May 13, 1958 E. A. STALKER 2,834,573

ROTOR CONSTRUCTION FOR FLUID MACHINES

Filed June 23, 1953

FIG-1

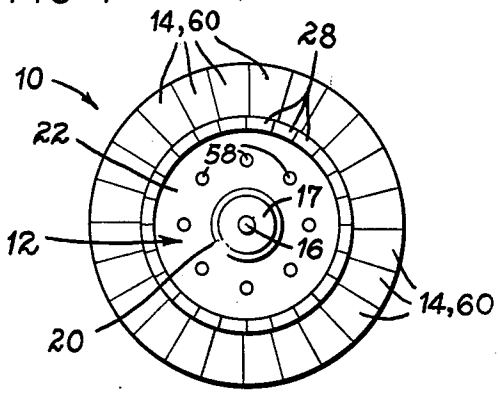


FIG-2

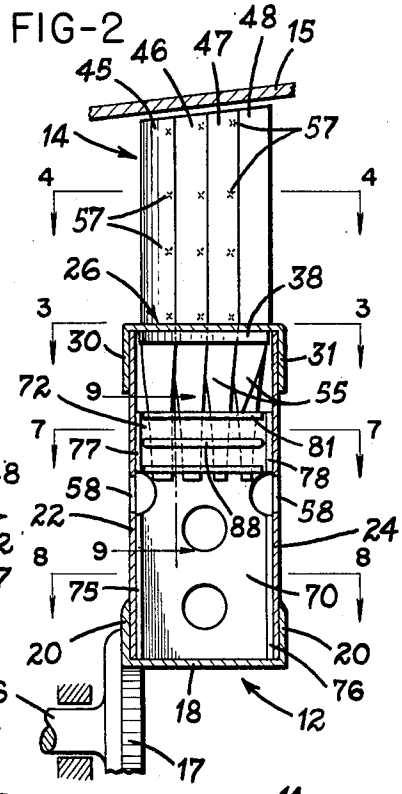


FIG-3

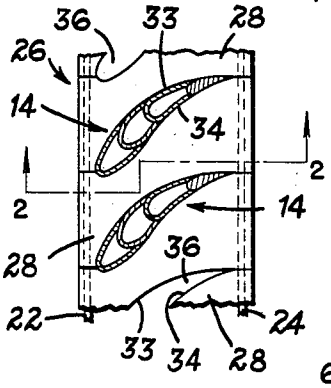


FIG-4

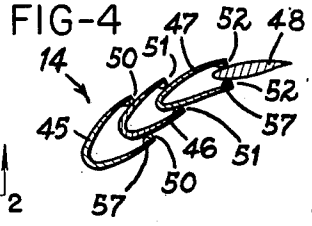


FIG-5

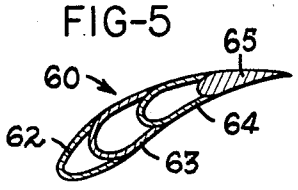


FIG-6

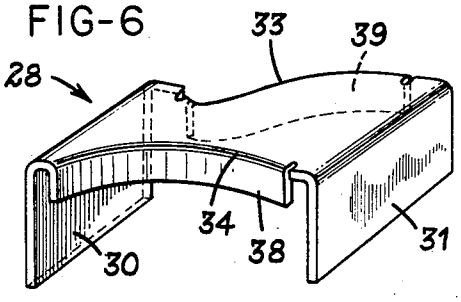


FIG-7

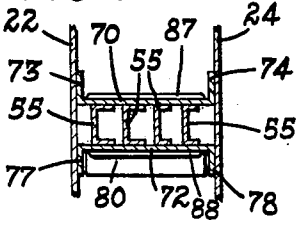


FIG-8

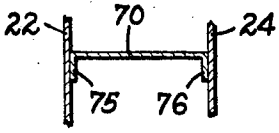


FIG-9

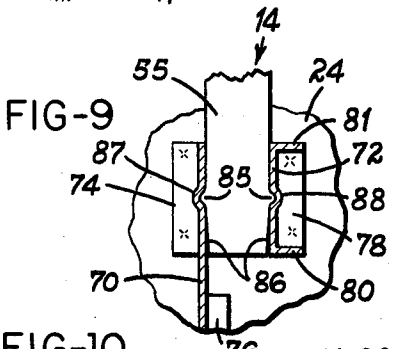
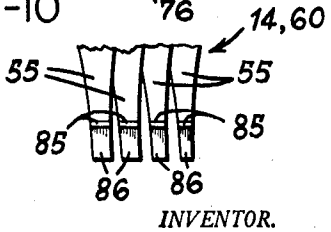


FIG-10



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ROTOR CONSTRUCTION FOR FLUID MACHINES

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Application June 23, 1953, Serial No. 363,472

15 Claims. (Cl. 253—39)

This invention relates to axial flow bladed rotors fabricated from sheet metal or other thin material.

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

Another object is to provide a rotor of sheet metal for economy of production.

Still another object is to provide a sheet metal rotor wherein the blades are independent sub-assemblies to facilitate production.

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

Fig. 1 is an axial front view of a rotor in accordance with the invention;

Fig. 2 is a fragmentary axial section taken on the line 2—2 of Fig. 3;

Fig. 3 is a fragmentary developed view taken on the line 3—3 of Fig. 2;

Fig. 4 is a sectional view of a blade structure on the line 4—4 of Fig. 2;

Fig. 5 is a similar view but of an alternate form of blade structure;

Fig. 6 is a perspective view of a rim segment;

Figs. 7 and 8 are fragmentary views of the blade supporting structure on the lines 7—7 and 8—8 respectively of Fig. 2.

Fig. 9 is a fragmentary section on the line 9—9 of Fig. 2 illustrating the blade retaining means; and

Fig. 10 is a fragmentary detail in side elevation of the shank end of a rotor blade.

The structures disclosed herein are for high speed machines operating with elastic fluids which are compressed or expanded significantly. That is the compressibility of the fluid plays the important role in the operation of the machine. The rotors may normally operate at speeds in the neighborhood of 1000 feet per second, that is, in the neighborhood of the velocity of sound. Compressibility becomes important at tip speeds of about 400 feet per second. Below this speed air and like gases can be treated as incompressible without introducing errors of significance.

It is difficult to build turbo-machinery to sustain the high stresses resulting from the high speed of operation and those machines currently successful have heavy blades, heavy blade bases and rotor hubs with heavy rims and hub disks, all of which are costly. In aircraft the weight is also a great disadvantage.

The present invention teaches a means of constructing such rotors of sheet or other thin material arranged in such fashion as to reduce the loads inward from the blade tips so as to make thin wall parts suitable. This greatly reduces the cost as well as the weight.

The blades are made of sheet metal of relatively thin walls as compared to the blade thickness. This limited thickness means a limited weight and hence limited centrifugal force of relatively small magnitude. By eliminating the blade bases no heavy rim is needed to receive them. In rotors with heavy rims and with recesses cut therein to receive the blade bases the pieces of thick rim

between the blades are not only useless for the strength of the hub structure but are actually an additional burden because the inner portions of the hub must carry the centrifugal load of these heavy rim segments. On the other hand if the blade is made of limited thickness and weight, the blade bases may be omitted and then the hub rim needs to carry only its own weight and accordingly can be made of limited thickness and weight. Then since the savings in centrifugal load accumulate inward from the blade tip at an increasing rate the central disk of the hub can be made of limited thickness and weight to sustain the greatly reduced centrifugal loads coming upon it. Thus, the hub structure can be made of sheet metal of a thickness comparable to the wall thickness of the blades.

The blade walls may have a thickness less than about 0.002 times the maximum tip diameter of the blades installed on their hub. The sum of the thicknesses of the the side plates may have a magnitude of about 0.003 times this maximum diameter or less.

In a typical case the blade walls may have a thickness of about 0.025 inch or as low as 0.008 if internal stiffeners are used in a rotor of about 36 inches diameter and the side plates may have a thickness of about 0.035 inch or less. The rim segments may have a thickness of about 0.020 inch, that is in the range of thicknesses of the blade walls.

Referring to the drawings, Fig. 1 shows a rotor 10 in accordance with the invention as having a hub assembly indicated generally at 12 carrying a plurality of blades 14. The rotor 10 is housed within a casing 15 and rotates about the axis of a stub shaft 16 driven by a suitable power source (not shown).

Shaft 16 with its flange portion 17 supports a channel shaped ring 18, which in turn has fused to the outwardly turned flanges 20, front and rear hub or side plates 22, 24. A rim 26 closes the peripheral gap of the spaced apart plates made up of a series of rim segments 28, one of which is illustrated in Fig. 6. Each segment is identical and have radially directed flanges 30, 31, faying in overhanging relationship with the plates 22, 24 respectively as best seen in Fig. 2. Flanges 30, 31 have a normal radial length of the order of one-half the maximum distance between the spaced hub plates, and are bonded to the plates by solder or other fusible metal.

The sides 33 and 34 of each segment are shaped so that adjacent segments, when assembled, cooperate both to define openings 36 having similar configurations as that of blades 14, as well as a continuous closure rim. Inwardly formed side flanges 38, 39 are provided on the sides of the segments and serve to support and secure the same to the blades by means of a fused metal bond with the side walls of the blades.

Blades 14 are preferably made up of a number of formed parts or sections 45—48 nested together as shown in Fig. 4. The sections are spaced apart from one another with the aft ends of sections 45—47 sprung apart from the root area to the outer ends thereof to define spanwise slots 50—52. The root portion of the blade is closed as shown in Fig. 3.

Each section below the root area is formed into an elongated integral shank portion 55 with a channel like cross section. This shank portion is adapted to serve as a means to attach the finished blade to the hub 12. Opposite walls of each section adjacent the slot area are fused together at spanwise spaced points 57 as indicated in Figs. 2 and 4.

Slots 50—52 serve to supply a flow of cooling air to protect the blades against hot turbine gases or to control the boundary layer on either the compressor or turbine blades. Additional air or other fluid cooling media

is supplied to the blades by way of a number of openings 58 in the hub plates 22, 24.

Fig. 5 illustrates a modified blade structure 60 having a plurality of formed sections somewhat similar to that of Fig. 4. In the modified form the rear edges of sections 62—65 are fused to the surface of adjacent nose portions of sections 63—65 respectively. Otherwise the structure is identical to that of blade 14 as described and shown in Fig. 4 except that the parts are so joined and brazed to form a continuous and uninterrupted smooth surfaced blade.

Individual blades are supported and aligned within the hub assembly by a thin wall web 70 on one side and bracket member 72 on the other side, Figs. 2 and 7 to 9. Webs 70 are made of sheet metal by stamping or pressing and have radially outer circumferential flanges 73, 74 and oppositely turned radially inner flanges 75, 76 spot welded and brazed to the hub plates. Brackets 72 are also made of sheet metal stock and are spot welded and brazed to the hub plates by means of flanges 77, 78 in spaced apart relationship with the webs 70, Fig. 9. Additional flanges 80, 81 serve to stiffen the bracket against centrifugal and side loads developed by the blades.

Preferably webs 70 and brackets 72 are assembled and welded to one of the hub plates before the other plate is assembled into place. Blades 14 or 60 are then inserted between a web and bracket. The shank ends of the blade section have a bead 85 extending transversely thereto and the portion of the shank below the bead is slightly tapered at 86 to facilitate assembly. The webs and brackets have oppositely extending grooves 87, 88 respectively to receive the beads 85 of the blade shanks. Thus each blade and its adjacent web and bracket are indented one relative to the other to locate the blade and provide additional strength to the sheet metal attachment means comprised of a web, a bracket and the inner end of the blade.

The tapered ends allow the shanks of a blade to be pushed radially inward between the bracket and the web until the bead 85 engages grooves 87, 88. A small springing of the web and bracket and the flanges of the shanks permits this engagement. The groove and bead also serve to locate the blade while the rotor is undergoing further work, and a solder is next placed at the joints and the rim segments 23 are assembled in place. After solder is placed at all joints the rotor is soldered together preferably by heating in a suitable furnace.

It is to be noted that the flanges are arranged to lap or fay the surfaces to which they are to be joined so that the centrifugal loads are carried by shear surfaces. The major part of the centrifugal load of each blade is preferably carried by shear flanges (73, 74, 77, 78) spaced substantially inward from the outer portions of the side plates. Thus the blades are supported by their shanks at a locality a substantial distance in from the perimeters of the side plates so that the weights of the bracket and the web are borne at a relatively small radius compared to the radius of the root of each blade. This lightens the load on the side plates and leads to a lighter structure adapted to sheet metal construction.

In the structure of this invention the centrifugal loads of the blades are carried to the side plates which are directed outward in the general radial direction along substantially straight lines so that the plates can resist the centrifugal loads in tension and consequently can be of limited thickness. In addition to the blade loads the side plates also carry loads from the rim segments. It is this combination of blade load and rim segment load as well as their own weight that the side plates resist in tension in order to have a limited thickness capable of sustaining the loads.

The side plates are spaced apart by a distance substantially equal to the axial length of the blades or at least a major fraction of this length so that the structure is strong enough to resist axial loads from the blades without significant deformation. This strength is augmented by the radial inward extension of the webs 70 and flanges 75, 76 radially inward to the plates 22, 24 of the hub assembly 12.

Each web 70, its associated bracket 72 and the adjacent portions of plates 22, 24 form a light weight sheet metal structure which acts as a holder for the individual blade.

By making the blades and rim means of limited weight, the accumulation of centrifugal load inward toward the axis of rotation is greatly reduced. It then becomes feasible to transfer the loads from the blade structural elements as for instance the shanks to the side plates by sheet metal stampings in the form of webs 70 or brackets 72. These webs or brackets then have sufficient surplus strength also to stiffen the rotor structure against axial loads. The elements transfer the blade centrifugal loads to the plates and relieve the rim means of radial loads, that is loads normal to the peripheral surface of the rim means. Consequently the rim segments are required to carry chiefly only their own centrifugal load and are substantially free of centrifugal forces developed in the blades as a result of which the rim means can be of relatively thin material.

Where the side plates have surfaces generated by a line rotated about the axis of rotation I designate the plates as being straight in axial section for ease of reference, particularly in the claims.

Since the centrifugal force varies as the square of the radius, a reduction in the radius to the joint can represent a substantial reduction in stress. For instance if the radius is reduced 10 percent the stress is reduced 20 percent. It is accordingly preferred to locate the joint carrying the blade stress to the side plates a substantial distance in from the hub rim 26.

In order not to dissipate the gain from moving the joint inward the connecting structure or elements between the blade root and the joint to the side plates must be light since the centrifugal force of elongated parts offsets to some extent the gain from the inward displacement of the joint. Consequently the connecting structure is made of sheet metal or sheet metal stampings.

The joints of the web to the side plates should be spaced inward from the hub rim by more than the radial depth of the front and rear flanges of the rim segments. This will be about equal to one-half the distance axially between the side plates. Preferably one or more of the webs should provide joints to the side surfaces at still further distances inward. This facilitates the carrying of the side load on the blades.

In an axial flow turbine or compressor rotor there is a substantial change in density and pressure of the elastic fluid passing through the rotor flow passages defined by the blades. To sustain the pressure and pressure variations from inlet to exit of the passages the hub must have a closed rim extending the length of each rotor passage. At the blade tips the case must extend axially along the lengths of the blades to sustain the pressures and their variation from inlet to exit.

An advantage in making the blades as individual parts is that they may be individually inspected for flaws and they may be individually selected for weight. Another advantage is that many small machines can produce the blades and they can be made in the plants of relatively small industries.

This application is a continuation in part of earlier application Serial No. 38,904, filed July 15, 1948, now Patent No. 2,649,278, issued August 18, 1953.

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

I claim:

1. In combination in an axial flow light weight rotor for interchanging force with an elastic fluid, a rotatable

hub structure comprising axially spaced sheet metal plates, a plurality of hollow axial flow blades of limited weight supported on said structure peripherally spaced thereabout and extending radially outward therefrom, said blades upon rotation developing limited centrifugal forces at the root ends thereof and a change in pressure and density of said fluid between the leading and trailing edges thereof, a plurality of radially extending webs peripherally spaced and extending axially from one said plate to the other, each said web having flanges on opposite sides thereof faying with the adjacent said plate, each said blade having a sheet metal element extending radially inward and secured to a said web, and a plurality of rim segments positioned between adjacent said blades to close the hub periphery and sustain said variation in pressure, said segments having flanges bonded to said blades and other flanges bonded to said plates, said elements serving to transmit said centrifugal forces to said web while leaving said segments substantially free of said forces, said webs and said rim segments cooperating to position said blades.

2. In combination in an axial flow light weight rotor for interchanging force with an elastic fluid, a rotatable hub structure comprising axially spaced sheet metal plates, a plurality of hollow axial flow blades of limited weight supported on said structure peripherally spaced thereabout, said blades upon rotation developing limited centrifugal forces at the root ends thereof and a change in pressure and density of said fluid between the leading and trailing edges thereof, a plurality of radially extending webs peripherally spaced and extending axially from one said plate to the other, each said web having circumferential flanges on opposite sides thereof faying with the adjacent said plates, each said blade having a sheet metal element extending radially inward and bonded to a said web, each said element and web being indented one relative to the other, and a plurality of rim segments positioned between adjacent said blades to sustain said variation in fluid pressure, said segments having flanges bonded to said blades and other flanges bonded to said plates, said elements serving to transmit said centrifugal forces to said webs while leaving said segments substantially free of said forces, said webs and said rim segments cooperating to position said blades.

3. In combination in an axial flow light weight rotor for interchanging force with an elastic fluid, a rotatable hub structure comprising axially spaced sheet metal side plates, a plurality of light weight hollow axial flow blades of sheet metal construction supported on said structure peripherally spaced thereabout, said blades upon rotation developing limited centrifugal forces at the root ends thereof and a change in pressure and density of said fluid between the leading and trailing edges thereof, a plurality of radially extending webs peripherally spaced and extending axially from one said plate to the other, each said web having circumferential flanges on opposite sides thereof faying with the adjacent said side plates, each said blade having a sheet metal element extending radially inward between adjacent said webs and being bonded thereto, and a plurality of sheet metal rim segments positioned between adjacent blades to sustain said variation in fluid pressure, said segments having flanges bonded to said blades and flanges bonded to said side plates adjacent the periphery thereof to close the hub structure periphery, said elements serving to transmit said centrifugal forces to said webs while leaving said segments substantially free of said forces.

4. In combination in an axial flow light weight rotor for interchanging force with an elastic fluid, a hub structure comprising axially spaced sheet metal side plates, a plurality of hollow axial flow sheet metal blades of limited weight supported on said structure peripherally spaced thereabout, said blades upon rotation developing limited centrifugal forces at the root ends thereof and a change in pressure and density of said fluid between the leading and trailing edges thereof, a plurality of radially extending webs peripherally spaced and extending axially from one said plate to the other, each said web having circumferential flanges on opposite sides thereof faying with the adjacent said side plates, each said web extending radially inward to a locality at a distance inward from the periphery of said side plates as great as the maximum axial dimension between said plates, each said blade having a sheet metal element extending radially inward and bonded by fused metal to a said web, and a plurality of sheet metal rim segments positioned between adjacent blades bonded thereto and to said side plates to close the hub periphery to sustain said variation in said fluid pressure, said elements serving to transmit said centrifugal forces to said web.

5. In combination in an axial flow light weight rotor for interchanging force with an elastic fluid, a rotatable hub structure comprising axially spaced sheet metal plates, rim means positioned about the peripheries of said plates defining a plurality of openings having flanges, a hollow sheet metal blade of limited weight positioned in each said opening and projecting radially outward therefrom, said blades upon rotation developing limited centrifugal forces at the root ends thereof and a change in pressure and density of said fluid between the leading and trailing edges thereof, each said opening having the contour of the root section of the blade therein, said rim means having radially directed flanges faying with a said plate and being bonded thereto by fused metal, said rim means between blades sustaining said variation in fluid pressure, each said blade being bonded to said opening flanges by fused metal, each said blade having an element fixed to a wall thereof and extending radially inward, and means bonded to the side surfaces of each said element fixing said elements to said plates at a locality spaced inward from said periphery by a distance at least as great as one-half the maximum distance between said plates, said elements serving to transmit said centrifugal forces to said plates while leaving said segments substantially free of said forces.

6. In combination in an axial flow light weight rotor for interchanging energy with an elastic fluid, a rotatable hub structure comprising axially spaced sheet metal plates, a plurality of hollow sheet metal blades of limited weight spaced peripherally about said hub structure and carried thereon, said blades upon rotation developing limited centrifugal forces at the roots thereof and a variation in pressure and density of said fluid between the leading and trailing edges thereof, and a thin walled rim means fixed to said plates defining peripherally spaced openings, said rim means having relatively small radial thickness less than 0.003 times the maximum diameter of said rotor, each said blade being positioned in a said opening, a plurality of sheet metal webs of limited wall thickness and weight spaced peripherally and fixed to said plates radially inward from the peripheries thereof, and a plurality of spaced sheet metal elements fixed to opposite walls of each said blade and extending radially inward between peripherally adjacent said webs, each said element being connected to pairs of adjacent said webs to transmit said force to said webs while leaving said rim means substantially free of said forces.

7. In combination in an axial flow rotor for interchanging energy with an elastic fluid, a rotatable hub structure comprising axially spaced sheet metal side plates, a plurality of hollow sheet metal blades of limited wall thickness and weight spaced peripherally about said hub structure and developing limited centrifugal loads at the root ends thereof upon rotation thereof, said blades upon rotation causing a change in pressure and density of said fluid between the leading and trailing edges thereof, a plurality of rim segments fixed to and about the peripheries of said plates, said segments having flanges defining peripherally spaced openings, said blades being positioned each in a said opening and being bonded by fused metal

to adjacent said flanges, a plurality of radially directed sheet metal webs spaced peripherally positioned between said side plates, each said web having a flange along a radial side thereof faying with a said side plate, and a plurality of sheet metal elements of limited wall thickness and weight fixed to a wall of each said blade and extending radially inward to a said web and being attached thereto to sustain said limited centrifugal load of each said blade and leave said segments substantially free of said load.

8. In combination in an axial flow rotor for interchanging energy with an elastic fluid, a rotatable hub structure comprising axially spaced sheet metal side plates, a plurality of hollow sheet metal blades of limited wall thickness and weight spaced peripherally about said hub structure and developing limited centrifugal loads at the root ends thereof upon rotation thereof, said blades upon rotation causing a change in pressure and density of said fluid between the leading and trailing edges thereof, a plurality of rim segments fixed to and about the peripheries of said plates, said segments having flanges defining peripherally spaced openings, said blades being positioned each in a said opening and being bonded by fused metal to adjacent said flanges, a plurality of radially directed sheet metal webs and brackets spaced peripherally positioned between said side plates, each said web and bracket having a flange along a radial side thereof faying with a said side plate, and a plurality of sheet metal elements of limited wall thickness and weight fixed to a wall of each said blade and extending radially inward to a said web and bracket and being attached thereto to sustain said limited centrifugal load of each said blade and leave said segments substantially free of said load.

9. In combination in an axial flow light weight rotor for interchanging energy with an elastic fluid, a rotatable hub structure, a plurality of hollow sheet metal blades of limited weight peripherally spaced about said hub structure and projecting radially therefrom and developing limited centrifugal loads upon rotation thereof, said blades upon rotation causing a substantial change in pressure and density of said fluid between the leading and trailing edges thereof, said hub structure comprising axially spaced side plates of limited weight, rim means fixed to said plates therebetween at the peripheries thereof and having a plurality of peripherally spaced openings each receiving therein a said blade, said rim means sustaining said variation in fluid pressure, and a plurality of peripherally spaced sets of radial webs and brackets fixed at opposite ends thereof to said side plates, each set comprising an associated web and bracket and the adjacent portions of said side plates defining a holder, each said blade extending radially inward from said peripheries into a said holder and being bonded thereto by fused metal.

10. In combination in an axial flow light weight rotor for interchanging energy with an elastic fluid, a rotatable hub structure, a plurality of hollow sheet metal blades of limited weight peripherally spaced about said hub structure and projecting radially therefrom and developing limited centrifugal loads upon rotation thereof, said blades upon rotation causing a substantial change in pressure and density of said fluid between the leading and trailing edges thereof, said hub structure comprising axially spaced side plates of limited weight, rim means fixed to said plates therebetween at the peripheries thereof and having a plurality of peripherally spaced openings each receiving therein a said blade, said rim means sustaining said variation in fluid pressure, and a plurality of peripherally spaced sets of radial webs and brackets fixed at opposite ends thereof to said side plates, each set comprising an associated web and bracket and with the adjacent portions of said side plates defining a holder, each said blade extending radially inward from said peripheries into a said holder and being bonded thereto by fused metal to said webs and brackets thereof, said webs having walls of limited thickness less than the thickness of a said plate.

11. In combination in an axial flow light weight rotor for interchanging energy with an elastic fluid, a hub structure, a plurality of hollow sheet metal blades of limited weight peripherally spaced about said structure and projecting radially therefrom, said structure comprising axially spaced plates, rim means fixed to said plates therebetween at the peripheries thereof and having a plurality of peripherally spaced openings each receiving therein a said blade, and a plurality of peripherally spaced sets of webs and brackets fixed at opposite ends thereof to said plates forming blade holders, each said blade extending radially inward from said peripheries into a said holder and being connected thereto.

12. In combination in an axial flow light weight rotor for interchanging energy with an elastic fluid, a hub structure, a plurality of hollow sheet metal blades of limited weight peripherally spaced about said structure and projecting radially therefrom, said structure comprising axially spaced plates, rim means fixed to said plates therebetween at the peripheries thereof and having a plurality of peripherally spaced openings each receiving therein a said blade, and a plurality of peripherally spaced sets of webs and brackets fixed at opposite ends thereof to said plates forming blade holders, each said blade extending radially inward from said peripheries into a said holder and being connected thereto, said webs and brackets comprised in said holder and the inward end of each said blade therein being indented one relative to the other.

13. In combination in an axial flow light weight rotor for interchanging energy with an elastic fluid, a plurality of hollow sheet metal blades spaced peripherally, a hub structure connected to and extending radially inward from said blades, said hub structure providing for the rotation of said blades at tip speeds sufficient to develop substantial variations in density and pressure of said fluid between said blades and a limited centrifugal force at the root end of each said blade, said hub structure including a sheet metal hub plate, a sheet metal rim means carried on said plate extending between said blades adjacent to the root ends thereof from leading to trailing edges thereof to sustain said variation in said fluid pressures, and sheet metal walls defining a plurality of peripherally spaced blade holders supported on said plate each serving to receive the inner end of a said blade in secured relation thereinto to sustain said centrifugal force while leaving said rim means substantially free of said force.

14. In combination in an axial flow compressor rotor for operation within a case, a hub structure incorporating a means of fixing blades therein comprising axially spaced sheet metal plates, a plurality of hollow sheet metal blades of limited thickness and weight supported on said structure peripherally spaced thereabout, said structure including a plurality of radially extending webs peripherally spaced and extending axially from one said plate to the other, each said web having peripheral flanges on opposite sides thereof faying with the adjacent said plate, and a plurality of rim segments positioned between adjacent said blades each having flanges secured by a fused metal bond thereto and other flanges secured by a fused metal bond to said plates, each said blade having a sheet metal element extending radially inward and secured to a said web by a fused metal bond, said blades of limited thickness cooperating with said bonds to enable said plates to have a limited thickness less than 0.003 times the maximum diameter of said rotor.

15. In combination in an axial flow machine for interchanging force with an elastic fluid, a case, a light weight axial flow rotor mounted in said case for rotation about an axis to develop a substantial change in density and pressure in said fluid comprising a hub structure including axially spaced rotor plates and a plurality of hollow axial flow blade structures supported thereon peripheral-

ly thereabout developing limited centrifugal forces at the inner ends of said blade structures in operation of said rotor, each said blade structure having a plurality of circumferentially spaced bracket elements secured to and extending between said rotor plates, said blade structure also having flanges faying the side surfaces of said bracket elements and being fixed thereto to sustain said limited forces, said hub structure including a rim means fixed to said plates and positioned between adjacent said blades adjacent to the perimeters of said plates to substantially close the hub periphery and sustain said change in pressure and side flanges on said rim

means extending in a generally radial direction and conforming to the shape of said blade structures to secure the same in assembled position.

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