June 2, 1959 E. A. STALKER 2,889,107

FLUID ROTOR CONSTRUCTION

Filed Jan. 3, 1955

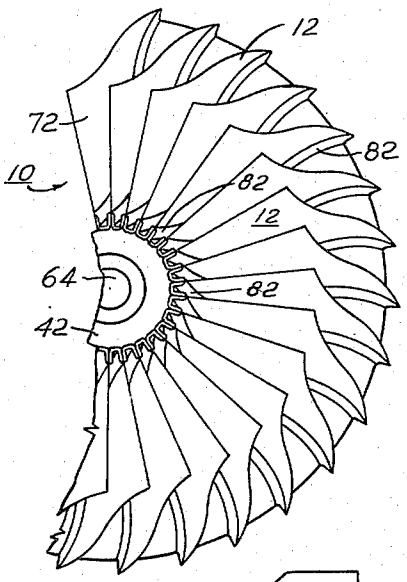


Fig. 2

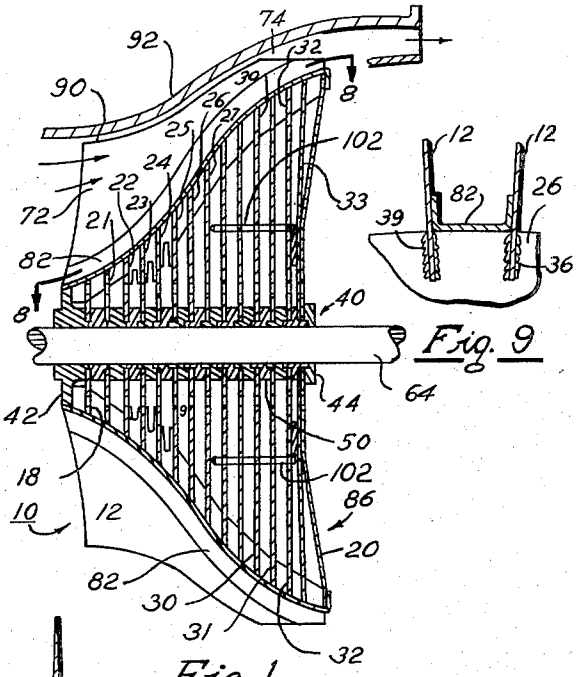


Fig. 1

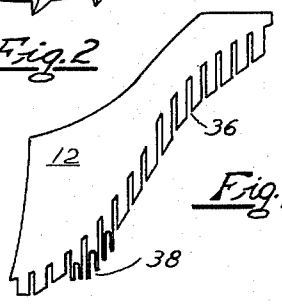


Fig. 7

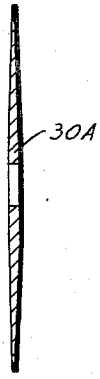
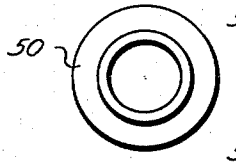


Fig. 3



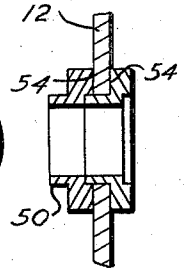


Fig. 4

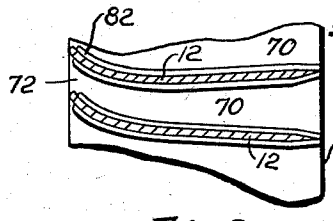


Fig. 5

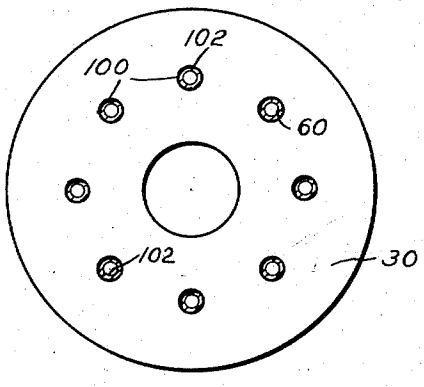


Fig. 6

Fig. 8

Fig. 9

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United States Patent Office

2,889,107

Patented June 2, 1959

2,889,107

FLUID ROTOR CONSTRUCTION

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Application January 3, 1955, Serial No. 479,593

9 Claims. (Cl. 230—119)

This invention relates to bladed compressor rotors for exchanging energy or force with a fluid.

An object of the invention is to provide a rotor of light weight which is economical to produce.

Other objects will appear from the specification, drawings and claims.

The above objects are accomplished by the means illustrated in the accompanying drawings in which—

Fig. 1 is an axial section through a rotor according to this invention;

Fig. 2 is a front fragmentary view of the rotor of Fig. 1;

Fig. 3 is a side elevation of a blade of the rotor;

Fig. 4 is an axial view of a hub element;

Fig. 5 is a fragmentary axial section through two adjacent hub elements;

Fig. 6 is an axial view of a disk;

Fig. 7 is an axial section of an alternate disk;

Fig. 8 is a fragmentary section on line 8—8 in Fig. 1; and

Fig. 9 is a fragmentary section on line 9—9 in Fig. 1.

In a mixed flow rotor the pumped fluid is displaced outward to obtain both radial and axial compression. To accomplish this the rotor passages between blades are directly radially outward and axially rearward. Each passage at its inlet has a large radial depth which decreases rearward, that is downstream of the passage flow, with the radial depth at the exit substantially smaller than the depth at the inlet. Customarily the exit depth is less than half that of the inlet.

In a mixed flow compressor the inner or hub surface of each rotor flow passage is substantially closer to the axis of rotation at the inlet than at the exit. The fluid accordingly has a substantial component of radial flow and receives significant compression from centrifugal action.

Rotors of the mixed flow configuration are difficult to machine if their structure is to be adapted to high tip speeds. Two types of construction have usually been employed. In one the rotor is cast of a light metal such as aluminum and then machined to provide smooth surfaces and to reduce the weight. In the other a forging of light metal is machined to the desired shape.

Because of the varying contours of the passages and blades both types are expensive. However, even more important, is the fact that light metals, aluminum for example, have poor fatigue properties. Since the rotor and particularly the blades are subject to severe vibration when rotated at such tip speeds as 1200–1400 feet per second, it is desired to use a material which has a high and definite fatigue strength. Steel (and its alloys) is such a material but its use entails machining from forgings for the best results, and since the material is heavy so much more machining is involved that the cost becomes very great.

In the present invention light weight is achieved and yet the cost of fabrication is lower than any of the other types heretofore used.

The blades are made of thin material preferably sheet metal such as a steel alloy. These are supported along their length by thin disks spaced apart axially.

In order to preserve the strength of the disks against peripheral stress therein they are preferably not slotted. It is the blades which are slotted to fit inward about the disk for forming a brazed joint.

A suitable closing means, comprising rim segments or the like, is provided between the blades to sustain the variation in pressure of the fluid flowing in the passages between the blades.

Referring to the drawings, particularly Figs. 1 and 2, the rotor is indicated generally as **10** comprised of the blades **12** peripherally spaced about an axis of symmetry or rotation. The blades are supported at their root ends on a plurality of axially spaced disks comprising two end disks **18** and **20** and intermediate disks **21—33** assembled in axially spaced relation with radially extending spaces between each pair of disks.

As shown in Figs. 2 and 3 each blade has a series of grooves such as **36** and **38** in its inner or root end. A disk fits into each groove and is fixed to the blades by fused metal between the disk and the blade at the lapping surfaces. The fused metal preferably provides fillets **39**, Fig. 9.

The disks are stacked axially, as shown in Fig. 1, each between two hub elements of the hub means **40**. The front hub element is **42** and the rear hub element is **44**. The intermediate hub elements are **50**. A typical hub element **50** is shown enlarged in Fig. 4 and in Fig. 5 together with a portion of a blade. The blade is fused to the side surfaces **54** of the hub elements so that the centrifugal load is carried by shear stresses in the joint between the disk and the hub element. The latter are also fixed together at their faying surfaces. Preferably the joints between the parts are made by solder or fused metal between them.

A typical disk **30** is shown in Fig. 6. It should have openings **60** for ventilation to facilitate soldering in a furnace employing a controlled atmosphere such as hydrogen, cracked ammonia, and the like.

The disks may also be tapered in thickness as shown by **30***a* in Fig. 7.

The rotor may be mounted on a shaft **64**, Fig. 1, to be rotated therewith.

As shown particularly in Figs. 2 and 8 the blades have the rotor flow passages **70** between them each extending from an inlet **72** at the front downstream to the exit **74** at the rear of the rotor.

The passages are closed at the inner or root ends of the blades adjacent the junctions of the blades with the respective disks by the rim means **80** which as shown here comprises the rim segments **82**. See Figs. 1, 2, 8 and 9. Preferably the segments are bonded to the blades by solder or other fused metal and also to the disks.

The assembly supporting the blades may be called the hub structure indicated as **86**.

The blades of the rotor have a sinuous contour **90** as seen in axial section and fit closely to the inside surface of the compressor case **92**, Fig. 1.

The disks are restrained from vibration by damper means **100** secured to a disk at a locality intermediate the hub elements or axis of rotation and the rim segments or inner ends of the blades. See Figs. 1 and 6.

The damper means comprises elements spaced peripherally about the axis of rotation and carried on each disk. Preferably these elements are loosely secured to each disk to bear on it under the action of centrifugal force. Preferably, too, the elements extend from disk to disk.

In Fig. 1 elements or tubes **102** are loosely carried in disk holes **60**. Such tubes are shown in Fig. 6 in cross

section. Each tube is sufficiently flexible that it bears radially outward against the surface of the hole which it occupies. The tubes are positioned axially by abutting against the disks adjacent to their ends.

To facilitate low cost fabrication, the hub structure is preferably of sheet metal construction. The disks are preferably cut by dies from sheet metal of the proper thickness, and the rim means is preferably formed in dies from sheet metal. Preferably the disks have a maximum thickness less than 2.5 percent of the axial distance between the end disks 18 and 20.

The blades may be cut from sheet metal and curved by the action of dies. For very high peripheral speeds at the blade tip, the thickness of each blade should be decreased from the root end toward the tip.

While I have illustrated specific forms of the invention, it is to be understood that variations may be made therein and that I intend to claim my invention broadly as indicated by the appended claims.

I claim:

1. In combination in a bladed rotor for exchanging energy with a fluid, a hub structure comprising a plurality of axially spaced sheet metal disks with radially extending spaces therebetween for rotation about the axis of symmetry thereof, hub elements positioned between said disks and bonded thereto by fused metal to space said disks apart axially, a plurality of sheet metal blades extending radially outward of and peripherally spaced about said hub structure defining flow passages having a large radial depth at the inlets thereof and decreasing in depth toward the exits thereof, each of said blades having axially spaced slots each receiving a portion of each of said disks thereinto, said blades being fixed to said disks by fused metal, and rim means fixed in said rotor at the junctions of said blades with said disks and extending from one blade to another providing inward walls bounding said rotor flow passages.

2. In combination in a mixed flow rotor for exchanging energy with a fluid, a hub structure comprising a plurality of axially spaced sheet metal disks with radially extending spaces therebetween for rotation about an axis of symmetry thereof, hub elements positioned between said disks and bonded thereto by fused metal to space said disks apart axially, said disks increasing in diameter rearward along said axis, a plurality of sheet metal blades extending radially outward of and peripherally spaced about said hub structure defining flow passages having a large radial depth at the inlets thereof and decreasing in depth toward the exits thereof, each of said blades having axially spaced slots each receiving a portion of each of said disks thereinto, said blades being fixed to said disks by fused metal, and rim means fixed in said rotor adjacent the inner ends of said blades and extending from one blade to another providing inward walls bounding said rotor flow passages.

3. In combination in a mixed flow rotor for exchanging energy with a fluid, a hub structure comprising a plurality of axially spaced sheet metal disks with radially extending spaces therebetween for rotation about the axis of symmetry thereof, hub elements positioned between said disks and bonded thereto by fused metal to space said disks apart axially, said disks increasing in diameter rearward along said axis, a plurality of sheet metal blades extending radially outwardly of and spaced peripherally about said structure and secured thereto, each of said blades decreasing in radial length rearward with said length at the rear end less than at the front end, and rim means fixed to said blades adjacent the inner ends thereof to enclose said disks.

4. In combination in a mixed flow rotor, a sheet metal hub structure comprising a front disk and a rear disk spaced apart axially, a plurality of axially spaced intermediate disks positioned between said front and rear disks and secured thereto for rotation therewith about the rotor axis, each said disk having an axial thickness less than 2.5 percent of said axial distance between said front and rear disks, a plurality of sheet metal blades extending radially outward of and spaced peripherally about said structure defining rotor flow passages having a large radial depth at the inlets thereof and decreasing depths toward the exits thereof, each of said blades being secured to each of said disks, and a plurality of rim segments secured in said rotor between adjacent said blades to enclose said disks and bound each rotor flow passage at the inward side thereof between adjacent said blades, each said passage having an exit and an inlet with the inward side of said exit positioned at a substantially greater radial distance from said axis than the inward side of said inlet is from said axis.

5. In a mixed flow compressor adapted to operate in a case, the combination of a sheet metal hub structure comprising a front disk and a rear disk spaced apart axially, a plurality of axially spaced intermediate disks positioned between said front and rear disks and secured thereto for rotation therewith about the rotor axis, a plurality of sheet metal blades spaced peripherally about said structure with rotor flow passages between said blades having their exits at a substantially greater radial distance from said axis than their inlets, each of said blades being secured to each of said disks, each of said blades fitting closely to said case, and a plurality of rim segments each extending between said blades adjacent the root ends thereof from front to rear thereof to bound said passages, each of said blades having a greater radial depth at its leading edge than at its trailing edge, each of said passages having an axial length greater than the radial depth thereof at the exit thereof.

6. In a mixed flow compressor adapted to operate in a case, the combination of a sheet metal hub structure comprising a front disk and a rear disk spaced apart axially, a plurality of axially spaced intermediate disks positioned between said front and rear disks and secured thereto for rotation therewith about the rotor axis, a plurality of sheet metal blades extending outwardly of and spaced peripherally about said structure with rotor flow passages between said blades, each of said blades being secured to each of said disks, each of said blades fitting closely to said case, and a plurality of rim segments each extending between said blades adjacent the root ends thereof from front to rear thereof to bound said passages, each of said blades having a greater radial depth at its leading edge than at its trailing edge, each of said passages having an axial length greater than the minimum diameter between the inward sides of said passages at the inlets thereof.

7. In combination in a compressor rotor defining an axis of rotation, a plurality of sheet metal disks spaced apart axially, a plurality of peripherally spaced sheet metal blades with each of said blades engaging with and being secured to the radially outer portions of a plurality of said spaced disks for rotation therewith about said axis tending to induce vibrations in said disks, and vibration damper means bearing on a plurality of said spaced disks at localities intermediate said axis and the inner ends of said blades and extending in the general axial direction from one disk to another.

8. In combination in a compressor rotor defining an axis of rotation, a plurality of sheet metal disks spaced apart axially, a plurality of peripherally spaced sheet metal blades with each of said blades engaging with and being secured to the radially outer portions of a plurality of said spaced disks for rotation therewith about said axis tending to induce vibrations in said disks, and vibration damper means bearing on said disks at localities intermediate said axis and the inner ends of said blades, said vibration damper means comprising elements extending through a plurality of said spaced disks at locali-

ties outward from said axis and bearing outward on said disks under the action of centrifugal force when said rotor is rotating.

9. In combination in a light weight bladed compressor rotor, a hub structure comprising a plurality of axially spaced disks including front and rear disks secured together for rotation about the axis of symmetry thereof, each of said disks increasing substantially in diameter rearward relative to the preceding disk, a plurality of blades extending radially outward of and peripherally spaced about said hub structure defining flow passages therebetween, and rim means extending peripherally about said axis at the roots of said blades and being bonded thereto along substantially the entire length thereof, said rim means lapping said front disk axially over the peripheral edge thereof and being bonded to said edge, said rim means having a radially extending

portion at said rear disk faying the surface thereof radially therealong and being bonded thereto.

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