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Holzapfel et al.

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[54] **ROTOR FOR FLUID FLOW MACHINES**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.**.... **29/156.8 R;** 415/199 R; 416/198 A; 416/201

[51] **Int. Cl.** **B23p 15/00**

[58] **Field of Search** .... 29/156.8 R; 416/198 R, 416/198 A, 201, 219; 415/199 R

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Assistant Examiner—Dan C. Crane
Attorney, Agent, or Firm—Craig & Antonelli

[57] **ABSTRACT**

A rotor arrangement and method of making the rotor arrangement for fluid flow machines having a plurality of rotor disks, each including a plurality of rotor blades, spaced from one another by intermediate ring members. The intermediate ring members are constructed as inner and outer rings with the inner ring welded to the adjacent rotor disk and the outer ring detachably slidably engaged over the inner ring by a dove-tail connection. The outer surface of the outer rings form a continuous surface with rotor blade platforms. Locking elements are connected at the platforms and the disk to hold the blades and outer rings from axial movement. With the slidable arrangement of the outer rings, disassembly of the rotor blades, etc., is facilated. A modification dispenses with the outer ring and includes labyrinth points on the inner ring which sealingly cooperates with a ring member of stator vane cascades interposed between the disks.

11 Claims, 5 Drawing Figures

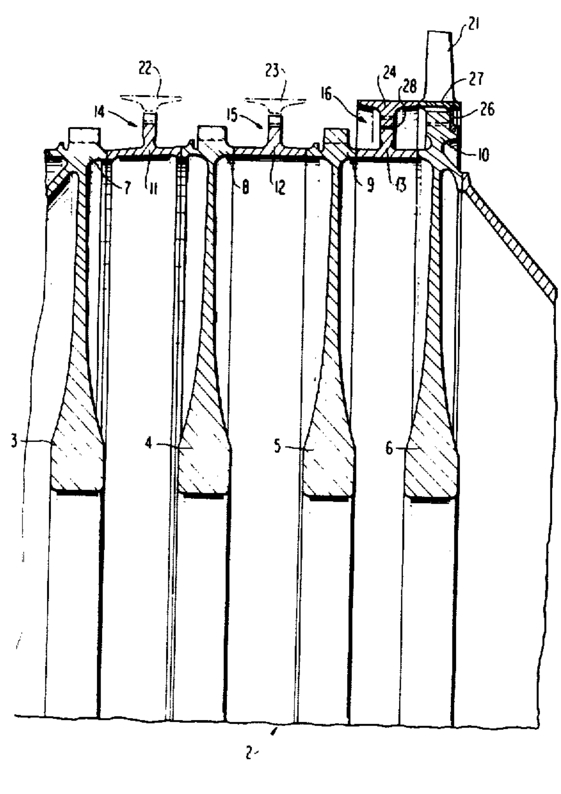


FIG.1

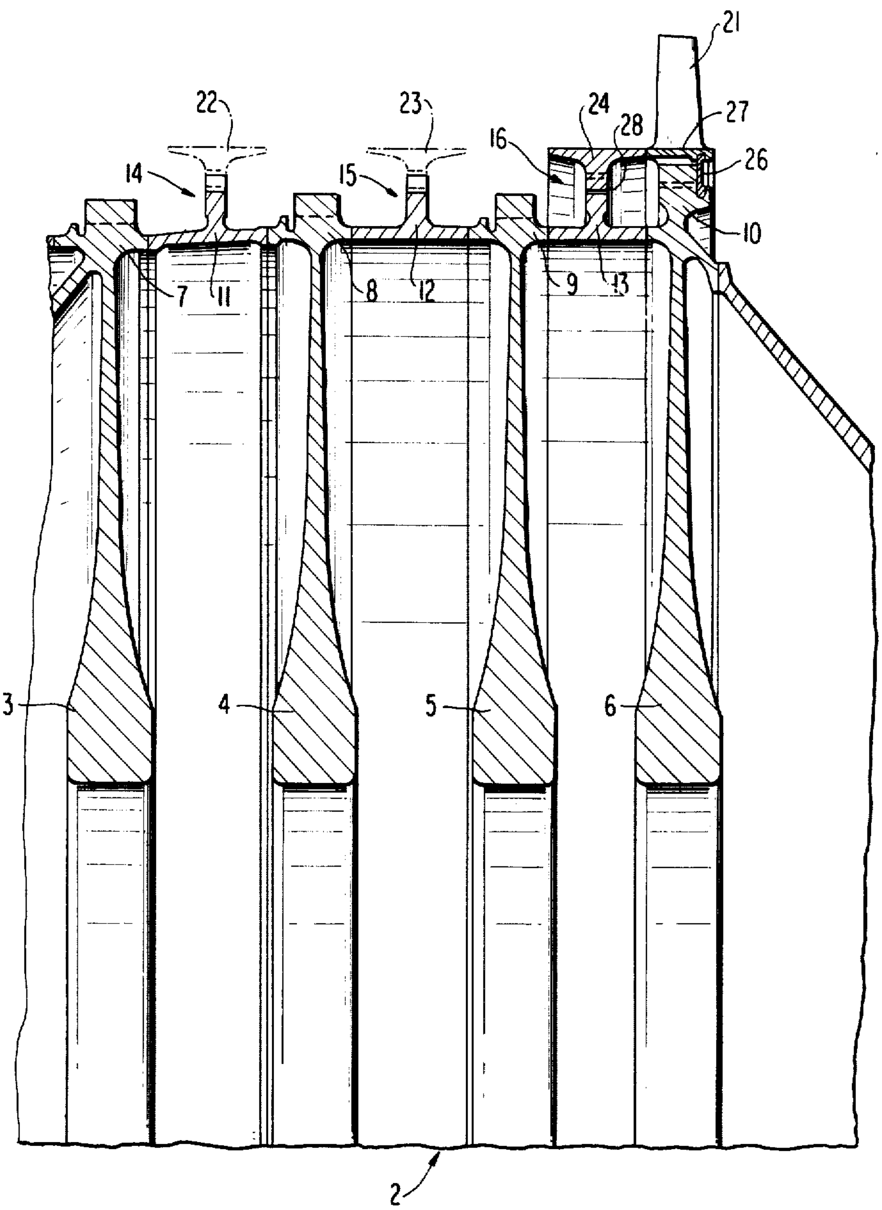
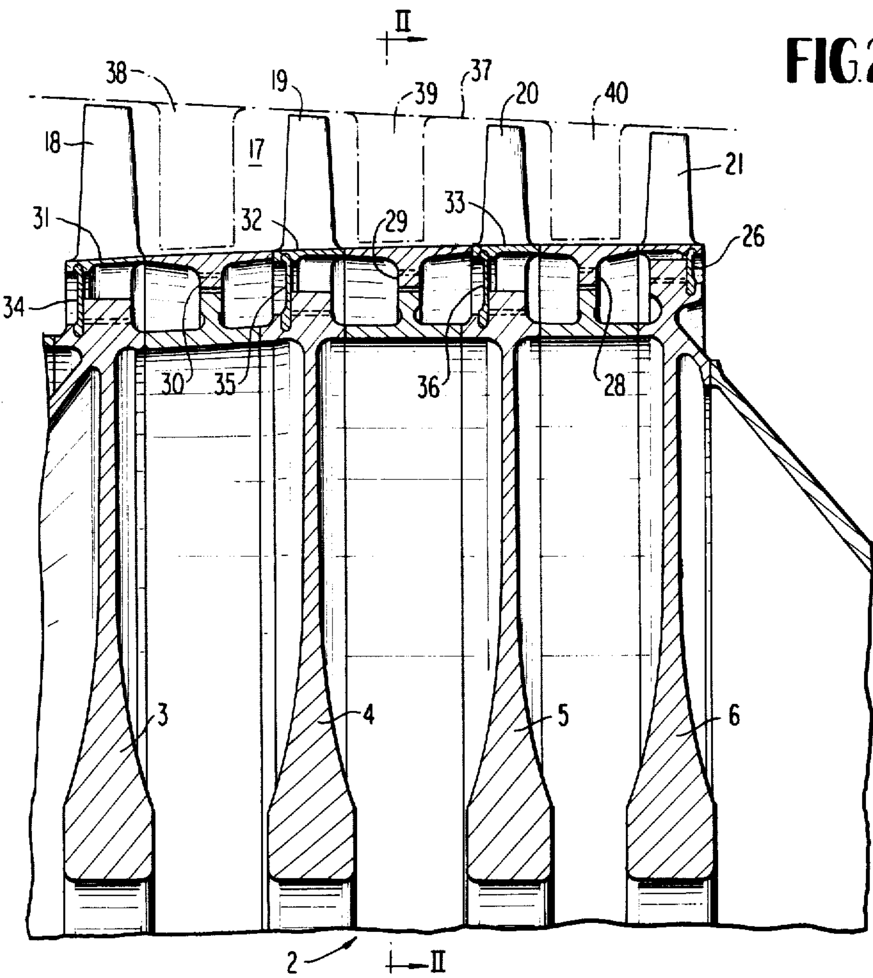


FIG.2


II
38
19
37
39
20
40
18
17
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II

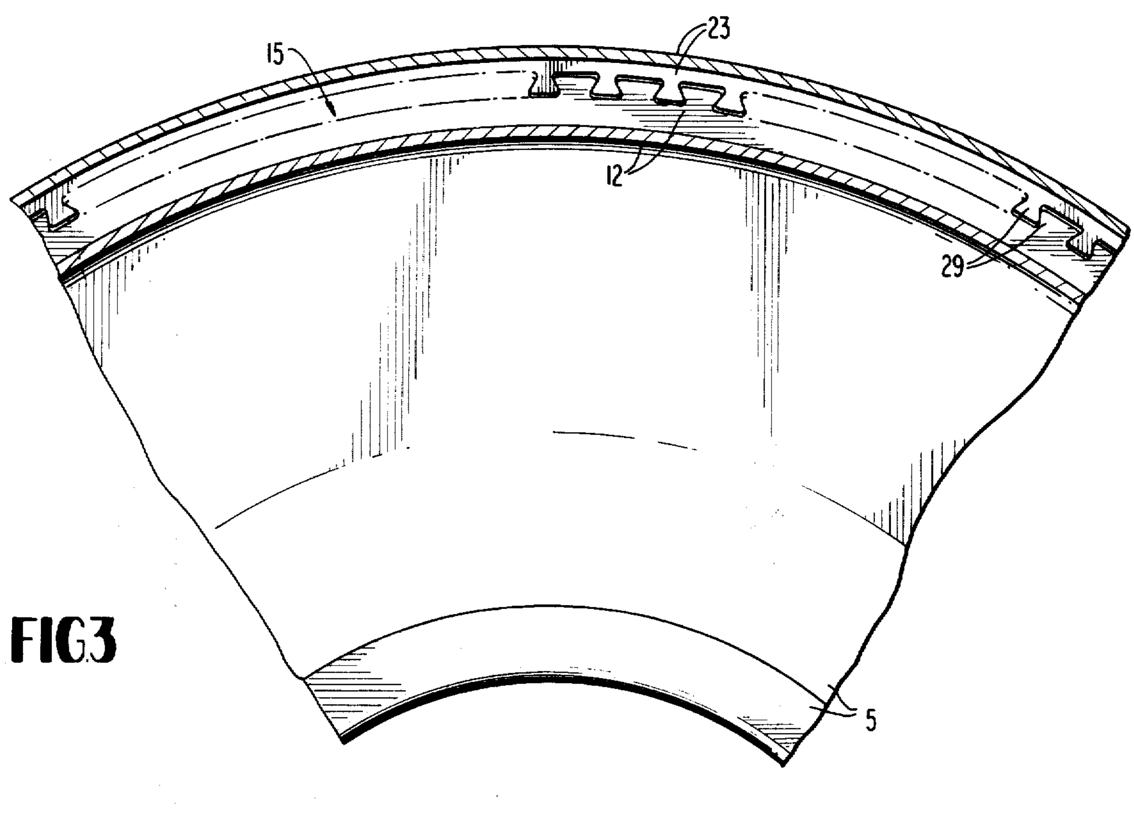

23
15
12
29
5

FIG.3

FIG 5

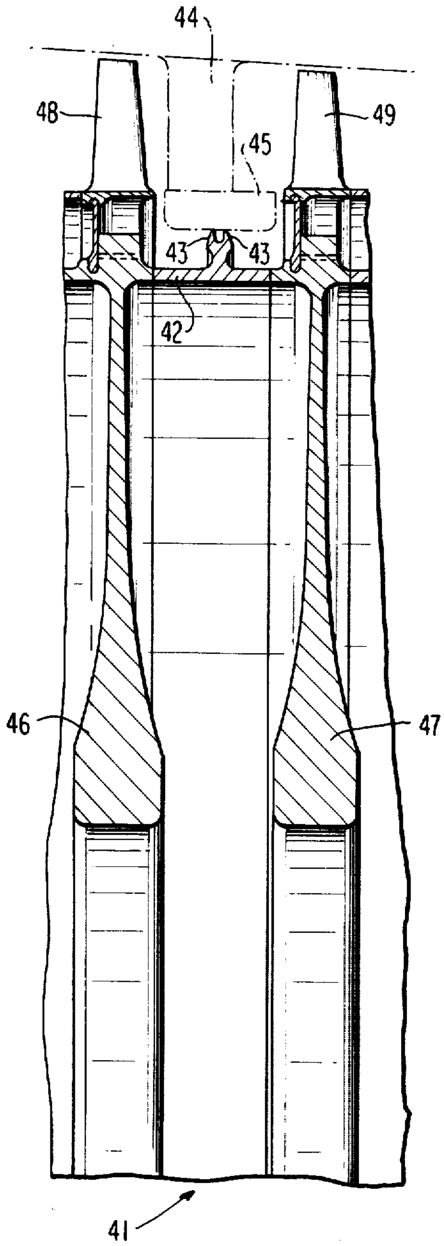
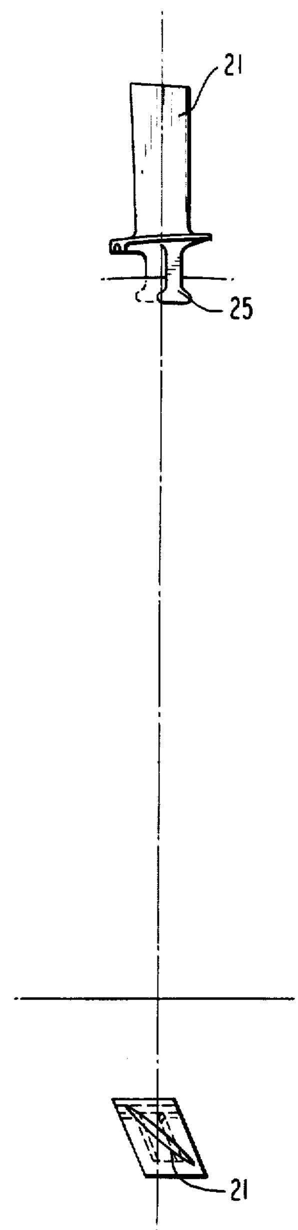


FIG 4



ROTOR FOR FLUID FLOW MACHINES

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a rotor for fluid flow machines in which a plurality of rotor disks are interconnected by means of intermediate rings welded or otherwise fixed in place between them.

Rotors in this category can normally not be disassembled, so that it is very nearly impossible to replace damaged components in especially the outer circumferential area of the rotor, such as the rotor blades attached to the rotor or to the rotor disks.

Also, considerable difficulties are encountered in the designing of such rotors when it is attempted to achieve an aerodynamically favorable, that is, smoothly faired wall structure between the blade platforms in rotors where it is desired to disconnectably connect the rotor blades to the rotor disks and where intermediate rings are welded in place in the outer circumferential area of the rotor.

Under the same conditions rotor constructions like those discussed above also cause notable difficulties when it is attempted to keep dead weight comparatively low.

A broad object of the present invention is to eliminate the disadvantages attributed to said rotors for fluid flow machines and to provide a rotor which permits of relatively high operating speeds and possesses the requisite strength to sustain such speeds while overcoming the abovediscussed disadvantages and while having a comparatively low dead weight.

To meet these and other objects the present invention contemplates the provision of a rotor for fluid flow machines of the said generic category in which the intermediate rings each include an inner member which is welded in place and an outer member which is slipped into place on the inner member. It is further contemplated by the present invention that said outer member forms a smoothly faired inner wall for the associated flow duct in conjunction with the platforms on adjacent blades.

In rotors contemplated by the present invention the inner members of the intermediate rings may be permanently connected to the disks by electron beam or friction welding. The inner members of the intermediate rings may further be composed of individual segments.

The present invention contemplates the provision of the outer member as a continuous closed ring and the provision of corresponding detachably slidably interengageable parts for circumferentially, and radially locking an inner and outer member together. In a further aspect, the present invention contemplates the provision of similar configurations for the interengageable parts on a plurality of axially aligned inner members so as to facilitate free passage of an outer member in the axial direction of the rotor over and past several inner members to a position in engagement with the corresponding mating inner member. Preferably enough play is provided for permitting passage of the outer member without leaving excess slack that cannot be taken up by elasticity of the outer member when finally assembled and used.

In a preferred embodiment contemplated by this invention the outer member of each intermediate ring forms a continuous ring having radially disposed internal teeth for sliding it axially into mating slots in the inner member of the intermediate ring, where the respective shape and number, or pitch, of these slots are essentially identical with the shape and pitch of the slots in the remaining inner members but will still ensure free passage of the outer member when this is being slipped into place. Alternatively, the teeth could be provided on the inner member and the slots on the outer members.

It is further contemplated by the present invention that the outer member of each intermediate ring is prevented from excessively expanding radially under service loads. A comparatively large number of suitably selected dovetailed teeth and slots ensures a maximally central position of the outer member of each intermediate ring.

According to the invention, dovetail slots in the inner members of the intermediate rings and in the outer members of the intermediate rings may be produced by broaching much like the dovetail slots in the blade shrouds of rotor disks. The dovetail slots in the inner members of the intermediate rings may be broached before welding exactly like those in the rotor disks.

The accuracy obtainable in shape and pitch of the dovetail slots in the outer and inner member of each intermediate ring contemplated by the present invention may be in the order of magnitude of that of the dovetail slots in rotor disks. Inasmuch as the outer member of each intermediate ring may be made elastic within reasonable limits, minor deviations in the shape of the outer member of the intermediate rings can be readily compensated during assembly.

Where a gentle incline exists of the inner contour of the blade duct, the present invention contemplates that the dovetail contour can be repeated unchanged on the same radius through several rotor stages, so that a corresponding number of outer members of the intermediate rings can be slipped with their teeth through the slots in the inner members of the intermediate rings. For other than dovetail connections, the present invention contemplates that the interengageable parts of several rotor stages be similar for inclined contour ducts.

In order to compensate for such minor inaccuracies in pitch as may be caused in manufacture, a certain amount of clearance can be provided between the teeth and the slots or other interengageable parts. Their elasticity and expansion under centrifugal force will nevertheless cause the outer members of the intermediate rings to fit snugly as soon as a certain, still low speed is reached. The resultant eccentricity of the outer members of the intermediate rings can be held within allowable limits.

In a further aspect of the present invention the blades and with them also the outer members of the intermediate rings may be arrested in their axial position by means of locking elements.

A further modification contemplated by the present invention is the arrangement of the inner members of the intermediate rings to be reworked to provide, for instance, labyrinth points, and that rotors intended for use in compressors may thus be retrofitted for cooperation with internally shrouded vane cascades.

The present invention further contemplates the method of making the rotor arrangements referred to above.

These and other objects, features and advantages of the present invention will become more apparent from the following description of several embodiments thereof, when taken in conjuction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal center section view of a rotor in accordance with the present invention which schematically illustrates the step-by-step assembly of the rotor;

FIG. 2 is a schematic longitudinal center section view of the fully assembled rotor of FIG. 1;

FIG. 3 is a partial schematic sectional view, with portions cut-away, taken along line II—II of FIG. 2;

FIG. 4 is a detail schematic view illustrating the configuration and attachment of the blade root to one of the rotor disks of FIGS. 1 and 2; and

FIG. 5 is a longitudinal center section schematic view illustrating an alternative embodiment of the rotor shown in FIGS. 1 and 2.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to the drawings wherein like reference numerals refer to like structures throughout the various views.

With reference to FIG. 1, the numeral 2 indicates an axial-flow compressor rotor which essentially comprises of the rotor disks 3, 4, 5, and 6. These rotor disks 3, 4, 5, and 6 are interconnected by welding them in the areas of their shrouds 7, 8, 9, and 10 to the inner members 11, 12, 13, of the intermediate rings 14, 15 and 16.

The welded axial-flow compressor rotor is fitted alternately and viewed from left to right with the rotor blades 18, 19, 20, 21 and the outer members 22, 23, 24, of the intermediate rings 14, 15, 16 (FIG. 1) preferably to suit the cross-sectional area of the compressor air duct 17 (FIG. 2) which may be narrowing in the direction of flow.

With reference to FIG. 1 the rotor blades 21, which have a dovetailed root exemplified by the numeral 25 in FIG. 4, are axially inserted in suitably shaped slots in the shroud 10 and restrained from axial displacement by means of a locking plate 26 which is connected to the shroud 10. The outer member 24, which forms a continuous ring, of the intermediate ring 16 is then slipped over the mating inner member 13 until its face contacts with the airfoil platform 27 of the blade 21. A dovetailed connection 28 arrests the outer member 24 in its circumferential as well as radial position on the inner member 13 of the intermediate ring 16. The pitch and the contour of the teeth and of their mating slots in the dovetail connection 28 are approximately identical with those in the dovetail connections 29, 30 (FIG. 2) of the intermediate rings 15, 14, so that the continuous-ring member 24 may readily be slipped with its teeth through the slots in the inner members 11, 12 of the intermediate rings 14, 15 entering in the dovetail connections 29, 30. The attachment or assembly of the remaining outer members 22, 23 and blades 20, 19, 18 then proceeds analogously, where the outer members 22, 23 of the intermediate rings 15, 14 form, together with the platforms 31, 32, 33, of the blades 18, 19, 20 a smoothly faired inner wall for the air duct 17 (FIG. 2).

FIG. 3 exemplifies a representative dovetailed connection 29 between the welded inner member 12 and the subsequently axially seated outer member 23 of the intermediate ring 15.

FIG. 2 shows additional locking plates 34, 35, 36 which limit the blade to disk connections at the forward end and are arranged between the respective shrouds 7, 8, 9 (FIG. 1) and blade platforms 31, 32, 33.

FIG. 2 further illustrates the outer duct wall 27 of the compressor air duct 17 which contains stator vanes 38, 39, 40.

It is also envisioned to slightly enhance the tooth clearance increasingly from right to left (FIGS. 1 and 2) while retaining the tooth pitch and slot contour of the dovetailed connections between the inner and outer members of the intermediate ring so as to ensure ease of positioning the outer members on the inner members.

FIGS. 1 and 2 exemplify an axial-flow compressor rotor 2 where the stator vane cascades are unshrouded at their inner diameter so that when the rotor is turning, the fixedly arranged outer members 22, 23, 24 of the intermediate rings 14, 15, 16 are completely free to move below the free ends of the stator vanes 38, 39, 40 without the intervention of sealing devices.

FIG. 5 illustrates an axial-flow compressor rotor 41 which differs from the embodiment on FIGS. 1 and 2 in that the inner member 12 of the intermediate ring 15 which was formerly slotted to accommodate the dovetailed connection 29 has now been shaped by reworking (42 in FIG. 5) to provide labyrinth points 43 which together with the inner ring 45 attached to the stator vanes 44, form a non-contacting or a contacting seal. In FIG. 5 the rotor disks are indicated with the numerals 46, 47 and their rotor blades with 48, 49.

The invention described and shown in light of FIGS. 1 to 5 may analogously be applied also to a turbine rotor.

Also, other embodiments reversing the teeth and slots on the inner and outer members from the arrangements shown in FIGS. 1–4 are contemplated by the present invention. Also, each of the inner and outer members could include both teeth and slots engageable with corresponding teeth and slots on the other member. Also, other interengageable connections than dovetail connections could be used.

While we have shown and described several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as will be apparent to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications.

What is claimed is:

1. A method of making a rotor arrangement comprising:

placing a plurality of rotor disks spaced from one another along a common axis,

slidably inserting a plurality of rotor blades in slots provided at the periphery of an endmost disk,

fixedly attaching an intermediate inner ring member to said endmost disk and to the next adjacent disk, and

axially slidably positioning a continuous intermediate outer ring member over the circumference of said inner ring member such that the outer surface of said outer ring member forms a continuous smooth surface with platform sections of said rotor blades, wherein said outer ring member is a continuous closed ring, and wherein said outer ring member and said inner ring member have corresponding detachably slidable interengageable parts for circumferentially and radially locking said outer and inner ring members to one another, said step of axially slidably positioning including interengaging said interengageable parts.

2. A method according to claim **1**, wherein said plurality of rotor disks includes at least three rotor disks, further comprising: slidably inserting a plurality of rotor blades in slots provided at the periphery of a second disk adjacent the endmost disk,

fixedly attaching a second intermediate inner ring member to said second disk and to a third disk adjacent thereto at the side opposite the endmost disk,

and axially slidably positioning a second intermediate outer ring member constructed as a continuous closed ring over the circumference of said second inner ring member such that the outer surface of said second outer ring member forms a continuous smooth surface with platform sections of said rotor blades.

3. A method according to claim **2**, wherein said second outer ring member and second inner ring member have corresponding detachably slidable interengageable parts for circumferentially and radially locking said second outer and second inner ring members to one another, said step of axially slidably positioning including interengaging said last mentioned interengageable parts.

4. A method according to claim **3**, wherein the configuration of the interengageable parts on each of the inner ring members is similar, and wherein the step of axially slidably positioning said first mentioned outer ring member includes sliding said first mentioned outer ring member over said second inner ring member with the interengageable parts of said second inner ring member permitting free passage of said first mentioned outer ring member thereover.

5. A method according to claim **4**, wherein the respective interengageable parts of said inner and outer ring members are constructed as mating dovetail shaped teeth and slots.

6. A method according to claim **5**, further comprising inserting locking plates between a platform of the endmost disk and the blades mounted thereon for preventing axial displacement of said blades.

7. A method according to claim **6**, further comprising inserting locking plates between platforms of each of the other disks and associated blades thereon for preventing axial displacement of said last mentioned blades.

8. A method according to claim **2**, wherein said steps of fixedly attaching said inner ring members to said disks includes welding of the respective inner ring members to respective ones of said disks.

9. A method according to claim **32**, wherein said steps of fixedly attaching said inner ring members to said disks includes welding of the respective inner ring members to respective ones of said disks.

10. A method according to claim **29**, wherein the dimensions of the interengageable parts at said second inner ring member are such as to permit a freer passage of said first mentioned outer ring member thereover than the passage of said first mentioned outer ring member over said first mentioned inner ring members.

11. A method of making a rotor arrangement comprising:

placing a plurality of rotor disks spaced from one another along a common axis,

fixedly attaching inner intermediate ring members to said rotor disks,

slidably inserting rotor blades in slots provided at the periphery of an endmost rotor disk,

locking said rotor blades in said endmost disk,

slidably inserting a first intermediate outer ring member over the outer circumference of said rotor disks and through slots provided on said inner intermediate ring members to contact platforms provided on said rotor blades,

slidably inserting rotor blades into slots of a second rotor disk with its platforms contacting the face of said first intermediate outer ring member, and

sequentially slidably inserting a plurality of further intermediate outer ring members and rotor blades into slots in the remaining rotor disks with the respective platforms of each rotor blade of a respective rotor disk contacting the face of the preceeding intermediate outer ring member such that the outer surface of said intermediate outer ring member forms a continuous smooth surface with the platform sections of said rotor blades.

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