, there is little if any shear stress imposed on the screw itself. In addition, stress concentration in the drum itself in the location of the hole drilled to receive the "stake" or screw is also avoided. This is particularly important when advanced lightweight, highly-stressed alloy materials are used to construct the drum body. With the close fit provided between the lug side walls **62**—**62** and the locking slot side walls **32**—**32**, the improved locking action as provided by my invention enables the tangential loads imposed on the blade platforms to be transmitted through the lugs to the drum without undue stress concentration. The described arrangement also eliminates or reduces substantially any high shear stresses which might be imposed on the jacking screw, thus increasing significantly the reliability of the locking action. Slight deformation of the hole threads is all that is required to lock the screw **68** from backing off. With the upper **56** of the lugs projecting into the rectangular shaped holes **50**—**50**, it will be obvious that the bladed members will not be permitted to move towards the loading slot or to partially enter it under large radial deformation of the rim. This is particularly important in the relatively small turbomachines wherein even a relatively small amount of deformation, due primarily to thermal expansion and centrifugal loads, could cause this to happen and thus increase the stresses imposed on the bladed members. With the above-described arrangement wherein two locking lugs are located close by and on either side of the loading slot, this cannot happen. It will also be clear that the locking devices are prevented from moving during rotor operation even though the adjacent bladed member platforms should separate slightly. Finally, friction alone is not relied upon to lock either the bladed members or the locking lugs in the groove.

Obviously many modifications and changes may be made to the illustrated embodiment without departing from the true scope and spirit of the invention as covered in the appended claims. It is therefore understood that the invention may be practiced other than as specifically described.

What I intend to claim and secure by Letters Patent is:

**1.** In a turbomachine rotor assembly including a flow-path surface having a circumferentially-extending channel therein, a divergent-walled groove in the innermost wall of said channel, and a plurality of airfoil members received in said groove, said members having abutting platform portions partially forming said flow-path surface and at least some of said platform portions having a cut-out therein, means restraining said airfoil members against movement within or separation from said groove comprising:

at least one locking slot having side walls extending partially transversely of the circumferentially-extending groove and radially-inward with respect to the rotor axis, substantially to the bottom of said groove, said locking slot having circumferentially-spaced load-bearing surfaces;

at least one locking lug, said lug including an upper portion having spaced side walls, a lower portion having spaced divergent end walls, and a threaded hole therethrough;

and jacking means threadably engaged in said hole, said jacking means being operable to cause the divergent end walls of said lug to forcibly engage the divergent walls of said groove for self-locking support of said lug, and the side walls of said lug to be in cooperating engagement with said locking slot side walls, with the upper portion of said lug being received in said cut-out in said abutting platform portions to prevent circumferential movement of said airfoil members in said grooves.

**2.** In a turbomachine:

a rotor body, said body having an outer surface, a circumferentially-extending channel in said outer surface, and a divergent-walled groove in the innermost wall of said channel;

a plurality of airfoil members, said members having root portions received in said groove for retention of said airfoil members against centrifugal force and platform portions having cut-outs therein and received in said channel and overlying said root portions in an abutting relationship to form a smooth flow-path in said turbomachine in cooperation with said outer surface;

and means for retaining said airfoil members in said groove including a transverse loading slot in said rotor body extending radially-inward, with respect to the rotor body axis, to the bottom of said divergent-walled groove, at least one transverse locking slot circumferentially-spaced from said loading slot and having side walls and extending radially inward to the bottom of said groove, said locking slot having circumferentially-spaced load-bearing surfaces, at least one locking lug, said lug including an upper portion having spaced side walls, a lower portion having spaced divergent end walls, and a threaded hole therethrough, and jacking means threadably engaged in said hole, said locking lug being receivable in said loading slot and movable circumferentially to

the vicinity of said locking slot, said jacking means being operable thereat to cause the end walls of said lug to be placed in substantial abutment with said circumferentially-spaced load-bearing surfaces and said lug side walls in cooperating engagement with said locking slot side walls with the upper portion of said lug being received in said cut-outs to prevent circumferential movement of said airfoil members in said groove and for self-locking support of said lug.

3. In a turbomachine rotor assembly including a flow-path surface having a circumferentially-extending channel therein, a divergent-walled groove in the innermost wall of said channel, and a plurality of airfoil members received in said groove, said groove having a loading slot extending substantially transversely thereof, said members having abutting platform portions having cut-outs therein and partially forming said flow-path surface, means restraining said airfoil members against movement within or separation from said groove comprising:

a pair of locking slots located equi-distant from the airfoil member loading slot and on either side thereof, said locking slots having side walls and extending partially transversely of the groove and radially inward, with respect to the rotor axis, substantially to the bottom of said groove, each of said locking slots having circumferentially-spaced load-bearing surfaces;

a pair of locking lugs, each of said lugs including an upper portion having spaced side walls, a lower portion having spaced divergent end wals, and a threaded hole therethrough;

and jacking means threadably engaged in each of said holes, said jacking means being operable to cause the divergent end walls of said lugs to forcibly engage the divergent walls of said groove, for self-locking support of said lugs and the side walls of said lugs in cooperating engagement with said locking slot side walls, with each of the upper portions of said lugs being received in said cut-outs in said abutting platform portions to prevent circumferential movement of said airfoil members in said groove.

4. In a turbomachine:

a rotor body, said body having an outer surface, a circumferentially-extending channel in said outer surface, and a divergent-walled groove in the innermost wall of said channel;

a plurality of air foil members, said members having root portions received in said groove for retention of said airfoil members against centrifugal force and platform portions having cut-outs therein and received in said channel and overlying said root portions in an abutting relationship to form a smooth flow-path in said turbomachine in cooperation with said outer surface;

and means for locking said members in said groove including, a loading slot in said rotor body extending transversely and radially-inward, with respect to the rotor body axis, to the bottom of said divergent-walled groove;

a pair of locking slots located qui-distant from the airfoil member loading slot and on either side thereof, said locking slots having side walls and extending partially transversely of the groove and radially inward, with respect to the rotor axis, substantially to the bottom of said groove, each of said locking slots having circumferentially-spaced load-bearing surfaces;

a pair of locking lugs, each of said lugs including an upper portion having spaced side walls, a lower portion having spaced divergent end walls, and a threaded hole therethrough;

and jacking means threadably engaged in each of said holes, each of said locking lugs being receivable in said loading slot movable circumferentially to the



vicinity of one of said locking slots, each of said jacking means being operable thereat to cause the end walls of the respective lugs to be placed in substantial abutment with the respective circumferentially-spaced load-bearing surfaces, and said lugs side walls in cooperating engagement with said locking slot side walls, with the upper portion of each of said lugs being received in said cut-outs in said abutting platform portions to prevent circumferential movement of said airfoil members in said groove and for self-locking support of said lugs.

5. In combination with a plurality of highly-stressed, thin-walled platform members received in a circumferential rotor divergent walled dovetail groove through a loading slot extending transversely thereof said platform members having cut-outs therein, means restraining said members against movement within or separation from said groove comprising:

at least one locking member, said member including a generally rectangular upper portion having oppositely-facing side walls, an enlarged lower portion formed by a continuation of said side walls, ears projecting laterally from each of said side walls adjacent the lower portion of said member, each of said ears having divergent end walls complementary-shaped with respect to the walls of said dovetail groove, and a threaded hole extending completely through said locking member;

and screw means threadably engaged in said hole including an enlarged bearing surface at one end thereof adapted to contact the innermost wall of said groove for reaction thereagainst, said locking member being received in said loading slot and movable in said groove, a locking slot having side walls and extending substantially transversely of said groove and having circumferentially-spaced load-bearing surfaces, said locking member being movable to a position immediately radially inward of said locking slot, said screw means being operable to cause said locking member divergent end walls to be placed in substantial abutment with said load-bearing surfaces and said lugs side walls in cooperating engagement with said locking slot side walls, said upper portion to project into said cut-outs in said platform members to prevent movement thereof in said groove and for self-locking support of said locking member.

6. In combination with a plurality of highly-stressed, thin-walled platform airfoil members received in a circumferential rotor divergent walled dovetail groove through a loading slot extending transversely thereof, said platform members having cut-outs therein, means restraining said members against movement within or separation from said groove comprising:

a pair of locking members, each of said members including a generally rectangular upper portion having oppositely-facing side walls, an enlarged lower portion formed by a continuation of said side walls, ears projecting laterally from each of said side walls adjacent the lower portion of said member, each of said ears having divergent end walls complementary-shaped with respect to the walls of said dovetail groove, and a threaded hole extending completely through said locking member;

a screw member threadably engaged in each of said locking member holes, said screw member including an enlarged bearing surface at the inner end thereof adapted to contact the innermost wall of said groove for reaction thereagainst;

a pair of locking slots located equi-distant from the airfoil member loading slot and on either side thereof, said locking slots having side walls and extending partially transversely of the groove and readilly inward thereof substantially to the bottom of said groove, each of said locking slots having a pair of circumferentially-spaced load-bearing surfaces, said

screw members being operable to locate said locking members in said locking slots with the divergent end walls in substantial abutment with the respective locking slot load-bearing surfaces and said locking member side walls in cooperative engagement with said locking slot side walls, the upper portions of said locking members projecting respectively, into said cut-outs to prevent movement of said platform members in said groove and for self-locking support of said locking members.



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