May 21, 1957 E. A. STALKER 2,792,983

AXIAL FLOW COMPRESSORS WITH ADJUSTABLE STAGES

Filed Nov. 5, 1954 2 Sheets-Sheet 1

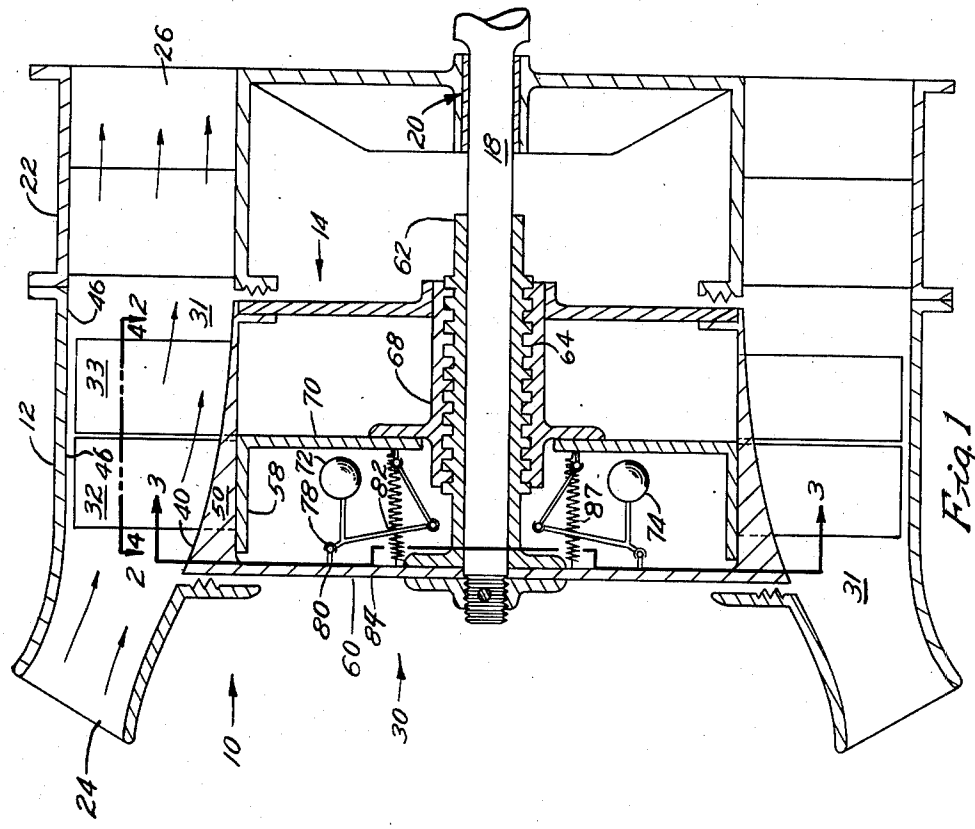


Fig. 1

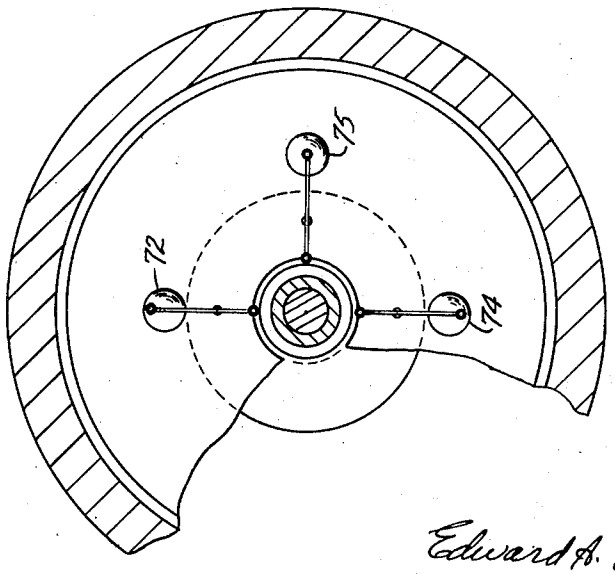


Fig. 3

INVENTOR.

Edward A. Stalker

May 21, 1957 E. A. STALKER 2,792,983

AXIAL FLOW COMPRESSORS WITH ADJUSTABLE STAGES

Filed Nov. 5, 1954 2 Sheets-Sheet 2

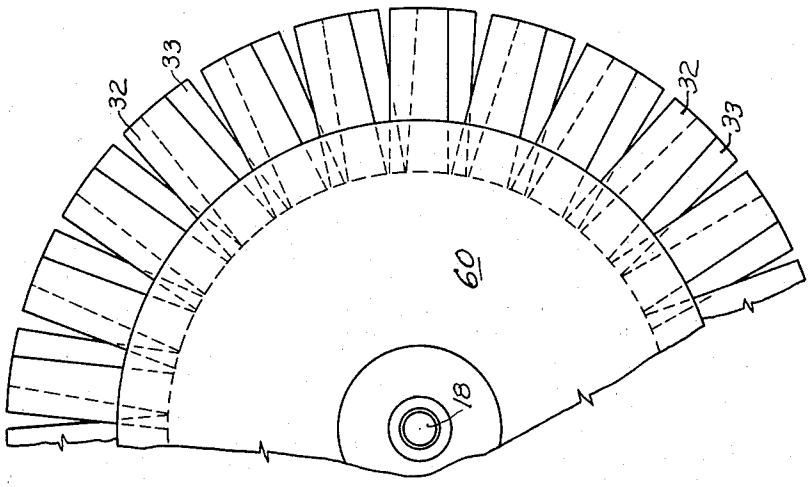


Fig. 6

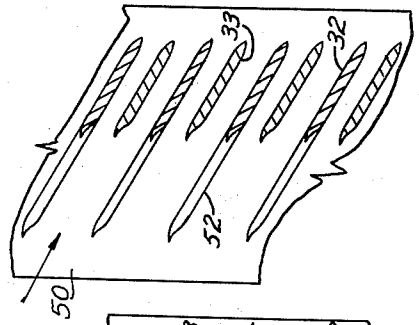


Fig. 4

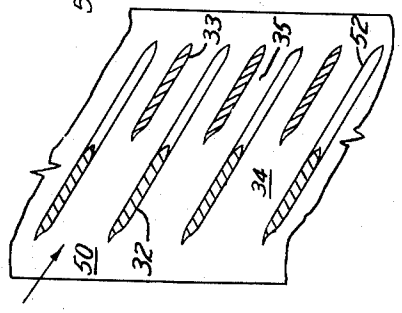


Fig. 2

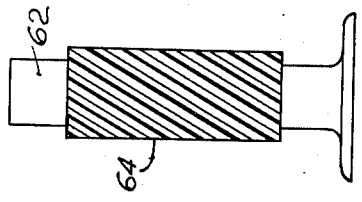


Fig. 5

INVENTOR.

Edward A. Stalker

United States Patent Office 2,792,983 Patented May 21, 1957

2,792,983

AXIAL FLOW COMPRESSORS WITH ADJUSTABLE STAGES

Edward A. Stalker, Bay City, Mich.

Application November 5, 1954, Serial No. 467,097

11 Claims. (Cl. 230—114)

This invention relates to fluid machines having bladed rotors, such as compressors and the like.

An object of the invention is to provide increasing fluid mass flow with increasing speed of rotation, particularly in the range of supersonic fluid speeds relative to the blades of the machines.

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

When a bladed rotor, for instance an axial flow compressor rotor, achieves supersonic speed relative to the fluid, the mass flow ceases to increase significantly with increasing time rate of rotation although the pressure increases rapidly. This is a well known characteristic of supersonic flow.

It is desirable to have the (time) rate of mass flow increase with increasing rate of rotation of the rotor, or some variation in mass flow with increasing pressure.

In this invention the rate of mass flow may be varied with respect to the rate of rotation and/or with respect to the change in pressure.

Referring now to the drawings the above objects are accomplished by the means illustrated in the accompanying drawings in which—

Fig. 1 is a fragmentary axial section through a compressor according to this invention;

Fig. 2 is a fragmentary development of the blading on line 2—2 in Fig. 1;

Fig. 3 is a fragmentary section on line 3—3 in Fig. 1;

Fig. 4 is a fragmentary development on line 4—4 (same as 2—2) in Fig. 1 with the front blades retracted;

Fig. 5 is a side view of the hub element of Fig. 1; and

Fig. 6 is a front axial view of the rotor of the compressor of Fig. 1.

Referring to the drawings the compressor is indicated generally as **10** in Fig. 1. It comprises the case **12** housing the rotor **14** mounted for rotation by its shaft **18** in bearing **20** which is supported by the stator housing **22**.

Fluid enters the case **12** through the annular inlet **24** and leaves the compressor through the annular exit **26**.

The rotor comprises the hub assembly **30** forming an annular duct **31** with the case **12** and a plurality of axial flow blades **32** and **33** carried on the hub assembly in two rows, the blades of each row being in peripherally spaced relation providing the rotor flow passages **34** between them for the front row and passages **35** for the rear row. The blade tips fit closely to the case to prevent significant back flow of the pumped fluid.

Fig. 2 shows the blades **32** positioned forward of blades **33**. Fig. 4 shows the front blades retracted to positions between the rear blades **33**. It will be observed that the cross section of the duct **31** is larger at the leading edges of the rear blades than at the leading edges of the front blades. Accordingly when the front blades are retracted to the rear blades the inlet cross sectional areas of the passages between blades is increased.

If the retraction of the front blades is made a function of the rate of rotation of the rotor the inlet cross sectional area can be made to increase with increasing rate of rotation.

The surface **40** of the hub assembly is inclined radially inward along the rearward or downstream direction of the general flow through the compressor. That is the outside diameter of the hub assembly decreases rearward along the rotor axis. Preferably the inside surface **46** of the case is cylindrical so that one row of blades can be shifted axially relative to the other while maintaining the same tip clearances with the inside surface of the case.

The retraction of the blades is accomplished by the mechanism shown particularly in Figs. 1 and 3.

The rear blades **33** are carried on the hub rim **50**. It has slots **52** (see Figs. 2 and 4) which permit the front blades **32** to extend inward to the movable rim **58** which seals the slots **52** in the rim **50**.

The rim **50** is integral or fixed to the disk **60** which is fixed to the hub **62** suitably mounted on shaft **18** to rotate with it.

The hub screw **62** carries the multiple threads **64** of pitch angle corresponding to the helical path of each blade when it is moved axially. The hub nut **68** engages the threads of the hub screw and is fixed to the disk **70** carrying the rim **58**. When the nut is moved axially along the screw the blades **32** move along their slots **52** with axial and peripheral components of motion.

The axial movement of the blades is made a function of a speed property of the rotor by means of the masses **72—75** shown in Figs. 1 and 3. As the rotor increases in peripheral speed the masses move outward about their hinges **78** carried in the brackets **80** fixed to disk **60**. Each mass has the arm **82** connected to disk **70** by a link **84** to push the nut **68** rearward and with it the front row of blades **32**.

The forward axial movement of the blades occurs when the rotor slows down. The fluid forces on the blades act forward to move the blades forward. These forces may be assisted also by a spring **87**. See Fig. 1.

For a passage of fixed geometry and having a throat the time rate of mass flow reaches a maximum for sonic velocity at the throat and does not increase significantly with increasing relative speed of the flow.

In the rotor of this invenion as the speed relative to the fluid increases the inlet of each passage is increased in cross sectional area. The throat area is preferably also varied to have a suitable relation to the inlet area. This is accomplished by the selection of the blade thickness and the contour of the surface **40** in axial planes. Preferably the cross sectional area at the throat decreases as the speed of rotation increases. See Figs. 2 and 4.

Preferably the blades have sharp leading edges with a small chordwise length of concave surface extending rearward from the leading edge. They are also preferably thin and overlap in axial view throughout their spans and the leading edge of a succeeding blade is preferably forward chordwise of the mid-chord point of a preceding blade.

Where the blades of a front row are retracted to positions between the blades of a rear row there is introduced a variation in the ratio of the cross sectional areas at the throat and inlet of each passage, as remarked earlier. In some applications the variation in the throat area may be less significant as for instance in operation at subsonic tip speeds, or where low cost and simplicity are significant. Then a single row of blades may be employed which is movable axially from one locality to another of the main flow duct.

Thus in Figs. 1 and 2, for instance, only the front blades **32** would be present. They would be retractable to a rearward locality like that occupied by the rear blades **33** as shown in these figures.

It will now be clear that I have disclosed a novel compressor which can operate in the range of supersonic speed with the rate of fluid flow increasing with increasing rate of rotation.

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

I claim:

1. In combination in a supersonic compressor for compressing an elastic fluid, a case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case for conduction of said fluid, a first row of blades carried on said hub means at a forward locality thereof in peripherally spaced relation thereabout dividing said duct into a plurality of rotor flow passages, a second row of peripherally spaced blades carried on said hub means rearward adjacent to said first row, said hub means having decreasing diameters rearward cooperating with said case to provide increasing cross sectional areas of said duct rearward therealong, means to displace said blades of said first now rearward to positions between said blades of said rear row where said annular cross section at the inlet side of said blades is greater than at said forward locality, and means to rotate said hub means and blades at blade tip speeds relative to said fluid forward adjacent to said blades greater than the speed of sound in said adjacent fluid.

2. In combination in a supersonic compressor for compressing an elastic fluid, a case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case for conduction of said fluid, a first row of blades carried on said hub means at a forward locality thereof in peripherally spaced relation thereabout dividing said duct into a plurality of rotor flow passages, a second row of peripherally spaced blades carried on said hub means rearward adjacent to said first row, said hub means having decreasing diameters rearward cooperating with said case to provide increasing cross sectional areas of said duct rearward therealong, means to displace said blades of said first row rearward to positions between said blades of said rear row where the annular cross section at the inlet side of said blades is greater than at said forward locality, each said blade having a sharp leading edge and increasing in thickness rearward therefrom, and means to rotate said hub means and blades at blade tip speeds relative to said fluid forward adjacent to said blades greater than the speed of sound in said adjacent fluid.

3. In combination in a supersonic compressor for compressing an elastic fluid, a case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case for conduction of said fluid, a first row of blades carried on said hub means in peripherally spaced relation thereabout dividing said duct into a plurality of rotor flow passages, a second row of peripherally spaced blades carried on said hub means at a forward locality thereof rearward adjacent to said first row, said hub means having decreasing diameters rearward cooperating with said case to provide increasing cross sectional areas of said duct rearward therealong, means to displace said blades of said first row rearward to positions between said blades of said rear row where the annular cross section at the inlet side of said displaced blades is greater than at said forward locality, each said blade having a sharp leading edge and increasing in thickness rearward therefrom, said blades of said combined front and rear rows overlapping in axial view and having the leading edges of succeeding blades chordwise forward of the mid-chord points of preceding blades, and means to rotate said hub means and blades at blade tip speeds relative to said fluid forward adjacent to said blades greater than the speed of sound in said adjacent fluid.

4. In combination in a supersonic compressor for compressing an elastic fluid, a case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case for conduction of said fluid, a first row of blades carried on said hub means at a forward locality thereof in peripherally spaced relation thereabout dividing said duct into a plurality of rotor flow passages, a second row of peripherally spaced blades carried on said hub means rearward adjacent to said first row, said hub means having decreasing diameters rearward cooperating with said case to provide increasing cross sectional areas of said duct rearward therealong, means to rotate said hub means and blades at blade tip speeds relative to said fluid forward adjacent to said blades greater than the speed of sound in said adjacent fluid, and means to displace said blades of said first row rearward to positions between said blades of said rear row as a function of said tip speeds whereby the inlet side of said displaced blades is at a locality of greater cross sectional area than at said forward locality.

5. In combination in a compressor for compressing an elastic fluid, a generally cylindrical case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case, said duct being directed along said axis for conduction of said fluid therethrough in the general axial direction, a row of blades in said duct carried on said hub means at a forward locality thereof in peripherally spaced relation thereabout with their leading edges extending outward of said hub means in the general radial directions and dividing said duct into a plurality of rotor flow passages, said hub means having decreasing diameters rearward cooperating with said case to provide increasing cross sectional areas of said duct axially rearward therealong, and means to displace said blades rearward to a locality where the cross sectional area of said annular duct is greater than at said forward locality.

6. In combination in a compressor for compressing an elastic fluid, a generally cylindrical case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case, said duct being directed along said axis for conduction of said fluid therethrough in the general axial direction, a row of blades in said duct carried on said hub means at a forward locality thereof in peripherally spaced relation thereabout with their leading edges extending outward of said hub means in the general radial directions and dividing said duct into a plurality of rotor flow passages, said hub means having decreasing diameters rearward cooperating with said case to provide increasing cross sectional areas of said duct axially rearward therealong, said blades at the tips thereof fitting closely to the duct surface of said case, and means to displace said blades axially rearward to a locality where the cross sectional area of said annular duct is greater than at said forward locality while retaining said blades in said closely fitting relation to said duct surface.

7. In combination in a supersonic compressor for compressing an elastic fluid, a generally cylindrical case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case, said duct being directed along said axis for conduction of said fluid therethrough in the general axial direction, a row of blades within said duct carried on said hub means in peripherally spaced relation thereabout with their leading edges extending outward of said hub means in the general radial directions and dividing said duct into a plurality of rotor flow passages, said duct having increasing cross sectional areas axially therealong, and means to move said blades axially in said duct to provide increased cross sectional areas for each said rotor passage at the inlet thereof during rotation of said rotor hub means and said blades.

8. In combination in a supersonic compressor for com-

pressing an elastic fluid, a generally cylindrical case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case, said duct being directed along said axis for conduction of said fluid therethrough in the general axial direction, a row of blades within said duct carried adjustably on said hub means in peripherally spaced relation thereabout with their leading edges extending outward of said hub means in the general radial directions and dividing said duct into a plurality of rotor flow passages, said duct having increasing cross sectional areas axially therealong, and means to move said blades axially to provide increased cross sectional areas for each said rotor passage at the inlet thereof during rotation of said rotor hub means and said blades as a function of the rate of rotation thereof.

9. In combination in a supersonic compressor for compressing an elastic fluid, a generally cylindrical case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case, said duct being directed along said axis for conduction of said fluid therethrough in the general axial direction, a row of blades within said duct on said hub means in peripherally spaced relation thereabout with their leading edges extending outward of said hub means in the general radial direction and dividing said duct into a plurality of rotor flow passages, and means to move said blades relative to said hub means to provide increased cross sectional areas for each said rotor passage at the inlet thereof during rotation of said hub means and said blades.

10. In combination in a supersonic compressor for compressing an elastic fluid, a generally cylindrical case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case, said duct

being directed along said axis for conduction of said fluid therethrough in the general axial direction, a row of blades within said duct on said hub means in peripherally spaced relation thereabout with their leading edges extending outward of said hub means in the general radial direction and dividing said duct into a plurality of rotor flow passages, and means to move said blades relative to said hub means to provide increased cross sectional areas for each said rotor passage with increasing rates of rotation of said hub means in response to said increasing rates.

11. In combination in a supersonic compressor for compressing an elastic fluid, a generally cylindrical case, a rotor hub means positioned in said case for rotation about an axis defining an annular duct with said case, said duct being directed along said axis for conduction of said fluid therethrough in the general axial direction, a row of blades within said duct on said hub means in peripherally spaced relation thereabout with their leading edges extending outward of said hub means in the general radial direction and dividing said duct into a plurality of rotor flow passages, said hub means having decreasing diameters axially therealong cooperating with said case to provide increasing cross sectional areas of said duct axially therealong, and means to move said blades relative to said hub means to provide increased cross sectional areas for each said rotor passage at the inlet thereof during rotation of said hub means and said blades.

References Cited in the file of this patent

FOREIGN PATENTS

364,732 Germany ---------- Dec. 1, 1922