

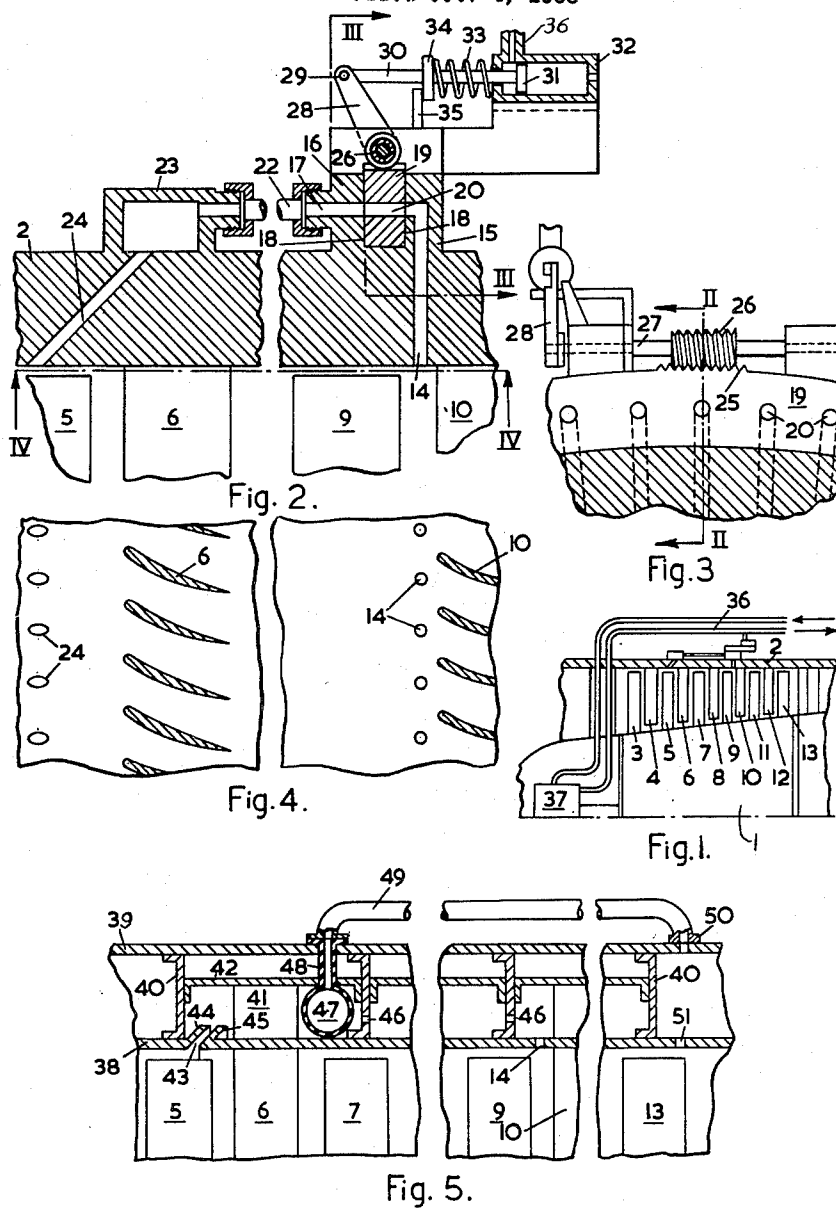
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MULTI-STAGE AEROFOIL-BLADED COMPRESSORS

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MULTI-STAGE AEROFOIL-BLADED COMPRESSORS

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8 Claims. (Cl. 230—114)

This invention relates to multi-stage aerofoil-bladed compressors.

A tendency exists for excessive vibration in the blades of one or more blade rows of such a compressor when operating at loads below the designed full load, which tendency may lead to a blade failure. In general the blades of all the rows towards the inlet end of the compressor approach a stalled condition at progressively reduced loads since the ratio of velocity of the working fluid transversely of the rows to the relative rotational velocity between the blades and fluid in the inlet rows is reduced as compared with the designed ratio. It is supposed that a critical stage may be reached when, due to slight differences in the geometry of individual blades of a particular row or to slight variations around the circumference of the row in the condition of the impinging flow, there is an instability in the flow through passages between some of the blades. In this event the remaining blades of the affected row are thought to be subjected to excitation loads resulting from the unstable flow and so are prone to vibration stresses greater than those experienced even at the designed full load. Again, at incidences higher than a particular critical value for blades of appropriate stiffness, stalling flutter (a torsional vibration about a longitudinal axis of a blade) may be excited, leading to similarly high blade stresses.

An object of the invention is to reduce the risk of excessive vibration stresses in the blades of a compressor.

The invention consists of a multi-stage axial flow compressor having a rotor with a circumferential row of aerofoil blades mounted on the rotor, the blades extending radially outwards from the rotor, and a circumferential wall structure surrounding the blades at their radially outer ends, wherein the wall structure has radially inwardly directed inlet means for admitting fluid to the flow path of the compressor which inlet means extend circumferentially of the wall structure at a region upstream of the outlet plane of the blade row, so that the fluid discharged from the inlet means produces a restriction in the transverse area of the working fluid flow path in the region of the blade row. The working fluid will by virtue of the restriction flow for at least a short distance with an increased axial component of velocity whereby the ratio of the axial component to the relative rotational component of velocity of working fluid impinging on the blade row is increased. The proneness to vibration is a characteristic of blades which are attached in the conventional manner at one end, the other end being free. In such blade the excitation loads on an incremental length of the free end of the blade contribute much more to the blade stress than those on a similar length of the attached end of the blade. The invention affords the possibility of inhibiting the excitation loads at the unattached ends of the blades of the row by screening the ends from the working fluid. Moreover this possibility is particularly advantageous

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when afforded in accordance with the invention in a rotor blade row, since the risk of blade failure is generally greater in a rotating row where the stress induced by vibration augments that due to centrifugal load. As the circumferential disposition in an affected blade row of the proportion of affected blade is not capable of pre-determination the introduction of fluid to produce a restriction in the working fluid flow path is effected by a further feature of the invention in a uniform manner circumferentially of the blade row.

In accordance with a further feature of the invention the fluid supplied to the inlet means is withdrawn from a subsequent point of the compressor. In this way a proportion of the working fluid is recirculated through an affected blade row thereby increasing the quantity of fluid traversing the row so that the above mentioned ratio of components of fluid velocity tends to be further increased. Moreover if the fluid is withdrawn from an intermediate point in the compressor there is no comparable increase in that ratio in the flow through blade rows after the withdrawal point.

In general the quantity of fluid introduced through the inlet means is desirably increased at progressively reduced compressor loads. Consequently the introduction of the fluid is preferably controlled by valve or similar means responding to compressor load which progressively limits the quantity introduced from a low to a high load condition. Thus the admission of fluid may be fully operative at starting and fully inoperative when the compressor reaches 60% to 70% of its full load.

The invention has a further application, again in multi-stage axial flow compressors, for maintaining at different load conditions a similar relationship between flow conditions in the various blade stages (known as matching the blade stages) by variably influencing the flow in one or more stages at different compressor loads.

The invention is best understood from the constructional embodiments thereof described below with reference to the accompanying drawings. In the drawings:

Fig. 1 is a half section of a multi-stage axial flow compressor embodying the invention taken along the rotational axis of the machine;

Fig. 2 is an enlarged view of a detail of the stator casing of the compressor of Fig. 1;

Figs. 3 and 4 are views seen in the direction of arrows III—III, IV—IV respectively of Fig. 2;

Fig. 5 is a view corresponding to that of Fig. 2 of an alternative construction applicable to the compressor of Fig. 1.

The compressor of Fig. 1 has a rotor 1 and stator casing 2 carrying alternate rows of moving and fixed blades 3 to 13 respectively spaced successively in the direction of flow of working fluid. Fig. 2 shows details of the stator casing in the region of blades 6 and 10. Immediately upstream of the row of stator blades 10 the stator casing 2 has a number of circumferentially spaced bleed holes 14 extending radially from its inner surface. These holes pass into but not completely through a radially upstanding circumferential flange 15 on the outer side of the casing 2. Spaced in the direction of the compressor inlet from this flange is a second similar flange 16. A number of holes 17 corresponding to the number of bleed holes pass through the second flange 16 and into but not through the first flange 15 in a direction parallel to the compressor axis to intersect in each case one of the bleed holes 14. The adjacent sides 18 of the flanges are in radial planes and afford sealing faces for a valve ring 19 located in the channel between the flanges 15, 16. The valve ring 19 embraces the casing circumferentially and has axially extending holes 20 passing completely through it which match the

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axial holes 17 in the flanges, the ring being rotatable about the casing from a position in which there is full communication between the bleed holes 14 and the holes 17 in the second flange 16 to a position where the bleed is entirely obstructed. The holes 17 in the second flange 16 are provided, on the side thereof towards the compressor inlet, with pipe connections and pipes 22 connected thereto which pass to a manifold 23 encircling the casing outwardly of the row of stator blades 6 from the compressor inlet. The stator casing has another circumferential series of bleed air inlet holes 24 which penetrate the inner surface of the stator casing approximately midway between the inlet and outlet planes of the rotor blade row 5. These inlet holes 24 are inclined outwardly and rearwardly through the casing each communicate with the bleed air manifold 23. The number of bleed inlet holes 24 is of the same order as the number of rotor blades 5 which is substantially equal to the number of stator blades 6. The number of holes is considered sufficient so long as it represented a substantial proportion of the number of blades 5. The number of bleed outlet holes 14 need not be as great as the number of inlet holes 24. The bleed inlet holes 24 are evenly spaced circumferentially of the stator casing 2, and their inclination is such that the air issuing from the holes will overcome the axial velocity of the working fluid leaving the stator blades 4 to the extent that the tips of the rotor blades 5 are cloaked at their leading edge from said working fluid. At the same time the bleed air is introduced with a radial component of motion so that a significant length of each of the rotor blades 5 inward of the tip is cloaked from the working fluid. It follows that the effective length of the rotor blades 5 is correspondingly reduced and with it the flow area available to the working fluid leaving the second stator row, whereby the axial component of velocity of the working fluid tends to increase. At the same time the flow of fluid in the compressor between the rows of rotor blades 5 and 9 is augmented as compared with the other blade rows by the quantity of the bleed fluid, again tending to increase the axial velocity component of the working fluid.

The valve ring 19 is provided on its outer periphery with a toothed sector 25 which is meshed with a worm 26 supported and axially located on the stator casing. The worm has a fixed shaft 27 on which is mounted a crank 28. The crank pin 29 is engaged by a connecting rod 30 extending approximately at right angles to the crank and carries a piston 31 which operates in a cylinder 32 attached to the stator casing. A compression spring 33 embracing the connecting rod bears against a collar 34 on the rod and the cylinder 32 to constrain the rod in a direction such that the collar engages a stop 35 on the stator casing, the holes 20 in the valve ring 19 being then fully aligned with the holes 17 in the adjacent flanges. The piston is arranged to respond to pressure in the cylinder to oppose the compression spring. The cylinder has a connection 36 to a fluid pump 37 driven from or with the compressor shaft to deliver fluid at a pressure rising with the compressor speed. As the compressor speed increases the valve ring is rotated so that the bleed is progressively obstructed. The bleed is arranged to be cut off when the compressor speed reaches a value proportionate to a load of 60-70% of the designed load of the compressor.

In an alternative construction the bleed may be introduced at more than one compressor stage from, for example, a single manifold, being preferably introduced in both stages near the rotor blade tips.

In the further construction of Fig. 5 as applied to an axial flow air compressor having similar blading to that of Fig. 1, the compressor stator casing consists of two circumferential walls 38, 39 of sheet material spaced radially from one another by diaphragms 40 outward of the rotor blades. The stator blades have root extensions

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41 passing through the inner wall and engaging an intermediate wall 42 extending axially between the diaphragms 40. Bleed inlet and outlet apertures are located in the same axial planes, relatively to the blade rows, as in Fig. 2 but the bleed inlet is a circumferential slit 43 formed between axially spaced portions of the inner casing wall 38. The adjacent edges of the inner wall portions have circumferential flanges 44, 45 extending outwardly and obliquely to the wall to direct the bleed air with an upstream component of motion. The bleed outlets are circumferentially spaced holes in the inner wall of the stator case. Communication between the bleed outlet 14 and inlet 43 is afforded by the wall cavity, the intervening diaphragms being apertured at 46 to ensure this. In the bleed passage formed within the wall cavity there is enclosed a circumferentially extending rubber tube 47 which is of initially flattened cross-section and is inflatable to engage the bounding walls of the passage and so to obstruct the bleed. The obstruction is progressively reduced as the tube is collapsed. The tube has a connection 48 passing through the outer casing wall 39 and a pipe 49 extends from connection 48 to a further connection 50 on the casing. The latter communicates through a hole 51 with the blade passage of the compressor outwardly of the last row of rotor blades 13. Thus the internal pressure of the tube 48 is progressively greater than the surrounding pressure as the pressure rise through the compressor i.e. the compressor load, is increased. The bleed will thus be unobstructed when the compressor is started and is arranged to be fully obstructed at 60%-70% of the full load of the compressor.

I claim:

1. A multi-stage axial flow compressor having an inner circumferential wall rotatable about an axis, an outer circumferential wall spaced radially outwards from said inner rotatable wall and defining therewith an axially extending main flow path for said working fluid, a circumferential row of elongated blades mounted on and rotatable with said inner wall and extending longitudinally between the latter and said outer wall, said blades being of aerofoil profile in transverse section and terminating in substantially radial inlet and outlet edges spaced successively in the direction of the main fluid flow along said path, conduit means located outside said outer wall and defining a passage separate from the main flow path and means to supply supplementary fluid to said conduit means, wherein said outer wall is apertured to provide inlet means for admitting supplementary fluid from said conduit means to said main flow path, said inlet means being disposed circumferentially round the outer wall at a region upstream of the outlet edges of the blades of said row, being directed partly radially inwardly and partly upstreamwardly with respect to the direction of the main fluid flow, and being so dimensioned that the supplementary fluid is discharged at such a velocity that it can penetrate inwardly across the main flow path beyond the radially outer ends of the blades.

2. A compressor according to claim 1 having valve means in said conduit means operable to interrupt the fluid flow therethrough.

3. A compressor according to claim 2 wherein said means to supply supplementary fluid includes said outer wall structure being apertured at a region downstream of said blade row to provide outlet means for working fluid, which outlet means communicates with said conduit means.

4. A compressor according to claim 2 having operating means for said valve means acting in dependence upon the rotational speed of the blades to progressively close the valve means as the rotational speed increases.

5. A compressor according to claim 2, having operating means for said valve means acting in dependence upon the pressure of compressed working fluid to close

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said valve means as the pressure of the compressed fluid increases.

6. A compressor according to claim 5 wherein said valve means is an inflatable sac, said wall structure being apertured at a region downstream of said blade row to afford a vent of compressed working fluid and having means connecting said vent to said inflatable sac.

7. A compressor according to claim 1, wherein said wall structure is apertured at a region downstream of said blade row to provide outlet means for fluid communicating with said conduit means, valve means in said conduit means operable to interrupt fluid flow there-through, and operating means for said valve means acting in dependence upon the rotational speed of the blades to progressively close the valve means as the rotational speed increases.

8. A compressor according to claim 1, wherein said wall structure is apertured at a region downstream of said blade row to provide outlet means for fluid communicating with said conduit means, valve means in said con-

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duit means operable to interrupt fluid flow therethrough, and operating means for said valve means acting in dependence upon the pressure of compressed working fluid to close said valve means as the pressure of the compressed fluid increases.

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