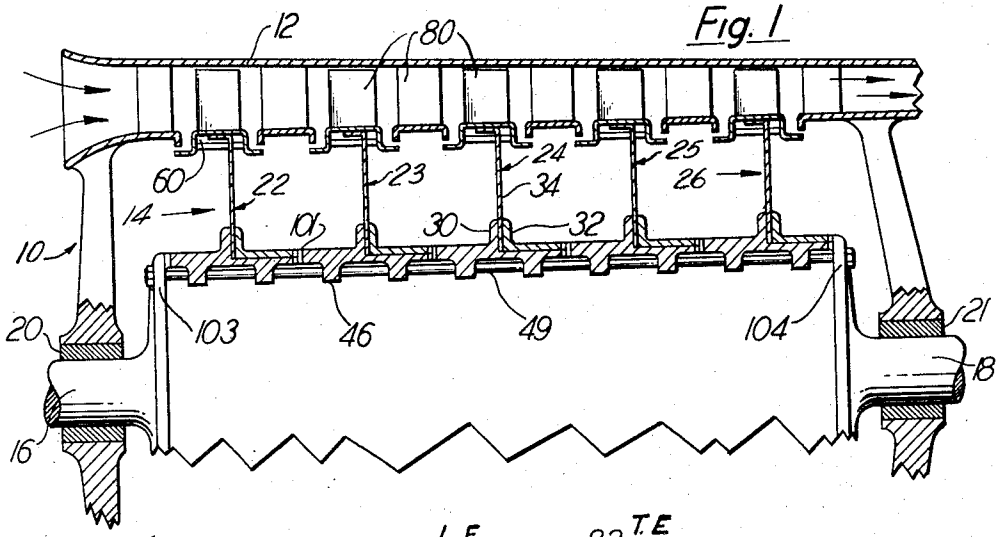
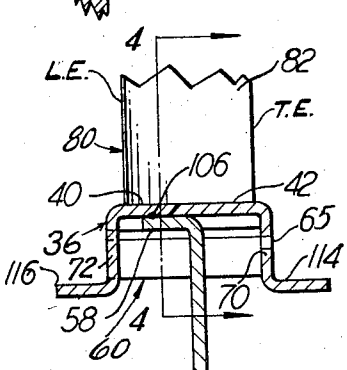
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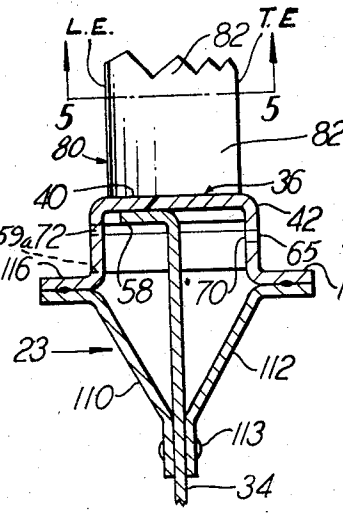
THIN WALL BLADED WHEELS FOR AXIAL FLOW MACHINES

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Fig. 1







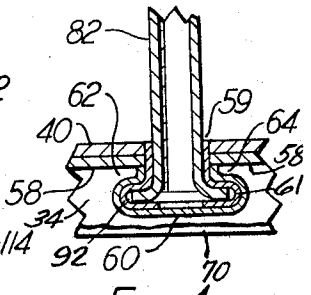


Fig. 4

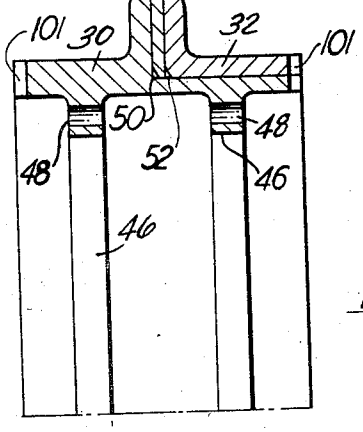


Fig. 10

Fig. 3

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THIN WALL BLADED WHEELS FOR AXIAL FLOW MACHINES

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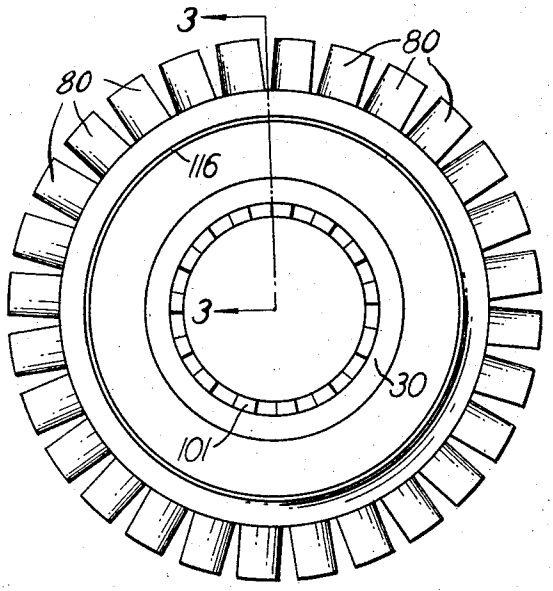


Fig. 2

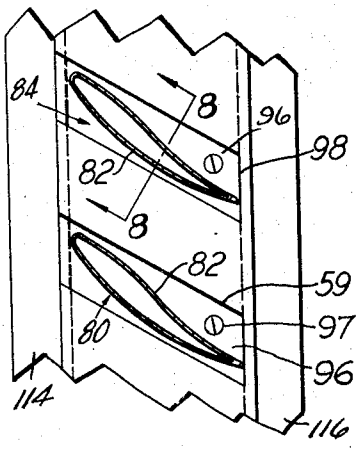


Fig. 7

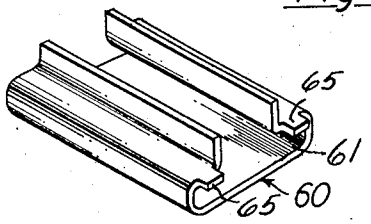


Fig. 6

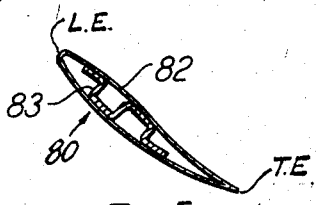


Fig. 5

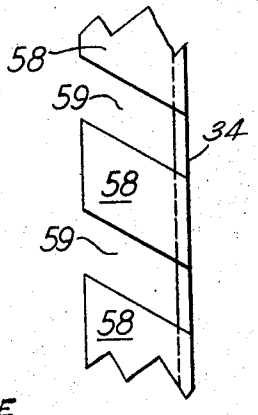


Fig. 7a

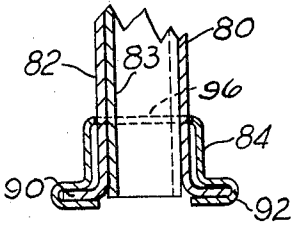


Fig. 8

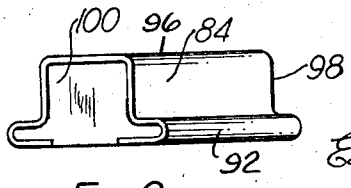


Fig. 9

INVENTOR.

Edward A. Stalker

United States Patent Office 2,875,948 Patented Mar. 3, 1959

2,875,948

THIN WALL BLADED WHEELS FOR AXIAL FLOW MACHINES

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Application January 19, 1953, Serial No. 331,859

12 Claims. (Cl. 230—134)

This invention concerns axial flow fluid machines adapted to interchange energy or forces with a fluid and is directed to wheels of thin wall construction and particularly to sheet metal wheels adapted to the replacement of individual blades or groups of blades.

Accordingly an object of this invention is to provide a wheel comprised of sheet metal pressings and parts.

Another object is to provide a sheet metal wheel wherein the blades are removable.

Still another object is to provide a sheet metal blade adapted for replacement in a wheel.

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 of an axial flow compressor according to this invention;

Fig. 2 is an axial view of a bladed wheel according to this invention;

Fig. 3 is a fragmentary section on line **3—3** in Fig. 2;

Fig. 4 is a fragmentary section on line **4—4** in Fig. 3;

Fig. 5 is a chordwise section of a blade on line **5—5** in Fig. 10;

Fig. 6 is a perspective view of a socket;

Fig. 7 is a fragmentary development of the blading of a wheel;

Fig. 7*a* is a fragmentary radial view of the rim of the hub plate or web;

Fig. 8 is a fragmentary section of a blade on line **8—8** in Fig. 7;

Fig. 9 is a front view of a blade base; and

Fig. 10 is a fragmentary axial section of the rim and associated structure of an alternate form of the invention.

In some usages of axial flow fluid machines it is desirable to provide blades which are replaceable especially in the case of injury or failure of a limited number of blades. This is difficult to provide in a wheel comprised of sheet metal pressings and parts.

When a bladed wheel of this invention is rotating at high tip speeds, i. e., in excess of about 400 feet per second, the fluid loads on the blades tend to bend the blades at their roots. The loads on all the blades tend to displace the rim of the wheel forward in the axial direction, that is in the upstream direction. These same loads also tend to rotate the rim about a circular axis passing peripherally through the axial sections of the rim. The rim resists this torsional load. The hub which includes the rim must be able to sustain these loads of bending and twist as well as the centrifugal loads arising from the high rate of rotation. Furthermore if the machine is installed in a vehicle large gyroscopic moments will occur on the wheel, which also tends to bend the blades about their root ends.

The present invention provides a wheel comprised of sheet metal pressings and parts including hollow sheet metal blades of relatively light weight which is

important in providing relatively thin and light hub structures.

By arranging the structure in the manner of this invention, heavy solid blade bases are eliminated and with them a wheel hub rim which would be thick in the radial direction to accommodate and sustain the blade bases is avoided. That is, the wheel is relieved of the customary heavy pieces of rim between the blade bases which load up the inner or unslotted part of the rim and the wheel hub plate or web without contributing any strength for carrying the peirpheral stress in the wheel but which add centrifugal load to the hub web. That is, by making the bodies of the blades of hollow thin sheet metal construction they are very light and accordingly the blade bases may be of thin sheet metal of the same order of thickness as the blade walls. By having the blades light and arranging for the centrifugal loads to be carried directly to the wheel plate or web rather than to the rim, the rim can be very light and it will generate only a limited centrifugal load on the plate which can then also be of thin sheet metal.

All these parts will be able to sustain their own centrifugal load and the centrifugal load accumulated on them inward from the tips of the blades with thin sheet metal. The thickness of the hub plate may be of the order of the blade wall thickness or less than about 0.003 times the wheel maximum or tip diameter. Thus the thickness of the wheel plate may be less than 0.100 inch for very large wheels. If the plate is made up of axially spaced sub-plates their total thickness can be of the same order as that of the single plate.

The thickness of the sheets comprising a blade wall may be less than about 0.002 times the maximum diameter of the wheel.

Referring now to the drawings, Fig. 1 shows a fragmentary axial section through an axial flow compressor indicated generally as **10** comprised of the case **12** and the rotor **14** supported by shafts **16** and **18** in bearings **20** and **21** for rotation about its longitudinal axis, that is the axis of the shafts.

The rotor is comprised of a plurality of wheels **22–26** which are held in fixed relationship.

All the wheels are similar so that it is sufficient to describe wheel **23**.

The hub structure or hub means comprises the cylindrical hub elements **30** and **32**, the disk or hub plate **34** and the hollow annular rim means **36**. The latter is comprised of the rim walls **40** and **42**, side walls **70** and **72**, and horizontal flanges **114** and **116**, respectively, each group of which as shown is preferably a continuous ring. These parts are fused together as shown clearly in Figs. 2 and 3.

The flanges **46** of the series of hub elements **30**, **32** are provided with peripherally spaced holes **48** through which the tie rods **49** pass to hold the series of wheels together.

The plate **34** is preferably spot-welded to hub elements **30** and **32** with wires of solder inserted in the peripheral grooves **50** and **52**, Fig. 3, to prepare the assembly for soldering. The spot-welds serve to hold the parts together until the soldering operation is completed. Soldering is preferably executed in a furnace with a controlled atmosphere.

The plate **34** has the peripheral flange **58** as shown in Figs. 3, 4 and 7*a*. This flange and the plate **34** have peripherally spaced openings **59** cut therein to receive the channel shaped sockets **60**. See Figs. 3, 4 and 6. As shown particularly in Fig. 3 the plate **34** embraces the socket by extending inward from the peripheral sides of the sockets, at **62** and **64**, Fig. 4, thereby carrying the centrifugal load of the entire rotating structure. The sockets are soldered to all surfaces faying therewith.

The channels or recesses **61**, Figs. 4 and 6, are formed along opposite sides of each socket **60** and open in the generally axial direction as shown in Fig. 7, so that blade base projections **92** may be slid thereinto.

Each socket abuts the inner surface of the rim side wall **70** with two prongs **65** passing through the side wall **70** as shown in Figs. 3 and 6, and passes through the opposite side wall **72** to be flush with the outer surfaces of this member.

The peripheral walls of the rim parts **40** and **42** extend between the side walls **70** and **72**, and the sockets **60** are preferably fixed to these walls which structure constitutes the peripheral wall of the rim means.

The peripheral walls of rim means **40** and **42** are fused to the flange **58** and side wall **72** has peripherally spaced diagonal slots **59***a* registering with the openings **59** in the flange **58**. These slots extend substantially to the side wall **70** but do not pass through it. See Figs. 3 and 7.

Each blade **80** is comprised of the hollow blade body **82**, internal stiffener **83**, and the base **84**. See Figs. 3–5 particularly. The body is formed from sheet metal fused together along the trailing edge T. E. and preferably continuous about the leading edge L. E. At the root end of the blade there is preferably a flange **90** which is clamped between the upper and lower parts of the folded flanges or lateral projections **92** of the blade base.

The shape of the cross section of the blade base adapts it to be slid into the socket **60** in the general axial direction with the projections **92** in the recesses **61**. See Figs. 3 and 6 particularly. Then the upper surface **96** of the base fills the opening in the rim means **36** and is preferably flush with the adjacent rim parts **40** and **42**. The screws **97**, Fig. 7 extend inward through the walls of sockets **60** to lock the blades in place against axial movement.

The side wall **70** closes off the opening **98** in the blade base at its rear end. The opening at the front end is closed by the plug **100** (Fig. 9) which is pressed and brazed in place in the opening.

The wheels are stacked with the clutch teeth of one engaging the clutch teeth of the other. As shown in Figs. 1–3 the clutch teeth are **101** cut in the members **30** and **32**. The wheels are held together axially by the tie rods **49** passing through the holes **48** in the hub flanges **46** and the flanges **103** and **104** on shafts **16** and **18** respectively.

In making the assembly of the wheel hub structure the rim element **40** is first spot-welded at **106** to the flange **58** of plate **34**. The upper end of element **40** is chamfered to form a recess with the flange **58**. The upper end of element **42** is beveled to fit into the recess which then serves as a keying device to keep the rim surfaces of elements **40** and **42** flush one with the other while both elements are soldered to the flange **58**.

In another form of the invention shown in Fig. 10 the rim means is given still greater torsional rigidity about a peripheral axis by the addition of the rim side walls **110** and **112** extending diagonally outward. They provide the transverse section of the rim means with a closed contour. They are each preferably continuous rings which are fixed to the structure after the other parts are joined together. This is particularly desirable if the joining is done by brazing since the joints can be visually inspected before attaching the rim side walls. Preferably these rings are welded or riveted to the horizontal flanges **114** and **116** of the rim parts **40** and **42**. These parts may also be soldered together. They are preferably fixed to the plate **34** at a locality which is substantially nearer the perimeter of the plate than to the outer perimeter of the hub elements **30** and **32**.

When the blade tips tend to bend forward the blades at their inner ends bear on the walls of the rim means and tend to twist it about a circular axis near the geometric center of the axial cross section of the rim means. In this invention the moment of inertia of the transverse or cross section of the rim means is large for a very low weight since the walls of the rim means are spaced relatively far apart. Since the rim means is adequate to sustain the torque put upon it by the blades the wheel hub plate is relieved of bending moments adjacent its perimeter and needs to carry chiefly the centrifugal loads from the rim means and blades.

It is desirable that opposite walls of the rim means be securely connected by other walls so that the walls can cooperate in providing an effective cross section for resisting torques thereon. Thus opposite walls or side rings **110** and **112** are connected by other walls to give the transverse section of the rim a substantially continuous contour.

In some instances it is desirable to employ only one of the side rings **110** or **112**. For instance the use of only **110** will strengthen the part **40** which has been relatively weakened by the slot to accommodate the socket **60**. If the side ring **112** is omitted the joints can all be inspected visually. For instance if solder material appears at the joint between the front end of the socket **60** and the side wall **72**, Fig. 10, this joint will be sound. Also if solder appears in the joint where the socket **60** passes through the web **34**, this joint will be sound. The joint where the socket **60** abuts the inside surface of side wall **70** is obviously inspectable.

The thickness of the hub plate may be of the order of the blade wall thickness or less than about 0.003 times the wheel maximum or tip diameter. Thus the thickness of the wheel plate may be less than 0.100 inch for very large wheels. If the plate is made up of axially spaced sub-plates their total thickness can be of the same order as that of the single plate.

The thickness of the sheets comprising a blade wall may be less than about 0.002 times the maximum diameter of the wheel.

In the preferred form of this invention for a rotor of 36 inches maximum diameter the blades **80** have sheet metal walls of a thickness as small as 0.010 inch. An internal stiffener **83** and rim **40**, **42** each may have a thickness of about 0.020 inch. The central web or plate **34** of the wheel hub may have a thickness of about 0.050.

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, a bladed wheel mounted for rotation at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in an elastic fluid flowing through said compressor, said wheel comprising a sheet metal plate extending generally radially, a plurality of hollow blades each having a base with a lateral projection, said blades being of sheet metal construction to have limited weight and being spaced peripherally about said plate and having their leading and trailing edges extending radially outward therefrom, sheet metal walls defining a plurality of sockets of limited weights spaced peripherally about said plate and fixed to a radially extending surface thereof forming a joint in shear, said blades and sockets of said limited weights developing limited centrifugal forces therein to be sustained by said plate during rotation of said wheel, each said socket having a recess extending laterally and opening in the general axial direction to receive a said base in sliding relation thereinto with said projection disengageably fitting into said recess to transmit the centrifugal load of said blade radially inward to said plate to be sustained thereby, and a sheet metal rim means extending between said blades to sustain said fluid pressure and being connected between said blades to said plate to transfer thereto its own centrifugal force adapt-

ing said rim means to have a wall thickness of the order of the thickness of said blade walls.

2. In combination in an axial flow compressor, a bladed wheel mounted for rotation at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in an elastic fluid flowing through said compressor, said wheel comprising a plate extending generally radially, a plurality of axial flow hollow blades each having a base with a lateral projection, said blades being of sheet metal construction to have limited weights, said blades being spaced peripherally about said plate and having their leading and trailing edges extending radially outward therefrom, said blade walls having a thickness of the order of 0.002 times the tip diameter of said wheel, sheet metal walls defining a plurality of sockets of limited weights spaced peripherally about said plate and fixed to a side surface thereof forming a joint in shear, said blades and sockets of said limited weights developing limited centrifugal forces during rotation of said wheel, said plate being of sheet metal with a wall thickness less than .003 times the tip diameter of said wheel to sustain said limited centrifugal forces from said blades and sockets, each said socket having a recess extending laterally and opening in the general axial direction to receive a said base in sliding relation thereinto with said projection fitting disengageably into said recess to transmit said limited centrifugal load of said blade radially inward to said plate to be sustained thereby, and a hollow sheet metal rim means extending between adjacent said blades continuously from the leading to the trailing edges thereof to sustain said fluid pressure and being connected to said plate to transfer thereto chiefly its own centrifugal force whereby said rim means has a wall thickness of the order of the thickness of said blade walls.

3. In combination in an axial flow compressor, a bladed wheel mounted for rotation at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in an elastic fluid flowing through said compressor, said wheel comprising a plate extending generally radially, a plurality of hollow axial flow blades each having a base with a lateral projection, said blades being of sheet metal construction to have limited weight and spaced peripherally about said plate and having their leading and trailing edges extending radially outward therefrom, thin walls of limited weight defining a plurality of sockets spaced peripherally about said plate and fixed to a side surface thereof forming a joint in shear, said blades and sockets of said limited weights during rotation of said wheel developing limited centrifugal forces therein to be sustained by said plate of sheet metal with a wall thickness less than .003 times the tip diameter of said wheel, each said socket having a recess extending laterally and opening in the general axial direction to receive a said base in sliding relation thereinto with said projection disengageably fitting into said recess to transmit the centrifugal load of said blade radially inward to said plate to be sustained directly thereby, and a sheet metal rim means extending between adjacent said blades to sustain said fluid pressure and being connected to said plate to transfer thereto chiefly its own centrifugal force adapting said rim means to have a wall thickness of the order of the thickness of said blade walls.

4. In combination in an axial flow compressor wheel adapted for rotation at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in a flow of fluid, a wheel hub structure comprising a separately fabricated hub plate extending generally radially, a separately fabricated rim means comprising annular sheet metal side walls in fixed relation on opposite sides of said plate adjacent to the perimeter thereof and extending radially and axially outward therefrom and fixed thereto, a rim wall means fixed to the outer edges of said side walls and extending therebetween to sustain said increase in pressure, said rim wall means having a plurality of peripherally spaced sockets fixed

therein extending from one said side wall to the other, a plurality of hollow sheet metal blades each having its leading and trailing edges extending radially and having a lateral projection on a side of the root thereof, each said socket having a laterally extending recess opening in the general axial direction disengageably receiving said blade projection thereinto in sliding relation to retain said blade therein during said high speed rotation of said wheel, and means for fixing each said socket to said hub plate for transferring the centrifugal load of said blades and rim means directly to said plate leaving said rim means substantially free of said loads from said blades.

5. In combination in an axial flow compressor wheel adapted for rotation at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in a flow of fluid, a wheel hub structure comprising a hub element and a hub plate fixed thereto and extending radially outward therefrom, a rim means comprising annular sheet metal side walls on opposite sides of said plate extending radially and axially outward therefrom and fixed thereto, said rim means including a rim wall means fixed to said side walls at the outer edges thereof and extending therebetween, said rim wall means having a plurality of peripherally spaced sockets fixed therein, and a plurality of hollow sheet metal blades each having its leading and trailing edges extending radially and having a lateral projection on opposite sides thereof, each said socket having laterally extending recesses opening in the general axial direction to disengageably receive the said blade projections thereinto in sliding relation, each said socket extending in the general axial direction from opposite sides of said plate and from one said side wall to the other and being fixed to said side walls and plate to transmit the centrifugal load of each said blade directly thereto during rotation of said wheel.

6. In combination in an axial flow compressor, a bladed wheel mounted for rotation at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in a flow of fluid, said wheel comprising a plate extending in a generally radial direction, a rim means including annular sheet metal side walls on opposite sides of said plate and fixed thereto, said rim means including a rim wall means fixed to said side walls and extending between the edges thereof to sustain said pressure, said rim wall means having a plurality of peripherally spaced separately formed sockets fixed therein extending between said side walls and fixed thereto, and a plurality of axial flow hollow sheet metal blades each having its leading and trailing edges extending radially and having a lateral projection on opposite sides thereof at the root ends thereof, each said socket having laterally extending recesses opening in the general axial direction to disengageably receive the said blade projections thereinto in sliding relation, each said socket being embraced by said plate and connected thereto.

7. In combination in an axial flow compressor, a bladed wheel mounted for rotation at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in an elastic fluid flowing through said compressor, said wheel including a wheel hub structure comprising a hub element and a sheet metal hub plate fixed to said element and extending outward therefrom in a generally radial direction, sheet metal walls defining a plurality of hollow axial flow blades spaced peripherally about said plate having their leading and trailing edges extending radially outward therefrom, a sheet metal annular rim means comprising spaced walls in fixed relation defining substantially closed cross sectional contours in axial planes fixed to said hub plate, a plurality of thin walled sockets of limited weight fixed to said rim means, each said blade having a lateral projection at the root end thereof, each said socket having a recess extending laterally and opening in the general axial direction disengageably receiving said projection in sliding relation thereinto to transmit the centrifugal load

of said blade radially inward to said plate to be sustained directly thereby, each said blade transmitting its centrifugal load during rotation of said wheel spanwise radially inwardly to said socket whereby said plate is subjected chiefly to tension loads, said rim means extending between adjacent said blades to sustain said fluid pressure and being connected to said plate to transfer thereto chiefly its own centrifugal load adapting said rim to be of thin sheet metal.

8. In combination in an axial flow compressor, a bladed wheel mounted for rotation about an axis at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in an elastic fluid flowing through said wheel, a rim means comprising spaced sheet metal walls extending continuously in a circle defining a hollow peripherally continuous ring, and a plurality of axial flow blades arranged in a single peripheral row having their leading and trailing edges directed outward in the general radial direction from said rim means whereby said blades extend spanwise along the general direction of centrifugal action thereon to be free of centrifugal bending moments enabling said blades to attain said tip speeds, said blades extending spanwise radially into said rim means in bearing contact therewith and secured thereto for supporting the centrifugal loads thereon, said blades during rotation of said wheel at said speeds receiving forces thereon from said fluid at localities radially outward from said rim means tending to bend said blades about a peripheral line and thereby applying a torsional load to said rim means in planes extending in the general direction of said axis, said rim means having a hollow cross section of closed contours in axial planes provided by said walls giving torsional rigidity in said rim means to sustain said torsional loads, and a sheet metal disk secured to said rim means and extending radially inward from said hollow cross section thereof to transmit radially directed forces between opposite portions thereof, and an element secured to said wheel for applying driving torque thereto for the rotation thereof at said speeds.

9. In combination in an axial flow compressor, a bladed compressor wheel mounted for rotation about an axis at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in an elastic fluid flowing through said wheel, said wheel including a hollow rim means comprising spaced sheet metal walls including at least two axially spaced separately fabricated sheet metal rings fixed together between said blades, a plurality of axial flow blades arranged in a single peripheral row having their leading and trailing edges extending outward in the general radial direction from said rim means whereby said blades extend spanwise along the general direction of centrifugal action thereon to be free of centrifugal bending moments enabling said blades to attain said tip speeds, said blades extending radially and spanwise into said rim means in bearing contact therewith and secured thereto for supporting the centrifugal loads thereon, said blades during rotation of said wheel at said speeds receiving fluid forces at localities thereon radially outward from said rim means tending to bend said blades about a peripheral line and thereby applying a torsional load to said rim means in planes extending in the general direction of said axis, said walls of said rim means enclosing a hollow interior and providing a wall boundary thereof closed in axial planes, said walls about said hollow interior being fixed together at their localities of contact adjacent to said hollow interior providing great torsional rigidity in said rim means in axial planes thereof to sustain said torsional loads, and a disk extending radially outwardly into said hollow interior for supporting said rim means and said blades.

10. In combination in an axial flow compressor wheel adapted for rotation about an axis at a blade tip speed

greater than 400 feet per second to effect a substantial increase in density and pressure in a fluid, said wheel including a plate, a hollow rim means having axially spaced side walls secured to said plate in fixed relation thereto, socket means positioned within said rim means and separately fabricated from said plate and secured thereto on a side surface thereof, said socket means having a recess therein opening in the general axial direction through a said side wall to receive a blade slid thereinto along the general axial direction, and a plurality of axial flow blades each positioned in said socket means and secured therein, said rim means extending between blades to sustain said increase in fluid pressure.

11. In combination in an axial flow compressor wheel adapted for rotation about an axis at a blade tip speed greater than 400 feet per second to effect a substantial increase in density and pressure in a fluid, said wheel including a plate, a plurality of sockets secured to said plate on a side surface thereof forming a joint in shear, hollow rim means secured to said plate and having front and rear side walls in fixed relation on opposite sides of said plate, each said socket being positioned within said rim means and secured to a said side wall, each said socket having a recess therein opening in the general axial direction through a said side wall to receive a blade slid thereinto along the general axial direction, and a plurality of axial flow blades each positioned in a said socket and secured therein, said rim means extending between blades to sustain said increase in fluid pressure.

12. In combination in an axial flow compressor for compressing an elastic fluid, a case, a light weight low cost wheel mounted in said case for rotation about an axis for creating a substantial difference in fluid pressure between the front and rear sides of said wheel, a hub, a supporting disk mounted on said hub, axially spaced side walls mounted on said disk in fixed relation thereto, radially extending walls bonded to said side walls over a substantial radial extent of the side surfaces thereof and defining channel shaped socket means extending between said side walls, a plurality of axial flow blades received in said socket means, said blades in cooperation with said case defining passages between said blades directed along the general axial direction and having inlets and exits and increasing in cross sectional area rearward therealong with each said exit greater in cross sectional area than said inlet to direct said fluid rearward in the general axial direction with substantially increased pressure and density in said fluid at said exits during operation of said compressor, said blades having faired leading and trailing edges for efficient operation of said blades in providing said increased pressure, each said blade being positioned between said walls of said socket means and extending radially outward thereof and being disengageably secured thereto for rotation therewith and with the tips of said blades closely conforming to said case to sustain said difference in pressure, and rim closure means extending between said blades adjacent the root ends thereof in close conformance with the contours of said blades and from leading to trailing edges thereof to sustain said increase of fluid pressure.

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