June 5, 1956 E. A. STALKER 2,749,028

BLADED ROTORS FOR ELASTIC FLUID MACHINES

Filed Sept. 10, 1952 2 Sheets-Sheet 1

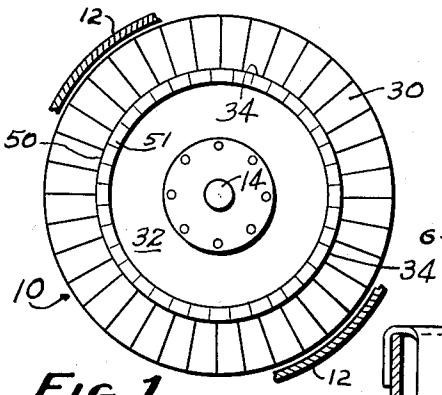


FIG. 1

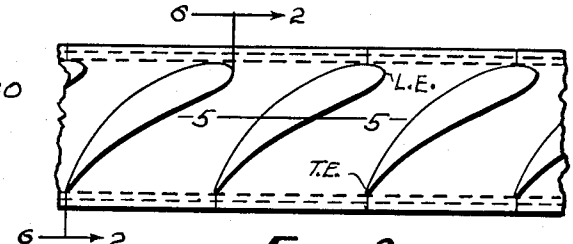


FIG. 3

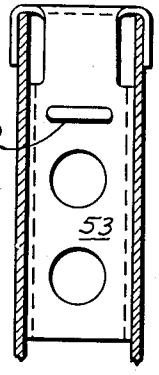


FIG. 6

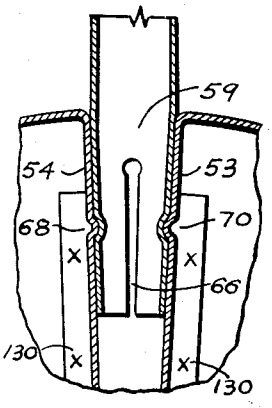


FIG. 5

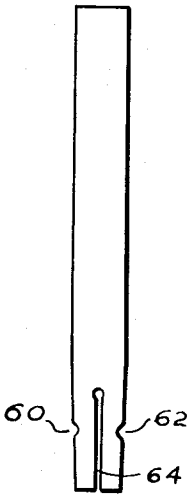


FIG. 7

FIG. 2

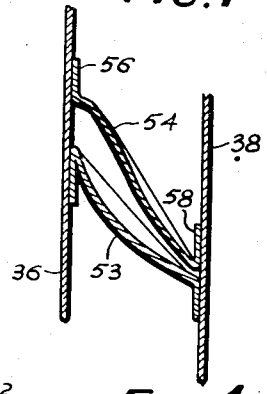


FIG. 4

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BLADED ROTORS FOR ELASTIC FLUID MACHINES

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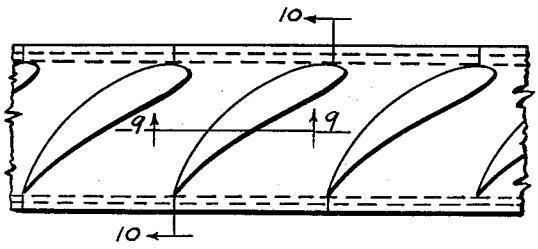


FIG. 8

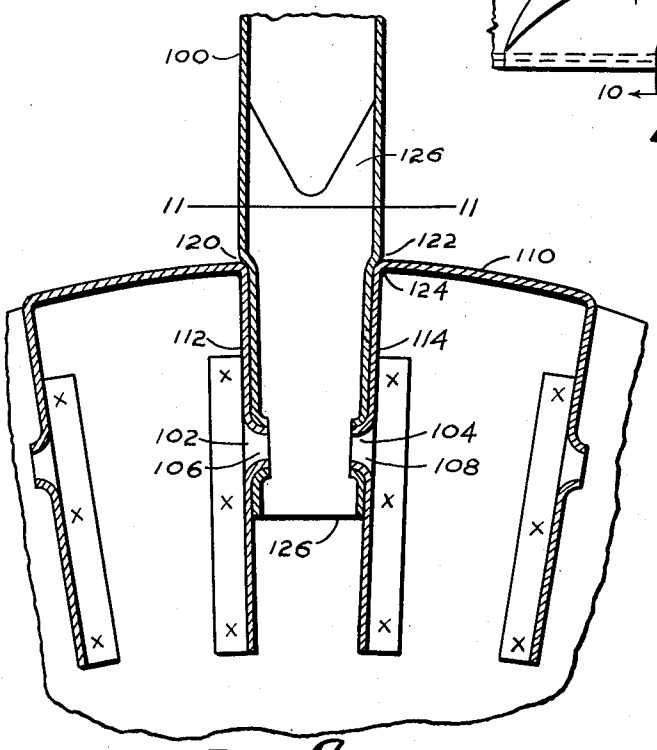


FIG. 9

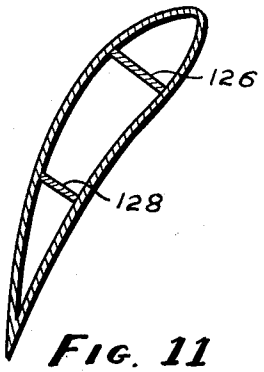


FIG. 11

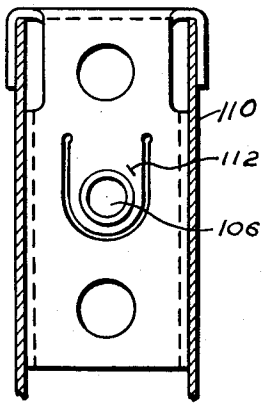


FIG. 10

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United States Patent Office

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BLADED ROTORS FOR ELASTIC FLUID MACHINES

Edward A. Stalker, Bay City, Mich., assignor to The Stalker Development Company, Bay City, Mich., a corporation of Michigan

Application September 10, 1952, Serial No. 308,861

10 Claims. (Cl. 230—134)

This invention relates to axial flow bladed rotors of sheet metal construction, adapted for use in axial flow machines for pumping elastic fluids.

An object of the invention is to provide a rotor which is economical to produce in large quantity and which is also light in weight.

Another object is to provide a sheet metal rotor having separate blades which require no blade bases.

Still another object is to provide a rotor of sheet metal construction wherein the blades can be inserted radially inward and be locked or keyed in position.

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

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

Fig. 1 is an axial view of a rotor according to this invention, shown in relation to fragments of a compressor case;

Fig. 2 is a fragmentary longitudinal section of the rotor of Fig. 1 on line 2—2 of Fig. 3;

Fig. 3 is a fragmentary development of the blades at their root end shown in relation to the rotor hub;

Fig. 4 is a fragmentary section on line 4—4 in Fig. 2;

Fig. 5 is a fragmentary section on line 5—5 in Fig. 3;

Fig. 6 is a fragmentary section on line 6—6 in Fig. 3 with the blade removed;

Fig. 7 is a leading edge view of a blade;

Fig. 8 is a fragmentary development of the blades of another rotor;

Fig. 9 is a fragmentary section on line 9—9 in Fig. 8;

Fig. 10 is a fragmentary section on line 10—10 in Fig. 8 with the blade removed; and

Fig. 11 is a section on line 11—11 in Fig. 9.

To facilitate production in large quantities, the blades are made separately by many small industries not equipped with large presses and furnaces. It is desirable to have the blades simple and readily inserted in the hub structure by unskilled hands.

Thus for simplicity, light weight and economical fabrication it is desirable to have blades which do not require the fitting or machining of blade bases and which are easily supportable in the hub structure without bases.

A compressor changes the density of the fluid flowing through it. In an axial flow machine this change is accomplished by adding velocity to the fluid and then slowing it down by diffusion. That is the fluid is given sufficient whirl speed so that when it is slowed down there is a significant change in density. Tip speeds of the blades are considered a criterion of whether a machine is a compressor or a simple fan. Compressors are considered to operate in the range above 400 feet per second, since not until this speed is reached with air is there a change in density significant for engineering purposes. At this speed the density change is about 4% which is just above the accuracy of common engineering measurements in industry.

When tip speeds exceed 400 F. P. S. the structural

problems become very difficult and increase in severity as the tip speed approaches the velocity of sound or even exceeds it.

At these high speeds new problems arise. It becomes difficult to provide blade attachments which are economical and strong. It also becomes difficult to provide rim segments which can sustain the high centrifugal loads without deformation and failure.

Successful high speed compressor rotors have employed solid blades which had heavy blade bases. These bases are fitted into a heavy hub rim which is suitably grooved to receive them. These heavy blades require heavy blade bases and these in turn require heavy hub rims. Furthermore the slotting of the rims to receive the blade bases destroys the peripheral continuity of the rim to resist peripheral stresses leaving heavy segments of the rims between blades which not only do not aid the hub in carrying its load but actually add to the load on the hub, since as remarked above, slots preclude the use of the material of these segments in carrying the peripheral stresses.

In the present invention the blades are made hollow of light sheet metal construction. Blade bases are not required and the centrifugal loads of the blades are carried directly to the side plates as the main structure for resisting the centrifugal loads. The rim is essentially a closure and at its ends is supported on the blades.

Thus by making the blades of limited weight the centrifugal load of the blades is greatly reduced. Since this load is small and limited, the heavy blade bases are eliminated, and because there is no heavy rim required to accommodate blade bases, the hub side plates can be of limited thickness and weight adapted to sheet metal construction. The thickness of the individual side plates, if the above theory is followed, can be less than about 0.0025 times the maximum rotor diameter, that is at the tips of the blades. The thickness of the respective blade and rim walls are substantially the same or less than the side walls.

Referring now to the drawings, particularly Figs. 1 and 2, the rotor is indicated generally as **10**. It is supported in the case **12** by the stub shafts **14** and **16** respectively in bearings **20** and **22** for rotation about axis **23**.

The rotor, Figs. 1 and 2, has the blades **30** spaced peripherally about the hub structure **32** with their leading and trailing edges (L. E. and T. E.) extending radially outward from the hub rim surface **34**.

The hub structure is comprised of the side plates **36** and **38** spaced apart axially and the rim segments **40** positioned between the blades, as well as the hub cylinder **44**.

Each rim segment, Figs. 1 and 2, is comprised of the curved rim wall **50**, the radially extensive flanges **51** and **52**, and the webs or elements **53** and **54**, Figs. 2 and 4. These have peripherally extensive flanges **56** and **58** faying with the side plates and bonded thereto.

Flanges such as **56** and **58** which are supported along a radially extensive line, I call, peripheral flanges. In like manner flanges such as **51** and **52** which are supported along a peripherally extensive line, I call, radial flanges.

The webs **53** and **54**, at their outer ends have contours which conform chordwise along the blades to their adjacent surfaces. Thus the web adjacent to the upper or convex surface of the blade fits closely to this surface so that they may be bonded together by fused metal means such as by soldering and the like.

The blades are hollow sheet metal structures preferably having side walls which are continuous or integral across the leading edge L. E. Preferably also the trailing edges

T. E. of the walls are fused together to form the trailing edge of each blade.

The sheet metal blade is fixed directly to the hub structure without a blade base which saves weight and cost as previously remarked. For this purpose the root end of each blade may be simply inserted into the socket **59**, Fig. 5, defined by adjacent webs **53** and **54** of adjacent rim segments and soldered in place. It is preferred however, to provide each blade with a positive means of holding it radially. For this each blade has the chordwise recesses or grooves **60** and **62** as shown in Figs. 5–7. Each blade also has the slots **64** and **66** at its leading and trailing edges extending upward a short distance from the root end. These slots permit opposite walls of the blade to be compressed toward each other slightly to enable the walls to be pushed past the chordwise projections **68** and **70** in the webs. See Figs. 5 and 6.

The projections nest in the grooves of the blades and assure surfaces at this locality which are in close or faying contact as required for soldering. For the flow of the soldering material, copper for instance, into the joint with wetting of both faying surfaces, the surfaces should be within about 0.003 in. of each other for certain results. Since the side surfaces of the projection and groove are somewhat parallel to the direction in which the blade walls and segment webs may separate these side surfaces do not separate by as much as the walls and webs.

In an alternate form of the invention shown in Figs. 8–10, the blades have flanged openings in their side walls. These flanges nest in flanged openings in the webs of the segments.

Thus in Fig. 9 the blades **100** each have the flanged openings (or recesses) **102** and **104** nesting respectively in the flanged openings **106** and **108** in the webs of the segments **110**.

In order for the blades to pass the hole flanges of the webs when the blades are inserted radially, the holes are in the tongues **112** and **114** as shown particularly in Figs. 9 and 10. These tongues spring back into place when the holes of the blade and webs register. In the soldering process the tongues are fused about their edges to the webs.

Each blade is narrower in the peripheral direction at its inward end below the recesses in its sides to facilitate entry between the webs of the rim segments.

The blades are preferably provided with the shoulders **120** and **122** to lap the corners **124** of the rim segments, whereby the angle between the blade wall and the segment approaches substantially a right angle.

The blades each have the spars **126** and **128** extending upward into the portion of the blade above the hub rim as shown in Figs. 9 and 11. This relieves the blade walls of stress concentration at the level of the rim arising from the side loads on them.

In assembling the rotor the peripheral flanges of the rim segments are spot-welded to the side plates by inserting an electrode through the central opening in one of the side plates.

The hub **44** is comprised of the parts **43** and **45** which are slid into position with respect to the side plates and spot-welded thereto by inserting electrodes through the openings **59** (Fig. 5).

All the spot-welded joints are subsequently soldered together preferably in a furnace with braze material such as copper, silver solder, and the like.

Compressor rotors of this invention have a static pressure rise along the passages between blades from leading to trailing edges thereof. To provide for this pressure rise the passages must have closed peripheral surfaces extending between blades from the leading to the trailing edges thereof. At the inner ends of the passages the rim segments sustain the static pressure while at the outer ends, the case performs this function.

Furthermore since there is a relatively large pressure rise from leading to trailing edges, the ratio of hub radius to blade tip radius must be relatively large of the order of 0.5 or more, and preferably 0.6 or more.

Preferably also, the blades are spaced peripherally apart less than a blade chord length to sustain the pressure difference between front and rear of the rotor without a return flow at the hub surface.

For rotors whose diameters are of the order of 35 inches, typical wall thickness for the blades is preferably of the order of 0.025 in. with a range from about 0.010 to about 0.035. The rim segments are of comparable thickness while the side plates may be somewhat thicker as for instance of the order of 0.035 in. and preferably not greater than about 0.050 in.

In order to achieve these limited thicknesses and weights, the surfaces of the side plates are generated by a substantially straight line extending outward from the axis of rotation. Thus the side plates appear straight in axial section between the locality of the rim and the locality of the hub cylinder **44**.

By making the blades hollow of sheet metal which permits the practical use of limited blade wall thickness the blade has a small or limited weight. The saving in weight in the blades reduces the load on the blade fastening and makes feasible the elimination of the blade base since the centrifugal stress is reduced both by the limited blade weight and the elimination of the blade base. These savings in turn cumulatively reduce the stress on the side plates so that they can be made of such limited thickness that they can be sheet metal structures. Thus it is not only the saving in weight made in the blades by making them hollow but the effect on the structure which carries the blades and sustains the centrifugal load. By starting with the blades the savings mount rapidly inward along the radius.

With these progressive limitations in weight inward along the radii, the parts can all be sheet metal pressings or stampings, reducing the weight by about 60% and the costs by a comparable amount.

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 an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a plurality of axial flow blades supported on said structure peripherally spaced thereabout and extending radially thereinto and between said plates, and a rim means comprising a plurality of peripherally spaced sheet metal rim segments each positioned between adjacent said blades, each said segment having an element extending radially inward and faying with the adjacent blade surface, each said blade being bonded to the adjacent said element, each said element having peripherally extensive flanges bonded to said side plates.

2. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a plurality of axial flow blades supported on said structure peripherally and extending radially inward between said plates, and a rim means comprising peripherally spaced sheet metal rim segments each positioned between adjacent said blades, each said segment having an element at peripherally opposite ends thereof extending radially inward and faying with the adjacent blade surface, said blade being bonded to the adjacent said elements on opposite sides thereof, each said element having flanges bonded to said side plates at localities inward from said blade.

3. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a plurality of axial flow blades supported on said structure peripherally spaced thereabout, and extending radially inward between said plates, and a rim means comprising peripherally spaced sheet metal rim segments each positioned between adjacent said blades, each said segment

having an element extending radially inward between said plates faying with the adjacent blade surface, said blade being bonded to the adjacent said element, each said rim segment having flanges directed radially inward at the front and rear thereof and bonded to said side plates, each said element also having peripherally extensive flanges bonded to said side plates.

4. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a plurality of axial flow blades supported on said structure peripherally spaced thereabout, and a rim means comprising peripherally spaced sheet metal rim segments each positioned between adjacent said blades, each said segment having an element extending radially inward between said plates and faying with the adjacent said blade surface, said blade being bonded to the adjacent said elements on opposite sides thereof, each said element having peripherally extensive flanges bonded to said side plates, each said blade having a recess therein, each said element having a projection adapted to nest in said recess.

5. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced side plates, a rim means comprising a plurality of peripherally spaced rim segments, each positioned between said plates and supported thereon, each said segment having a peripherally extending rim wall and elements at peripherally opposite ends thereof extending radially inward, said elements of adjacent said segments defining therebetween a plurality of sockets, each adapted to receive a blade, each said element having a part overlapping and supported on a said side plate, and a plurality of blades each positioned in a said socket and fixed to adjacent said elements.

6. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a rim means comprising a plurality of peripherally spaced sheet metal rim segments each positioned between said plates and fixed thereto, each said segment having a peripherally extending rim wall and elements at peripherally opposite ends thereof extending radially inward, said elements of adjacent said segments defining therebetween a plurality of sockets each adapted to receive a blade, each said element having a part extending adjacent and fixed to said side plates, and a plurality of hollow sheet metal blades each positioned in a said socket in faying relation to adjacent said elements, each said blade being fixed to adjacent said elements.

7. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a rim means comprising a plurality of peripherally spaced sheet metal rim segments each positioned between said plates and fixed thereto, each said segment having a peripherally extending rim wall and elements at peripherally opposite ends thereof extending radially inward, said elements of adjacent said segments defining therebetween a plurality of sockets, each adapted to receive a blade, each said element having a flange faying with a said side plate and fixed thereto, and a plurality of hollow

sheet metal blades each positioned in a said socket in faying relation to adjacent said elements, each said blade being fixed to adjacent said elements.

8. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a rim means comprising a plurality of peripherally spaced sheet metal rim segments each positioned between said plates and having front and rear flanges fixed thereto, each said segment having a peripherally extending rim wall and elements at peripherally opposite ends thereof extending radially inward, said elements of adjacent said segments defining therebetween a plurality of sockets each adapted to receive a blade, each said element extending inward and having a part bonded to a said side plate at localities substantially inward radially from said front and rear flanges, and a plurality of hollow sheet metal blades each positioned in a said socket in faying relation to adjacent said elements, each said blade being fixed to adjacent said elements.

9. In combination in an axial flow compressor rotor, a hub structure comprising axially spaced sheet metal side plates, a rim means comprising a plurality of peripherally spaced sheet metal rim segments each positioned between said plates and fixed thereto, each said segment having a peripherally extending rim wall and elements at peripherally opposite ends thereof extending radially inward, said elements of adjacent said segments defining therebetween a plurality of sockets each adapted to receive a blade, each said element having a flange at each of its front and rear ends bonded by fused metal each to the adjacent side plate, each said rim wall being fixed to said side plates, and a plurality of hollow sheet metal blades each positioned in a said socket in faying relation to adjacent said elements, each said blade being fixed to adjacent said elements.

10. In combination in an axial flow compressor rotor adapted to operate within a case, a hub structure adapted for rotation about an axis and incorporating a means of fixing blades therein comprising axially spaced sheet metal side plates, a rim means comprising a plurality of peripherally spaced sheet metal rim segments each positioned between said plates and fixed thereto, each said segment having a peripherally extending rim wall and elements at peripherally opposite ends thereof extending radially inward, said elements of adjacent said segments defining therebetween a plurality of sockets each adapted to receive a blade, each said element being fixed to said side plates, and a plurality of hollow blades having sheet metal walls of limited thickness, each said blade being positioned in a side socket in faying relation to adjacent said elements and fixed thereto, said blades of limited wall thickness in cooperation with said means of fixing adapting said side plates to have a limited thickness comparable to said blade wall thickness and not greater than about 0.0025 times the rotor maximum diameter.

No references cited.