Feb. 16, 1960 E. A. STALKER 2,925,248

BLADED WHEELS FOR AXIAL FLOW MACHINES

Filed May 22, 1953

2 Sheets-Sheet 1

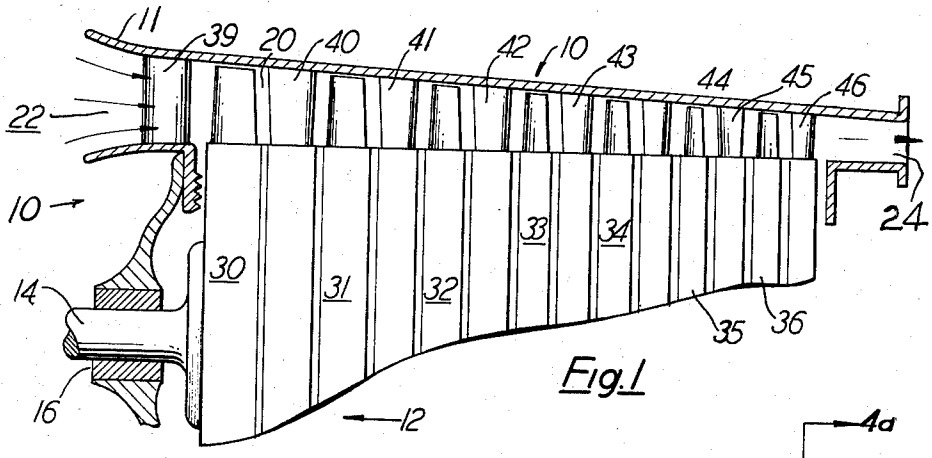


Fig. 1

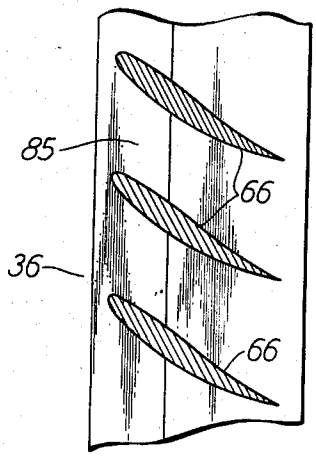


Fig. 3

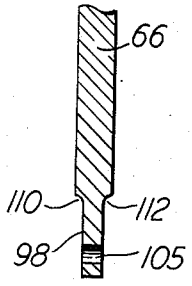


Fig. 4a

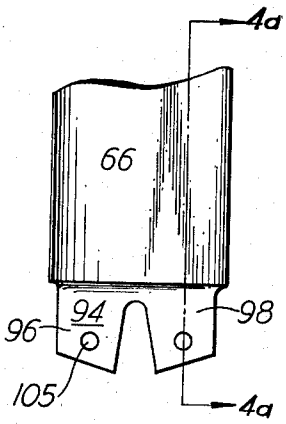


Fig. 4

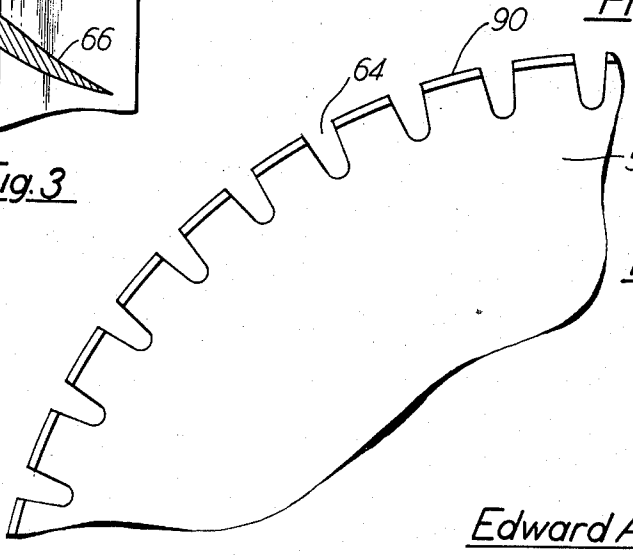


Fig. 5

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BLADED WHEELS FOR AXIAL FLOW MACHINES

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2 Sheets-Sheet 2

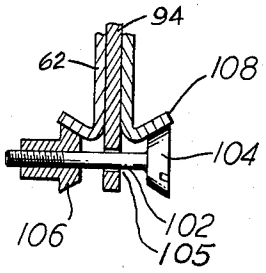


Fig. 7

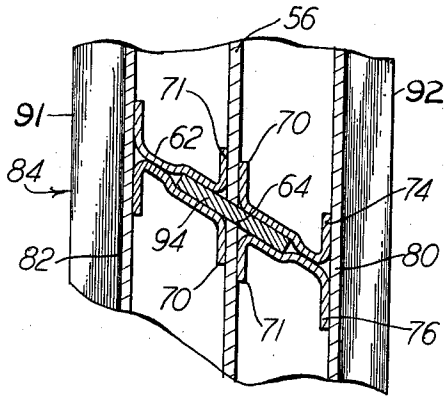


Fig. 6

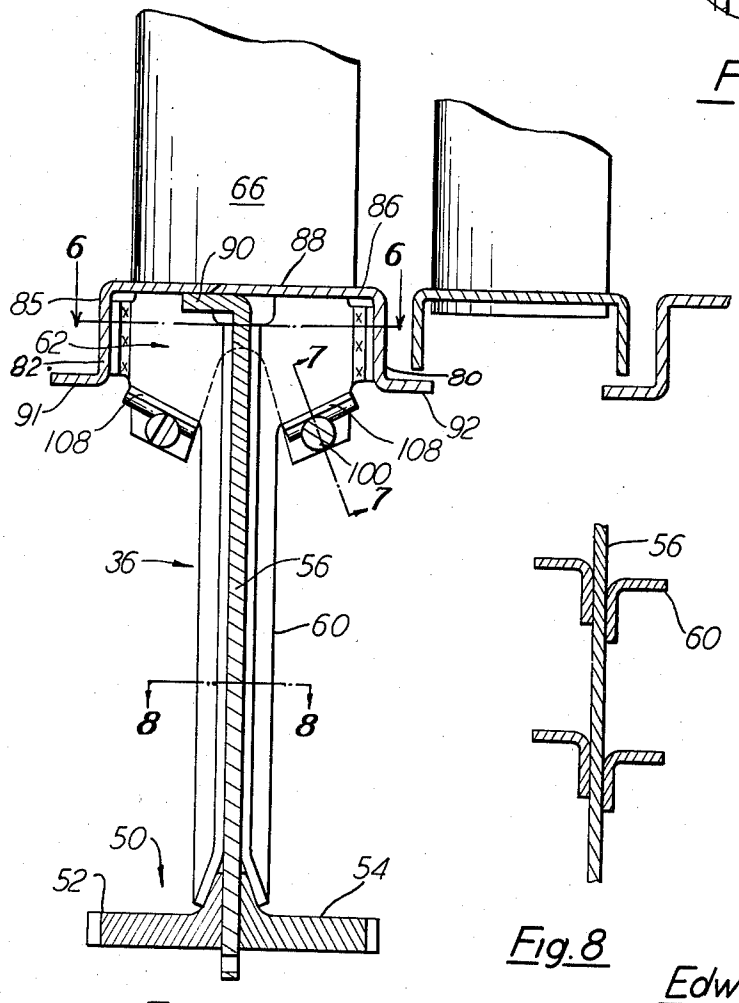


Fig. 2

Fig. 8

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2,925,248

BLADED WHEELS FOR AXIAL FLOW MACHINES

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Application May 22, 1953, Serial No. 356,690

12 Claims. (Cl. 253—39)

This invention relates to bladed wheels for axial flow compressors, turbines, and the like, particularly to constructions of low weight and cost.

In this invention of which the drawings show a preferred embodiment, the wheel is made of thin wall parts preferably sheet metal parts, and pressings. The blades are inserted radially into sockets and secured therein by disengageable means so that injured blades, for instance, can be readily replaced.

If the blades are made hollow of sheet metal or if they are small relative to the tip diameter of their wheel, or if their weights are small by reason of the use of light metals, the centrifugal loads at the roots, due to their weight, will be relatively small.

The wheels of the rearward stages of an axial flow compressor have very small radial and chordwise dimensions. For instance in about the last stage the blade span (radial length) may be only about 5% of the tip diameter of the wheel. Blades in this category are relatively light in relation to the hub structure of the wheel and impose only small centrifugal loads on a hub structure. Since the centrifugal loads of the blades are small the hub structure can be made of sheet metal by transferring the loads to the hub disk leaving the rim means substantially free of centrifugal loads from the blades. Further since the blade centrifugal loads are small relatively simple attachment means can be employed of a disengageable nature.

An object of this invention is to provide a light hub structure adapted to receive replaceable blades.

Another object is to provide a hub structure of sheet metal parts defining thin wall sockets adapted for securing therein disengageable blades.

Still another object is to provide a bladed wheel particularly adapted to save weight in the rear stages of an axial flow compressor.

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 a fragmentary axial section through an axial flow compressor;

Fig. 2 is a fragmentary section of a rear wheel of the compressor of Fig. 1;

Fig. 3 is a fragmentary development of the blades of the wheel of Fig. 2 showing the blades in section near their root ends;

Fig. 4 is a side elevation of a blade;

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

Fig. 5 is a fragmentary axial view of a wheel disk isolated from the wheel hub;

Fig. 6 is a fragmentary section of a wheel on line 6—6 in Fig. 2;

Fig. 7 is a fragmentary section on line 7—7 in Fig. 2; and

Fig. 8 is a fragmentary section on line 8—8 in Fig. 2.

It is commonly understood in engineering and industry

that sheet metal construction is limited to sheets whose planar dimensions are large in comparison to their thicknesses for thicknesses less than about 3/16 of an inch. Sheets of greater thickness are called plates. (Steel sheet and plate manufacturers list their product of large planar dimensions of 3/16 or less as sheets and greater thickness as plates.) Sheet metal constructions are comprised of parts which are cut out from sheet material and require cutting which is chiefly limited to defining the contours of the part in the plane of the sheet, or to such parts which are subsequently given another shape by pressing with a die.

A preferred form of the invention will now be described with particular reference to the drawings.

Referring particularly to Fig. 1 a compressor is indicated generally as **10**. The case **11** houses the rotor **12** which is rotatably borne on suitable shafts of which the front one is **14** in bearing **16**.

The case and rotor define the annular duct **20** for a main flow of fluid entering at inlet **22** and leaving through exit **24**.

The rotor is comprised of a plurality of bladed wheels **30–36** of which one namely **36** will be described. The others may be constructed similarly.

There are a plurality of stators **39–46** interspaced with the rotors.

The wheel **36** is shown in section in Fig. 2. Its hub structure is comprised of disk **56** and the hub or hub means **50** made of the two toothed elements or rings **52** and **54** fixed to the sheet disk **56** preferably by fused metal. The disk **56** is preferably fabricated separately from the hub. On each side of the disk at each blade location is a rib **60** preferably of angle cross section throughout the portion extending from the hub outward to the neighborhood of the periphery of the disk so that elements such as the legs of the ribs extend outwardly from the disk to stiffen it against axial forces. The ribs are bonded to the disk by fused metal such as solder.

To insure a light hub structure the rings **52** and **54** are preferably spaced outward from the axis of shaft **14** by more than 30% of the radius of the hub structure.

Near the disk periphery, Fig. 2, there is a socket means comprising a plurality of peripherally spaced blade sockets **62**, Figs. 2 and 6. The sockets may be integral or fixed to the ribs as shown. In either case they are preferably fabricated separately from the disk. The annular disk **56** has cut-outs **64** at peripherally spaced localities to accommodate the root ends of a plurality of individual or separate blades **66** which are positioned in the sockets and are accordingly spaced peripherally about the disk. These blades may be solid as shown, particularly where they are relatively small or made of light metal. These sockets each have the flanges **70** and **71** fixed to the disk **56** by fused metal such as solder to transfer centrifugal forces from the blades to the disk by shear stress on the side surface of the disk, thus giving low structural weight and preserving the integrity of the disk. Each socket also has flanges **74** and **76** fixed to the legs **80** and **82** of the rim means **84**. The hub structure and the sockets exclusive of the ribs are called the hub structure means.

For easy representation in Fig. 1 the convention of showing only the blade at the ends of the diameter is followed although all rotors have blades spaced uniformly about the whole perimeter.

The rim means is comprised of the two parts **85** and **86** joined above the flange elements **90** to which they are fixed. These parts are preferably made as formed sheet metal comprising pressings, spinnings and the like fabricated separately from the disk. These parts define the rim wall **88**. The rim means has the seal rings **91** and **92**. The radial flanges of **85** and **86** are each fixed

to the hub disk **56** at localities spaced outward from the hub **50** and preferably adjacent to the periphery of said disk. The radially directed legs **80** and **82**, Fig. 6, may be considered as short side plates which terminate with limited radial extent to facilitate inspection of the joints between the various parts.

Each blade **66** has a part secured in a socket. Thus the root end **94** has the two legs **96** and **98**. See Fig. 4 and 4*a*. Each root end fits into a socket **62** with its legs **96** and **98** straddling the disk **56** and preferably protruding from the inner end of the socket.

Each blade is secured in the socket against outward displacement by disengageable fastener means comprising the fasteners **100** which are shown in Figs. 2 and 7. Each fastener is comprised of the bolt **102** having the conical head **104**. The bolt passes through a hole **105** in the blade root and is fitted with a conical nut **106**. The conical surfaces of the head and nut bear on the inclined flanges **108** of the socket. When the nut and head are pulled toward each other by turning the bolt the blade is drawn radially inward into the socket so that the shoulders **110** and **112** bear on the outer edges of the socket **62**.

The flanges **108** as shown in Fig. 2 are inclined in the fore and aft direction to facilitate holding the blade rigid.

In the wheels like **36** the sheet metal disk **56** is positioned radially inward from the root ends of the individual blades and axially between their leading and trailing edges. This type of wheel may be called a central disk wheel.

This invention includes compressor wheels for increasing the static pressure and density of an elastic fluid. In order to achieve a significant change in density with an axial flow compressor each wheel must be operated at a speed high enough to effect a significant change in density, that is a change which in magnitude is outside the usual order of engineering accuracy in industry. Thus machines are considered to be compressors as distinguished from fans or blowers at tip speeds of about 400 feet per second or more. At such a speed the average change in density along the blade length is about 3% which is just about the common order of accuracy of measurement of the density. Such compressors are expected also to operate at blade tip speeds close to the velocity of sound. At such speeds the change in pressure may be more than 70% or more than 10 pounds per square inch for air inducted at atmospheric pressure.

Since in a compressor and turbine wheel there is a substantial pressure variation from front to rear of a wheel the ratio of the hub radius to the blade tip radius is relatively large of a value of the order of 0.5 and preferably greater so that the pressure difference between front and rear sides can be sustained without a return flow at the hub such as occurs in a fan. For the same reason the blades are spaced peripherally close together, preferably about one chord length or less apart.

Commonly half to all the pressure rise occurs in the rotor between the leading and trailing edges. To sustain such an increase in pressure along the rotor passages from leading to trailing edges of the blades the hub rim between adjacent blades and from leading to trailing edges is a fair and continuous surface. Also at all rotative speeds the case must fit closely about the blade tips which are contoured to the cylindrical surface of the case along substantially the whole length of the blade chord.

To diffuse the flow between blades to achieve a pressure rise the flow should follow the blade surfaces without eddies. Accordingly the blades should have rounded edges. They should have sharpened trailing edges to be efficient.

Because of the limited weights of the blades and the rim means the disk can have a limited thickness of the order of 0.003 times the wheel maximum diameter (tip diameter) or less. Thus rather large disks can have a thickness less than 0.050 of an inch. These would be costly and difficult to machine. The blades and rim means may have wall thicknesses less than the disk thickness.

Also the rim means can have wall thicknesses less than the thickness of the hub disks if desired.

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 machine for interchanging energy with an elastic fluid, a case, a wheel hub structure means mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure means in peripherally spaced relation thereabout, said blades and hub structure means being adapted for rotation at high tip speeds developing a substantial variation in pressure and density of said fluid flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure means comprising a sheet metal disk, whose maximum thickness is less than 0.003 of the diameter between the tips of said blades, and sheet metal pressings defining a plurality of peripherally spaced separately fabricated sockets fixed to said disk, a rim means fixed to said disk and to said sockets and extending in the general axial direction between the leading and trailing edges of said blades and from blade to blade to sustain said variations in pressure, said rim means and said sockets having cooperating flanges faying and secured to each other, each said blade having a root end portion positioned in a said socket, and a fastener means operating on each said portion and attaching each said blade to said hub structure means in wedging relation to secure said root portion against said socket walls for transferring said centrifugal force to said disk.

2. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure means mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure means in peripherally spaced relation thereabout, said blades and said hub structure means being adapted for rotation at high tip speeds developing a substantial variation in pressure and density of said fluid flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure means comprising a sheet metal disk and sheet metal pressings defining a plurality of peripherally spaced sockets fixed to said disk, said disk having a thickness less than .003 of the diameter between tips of said blades, a rim means carried by said disk and extending in the general axial direction between the leading and trailing edges of said blades and from blade to blade to sustain said variations in pressure, said rim means being structurally free of said blades with respect to the transmission of centrifugal force from said blades to said rim means each said blade having a root end portion positioned in a said socket and extending radially inwardly beyond the walls of said socket, and a fastener means bearing on each said blade and on said hub structure means in wedging relation thereto to secure said root portion against said socket walls for transferring said centrifugal force to said disk while keeping said rim means relatively free of said force thereby adapting said rim means to carry only its own centrifugal load and whereby to have a radial thickness of the rim wall thereof less than the thickness of said disk.

3. In combination in an axial flow machine for interchanging energy with an elastic fluid, in a case, a wheel hub structure means mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure means in peripherally spaced relation thereabout, said blades and hub structure means being adapted for rotation at high tip speeds developing a substantial variation in pressure and density of said fluid

flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure means comprising a sheet metal disk whose maximum thickness is less than 0.003 of the diameter between the tips of said blades, and sheet metal pressings defining a plurality of peripherally spaced sockets fixed to said disk, a rim means carried by said disk and extending in the general axial direction between the leading and trailing edges of said blades and from blade to blade to sustain said variation in pressure, said rim means comprising a separate sheet metal pressing having parts faying with parts of said sockets and extending in the generally radial direction to secure said parts together, each said blade having a part positioned in a said socket, and disengageable means operating on said part securing each said blade in its respective socket for transferring said centrifugal force to said disk.

4. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure means mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure means in peripherally spaced relation thereabout, said blades and said hub structure means being adapted for rotation at high tip speeds developing a substantial variation in density and pressure of said fluid flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure means comprising a disk and a plurality of peripherally spaced sockets fixed to said disk, said disk closely adjacent to its perimeter being thin relative to the axial length of said blades at the root end portions thereof, a separate rim means carried by said disk and extending in the general axial direction between the leading and trailing edges of said blades and from blade to blade to sustain said variation in pressure, each said blade having a part positioned in a said socket and extending radially inwarly beyond the walls of said socket, and disengageable fastener means bearing on each said part and on said socket in wedging relation to secure said root end against the walls of said hub structure means for transferring said centrifugal force to said disk.

5. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure in peripherally spaced relation thereabout, said blades and said hub structure being adapted for rotation at high tip speeds developing a substantial variation in density and pressure of said fluid flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure comprising a disk, said disk closely adjacent to its perimeter being thin relative to the axial length of said blades at the root end portions thereof, walls defining a plurality of peripherally spaced sockets fabricated separately from said disk and fixed to said disk, said socket having an opening facing radially outward to receive a blade radially thereinto, a rim means carried by said disk and extending in the general axial direction between the leading and trailing edges of said blades and closing the space from blade to blade to sustain said variation in pressure, each said blade extending through said rim means along the major part of the blade chord length and having a root end portion positioned in a said socket, and disengageable fastening means securing each said blade in its respective said socket.

6. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure in peripherally spaced relation thereabout, said blades and said hub structure being adapted for rotation at high tip speeds developing a substantial variation in density and pressure of said fluid flowing between said blades and developing centrifugal forces at the root ends

thereof, said hub structure comprising a sheet metal disk whose maximum thickness is less than 0.003 of the diameter between the tips of said blades, a plurality of separately fabricated sockets fixed to said disk, a rim means carried by said disk and extending in the general axial direction between the leading and trailing edges of said blades and from blade to blade to sustain said variation in pressure, each said blade having a part positioned in a said socket and extending radially inwardly beyond the ends of said sockets, and separate fastening means securing each said part in its respective said socket and exposed to axial view.

7. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure in peripherally spaced relation thereabout, said blades and said hub structure being adapted for rotation at high tip speeds developing a substantial variation in density and pressure of said fluid flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure comprising a sheet metal disk whose maximum thickness is less than 0.003 of the diameter between the tips of said blades, walls defining a plurality of peripherally spaced separate sockets fixed to said disk, a separate rim means carried by said disk fixed thereto and extending in the general axial direction between the leading and trailing edges of said blades and closing the space from blade to blade to sustain said variation in pressure, each said blade extending through said rim means along the major part of the blade chord length and having a root end portion positioned in a said socket, each said blade having a spanwise slot in said root portion adapting said portion to straddle said disk, and disengageable fastening means securing each said blade in its respecive said socket.

8. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure means mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure means in peripherally spaced relation thereabout, said blades and said hub structure means being adapted for rotation at high tip speeds developing a substantial variation in pressure and density of said fluid flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure means comprising a sheet metal disk, and walls defining a plurality of peripherally spaced separately fabricated sockets fixed to said disk, a separately fabricated rim means carried by said disk and extending in the general axial direction between the leading and trailing edges of said blades and from blade to blade to sustain said variation in pressure, said rim means being structurally free of said blades with respect to the transmission of centrifugal force from said blades to said rim means each said blade having a root end portion positioned in a said socket, and a fastener means connected to each said blade root and bearing on said respective sockets in wedging relation to secure said root portion against said socket walls in fixed angular relation thereto for transferring said centrifugal force to said disk while keeping said rim means relatively free of said force thereby adapting said rim means to carry only its own centrifugal load whereby to have a radial thickness of the rim wall thereof less than the thickness of said disk, said disk having a thickness less than 0.003 times the diameter between the tips of said blades.

9. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure in peripherally spaced relation thereabout, said hub structure comprising a hub element and a disk bonded thereto and extending radially outward therefrom,

said disk closely adjacent to its perimeter being thin relative to the axial length of said blades at the root end portions thereof, a plurality of peripherally spaced ribs lapping said hub element and being fixed thereto, said ribs extending radially outward along said disk and being fixed thereto along the central portion of the radial extent of said disk for transfer of centrifugal forces thereto, said blades being connected to said ribs, and rim means fixed to said disk and extending between blades and between the leading and trailing edges thereof.

10. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure means mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure means in peripherally spaced relation thereabout, said blades and said hub structure means being adapted for rotation at high tip speeds developing a substantial variation in density and pressure of said fluid flowing between said blades and centrifugal forces at the root ends thereof, said hub structure means comprising a sheet metal disk and a plurality of peripherally spaced separately fabricated sockets fixed to said disk, said disk closely adjacent to its perimeter being thin relative to the axial length of said blades at the root end portions thereof, each said socket having an opening facing radially outward to receive a blade radially thereinto, a rim means carried by said disk and fixed to said sockets and extending in the general axial direction between the leading and trailing edges of said blades and closing the space from blade to blade to sustain said variation in pressure, each said blade having a part positioned in a said socket and extending through said rim means along the major part of the blade chord length, and a fastener means bearing on said sockets and on said parts exerting an inward pressure on said blades.

11. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure in peripherally spaced relation thereabout, said blades and said hub structure being adapted for rotation at high tip speeds developing a substantial variation in density and pressure of said fluid flowing between said blades and developing centrifugal forces at the root ends thereof, said hub structure comprising a hub element and a disk fixed thereto extending radially outward therefrom, a plurality of peripherally spaced separately fabricated sockets fixed to said disk, each said blade having a root end portion in a said socket, said disk having a thickness less than 0.003 times the wheel maximum diameter, a plurality of peripherally spaced ribs fixed to a side of said disk, said ribs extending to localities adjacent to said sockets, a rim means carried by said disk and extending in the general axial direction between the leading and trailing edges of said blades and from blade to blade to sustain said variations in pressure, and separate fastening means bearing on said blade portion and said socket securing said blade therein.

12. In combination in an axial flow machine for interchanging energy with an elastic fluid, a case, a wheel hub structure means mounted in said case for rotation about an axis, a plurality of axial flow blades carried on said hub structure means in peripherally spaced relation thereabout having the leading and trailing edges extending radially outward therefrom, said blades and said hub structure means being rotatable at high blade tip speeds developing a substantial variation in pressure and density of said fluid flowing between said blades and developing centrifugal force at the root ends thereof, a rim wall secured on said hub structure means adjacent the periphery thereof and extending between the leading and trailing edges of said blades and closing the space from blade to blade to sustain said variation in pressure, said hub structure means having radially extending spaced walls inwardly adjacent the periphery thereof and secured to said rim wall, each said blade having an integral root end inwardly of said rim wall and received between said spaced walls for support thereby against centrifugal force, said root end including separate legs integral therewith respectively adjacent the leading and trailing edges of each blade, each said leg extending beyond said hub structure means exposing edges of said legs to axial view, and means fixing said legs to adjacent said spaced walls.

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