May 5, 1953 L. M. KROUSE ET AL 2,637,488

COMPRESSOR

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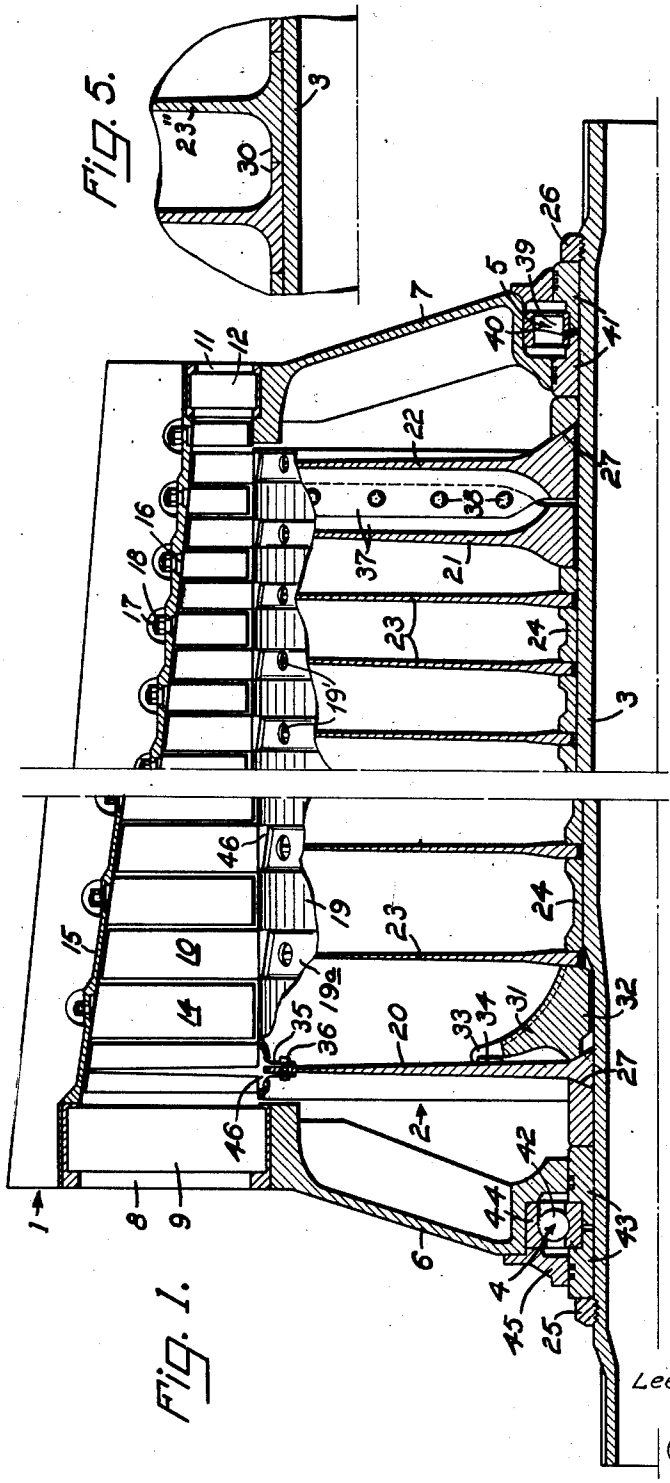


Fig. 1.

Fig. 5.

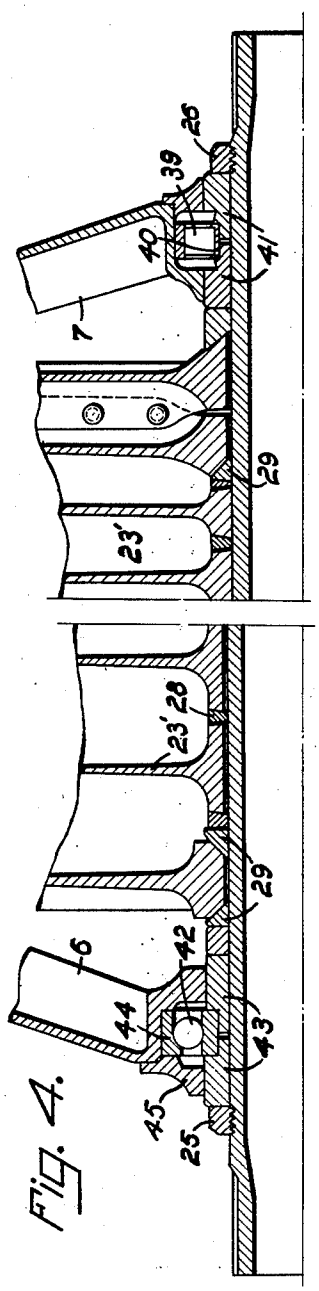


Fig. 4.

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Fig. 2.

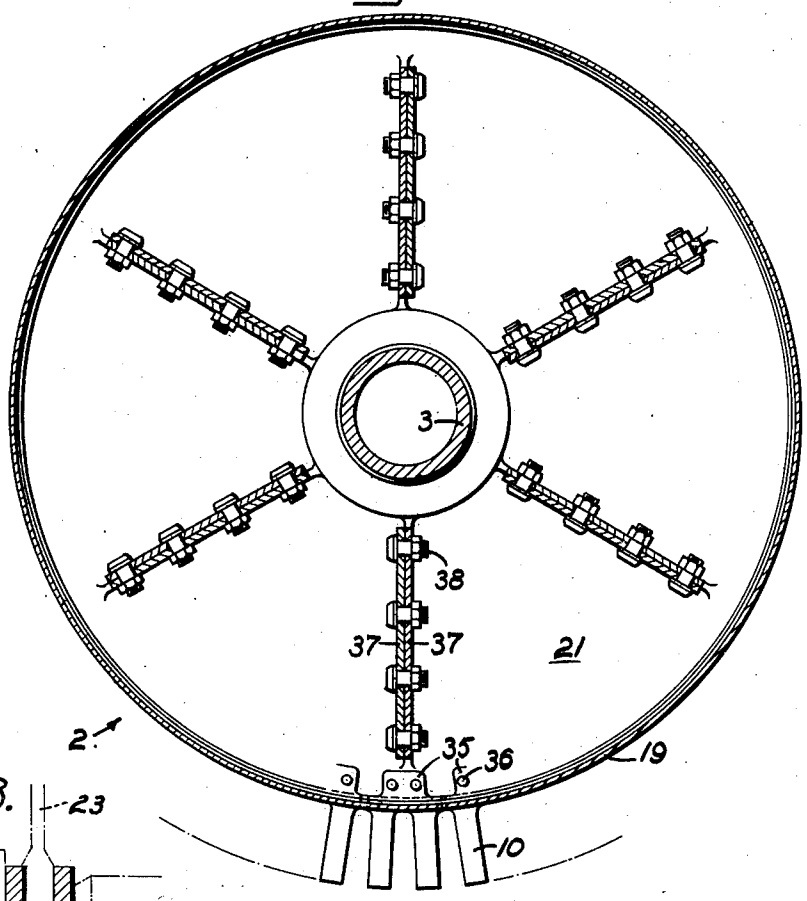


Fig. 8.

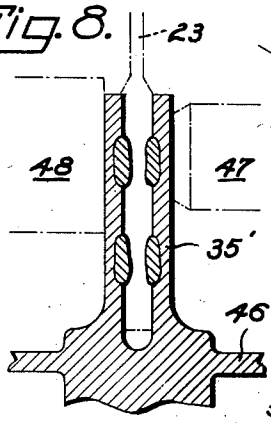


Fig. 3.

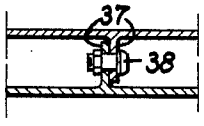


Fig. 7.

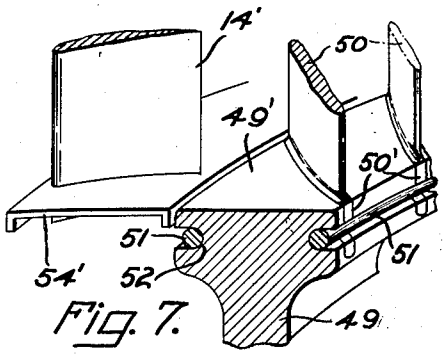
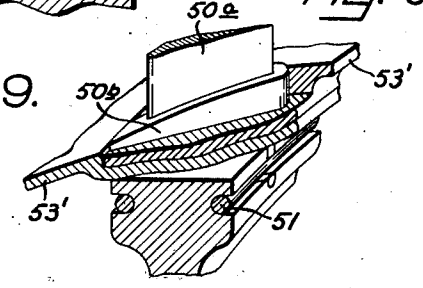


Fig. 9.



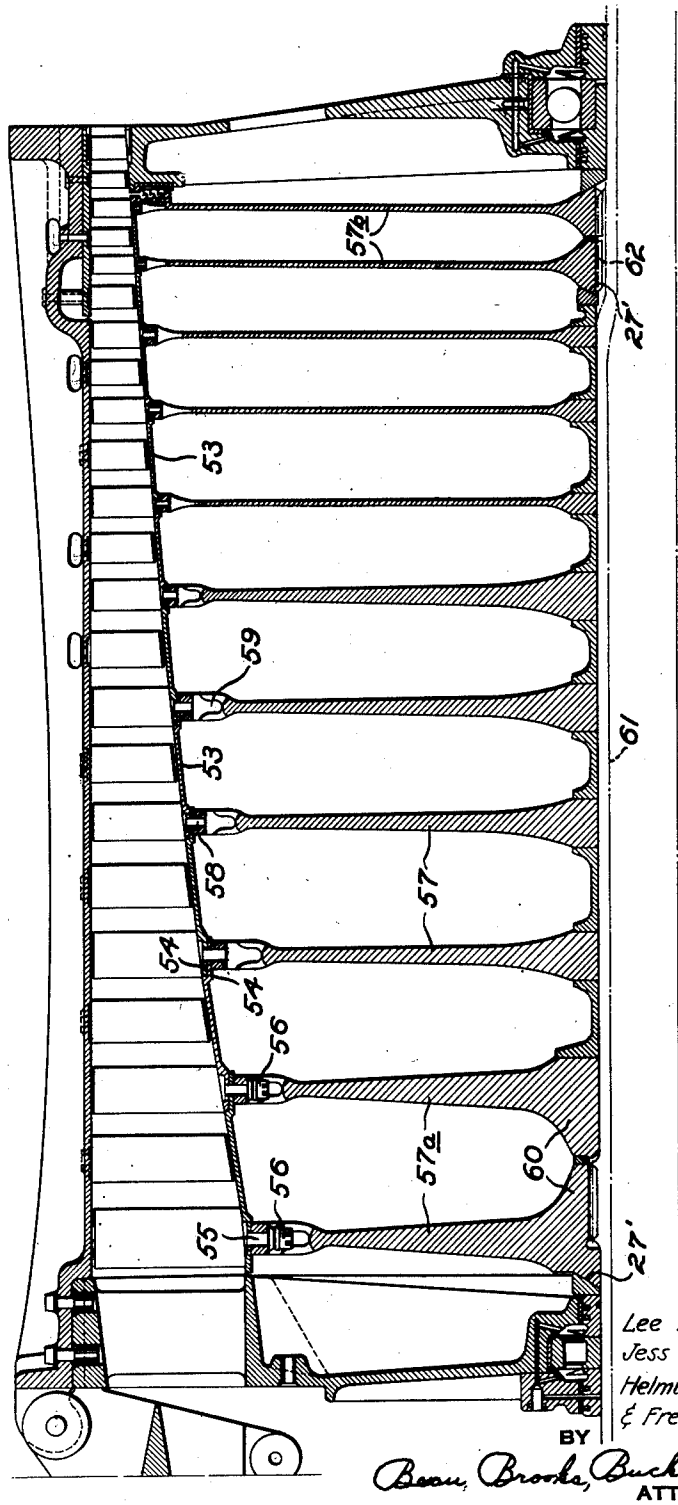
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Fig. 6.



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COMPRESSOR

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5 Claims. (Cl. 230—122)

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This invention relates to the fluid impelling and/or fluid impelled art and particularly to a rotor construction and the mounting of the blades thereon. In the turbine field especially wherein are encountered severe strains and stresses incidental to high rotative speeds, the prior rotor structures have been quite heavy and cumbersome.

The primary object of the present invention is to provide a light weight rotor of practical and durable construction, and one that may be produced economically and maintained in repair most readily.

An equally important object of this invention is to provide the lightest possible construction for the moving-blade carrying members by securing the most efficient usage of the material contained therein.

The invention further has for its object to provide a novelly fabricated structure of simple design which will satisfactorily withstand or accommodate the axial thrust placed upon the rotor by the air impelling blades thereof and effectively transmit the driving torque during operation.

It is well known that a disk can be made the lightest possible structure to resist a given radial loading due to blades attached to its periphery when the combination is rotated at high speeds. It is also well known that a tubular shell can be made the lightest possible structure to resist lateral bending due to loads transverse to its axis. Such transverse rigidity is required in a rotor to minimize undesirable vibrations of the rotor and in particular to avoid instability conditions by raising the critical speed of the rotor above the normal operating range. Further, it is well known that disks and shells, particularly when the thickness of such structure is reduced to the minimum necessary for resistance to rupture alone, are liable to instability and vibratory conditions which may impair their ability to carry the blades in a chosen path and/or may materially shorten the life of these structures.

It is also well known that a centrally-holed disk may be made lighter for a given loading if splines or other discontinuities which act as "stress-raisers" at the central hole periphery are avoided. Provision for transmitting the tangential loadings on the blades to the rotor shaft may then be made by means of friction between members fixed to the shaft and clamped to the disk and the disk itself. Hithertofore such frictional contact surfaces have not been disposed so as to aid the disk in resisting centrifugal forces.

It has also been the practice heretofore to utilize the separate advantages, and to counteract the disadvantages, of the other by combining blade carrying disks with a tubular shell structure. The resulting structure has the blade-carrying ability of the disks and the transverse

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rigidity of the shell while the instabilities of the thin disks and shell are avoided by their mutual reinforcements. Such combination has been made, however, either by means whereby the structural efficiency of the members has been impaired by "stress raisers" or by making the shell diameter less than the diameter of the disks or else by welding together rimmed disks in which the wide rims form part of the final shell. This last means of assemblage has disadvantages in limitation on materials used, in the special techniques and in the weight of material in preparation of the parts required for manufacture, and in the difficulty of maintaining in repair, as well as other difficulties attendant on assemblage of the blades to the structure.

Another disadvantage that such composite structures have heretofore suffered under is the diaphragm vibration of the disks which are only secured at their rims and are free to vibrate normal to their plane elsewhere. Still another disadvantage of such composite structures hithertofore has been the massiveness of the disks at either end of the rotor required to transmit the transverse bending moments from the shell to the stub shafts projecting from the rotor.

One phase of the invention resides in the anchorage of the blades to a plurality of axially spaced disks through a shell encircling the disks, in such a manner as to clamp the shell to the disks and bind blades, disks and shell into a unitary whole.

Further, the invention resides in the manner of clamping the disks together on a hub to ensure greater rigidity of the disks and/or to frictionally transmit the tangential forces from the blades to the hub, which clamping action may be effected by means which will assist the disks in resisting centrifugal forces.

Again, the invention will be found to reside in structural features which enable a firm anchorage for the blades of the rotor.

The invention will be comprehended more readily from the following description, reference being had to the accompanying drawings, wherein:

Fig. 1 is a fragmentary longitudinal section through the upper half of the improved compressor constructed in accordance with the present invention;

Fig. 2 is a cross sectional view through the rotor depicting more clearly the construction designed for resisting the axial thrust thereon incidental to its operation;

Fig. 3 is a detailed sectional view through one set of the interlocking strain resisting ribs;

Fig. 4 shows a modified securement for the rotor body forming disks;

Fig. 5 depicts a further modified mounting for the disks;

Fig. 6 is a fragmentary view in longitudinal

section depicting a modified compressor construction; and

Figs. 7, 8 and 9 illustrate modified modes of anchoring the rotor blades in place.

Referring more particularly to the drawings, the numeral 1 designates the stator of the improved compressor and 2 the rotor, the latter being fixedly carried by a shaft 3 which has journal support in the bearings 4 and 5 of the stator end frames 6 and 7, respectively. In the forward end frame 6 of the stator is an annular air receiving opening 8 in which are arranged the guide vanes 9 that serve to direct the inflowing air against the rotor blades 10 for most effectively moving the air. Within the air delivery opening 11 of the aft end frame 7 are arranged the fixed guide vanes 12 which may serve to direct the high pressure discharge into the usual combustion chamber (not shown) of the well-known gas turbine system. The rotor blades 13 extend radially from the periphery of the main rotor body and are disposed in rows thereabout in alternation with rows of fixed blades 14 on the stator frame 15. The stator blades may be made adjustable as well as replaceable by equipping them individually with circular hubs 16 and mounting shanks 17 threaded to receive the clamp nuts 18. By thus mounting the stator blades 14 they may readily be assembled on the stator shell and adjusted for their most efficient performance.

For lightness, the rotor body is made with an outer shell 19 and a supporting framework of disks. The number of body disks employed will depend upon the length of the drum-like rotor, and the end disks 20, 21 and 22 will preferably be heavier than the intermediate disks 23. The several disks are spaced apart on the rotor shaft 3 by spacing collars 24 which form therewith a composite hub and also serve to anchor the disks to the shaft when axial clamping pressure is brought to bear upon the assembly by the clamp nuts 25 and 26. For this purpose the hub-forming portions of the disks may be reinforced and shaped to provide a wedging embrace, as depicted at 27. Likewise, the spacing collars may have cooperating cam faces, as shown at 28 in Fig. 4 wherein ring-shaped wedges 29 are utilized to anchor the heavier end disks on the shaft. Or, the hub-forming portions of the disks may be extended, as shown at 30 in Fig. 5, to constitute the desired spacing medium and thereby eliminate the necessity of the separate spacers. In lieu of the wedge rings 28, the preferred embodiment of Fig. 1 employs a relatively heavy torque ring 31 which is splined on the shaft at 32 and has radial fingers 33 interengagingly straddling lugs 34 on the end disk 20.

The rotor construction just described is light in weight and readily fabricated. The several disks may attenuate radially toward their peripheries and be attached thereat to the shell. This is accomplished herein by having the blades anchored directly to the disks, and for this purpose the shell is formed with a peripheral series of holes 19' in the plane of each disk. Through these holes extend the anchoring stems 35 of the blades 13 for being secured to the disks. The blades seat upon the shell to form an interlock therewith which, when they are anchored to the disk, will bind the shell and the disks into a rigid unit. If desired, the rotor blades may have divided shanks 35 for straddling the peripheral edges of the disks for securement thereto by suitable anchor fasteners, such as rivets 36, as a means of securement between the disks and the shell. The broadened bases 46 of the blades seat in recesses 19a in the shell for lying flush with its outer surface and to afford support against angular displacement.

For reinforcing the rotor structure against axial thrust, two or more of the disks may be united rigidly to preclude relative lateral motion therebetween. To this end, the heavier disks 21 and 22 are provided on their adjacent faces with radial ribs 37, each rib of one disk overlapping a companion one of the other disk and being secured to such companion rib throughout its length by suitable fastening means 38. This provides a braced section in the fabricated rotor which gives rigidness thereto against the reactive forces from the air moving blades.

The end frames 6 and 7 of the stator housing provide journal support for the shaft 3, as above stated. Antifriction bearings may be arranged in a manner to facilitate assembly of the rotor. In one end frame is mounted a roller bearing 39 having its inner race 40 removably carried by a pair of cooperating sealing rings 41. Likewise, a ball bearing 42 is mounted in the end frame 6 by means of the sealing ring carriers 43, the frame-carried race 44 being secured by the bearing cap 45.

The divided shanks 35', Fig. 8, may be spot welded to the disk as an alternative mode of blade attachment, this being conveniently accomplished by the cooperating electrodes 47 and 48. Or the disks 49 may have a broad rim 49', Fig. 7, formed with inclined seats in which the blades 50 have their roots or shanks 50' placed in a manner to lie flush with the side faces of the rim. Thus, spaced parts on the disk straddle the blade shanks. The blade attachment is rendered secure by anchor fasteners in the form of wire rings 51 which fit in lateral annular grooves or seats 52 in the opposite side faces of the rim and the flush portions of the blade shanks. This simplified mode of blade attachment transmits the blade loads to the disks by double shear on the wire rings at both the leading and trailing blade edges. The anchor rings will be retained in place by suitable means such as by peening or rolling the outer edges of the grooves (not shown).

The shell of the drum may be of solid sheet formation, as illustrated in Fig. 1, or it may be composed of a series of ring shaped sections 53 having their margins 54 offset to nest in or telescopically fit the marginal portions of the adjoining sections, as shown in Fig. 6. By making the drum sections of progressively increased diameters the rotor will take on the form of a flaring body. Preferably, the several sections will be secured together by the blade mounting shanks 55 and their thread engaging nuts 56 which latter serve to unite the drum, blades and disks 57 into one rigid rotor structure. The rotor blade shanks 55 extend inwardly through radial holes 58 into pockets 59 in the disks for receiving the nuts 56 which act in radial tension upon the disks as they draw the blades and the shell inwardly to provide a practical structure in which the blades may be angularly adjusted in a manner similar to the stator blades 14 in Fig. 1. Obviously, the stator shell 15 may be composed of ring sections in like manner as the rotor of Fig. 6.

Or, the shell of the drum may be effectively fabricated by interposing rings 54' between the rims 49' of the adjacent disks 49, and suspending such rings from the stator housing by means of the stator blades 14'. The rings close the spaces intervening the rims 49' and cooperate therewith in forming a cylindrical shell upon which the rotor blades 50 operate. The closure rings 54' may be considered as constituting the inner shell of the compressor through which the disk carried rotor blades 50 extend. As an alternative construction, depicted in Fig. 9, the shell may be composed of rings 53' overlapping one another at their margins and having such overlapping margins formed with apertures through which the enlarged shanks 50*b* of the blades 50*a* extend for anchorage by the rings 51, all in a manner similar to the disclosure of Fig. 7.

In lieu of the special reinforcement 37, 38, the rotor disks 57, Fig. 6, may be more substantial and, if desired, with a reduction in thickness in the larger disks. The smaller but more rigid disks 57*a* may have enlarged hubs 60 splined to the shaft 61 for better withstanding the torque strains as well as the axial stresses. The lighter but larger disks 57*b* at the opposite end of the rotor also may be interlocked to the shaft by the feathers 62. Therefore, when the rotor hub components are compressed by the clamp nuts, similar to nuts 26, they cooperate with the tapered rings and hub surfaces 27' and effectively stretch the shaft 61 so that the latter will act as a loaded spring, or tie member, thereby transmitting torque through the friction on the surfaces 27' and relieving the splines of any sudden shock or intermittent vibratory loads. The rotor will therefore be rigid in structure and firmly fixed to the shaft.

The compressor is light in weight but nevertheless durable in construction by reason of the tie-in connections between the component parts which make up the rotor. The drum shell is relieved of the full load of the blades but is nevertheless interlocked to the disks thereby. The torque strains are transmitted in a practical manner to the rotor disks while the latter are designed to successfully resist the axial thrust. While the foregoing description has dwelt largely upon the disclosure as being applicable to the axial flow compressor, the invention is capable of use in other types of fluid flow machines where a light weight high speed rotor is desired, such as turbines, fluid motors and pumps, all being comprehended in the term compressor.

The foregoing description has been given for ease in understanding the invention and without any thought of limiting its scope beyond that defined in the appended claims, since the inventive principles are capable of assuming other physical embodiments without departing from the spirit of the invention set forth.

What is claimed is:

1. A stator element and a rotor element, one of said elements comprising a tubular body composed of ring-like sections each having its opposite margins telescopically fitting the margins of adjacent sections, and blades carried by said body and having anchoring shanks extending through openings in the overlapped margins for securing the sections against axial displacement.

2. A rotor comprising a shell composed of a plurality of ring-like sections having marginal portions interfitting one another in a telescopic

manner, a plurality of axially spaced disks arranged within the shell and supporting the same at the interfitting margins, and blades carried by the shell and having shank parts extending through and close fitting to openings in the interfitting margins and anchored to the underlying disks.

3. A rotor comprising axially spaced disks each having an annular series of pockets adjacent its margin thereabout, an enclosing shell supported by the disks, the shell and disks having registering holes opening into the pockets, blades seating on the shell and having shanks extending through the holes and into the pockets, and means in the pockets engaging the shanks to secure the blades and shell to the disks.

4. A rotor comprising a series of axially spaced disks each relatively thin and flexible in an axial direction and enclosed by overlapping margins of two cooperating rings forming a portion of an outer shell, a fluid impelling blade having as an integral part a base and a depending shank, the base being recessed within one of the cooperating rings to form a smooth exterior surface for the shell, and the blade shank extending radially inwards through the overlapping margins of the cooperating rings of the shell and into a recess in the margin of the disk, and a fastener attached to each blade shank and acting to align the cooperating rings of the shell and said fasteners acting radially to tension the thin flexible disks and thereby render the structure resistant to all operational loads.

5. A rotor comprising a shaft, a plurality of axially spaced relatively thin flexible disks on the shaft, an encircling shell enclosing the disks, and fluid impelling blades, a torque transmission means consisting of splines between one or more of the disks and the shaft, means for centering and compressing the disks against conical rings on the shaft, said blades having depending shanks which extend radially inward from the outer surface of the shell and through rim portions of the disks, the shanks being secured by fastening means recessed into holes through the disks, the shaft together with the conical ring tightening means and the blade shanks as well as such fastening means serving to align the entire structure and make it resistant to all operational loads and stresses.

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