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HIGH SPEED ROTOR FOR CENTRIFUGAL COMPRESSORS AND THE LIKE

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Fig. 1.

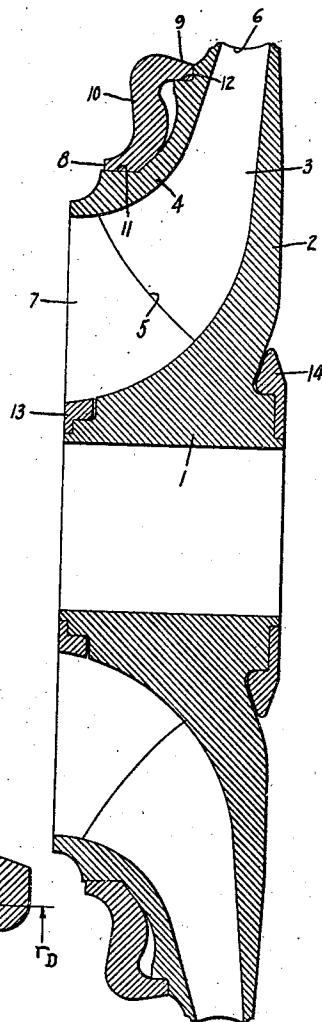
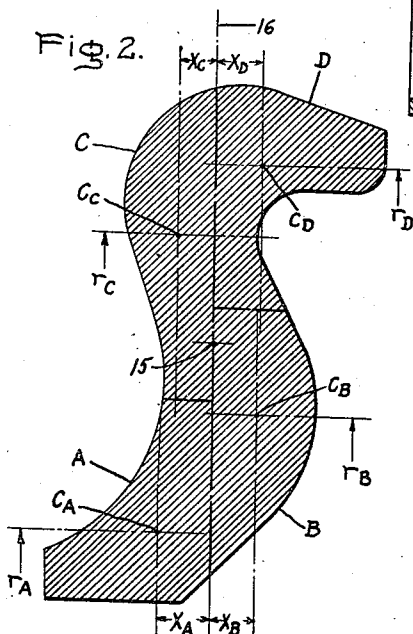


Fig. 2.



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UNITED STATES PATENT OFFICE

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HIGH-SPEED ROTOR FOR CENTRIFUGAL
COMPRESSORS AND THE LIKEKenton D. McMahan, Scotia, N. Y., assignor to
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8 Claims. (CL 230-134)

The present invention relates to rotors such as rotors for centrifugal compressors and the like, intended for operation at high speed and has for its object to provide an improved construction and arrangement in rotors of this type.

The invention is especially applicable to shrouded impellers for high speed centrifugal air compressors and it is this application of my invention which I have elected specifically to illustrate and describe. It is to be understood, however, that the invention is not limited thereto necessarily.

For a consideration of what I believe to be novel and my invention, attention is directed to the following specification and to the claims appended thereto.

In the drawing, Fig. 1 is a sectional view of a shrouded impeller embodying my invention, and Fig. 2 is a sectional view of a reinforcing ring with a diagram therein.

Referring to the drawing, 1 indicates the hub of the impeller, 2 the web, 3 the impeller vanes and 4 the shroud. The inlet ends of the vanes are indicated at 5 and the discharge ends at 6. The impeller receives air or other gas to be compressed through the annular inlet 7 and discharges it at the periphery of the impeller. The air or other gas enters in an axial direction, is turned gradually and is discharged radially. A structure such as that so far described may be formed as an integral casting, the shroud 4 being cast integral with and carried by the vanes 3.

For certain applications, such as for example superchargers for aircraft, it is desirable that the impeller be constructed of light weight material such as an aluminum alloy in order to keep down the weight. At the same time, such impellers are required to operate at high speeds, speeds of the order of 20,000 R. P. M., for example. This means that the centrifugal stresses are high, a thing which presents a serious problem especially in connection with the shroud since the bursting stresses in it are high.

According to my invention, I reinforce the shroud 4 by means of two high strength steel rings, an inner ring 8 located adjacent to the hub and an outer ring 9 located adjacent to the periphery and I tie the outer ring to the inner ring by means of a tie ring 10 which is reversely curved or S-shaped in transverse section. The use of the tie ring 10 to anchor the outer ring 9 to the inner ring 8 is an important feature of my invention. By its use, the inner ring 8 which is closer to the axis of rotation and hence subject to lower centrifugal stresses assists in carrying the outer ring 9 which is further from the axis of rotation and hence subject to higher centrifugal stresses. And by making the tie ring S-shaped in cross section, centrifugal force tending to stretch ring

10, i. e., straighten it, serves to force outer reinforcing ring 9 more firmly on its seat.

The rings 8 and 9 and the tie ring 10 form a unitary ring structure. Viewed from one aspect, they may be considered a single S-shaped ring or ring structure having axially extending ends 8 and 9 for engaging respectively surfaces 11 and 12 of the shroud. Surfaces 11 and 12 are given a reverse taper, i. e., they are tapered inwardly, and the ring structure is positioned with a shrink fit. I have found that by cooling the impeller casting to a temperature of the order of -80° F. and heating the ring structure to a temperature of the order of 400° F., the ring structure may be readily positioned on the shroud and a good shrink and reverse taper fit obtained.

For best results, it is important that the reinforcing ring structure support the impeller shroud at the inner and outer surfaces 11 and 12 and at the same time be free from a twisting moment tending to unhook the ring structure from the shroud's outer surface 12 due to forces acting on the ring when the impeller is rotating at high speed. To this end, the contour of the ring is such that the forces in the one portion of the ring structure tending to twist the structure and unhook the end 9 is, at least, equalized by the forces in another portion of the ring structure tending to twist the structure in the opposite direction. This result is obtained by the use of a ring structure which may be S-shaped in cross section and dimensioned as illustrated particularly in Fig. 2. Referring to Fig. 2, 15 indicates the center of gravity of the ring structure and 16 indicates a radial line through the center of gravity dividing the ring into two portions. A first approximation of the desired condition is obtained by dividing the ring into four equal sections indicated A, B, C and D about the radial center line 16 of the ring section, by determining the centers of gravity of the respective sections, which centers of gravity are indicated at CA, CB, CC and CD, and by satisfying the equation

$$r_A \cdot X_A + r_C \cdot X_C = r_B \cdot X_B + r_D \cdot X_D$$

where:

r_A , r_B , r_C and r_D = radii of the center of gravity of the respective sections A, B, C and D, and

X_A , X_B , X_C and X_D = distances from center of gravity of the respective sections to the center line of the ring.

A more detailed and accurate determination of the desired condition may be arrived at by other methods but I have found the approximate method sufficiently accurate for practical purposes.

While I have represented the reinforcing ring 10 as being S-shaped in cross section, it is possible to design rings having other shapes which

will exhibit the specified characteristics at high speed. It should be understood that my invention covers reinforcing rings of all cross section shapes so designed that the influence of centrifugal forces at high rotational speeds tending to deflect the outer ring portion away from contact with the outer shoulder of the rotor wall is substantially or completely equalized by centrifugal forces acting on some other portion of the ring tending to cause the outer end portion to move radially towards the shoulder. With rotor walls of certain shapes it is possible, and may be desirable, to "over-compensate," that is, design the cross section so that the net force tending to move the outer end portion of the ring into tighter engagement with the outer shoulder increases as centrifugal force increases. The exact design required to produce the desired result depends on the shape of the wall to be reinforced, and must be determined in each particular case by analysis and calculation verified by experiment.

In the present instance, the hub 1 is shown as being reinforced by suitable high strength steel rings 13 and 14 which may be positioned with a shrink fit. These rings serve to strengthen the aluminum alloy casting and in addition function to hold the ends of the bore of the hub more nearly to size at all operating speeds.

By my invention, I am enabled to construct a rotor which is light in weight but which at the same time is capable of operating at high speeds.

While the use of the invention in the construction of shrouded impellers for centrifugal compressors, such as superchargers for aircraft engines, is an important application of my invention, it will be clear that the invention is not limited necessarily to this use but may be used wherever found applicable.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A rotor subject to high centrifugal stresses comprising a disk member having an outer surface forming two axially and radially spaced outer annular shoulders, and a reinforcing ring substantially S-shaped in cross-section with inner and outer end portions forming radially and axially spaced inner surfaces tightly engaging the respective outer shoulders of the disk member to resist radial expansion thereof and an intermediate portion connecting the end portions and having a surface axially facing the disk member and gradually curving away therefrom in radial direction.

2. A rotor comprising a disk member having a central opening and an outer annular edge, said disk member having an outer surface forming a first annular shoulder near the opening and a second annular shoulder near the outer edge, and a reinforcing structure permitting operation of the disk member at speeds at which the centrifugal stresses therein reach magnitudes of the order of the bursting stresses of the disk member, said reinforcing structure comprising a solid ring member substantially S-shaped in section and having axially and radially spaced cylindrical surfaces forming a shrink fit with the first

and second shoulders respectively of said disk member.

3. A rotor for a high speed centrifugal machine or the like comprising a hub, a web, blades carried by the web, a shroud for the blades and reinforcing means for the shroud comprising a ring structure having inner and outer portions tightly engaging the shroud at radially spaced locations so as to relieve centrifugal stresses in the shroud and an intermediate portion connecting the inner portion with the outer portion so that the former helps to support the forces set up in the latter by centrifugal force.

4. In combination with a high speed rotor having a radially extending wall subject to centrifugal bursting stresses in operation, reinforcing means for said wall comprising a ring structure having inner and outer portions tightly engaging the wall at radially spaced locations to relieve centrifugal stresses in the wall and an intermediate portion connecting the radially outer portion to the radially inner portion so that the latter helps to support the forces set up in the former by centrifugal force.

5. In combination with a high speed rotor subject to centrifugal bursting stresses in operation and having a wall with radially and axially spaced cylindrical shoulders, a reinforcing structure for the wall comprising a ring substantially S-shaped in cross section and having radially and axially spaced inner and outer portions tightly engaging the respective shoulders to relieve centrifugal stresses in the wall, the cross section of said ring being so shaped that when operating at high speed the forces acting on a certain part of the ring tending to move the radially outer portion from engagement with the outer shoulder are substantially balanced by forces acting on another part of the ring tending to move the outer portion into tighter engagement with said shoulder.

6. In a high speed rotor having a wall requiring support at both inner and outer radially spaced portions to withstand centrifugal stresses, a reinforcing ring for said wall having a curved cross section with radially spaced inner and outer end portions and an interconnecting portion arranged to transmit forces set up during operation from one end portion to the other, the inner end portion tightly engaging the outer surface of an annular shoulder formed on a radially inward portion of the wall and the outer end portion tightly engaging the outer surface of an annular shoulder formed on a radially outer portion of the wall, the cross section of the ring being so shaped that at high speeds the centrifugal forces acting on a certain portion of the ring tending to cause the outer portion to deflect away from the outer shoulder on the wall are substantially equalized by the forces acting on another portion of the ring tending to cause the outer portion to deflect towards said shoulder.

7. In a high speed rotor having a wall requiring support at both inner and outer radially spaced portions to withstand centrifugal stresses, radially spaced inner and outer annular shoulders formed on the wall, and a shrink-fitted reinforcing ring for said wall having a curved cross section with radially spaced inner and outer end portions and an interconnecting portion arranged to transmit forces set up during operation from one end portion to the other, the inner end portion tightly engaging the outer surface of the annular shoulder formed on a radially inward portion of the wall and the outer end por-

tion tightly engaging the outer surface of the annular shoulder formed on a radially outer portion of the wall, at least one of said shoulders having a substantially cylindrical outer surface tapering slightly to a smaller diameter in the direction toward the wall and the ring having a cross section so shaped that at high speeds the centrifugal forces acting on a certain portion of the ring tending to disengage the outer end portion from the outer shoulder are substantially equalized by the forces acting on another portion of the ring tending to deflect the outer portion towards said shoulder.

8. In a high speed rotor having a wall requiring support at both inner and outer radially spaced portions to withstand centrifugal stresses, a reinforcing ring for said wall having a curved cross section with radially spaced inner and outer

5 end portions and an interconnecting portion arranged to transmit forces set up during operation from one end portion to the other, the inner end portion tightly engaging the outer surface of an annular shoulder formed on a radially inward portion of the wall and the outer end portion tightly engaging the outer surface of an annular shoulder formed on a radially outer portion of the wall, the cross section of the ring being so shaped that the integral of the moments produced by centrifugal forces acting on a certain portion of the ring tending to rotate the cross section of the ring counterclockwise is substantially balanced by the integral of the moments of the forces acting on the other portions of the ring tending to deflect the cross section clockwise.

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