May 25, 1937. U. MEININGHAUS 2,081,148

DISK CONSTRUCTION FOR RADIAL FLOW MACHINES

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Fig. 1

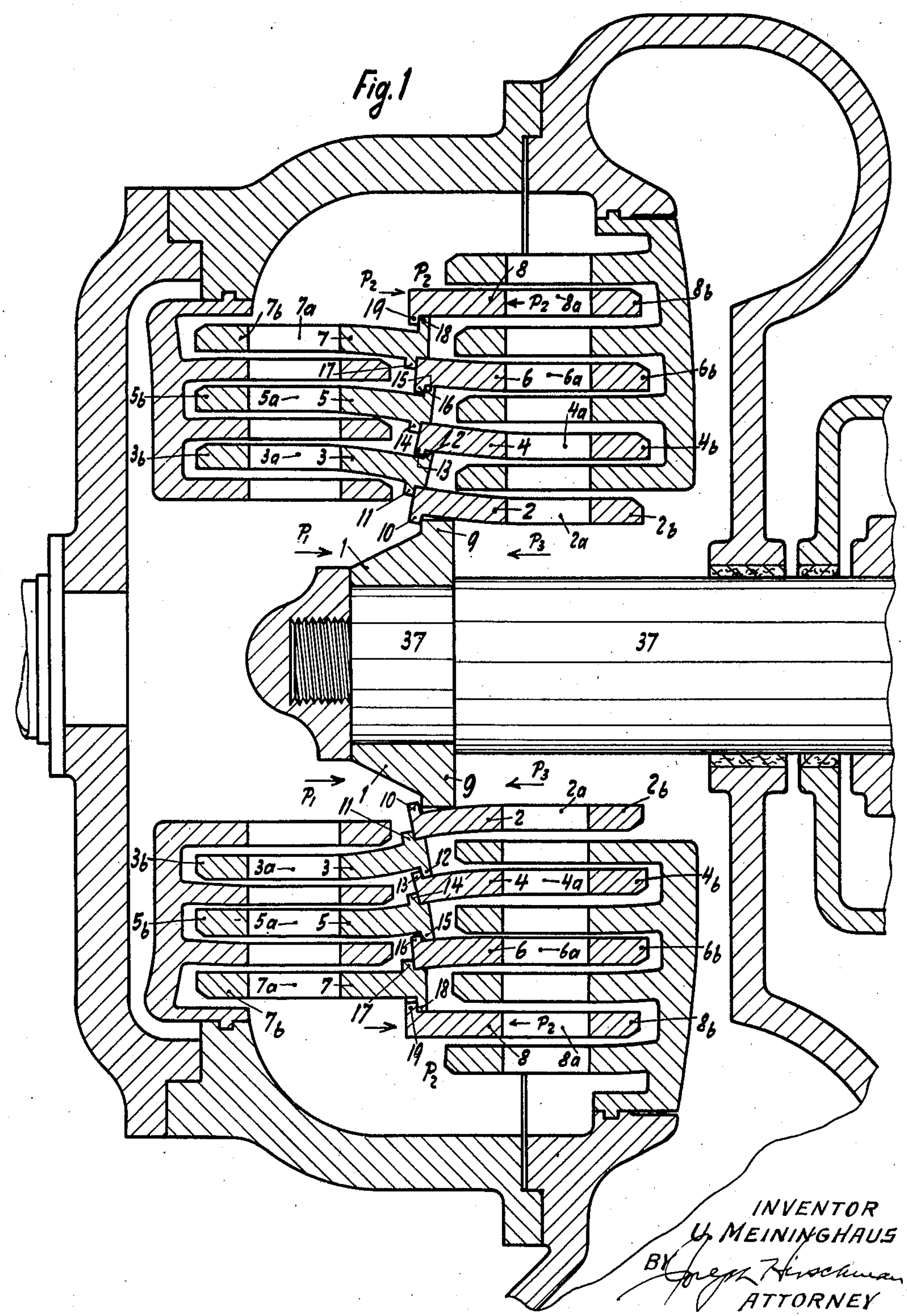

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Fig. 2

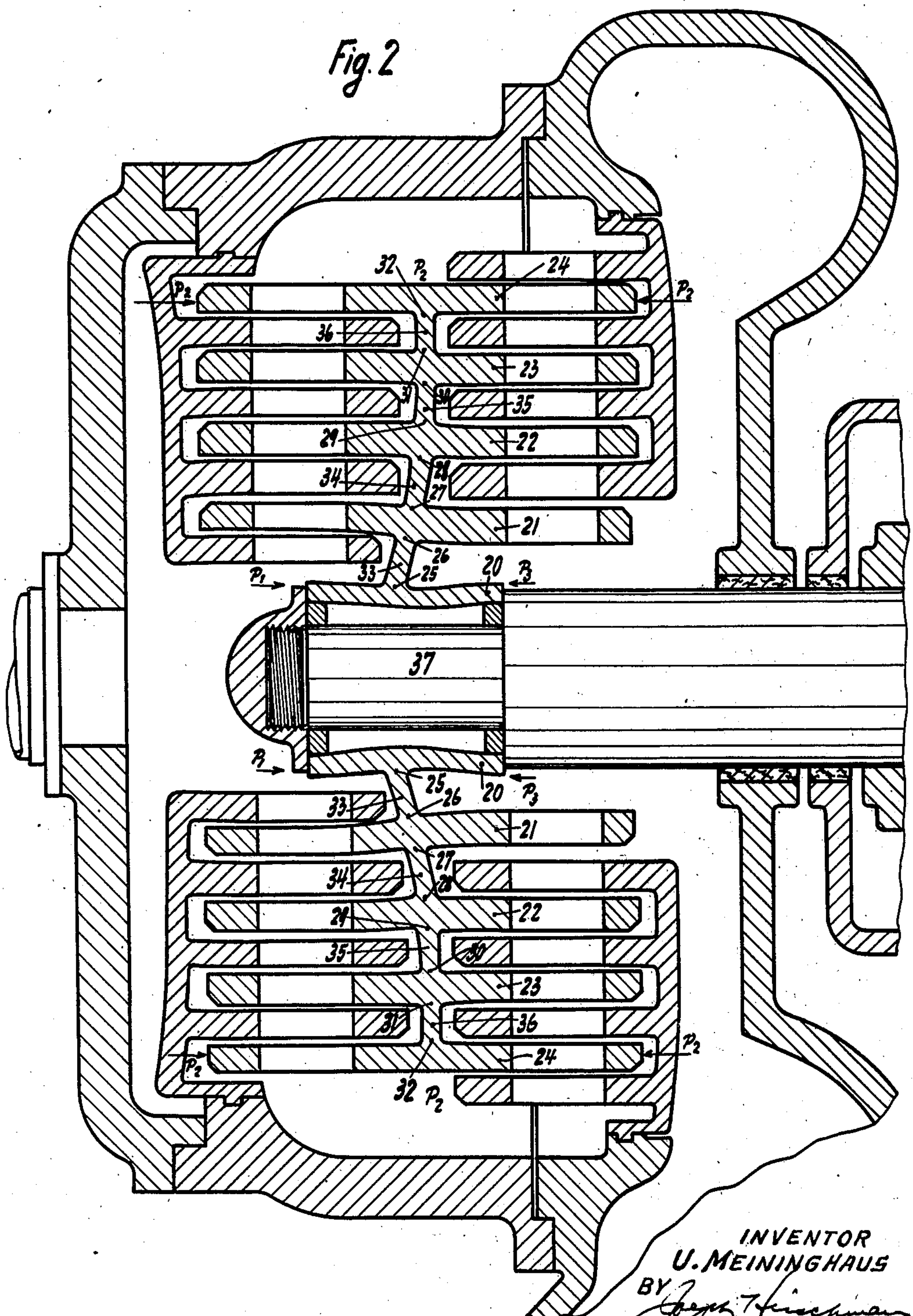

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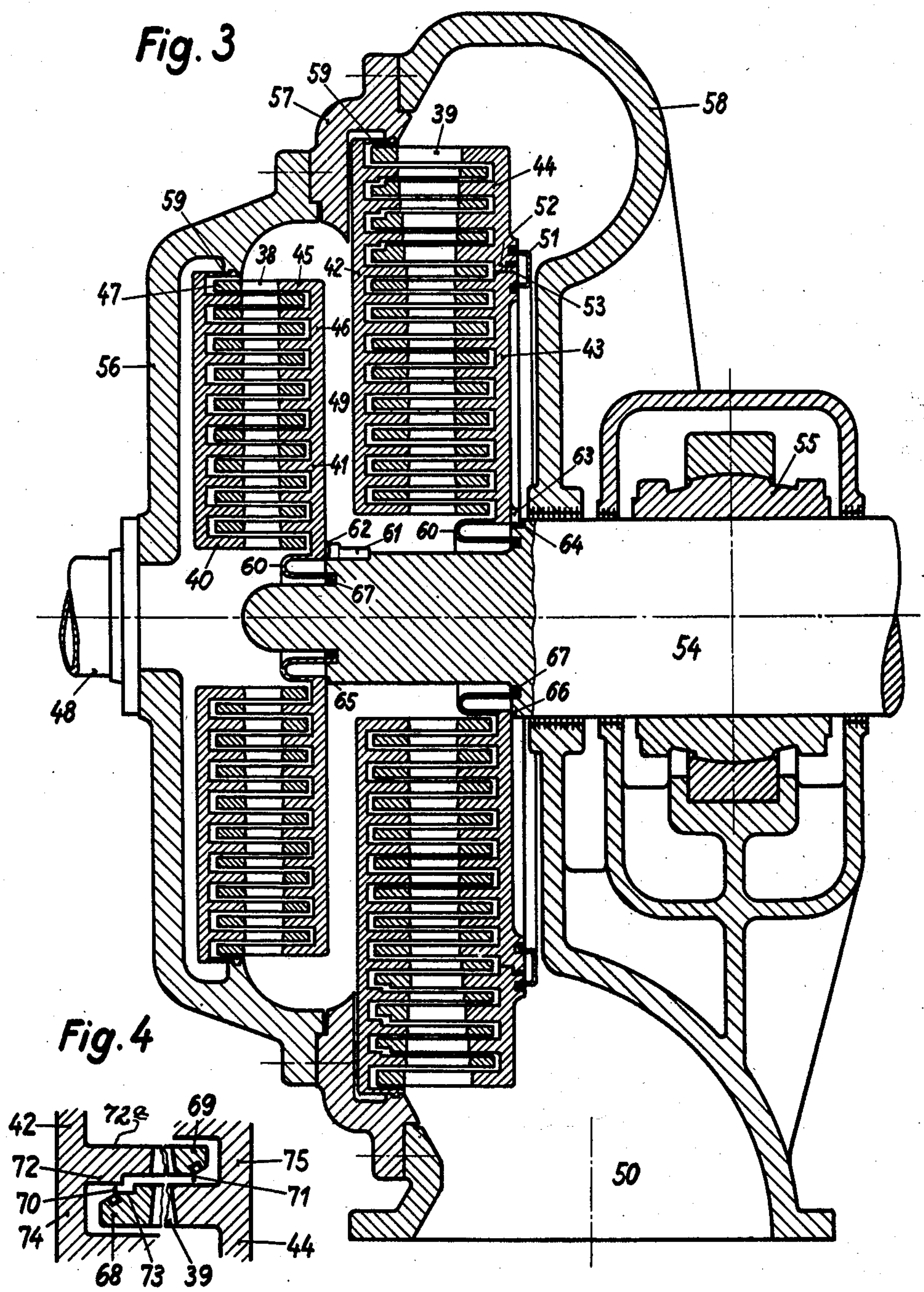
Fig. 3



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DISK CONSTRUCTION FOR RADIAL FLOW MACHINES

Ulrich Meininghaus, Mulheim-Ruhr, Germany

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7 Claims. (Cl. 253—87)

My invention relates to the construction of disks for use in machines wherein they are exposed to the action of a heated medium and are subjected to axial thrust, as in a radial flow turbine where they support the turbine blades.

In certain constructions annular elements arranged concentrically to each other and contacted by a heated medium have to be supported in such a way that they are able to contract or expand freely according to changes in the temperature of the surrounding medium, while the support has to be capable of resisting considerable thrust in axial direction. Thus the centrifugal force of the blades in turbines impinged in radial direction is for instance advantageously taken up at both blade ends by means of rings. While the one ring—called the head ring—floats freely between the corresponding rings of the adjacent rows of blades, being retained in a centric position by the other ring through the blades, the other ring—called the root ring—has to be centrically supported and besides must transfer the torque generated in the row of blades which is fastened to it.

In this case it is of extreme importance that the root rings arranged between the head rings of the adjacent rows of blades be able to follow the changes in diameter produced by expansion or contraction due to variations in temperature of the driving medium just as freely and quickly as the adjacent head rings. Any difference in contraction or expansion and therewith in the changes of the diameters immediately causes wear of the fine sealing edges between the rings of blades and increases accordingly the steam leakage. As these fine edges match against the corresponding rings with clearances of only from 0.1 to 0.2 mm., an increase of these clearances by from 0.1 to 0.2 mm. would thus double the leakage of steam.

Such a support of the root rings should retain sufficient "heat flexibility", i. e. sufficient flexibility to contract or expand according to changes in the temperature, and at the same time transfer the torque. But during the flow of the driving medium through the turbine along the disk in radial direction said medium expands and diminishes in pressure. Thus differences in pressure between both sides of the support are produced and accordingly the support has to withstand considerable axial thrusts while at the same time no leakage through the support due to the pressure difference should occur.

Finally it is required that the weight and the extension of the support be as small as possible because the weight and the axial length of the rotating parts will determine in known manner the actual length of the turbine or the number of stages which may be arranged in series along the axis (critical speed, distance of bearings). The reduction of the weight and the axial length of the rotating parts is especially important when an overhanging shaft is used which may be of advantage with turbines impinged in radial direction.

The requirements which have to be fulfilled by said support are therefore to retain the annular elements in a centric position, to transfer the torque of the blades, to allow for sufficient "heat flexibility" of the annular elements, to withstand the axial thrust due to pressure difference, to prevent leakage due to the pressure difference, and yet have an axial length which is as small as possible.

The present invention has as its object to combine the highest economy in production with the meeting of all of the above mentioned requirements.

Taking account of the fact that the axial extension (thickness) cannot be adequately diminished so as to enable the support to receive and dissipate heat sufficiently rapidly while retaining enough strength against thrust, the invention aims at attaining this feature by correspondingly diminishing the radial extension (thickness). The invention is based on the conception that annular elements which are supported on two different diameters and are stressed at the supports by thrust in axial direction retain even then a considerable resistance against distortion if their extension in radial direction is less than in axial direction, and consists therefore in extending the annular elements less in radial direction than in axial direction and thus withstanding the forces occurring in axial direction mainly by means of tangential stresses which are substantially equally distributed in radial direction throughout the annular elements. With such annular elements the radial stresses—shear being negligible—vanish substantially completely, the forces occurring at each diameter being taken up directly at almost the same diameter by means of tangential stresses. In this way a heretofore unattained utilization of the material is effected as the stresses are not transferred any longer in radial direction to an already highly stressed part of the annular element, but are substantially equally distributed throughout the total radial extension of the annular element. The lack of radial stresses—shear being neglected—and the herewith attained good distribution of the tangential stresses are caused by making the outside and inside diameter of the annular element close to each other, i. e. providing a small radial extension as the tangential stresses which are at equal distortion inversely proportional to the diameter hardly vary with almost equal diameters. The material is utilized in a surprisingly good way, and even with small thickness the element will have an adequate resistance against thrust without being overstressed. As far as the "heat flexibility" is concerned, this is not altered by the fact that the small extension of the annular element is now arranged in radial direction.

In the application of said inventive idea to turbines impinged in radial direction the invention makes it possible to simplify extremely the construction by employing the root rings of the blades as structural elements for a disk subjected to thrust while, as above described, their resistance to distortion against axial thrusts which act at different diameters is made use of to stiffen the so constructed disk by supporting elastically the root rings against each other. Such a construction fulfills all the requirements mentioned above to a sufficient degree, the weight and the axial length of the support especially being diminished and the cost of manufacturing being reduced to a degree which heretofore had been thought of as impossible. Furthermore, a sufficient "heat flexibility" of the annular elements is secured by the fact that all parts, at least in one direction—either in radial or in axial direction—do not exceed a given maximum thickness and that in this way all parts are able to expand or contract at the same time, the whole construction thus following sufficiently rapidly the changes in temperature.

The drawings show schematically and by way of example, two constructions according to the inventive idea applied to disks with centre bore which are supported at the inner diameter. In said drawings,

Fig. 1 is a diagrammatic view for the purpose of explaining the inventive idea and shows a central section through a steam turbine with a rotating disk formed of separate annular elements which are joined to each other;

Fig. 2 is a similar view of a modified construction; and

Fig. 3 shows a section through a modified form of the invention and illustrates two radially impinged rotors or disks in series;

Fig. 4 shows a detail.

According to Fig. 1, the rotating disk consists of annular elements **1**, **2**, **3**, **4**, **5**, **6**, **7**, and **8**, formed separately from each other and arranged concentrically to each other and joined elastically with each other. The constructions illustrated are based on conditions which occur with turbines impinged in radial direction. The pressure of the working medium diminishes at the side of entrance from the pressure P_1 at the inner diameter to the pressure P_2 at the outer diameter while the pressure drops at the other side from the pressure P_2 at the outer diameter to the pressure P_3 at the inner diameter. At such a pressure distribution the annular elements **1** to **8** will be distorted in the manner illustrated, the distortion being exaggerated for the sake of clarity. It will be seen that the rings resist the distortion caused by the pressure difference on account of the fact that they are elastically supported on each other by flanges **9** to **19**. No additional support of the annular elements is required.

Fig. 2 shows a way of applying the invention to a construction which has been simplified as compared with Fig. 1. The showing of the distortions is based on the same pressure conditions as in Fig. 1. In Fig. 2 the annular elements are elastically joined in a most simple way by means of thin walled joints which are integral with the elements. These joints are absolutely tight against the pressure difference and also elastic and are strong enough to resist the distortions and stresses which may occur. This construction shows the roots **25** to **32** of the joints **33** to **36** arranged in the centre of the annular elements **20** to **24**. Said arrangement has the advantage that during rotation of the disk the centrifugal forces do not tend to increase the inclination of the annular elements at the joints. This feature is, however, in no way an indispensable part of the invention, as the roots of the joints may just as well be arranged out of centre or even at one end of the annular elements, as shown with the cooperating non-rotating disks. With the roots of the joints at one end of the annular elements the rear side of the disk will be smooth and of minimum surface and the heat transfer will be much less than with the arrangement shown in Fig. 2 for the rotating disk. The pressure will then be constant at one side of the disk and diminish only along the other side.

The construction of the disk from several annular elements arranged concentrically to each other and joined with each other elastically may be effected in different ways. The words "elastic joint" are intended to mean any joint which on the one hand assures joining the single rings to each other tightly against pressure difference, while on the other hand such a joint allows for sufficient temporary, that is, elastic distortion of the annular elements. Such a joint would, for instance, be provided by a construction in which the single rings are formed separately from each other, but are hooked to each other by means of annular shoulders and recesses or similar arrangements. A construction which is easier and cheaper to manufacture is obtained if the annular elements are connected to each other by means of thin walled joints integral with the rings. Such thin walled joints between the annular rings may be dimensioned in such a way that they are sufficiently elastic, but still adequately strong to withstand the resulting distortions and stresses. If the axial thickness of the joints is equal to or smaller than the radial thickness of the annular elements then also an adequate "heat flexibility" of the joints has been secured.

To avoid overstressing the joint **33** the inner annular element **20** which is supported on the torque transferring shaft **37** has to be of such a radial thickness and radial length that the angle of distortion occurring under load at the root **25** of the joint **33** will be substantially the same as the angle of distortion of the adjacent annular element **21** at this point in spite of the fact that the ends of the inner annular elements are fastened to the shaft with a press or shrunk fit or in some other way and therefore cannot expand or contract freely. By dimensioning the axial thickness of the joints equal to or smaller than the radial thickness of the annular elements an unimpaired heating or cooling and the free expansion or contraction of said elements are secured.

The blades in Figs. 1 and 2 are indicated by the reference characters 2a, 3a, 4a, 5a, etc.; while the head rings are designated as 2b, 3b, 4b, etc.

Fig. 3 shows a section through a back pressure turbine in which the blades or rows of blades 38 and 39 are supported by disks 40, 41, 42, 43, and 44, these disks being constructed according to the invention. The structural elements of the disk 41 for instance are the root rings 45 which support one end of the blades 38. Said elements are linked to each other by the elastic joints 46. The other end of the blades 38 is supported by the head rings 47. Steam enters through the inlet pipe 48, flows in an outward direction through the row of blades 38 where it gives off part of its work, streams back through the conduit 49 towards the shaft, and impinges now the row of blades 39 again in radial direction giving off the remainder of its work and leaving the turbine at 50. Giving off its work the steam expands and gradually drops in pressure. A pressure difference between the two sides of the above mentioned disks arises creating an axial thrust. According to the invention the disks are capable of resisting these thrusts, but the thickness of their walls nowhere exceeds a value which may prevent their following the changes of temperature of the working medium.

In Fig. 3 the elastic joints of the disks are arranged at one end of the foot rings; this arrangement has the advantage that the steam flows through the blades in an outward direction only, the area of flow increasing with the diameters of the rings in accordance with the expansion of the steam. To relieve the bending stresses caused by the centrifugal force and resulting from the unbalanced arrangement the disks 43 and 44 have been separated and linked by the elastic joint 51. This very thin elastic joint is relieved of the thrust by the shoulders 52 and 53. The disks 41, 43, and 44 rotate and are fastened to the shaft 54 which is supported by the bearing 55; the disks 40 and 42 are stationary and are supported by the housings 56 and 57, the latter being attached to the housing 58. To allow for free expansion and contraction, the stationary disks 40 and 42 are connected to the housings by thin, elastic joints 59 and the rotating disks 41 and 43 are connected in a similar manner by the thin, elastic joints 60 to the shaft. The thin, elastic joints 60 of the rotating disks are not able to transfer the great force due to the torque on their circumference when the diameter is small as the force increases with decrease of the diameter. To make the arrangement feasible a key 61 is provided at the shaft which fits with its surfaces running in radial direction in a slot on a shoulder 62 of the disk 41. In this way the torque is transferred directly from the disk 41 to the shaft 54 thereby relieving the thin, elastic joint 60 without interfering with the free expansion or contraction of the disk 41 in radial direction. The torque of the disk 43 is transferred in a similar way by the surfaces of the projection 63 of the disk 43 running in radial direction and fitting in a slot 64 on the shaft. The elastic joints 60 are relieved of the thrust for the same reason. The disks 41 and 43 rest at their surfaces 65 and 66, which run also in radial direction, against corresponding shoulders on the shaft. These surfaces, too, do not interfere with the free radial expansion or contraction of the disks. The elastic joints 60 which are integral with the disks are fastened to the shaft by caulking the free end into a notch by means of caulking wire as shown at 67; this way of fastening insures a joint which may always easily be separated and again renewed in spite of the fact that the joint is subjected to the action of the hot steam. Besides the joint takes very little space in radial direction. This latter feature is of great importance if a rather large number of disks has to be employed, as the joints increase in diameter to allow for assembling.

Fig. 4 shows on an enlarged scale a special feature of the rotating disk 44 of Fig. 3. It is known that the diameter of a ring or disk rotating at high speed becomes enlarged under the action of centrifugal force; and the proportional increase is greater for disks of larger diameter. For the efficiency of the turbine it is rather important that the leakage of the steam around the head rings 68 and 69 be diminished as much as possible. For this reason nickel strips 70 and 71 are caulked into the head rings by means of caulking wire as shown in Fig. 4. The edges of these nickel strips point outwards on the rotating head rings, but inwards of the stationary head rings, thus insuring that the clearances will diminish when the rotating parts increase their diameter under the action of the centrifugal force. With such an arrangement bosses and recesses 72 and 73 have to be provided at the foot and head rings so as to permit change in the outer diameter of one of the corresponding nickel strips, such as the strip 70, and thus to insure the possibility of shifting the other nickel strip thereover during the assembly of the turbine. With disks according to the invention it is of the utmost importance that said bosses and recesses be arranged on the head rings of the rotating parts and on the root rings of the stationary parts. In view of the great stresses due to the centrifugal force to which the rotating blade rings of large diameter are subjected, the rotating blades will have a greater radial extension (thickness) than the stationary blades which will be made as small as possible to allow for as great a number of stages in a given space as possible. Such a case is represented by the disk 44 in Fig. 4. In such a case the arrangement shown in Figs. 4 and 3 for the disks 42 and 44 results in a practically equal length of the elastic joints for both disks in spite of the fact that the radial extension of the blades is different. Were the arrangement otherwise, the elastic joint 74 might be too long to resist the thrust or the elastic joint 75 too short to allow for sufficient distortion of the root rings without overstressing the joint. Besides the distribution of the masses of the rings 68 and 72a is surprisingly uniform, thus insuring an equal heating and cooling.

Finally, Fig. 4 shows a way of caulking in the nickel strips 70 and 71 which has great advantages. If the caulking is done in straight radial direction a replacement of damaged nickel strips in the assembled blading is impossible because the one head ring makes the next one inaccessible. If the caulking is done in straight axial direction the free radial length of the nickel strip is necessarily increased. This means greater difference in the outer and inner diameter of the free end of the strip and therefore a greater deformation when bending the straight strip to fit it to the diameter of the ring. The nickel strips are overstressed and break. According to the Fig. 4 the caulking is done in an inclined direction. The caulking may thus be done on the assembled blading, but the radial extension of the free end of the nickel strip is by no means increased. The edge along which the nickel strip extends across the gap is preferably rounded off to prevent injuring the strip. The inclination of the surface into which the caulking is done should not exceed 45° as compared with the axial direction for the same reason. Arranging the notch into which the nickel strip is fastened by means of a caulking wire in an inclined direction has in addition the advantage that the resistance of the caulking wire against the centrifugal force is increased as compared with the resistance of a caulking wire caulked in radial direction.

I desire to call attention to my copending application Ser. No. 682,178, filed July 26, 1933, wherein is disclosed and claimed an arrangement in which the connecting or joint members between the annular elements or rings do not lie in a radial plane normal to the shaft axis but rather along an inclined surface, such as the surface of a cone or of a paraboloid of revolution. The present application is directed to the construction of the annular elements or rings themselves, without limitation as to the specific structure of the joint members.

I claim:

1. A disk capable of withstanding thrust and suitable for use in machines working with a medium flowing in a radial direction, comprising a plurality of annular elements which are continuous in the tangential direction, said elements being of lesser thickness in the radial direction than in the axial direction, and arranged concentrically to each other, flexible joints capable of temporary distortion under stress disposed between and connecting said elements and being adapted to transfer axially directed forces in opposite directions to said elements at two different diameters of said elements, thereby exerting a torque on said elements around a tangentially directed neutral axis and generating tangential stresses in said elements, whereby said elements withstand the action of said axially directed forces chiefly by means of said tangential stresses.

2. A disk according to claim 1, wherein the annular elements are connected by means of joints which extend substantially perpendicularly to the axis of the disk.

3. A disk according to claim 1, wherein the annular elements are connected to each other by means of joints which are integral with said elements.

4. A disk according to claim 1, wherein the annular elements are connected by joints whose axial thickness is approximately equal to the radial thickness of the annular elements.

5. In combination, a rotary disk and a stationary disk constructed according to claim 1, said rotary disk having blades adapted to be impinged by an elastic fluid in a radial direction, carrier rings arranged to support one end of said rotary blades and serving as the annular elements of said rotary disk, said stationary disk having stationary blades adapted to be impinged by such elastic fluid in a radial direction, and carrier rings arranged to support one end of said stationary blades and serving as the annular elements of said stationary disk.

6. In combination, an interfitted rotary disk and stationary disk constructed according to claim 1, said rotary disk having blades adapted to be impinged by an elastic fluid in a radial direction, carrier rings arranged to connect the outer ends of the rotary blades and fitted with sealing members directed radially outwards, the other ends of said rotary blades being supported by the annular elements of said rotary disk, and said stationary disk having stationary blades adapted to be impinged by such elastic fluid in a radial direction, carrier rings arranged to connect the outer ends of the stationary blades and fitted with sealing members pointing radially inwards, the other ends of said stationary blades being supported by the annular elements of said stationary disk, the inner faces of said last mentioned annular elements having bosses cooperating with the sealing members of the rotary carrier rings.

7. A disk according to claim 1, wherein the disk is connected with its support through the innermost annular element, and wherein the radial extension of such annular element is only a small fraction of its extension in the axial direction, so that the angle of distortion occurring under load at the root of the joint which connects such element with the adjacent element is substantially equal to the angle of distortion occurring at the other root of the same joint under the influence of said adjacent annular element, the action of the axially directed forces being taken care of chiefly by the other annular elements.

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