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
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 axial 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
3,749,516

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 hub of impeller 20 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 40 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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