Dec. 18, 1962 C. A. MACALUSO ETAL 3,069,070

DIFFUSER VANE SYSTEM FOR TURBOMACHINERY

Filed Nov. 14, 1961 2 Sheets-Sheet 1

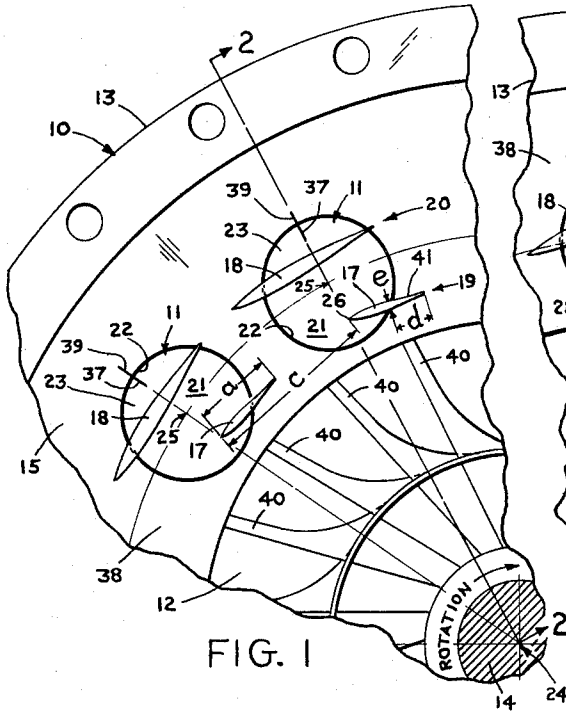


FIG. 1

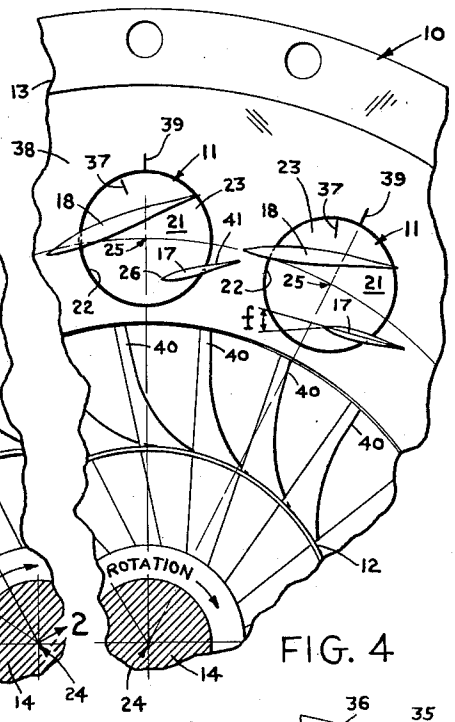


FIG. 4

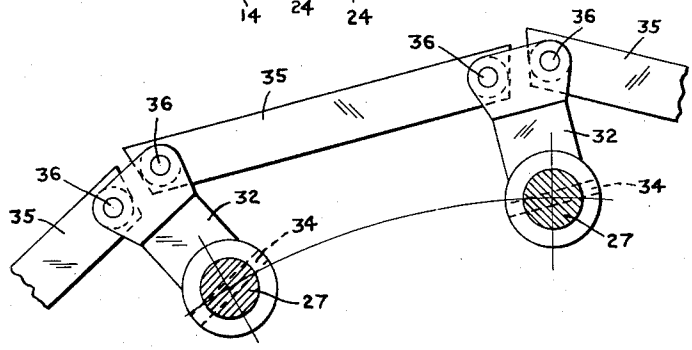


FIG. 3

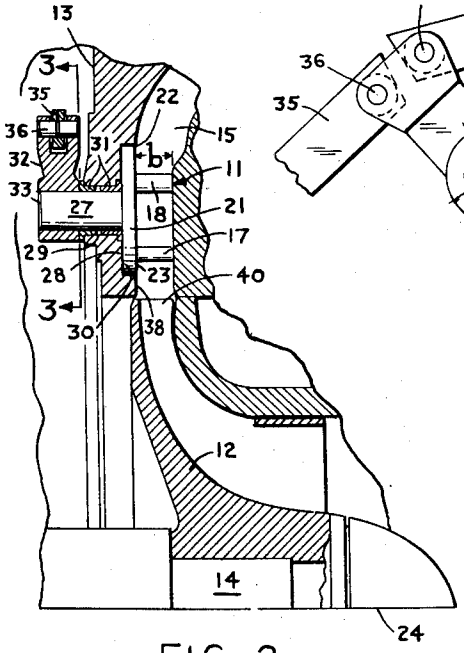


FIG. 2

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DIFFUSER VANE SYSTEM FOR TURBOMACHINERY

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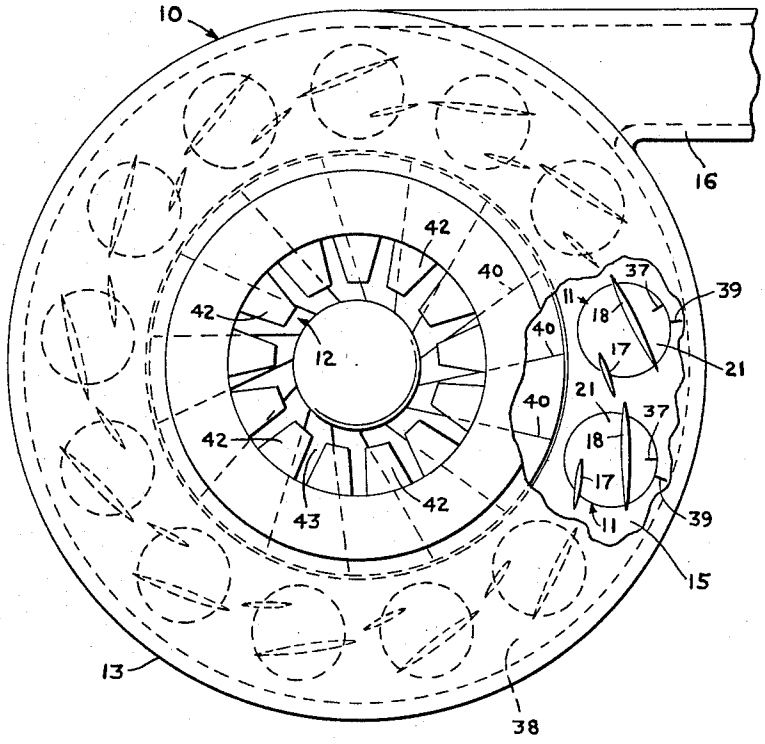


FIG. 5

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DIFFUSER VANE SYSTEM FOR TURBOMACHINERY

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This invention relates generally to turbomachinery. More particularly the invention relates to a rotatable diffuser vane system for turbomachinery.

The use of rotatable diffuser vanes in turbomachinery is well known in the art, but their use has been limited to that of systems using a single row of diffuser vanes. However, for many operations the use of the prior art single row diffuser vane systems has led to a lowered efficiency resulting from losses due to friction, boundary layer separation, vane vibration and surging.

It is the object of the present invention to raise the efficiency throughout a wide range of flow and to improve performance by using a novel diffuser vane system which prevents or avoids the difficulties in the prior art.

In accordance with the present invention a turbomachine is provided which comprises a casing having an inlet means and an outlet means therein. An impeller is disposed in the casing between the inlet means and the outlet means. There are a plurality of rotatable members circumferentially spaced in said outlet means. Also at least two rows of radially sapced vanes are disposed in the outlet means with one vane from each of the rows of vanes mounted on each of the members. Means are operatively associated with each of the rotatable members and adapted to rotate the members to maintain the optimum incidence angle of the vanes mounted on the members.

One of the objects of this invention is to minimize the frictional losses by controlling the solidity ratio and aspect ratio of the diffuser vane system.

Another object of this invention is to lower the energy loss by limiting the boundary layer growth of the diffuser vane system.

Another object of this invention is to simplify the mechanical arrangement of the rotatable diffuser vane system.

Another object of this invention is to provide for improved efficiency throughout a wide range of flow by rotatable diffuser vane means.

Another object of this invention is to prevent resonance and excessive vibration of the vane members.

Still another object of this invention is to balance the forces acting on the rotatable diffuser vanes so as to reduce the torque required to rotate the discs the vanes are mounted on.

Still another object of this invention is to eliminate stalling of the fluid flowing in the diffuser vane system thereby preventing surge.

With these and other objects in view, as may appear from the accompanying specification, the invention consists of various features of construction and combination of parts which will be first described in connection with the accompanying drawings, showing a diffuser vane system of a preferred form and the features forming the invention will be specifically pointed out in the claims.

In the drawings:

FIGURE 1 is a partial section perpendicular to the axis of the impeller and embodying the novel diffuser vane system.

FIGURE 2 is a section taken in the direction of line 2—2 of FIGURE 1.

FIGURE 3 is a section taken in the direction of line 3—3 of FIGURE 2.

FIGURE 4 is a partial section perpendicular to the axis of the impeller and showing the vane angle changed.

FIGURE 5 is a front view of the turbomachine partly broken away and showing the inlet guide vanes and the novel diffuser vane system.

Referring more particularly to the drawings FIGURE 1 shows a turbomachine **10** in which the novel diffuser vane system **11** is used.

The turbomachine **10** could be any type of pump or compressor, for example, having a driving impeller **12** in a casing **13** and mounted on a shaft **14**, the shaft **14** being connected to a suitable source of power (not shown).

The diffuser vane system **11** as shown in FIGURES 1 and 2 is located in the discharge passageway **15** of the casing **13** adjacent the outlet **16** but it is understood that certain applications may warrant the use of this type system in a suitable inlet and it is understood that such a modification is within the scope of this invention as hereinafter described and claimed.

Accordingly the diffuser vane system **11** utilizes vanes **17** and **18** arranged in radially spaced rows, there being shown an inner row of vanes **19** and an outer row of vanes **20** but it is clear that any suitable number of rows of vanes could be used. One vane **17** from the inner row of vanes **19** and one vane **18** from the outer row of vanes **20** is mounted on a plurality of rotatable discs **21** which are disposed in equidistant circumferentially spaced circular recesses **22** in the wall **38** of the passageway **15**.

The vanes **17** and **18** are of shorter length than could be used in a single vane row system. This is especially important in considering and designing for each row of vanes the optimum aspect ratio b/a, the solidity ratio a/c, in order to limit boundary layer growth, friction losses, vane vibration and surging; where b is the span of the vane; a is the length of the vane; c is the distance between leading edges of adjacent vanes of the same row. These symbols are shown in FIGURES 1 and 2.

The vanes **17** and **18** are mounted on the outboard side **23** of the discs **21** substantially perpendicular to a line passing through the axis **24** of the impeller **12** and the center **25** of the disc **21** and the vane **17** has its leading edge **26** located substantially on this line. Vane **18** is then positioned, as shown in FIGURE 1, so that the forces acting on vanes **17** and **18** will be balanced about the center **25** of the disc **21** and no resulting moment will be created about shaft **27**.

Shaft **27** is connected to the inboard side **28** of the discs **21** as illustrated in FIGURE 2. The recess **22** has a bore **29** and a counterbore **30** therein. Bearing members **31** are provided, one being put on before the shaft **27** is placed through the bore **29** and one put on thereafter. Bearing members **31** do not restrict the rotation of the discs **21** and prevent leakage about shaft **27**.

To provide for simultaneous rotation of the discs **21** which in turn will adjust the incidence angle f of the vanes **17** and **18** a clevis **32** is mounted outside the casing **13** on the outer end **33** of each shaft. The clevis **32** is held in position by a locking pin **34**.

Linkage **35** is connected to the clevis **32** by pins **36** as illustrated in FIGURE 3. This linkage interconnects all the shafts and may be moved in any suitable manner such as by a lever (not shown). The simultaneous rotation of a plurality of discs is well know in the art and can be coupled with an angle indicator (not shown) which is also well known to show the rotation angle of the vanes.

The discs **21** as shown in FIGURE 1 are marked as at **37** which corresponds to a mark **39** on the wall **38** of the passageway **15** and indicates the normal operative position. This position can be changed as shown in FIGURE 4 by rotating the discs **21** to maintain an optimum incidence angle corresponding to the flow characteristics.

The vanes 17 and 18 are equidistantly circumferentially spaced in their respective rows in the balanced position hereinbefore described. This spacing allows the boundary layers formed on the vanes 17 of the inner row of vanes 19 to be shed between the vanes 18 of the outer row of vanes 20.

The vanes 17 are adjacent the discharge tip 40 of the impeller 12 and therefore in an area in which the fluid flow will have the highest Mach number. Because of this the vanes are designed to be lightly loaded or in other words vanes 17 are of a smaller profile than vanes 18. Also on rotation of discs 21 the leading edge 26 of the vanes 17 describes an arcuate path away from the axis 24 of the impeller 12 as it is located normally at the closest radial distance to the axis 24 of the impeller 12. Thus the vane 17 will not enter an area of higher Mach number than that encountered during normal operation. Further the trailing end 41 of the vanes 17 extend over the side of disc 21 and has an d/e ratio which does not exceed 5 to prevent resonance and consequent high amplitude vibration from developing; where e is vane thickness at the point of extending over the side of disc 21 and d is vane overhang length.

The vanes 18 of the outer row of vanes 20 are designed to be highly loaded as they are in an area of lower Mach number.

The vanes 17 and 18 are fixedly connected to each of the discs 21 substantially parallel to each other in a balance position to facilitate easy rotation of the discs 21 and to prevent creating a moment about the shaft 27. But the angular relationship of vanes 17 and 18 may be varied within 20° from this parallel relationship in order to accommodate a wide range of design conditions.

As the flow characteristics change the discs 21 and correspondingly the fixed vanes 17 and 18 thereon are rotated to adjust the incidence angle f illustrated in FIGURE 4 thus eliminating incidence losses and stalling of the fluid flowing in the diffuser vane system 11 and preventing surge.

This invention permits a greater overall conversion of kinetic energy to pressure energy for a given loading on a single vane row system.

If inlet guide vanes 42 illustrated in FIGURE 5 are used in the inlet 43 it is preferred that they be provided in the same number as that of the discs 21 to prevent development of non-symmetrical flow caused by the wakes from the inlet guide vanes 42 interacting with the vanes 17 and 18. It will be understood that this invention is not to be limited to the specific construction or arrangement of parts shown, but that they may be widely modified within the invention defined by the claims.

What is claimed is:

1. A turbomachine comprising:
(a) a casing having an inlet means and an outlet means therein,
(b) an impeller disposed in said casing between said inlet means and said outlet means,
(c) a plurality of rotatable members circumferentially spaced in said outlet means,
(d) at least two rows of radially vanes disposed in said outlet means with one vane from each of said rows of vanes mounted on each of said rotatable members,
(e) means operatively associated with each of said rotatable members and adapted to rotate said rotatable members to maintain the optimum incidence angle of said vanes mounted on said rotatable members.

2. The combination claimed in claim 1 wherein the vane from each of said rows of vanes has the cord line thereof forming an angle between 0° and 20° with the plane passing through the axes of said impeller and said rotatable member.

3. The combination claimed in claim 1 wherein the vanes of each of said rows of vanes are mounted on said rotatable members in substantially parallel relationship with each other.

4. The combination claimed in claim 15 wherein each of said vanes of said rows of vanes are mounted on said rotatable member in a normally operative position in a substantially perpendicular relationship with a line passing through the axes of said impeller and said rotatable member and on rotation of said rotatable member the incidence angle of said vanes thereon can be selectively positioned.

5. The combination claimed in claim 1 wherein
(a) said first row of vanes closest the discharge tip of said impeller and of substantially smaller profile than the profile of said second row of vanes remote from the discharge tip of said impeller
(b) said first row of vanes in a higher Mach number area than said second row of vanes and for a corresponding incidence angle said first row of vanes adapted to the more lightly loaded than said second row of vanes whereby boundry layer growth thereon is reduced.

6. The combination claimed in claim 1 wherein said second row of vanes of a substantially larger profile than the profile of said first row of vanes be said second row of vanes in a lower Mach number area than said first row of vanes and for a corresponding incidence angle said second row of vanes adapted to convert a maximum of the velocity energy of the fluid flowing in the outlet means into pressure energy.

7. The combination claimed in claim 6 wherein:
(a) each of said vanes of said first row of vanes having the leading edge thereof located on the plane passing through the axis of said impeller and said rotatable member in a normally operative position
(b) the leading edge of said vanes to prescribe an arcuate path away from the axis of said impeller on rotation of said rotatable member in a direction opposite to the rotational direction of said impeller to prevent the leading edge of said vane from getting closer to the discharge tip of said impeller and thereby entering a higher Mach number area of fluid flow.

8. The combination claimed in claim 7 wherein
(a) each of said vanes of said second row of vanes disposed on said rotatable member in normal operative position a greater radial distance from the axis of said impeller than the radial distance of each of said vanes of said first row of vanes
(b) the leading edge of each of said vanes of each row of vanes facing the direction of rotation of said impeller
(c) the leading edge of said vanes of said second row of vanes to extend over the side of said rotatable member whereby the weight of said vanes of said first row of vanes will not impinge on said vanes of said second row of vanes.

9. A turbo machine comprising
(a) a casing having an inlet means and an outlet means therein
(b) said outlet means including an annular passageway means in said casing
(c) an impeller in said casing between said inlet means and said passageway means
(d) said passageway means having a plurality of circular recesses equal distantly spaced in circumferencial relationship to each other
(e) each of said recesses having a bore therethrough
(f) a disc member disposed in said recess and having a shaft connected to the inward side thereof to extend through the bore in said recess
(g) means connecting each of said shafts and adapted to rotate each of said shafts thereby rotating said discs
(h) an inner row of vanes and an outer row of vanes radially spaced from the axis of said impeller and one vane from each of said rows of vanes mounted on each of said discs
(i) each of said vanes of said inner row of vanes hav-

ing the leading edge thereof located on the plane passing through the center of said disc and the axis of said impeller in a normally operative position and on rotation of said disc in the direction opposite to the rotational direction of said impeller the leading edge of said vane will describe an arcuate path away from the axis of said impeller to prevent the leading edge from entering a higher Mach number area of fluid flow nearer the discharge tip of said impeller.

10. The combination claimed in claim 9 wherein

(*a*) said inner row of vanes closer to the axis of said impeller and of a substantially smaller profile than said outer row of vanes

(*b*) said inner row of vanes in a higher Mach number area of flow than said outer row of vanes and for a corresponding incidence angle each vane of said inner row of vanes is so constructed and arranged that they can be lightly loaded to reduce boundary layer growth thereon while each vane of said outer row of vanes is so constructed and arranged that they can convert a maximum of velocity energy of the fluid flowing in the outlet means into pressure energy.

11. The combination claimed in claim 10 wherein:

(*a*) each of said vanes in said inner row of vanes has a trailing end extending over the side of said disc

(*b*) said trailing end of said vanes has a ratio of the total extension to the thickness at the point of extending over the side of said disc not to exceed 5 to prevent high amplitude vibration and resonance.

12. The combination claimed in claim 11 wherein

(*a*) each of said discs having said vane of said outer row of vanes normally mounted on the half of said disc above and a predetermined distance from the center thereof

(*b*) each of said discs having said vane of said inner row of vanes normally mounted on the half of said discs below the center thereof a sufficient distance therefrom to create a substantially equal amount acting about the center of said disc for corresponding incidence angles to permit easy rotation of said discs.

13. The combination claimed in claim 12 wherein:

(*a*) each of said discs having said vane of said inner row of vanes normally mounted on the half of said disc below the center thereof adjacent the discharge tip of said impeller,

(*b*) each of said discs having said vane of said outer row of vanes normally mounted on the half of said disc above the center thereof remote from the discharge tip of said impeller,

(*c*) each of said discs having said vanes from said inner row of vanes and said outer row of vanes mounted thereon in a normally operative position in

substantially perpendicular relationship with a line passing through the axis of said impeller and the center of said disc whereby said vanes act to diffuse the fluid flowing in said passageway means.

14. The combination claimed in claim 13 wherein:

(*a*) each of said discs adapted to be rotated simultaneously by said means operatively associated therewith to maintain the optimum incidence angle of said vanes mounted substantially parallel thereon whereby the diffuser vane efficiency can be maintained over a wide range of flow.

15. A turbomachine comprising:

(*a*) a casing having an inlet means and an outlet means therein,

(*b*) said outlet means including an annular passageway means in said casing,

(*c*) an impeller disposed in said casing between said inlet means and said passageway means,

(*d*) a plurality of discs disposed in said passageway means with substantially equidistant circumferential relationship therebetween and adapted to be rotated,

(*e*) each of said discs having a pair of radially spaced substantially parallel vanes mounted thereon,

(*f*) said pairs of vanes extending substantially the full width of said passageway means,

(*g*) the inner vane is closer to the axis of said impeller and of substantially smaller profile than the outer vane,

(*h*) said inner vane and said outer vane to coact to diffuse the fluid flowing in said passageway means whereby the velocity energy of the fluid can be converted to pressure energy,

(*i*) means interconnected between each of said discs to rotate said discs whereby the incidence angle of said pairs of vanes can be changed to obtain diffusion corresponding with the fluid flow conditions.

16. The combination claimed in claim 15 wherein:

(*a*) guide vanes are disposed in said inlet means,

(*b*) said guide vanes of the inlet means and said pairs of vanes of said passageway means of equal number to prevent non-symmetry of flow in said outlet means caused by guide vane wakes interacting in the passageway means.

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