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Samurin et al.

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[54] **ROTOR STRUCTURE FOR TURBO MACHINES**

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[52] **U.S. Cl.** **416/199,** 416/244

[51] **Int. Cl.** **F01d 5/06**

[58] **Field of Search** 416/198–201; 287/52.04; 415/134

[56] **References Cited**

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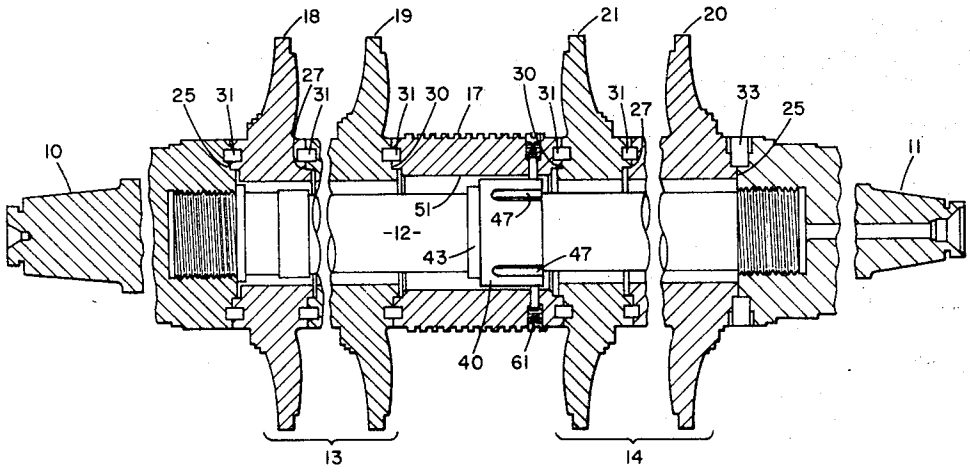
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[57] **ABSTRACT**

The invention relates to a turbo machine rotor structure employing a thru-bolt extending through the rotor assembly and attached at its ends to stub shafts. Force producing means is provided to exert a restraining force between the rotor assembly and the thru-bolt to maintain the thru-bolt properly preloaded and centered in the rotor assembly in the preferred arrangement. A sleeve member has an end portion fixedly secured on the thru-bolt as by a shrink fit. The remainder of the sleeve is formed with slots extending from the opposite end of the sleeve and terminating at the fixed end portion thereof. The slots form circumferentially spaced apart resilient cantilever portions extending from the fixed portion of the sleeve and being spaced in concentric relation to the thru-bolt and the bore of the rotor assembly. The rotor assembly is provided with means such as radially disposed screw members for exerting a radially inward force against the free ends of the cantilever portions and serving to center the thru-bolt in respect to the rotor assembly and to exert a restraining preloading force on the cantilever portions.

2 Claims, 3 Drawing Figures



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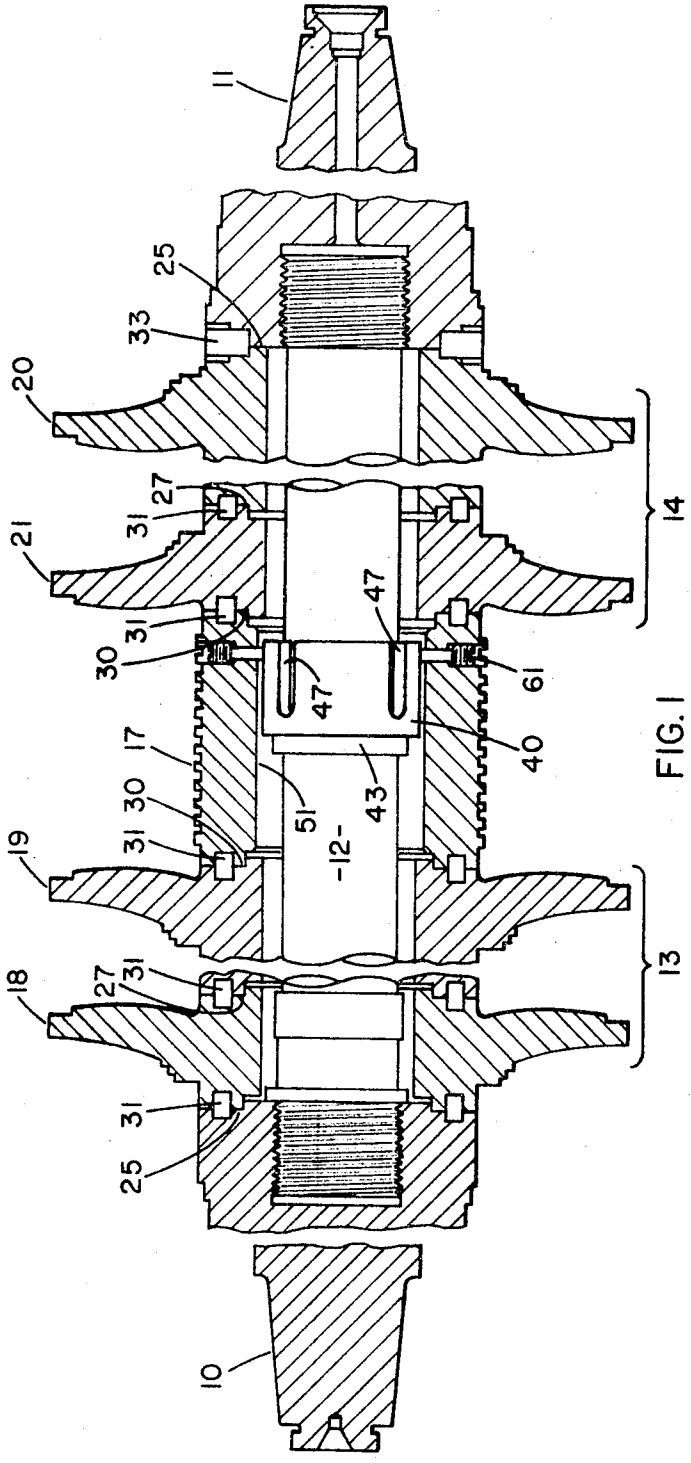


FIG. 1

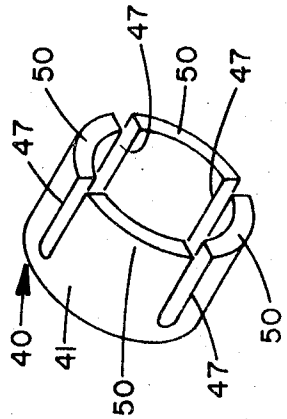


FIG. 3

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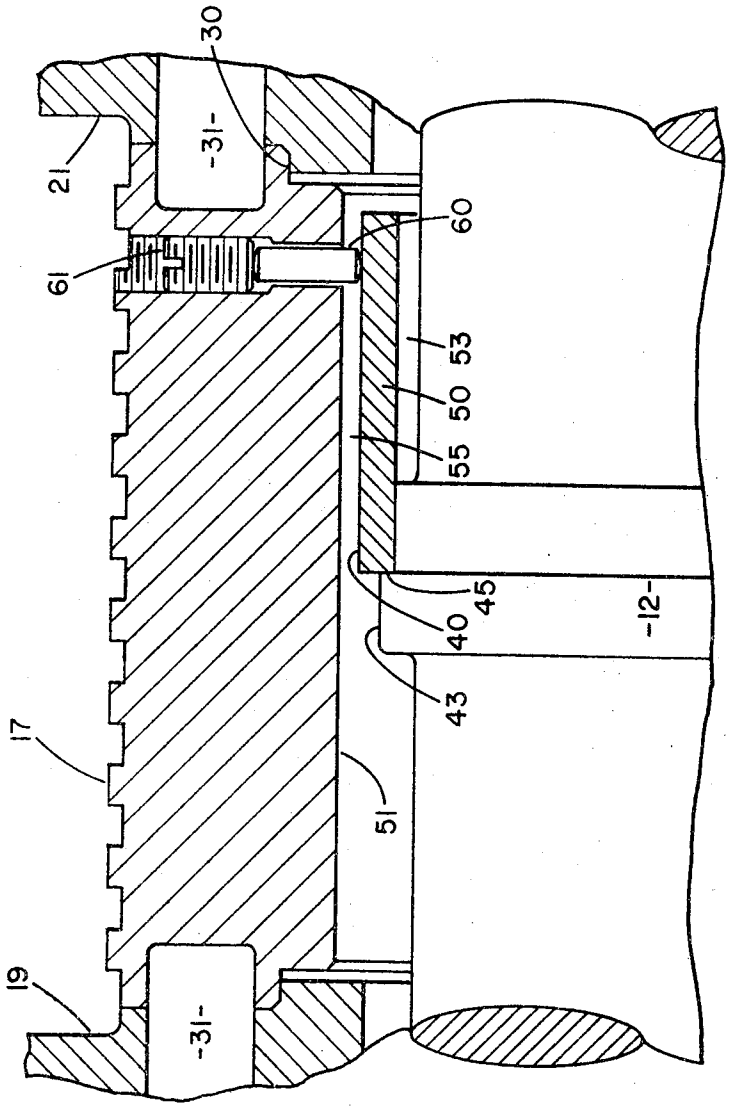


FIG. 2

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ROTOR STRUCTURE FOR TURBO MACHINES

BACKGROUND OF THE INVENTION

In the manufacture of turbo machines of the multi-stage type, as centrifugal compressors, axial flow compressors, and turbines, there are advantages in employing rotors of composite structure wherein the wheels are arranged in stacked formation between the stub shafts which are fixedly secured to the ends of a thru-bolt. The wheel assembly is formed with an axially extending bore passage having a diameter greater than that of the thru-bolt whereby there is an annular space between the thru-bolt and the bore of the rotor assembly.

In machines of this type, the thru-bolt is of substantial length and there are inherent problems associated with such a structure, particularly with bolt resonance and rotor imbalance caused mainly by deflection or radial displacement of the bolt relative to the rotor structure. The high speed at which these machines are operated aggravates the problem. An arrangement to overcome such problems is disclosed in the co-pending application of Hansen and Huesgen, Ser. No. 78,728, filed Oct. 7, 1970, now U.S. Pat. No. 3,680,979.

This invention has as an object a rotor structure economical to manufacture and assemble and which provides for the centering of the thru-bolt relative to the rotor structure and effects a restraining preloading force on the thru-bolt to control the natural frequency thereof and avoid resonance at operating conditions.

SUMMARY OF THE INVENTION

In the disclosed embodiment of the invention disclosed, a sleeve member is formed with slots extending from one end of the sleeve axially thereof and terminating in spaced relation to the opposite end of the sleeve providing a solid annular end portion. The annular end portion is fixed to the thru-bolt, in the central area thereof, as by a shrink fit. The slots provide resilient cantilever portions extending from the fixed portion of the sleeve in concentrically spaced relation to both the thru-bolt and the bore of the rotor assembly. A radially disposed member is threaded in the rotor assembly in registration with each cantilever portion of the sleeve, and serves to exert an inward force of variable pressure against the free ends of the cantilever portions to center the thru-bolt in the rotor assembly and to exert a preloading force between the rotor assembly and the thru-bolt.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a foreshortened lengthwise sectional view of a rotor structure in which our invention is incorporated;

FIG. 2 is an enlarged sectional view of the upper center portion of FIG. 1; and

FIG. 3 is a view in perspective of the sleeve member.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The composite rotor structure shown, as an example in FIG. 1, is incorporated in a multi-stage twin type centrifugal gas compressor. The rotor includes stub shafts **10, 11** fixedly secured to the ends of the thru-bolt **12.** A group **13** of impellers is positioned about the end portion of the thru-bolt attached to the stub shaft **10,**

and a second group **14** of impellers is mounted in proximity to the stub shaft **11.**

A cylindrical seal member **17** is positioned intermediate the groups of impellers **13, 14.** In the foreshortened view, FIG. **1,** only the first and last stage impellers **18, 19** are shown in the group **13,** and in like manner, the first and last stage impellers **20, 21** in the group **14.**

The impellers abutting against the stub shafts **10, 11** are impellers **18** and **20,** and the stub shafts are formed with shoulder structures **25.** Also, the abutting areas between the respective impellers are formed with similar shoulder areas **27.** Also, there is a shoulder engagement **30** between the ends of the seal member **17** and the adjacent impellers **19, 21.** The shoulder structures **25, 27, 30** serve to center the impellers and the seal member **17,** maintaining the impellers and the seal member in coaxial alignment. Driving means in the form of pins **31** are positioned intermediate the impellers and the seal member **17,** and between the impeller **18** and the stub shaft **10.** Radially disposed keys **33** are inserted between the impeller **20,** and the stub shaft **11.** The pins **31** and keys **33** serve to provide a driving connection to the impeller assembly from the stub shafts **10, 11.**

In the assembled form, the stub shafts **10, 11** are threaded onto the ends of the thru-bolt **12** whereby the impellers and sleeve member **17** are compressed axially to form a rigid structure for rotation in unison.

As previously stated, the thru-bolt **12** is of appreciable length, especially in view of the fact that the compressor is of the multi-stage type, and furthermore, is of the twin type having the separated impeller groups **13** and **14.** Such long thru-bolts result in bolt resonance and imbalance at the high speeds at which these rotor assemblies are operated. This invention is directed to a structural arrangement wherein deflection or radial displacement of the thru-bolt is prevented, the bolt being maintained centered with the rotor structure, and also stiffened to increase the natural frequency of the bolt which avoids resonance thereof at operating speeds. These advantages are obtained by providing a force producing means operable to exert a restraining force between the rotor assembly and the thru-bolt.

A support sleeve **40** is mounted on thru-bolt **12** in the medial area thereof. The sleeve member **40** is formed with an integral cylindrical end portion **41** which is fixed to the thru-bolt **12** as by a shrink fit. Preferably the sleeve member **40** is of cylindrical formation having a side wall of uniform thickness, and the thru-bolt **12** is formed with an enlargement **43** terminating at a radial shoulder **45,** see FIG. **2.**

The sleeve member **40** is formed with a plurality of slots **47** extending in a direction axially of the sleeve from the integral end portion **41** to the opposite end of the sleeve. The slots **47** form a plurality of circumferentially spaced apart cantilever portions **50,** see FIG. **3,** which extend from the solid end portion **41** in concentrically spaced relation to the thru-bolt **12** and to the bore **51** in the seal sleeve **17.** That is, there is an annular space **53** between the cantilever portions **50** and the thru-bolt **12** and an annular space **55** between the cantilever portions and the bore of the seal member **17.** The sleeve member is heat treated to impart resiliency in the cantilever portions **50.**

The invention includes means for exerting a preloading force on the free ends of the cantilever portions **50.** The cantilever portions exerting a restraining force

maintain the thru-bolt properly centered in the rotor assembly.

The seal member **17** is formed with a plurality of radially disposed apertures arranged in registration with the cantilever portions **50** for the reception of pins **60.** The pins **60** are slidably mounted in the seal member **17** and are positioned to engage the free ends of the cantilever portions **50.** The outer portions of the apertures formed in the seal member are counter bored and threaded to receive adjusting screws **61,** which engage the outer ends of the pins **60.** With this arrangement, by controlled tightening the screws **61,** inward radial force is applied to the free ends of the cantilever portions **50,** and the thru-bolt **12** can be properly centered in the rotor structure and maintained against radial displacement therein. The restraining force so applied to the support sleeve effects a stiffening thereof to increase the natural frequency of the thru-bolt and avoid resonance thereof at operating speeds.

In brief, the rotor structure is assembled by arranging the impeller in the group **13** in stack formation. The thru-bolt **12** is threaded into the stub shaft **10.** The stack of impellers in the group **13** is sleeved over the bolt against the stub shaft **10.** The seal member **17** is then positioned on the assembly and the shaft marked to register the position of the radial apertures in the seal member. The seal member **17** is then removed. The support sleeve **40** is heated and positioned on the enlargement **43** of the thru-bolt **12** against the shoulder **45** and with the cantilever portions **50** arranged in registration with the marks previously applied to the shaft. Upon cooling the solid end portion of the sleeve **40** has a tight shrink fit with the bolt **12.**

The seal member **17** is passed over the sleeve **40** in abutting relation with the impeller **19.** The stack of impellers **14** is then positioned against the seal **17** and the stub shaft member **11** is threaded on the thru-bolt. A procedure is employed in this last step which results in the compression of the impeller assemblies and seal member **17** being of predetermined value. When the stub shaft **11** is tightened to produce the desired compressive force on the impeller assembly, keys **33** are inserted between the hub of impeller **20** and the stub shaft **11.** Accordingly, the stub shafts **10, 11,** sleeve **17** and impellers are fixed together for rotation in unison.

Following the assembly of the rotor structure as above described, the pins **60** are placed in the apertures in the sleeve **40** and then the screws **61** are threaded inwardly to apply the designed centering force on the cantilever portions **50.**

The screws **61** acting on the cantilever portions **50** apply an initial preload on the bolt with respect to the rotor. During operation at high speed, the seal sleeve **17** grows radially reducing the initial restraining preloading force. However, the cantilever portions at high speed apply a loading through the pins **60** to the seal member **17** of the rotor to keep the thru-bolt in position. The principle involved is the natural mode of deflection under rotation of the cantilever sections **50.** The free ends of the cantilever portions swing out radially and apply the above mentioned loading.

While a preferred embodiment of this invention has been described for purposes of illustration, it will be appreciated that this invention may be otherwise embodied within the scope of the following claims.

We claim:

1. A rotor structure for turbo machines comprising a thru-bolt, a stub shaft fixed to each end of said thru-bolt, a rotor assembly mounted intermediate said stub shaft and being fixedly secured thereto, said assembly being formed with an axially extending bore passage spaced concentrically about said thru-bolt, and force producing means carried in part by said rotor assembly and adjustable to exert a radial inward restraining force of variable magnitude on said thru-bolt, said force producing means including a sleeve member fixedly mounted on said thru-bolt and formed with a circular series of resilient cantilever portions extending in concentric spaced relation to said thru-bolt and the bore in said rotor assembly.

2. A rotor structure as set forth in claim **1,** wherein said sleeve member includes an end portion fixedly secured to said thru-bolt in the medial area thereof, and means mounted in said rotor assembly for engagement with said cantilever portions and operable to exert an inward pressure of varying extent thereon.

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