US 20050047943A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2005/0047943 A1
Jarrah (43) Pub. Date: Mar. 3, 2005

(54) COMPRESSOR SURGE PREVENTION VIA DISTINCT BLADE SHAPES

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(21) Appl. No.: 10/652,868

(22) Filed: Aug. 29, 2003

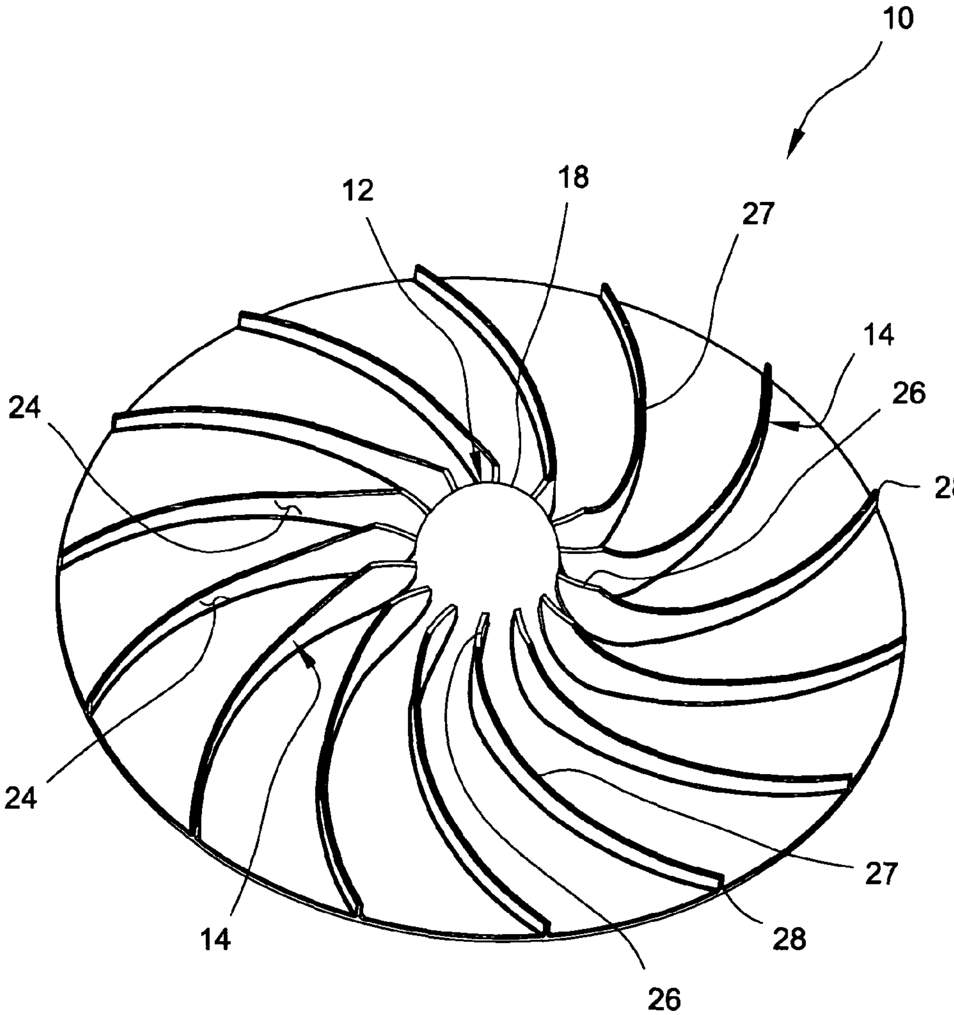
Publication Classification

(51) Int. Cl.[7] F04B 17/00

(52) U.S. Cl. 417/423.1; 417/572

(57) ABSTRACT

A compressor includes a vaneless diffuser, a volute in fluid communication with the diffuser, and an impeller operable to compress a fluid stream and direct the fluid stream to the diffuser. The impeller includes a hub having an axis of rotation and a plurality of blades extending therefrom. The blades include a surface defined by an axial direction (Z), a radius (R) defined from the axis of rotation of the hub, and a polar angle (⊖), whereby ⊖ is substantially defined by the equation: ⊖=a*[natural logarithm of (R)]+b.



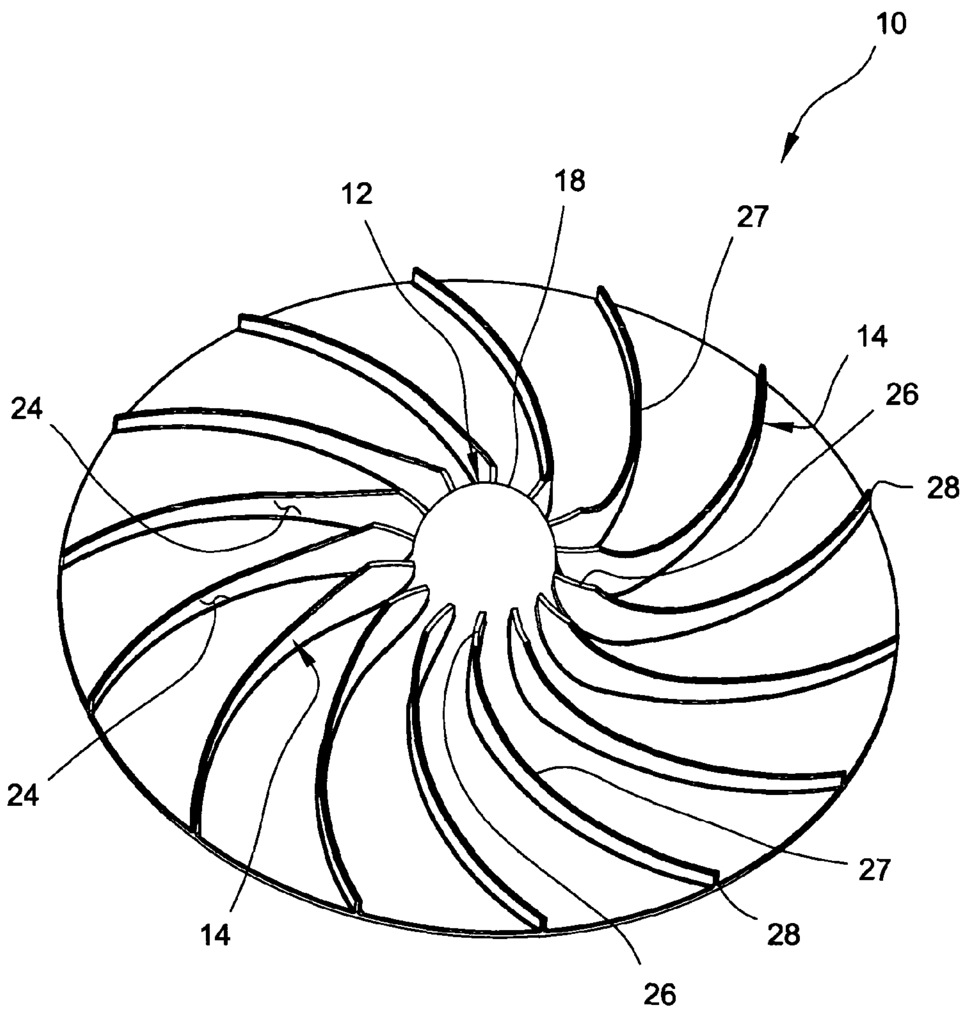
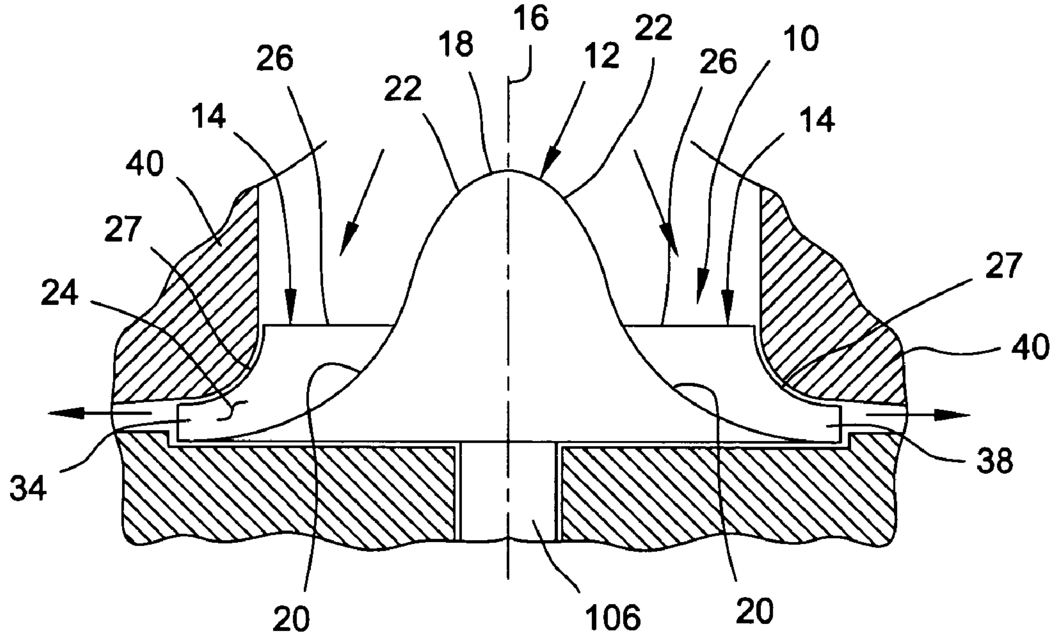


FIG 1


16
18
12
22
26
10
22
26
14
14
40
27
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24
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34
38
20
106
20

FIG 2

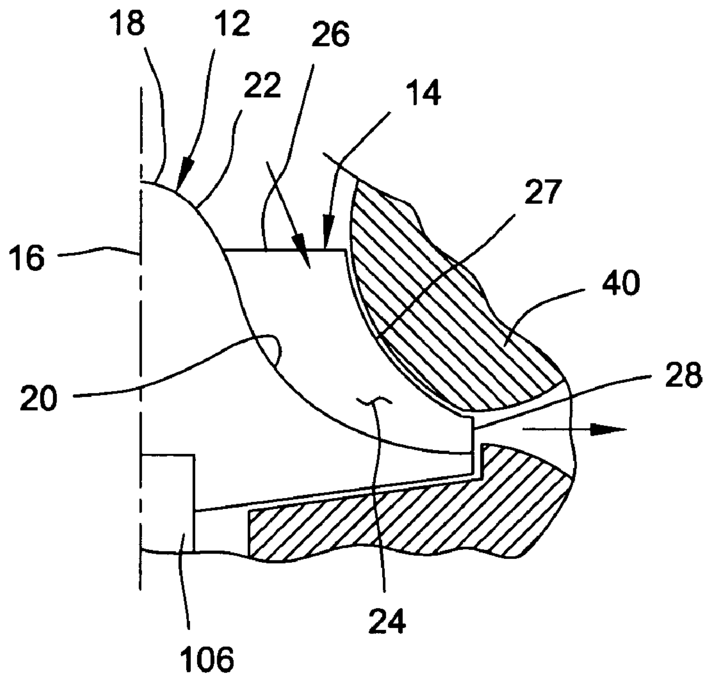
18
12
26
22
14
27
16
40
20
28
106
24

FIG 3

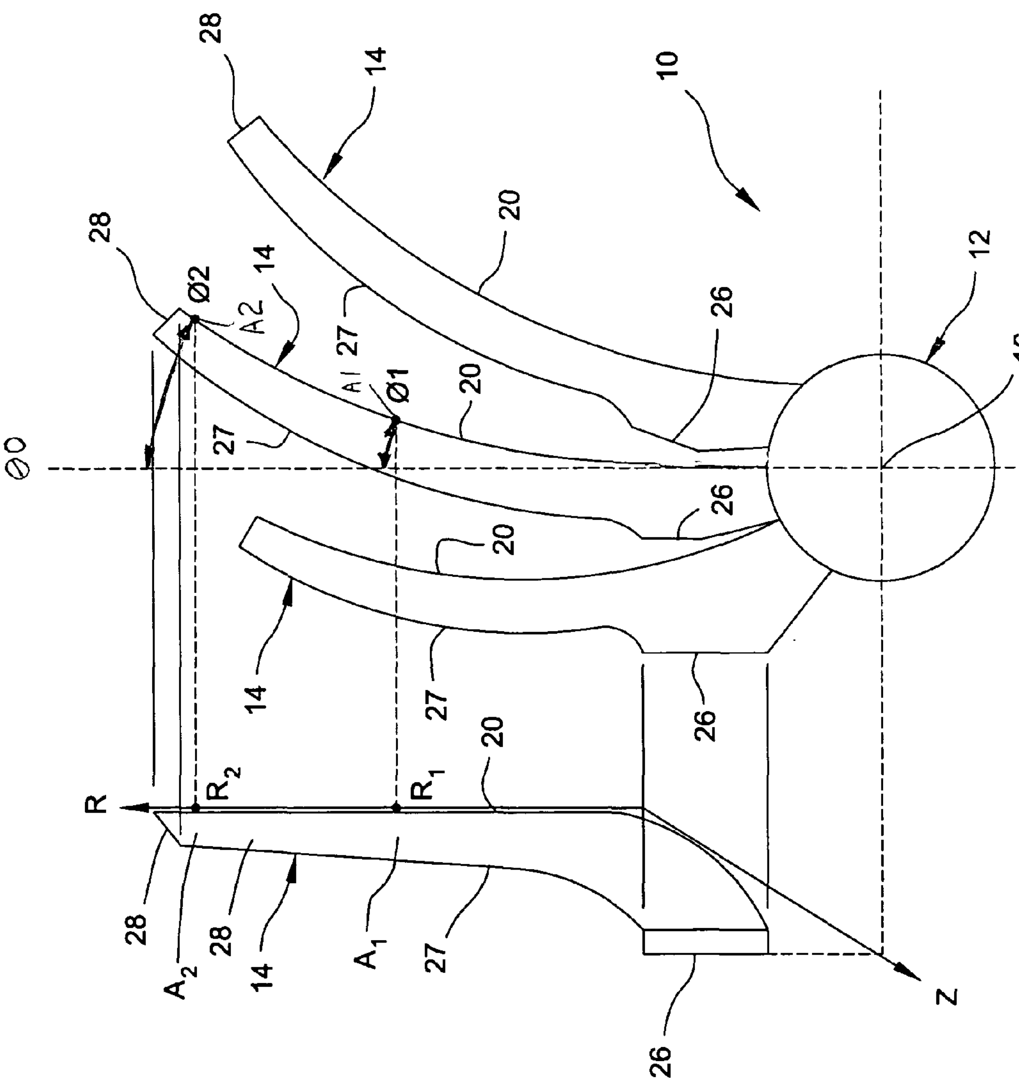
28
14
10
28
Ø2
A2
14
20
12
A1 27
Ø1
26
16
20
ØO
27
26
20
14
27
26
R
R2
R1
20
28
A2
28
14
A1
27
Z
26

FIG 4

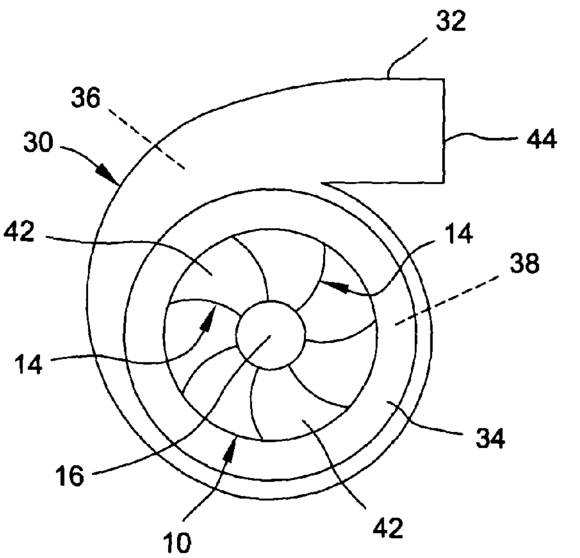

FIG 5

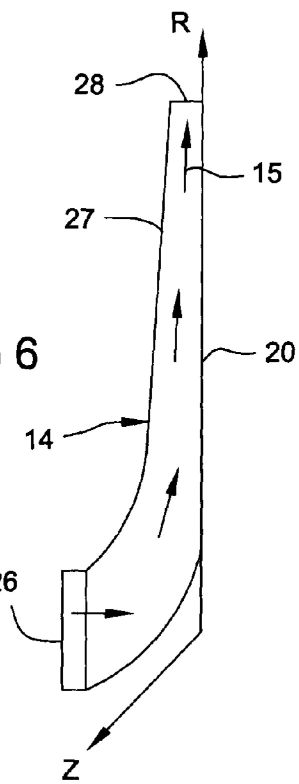

FIG 6

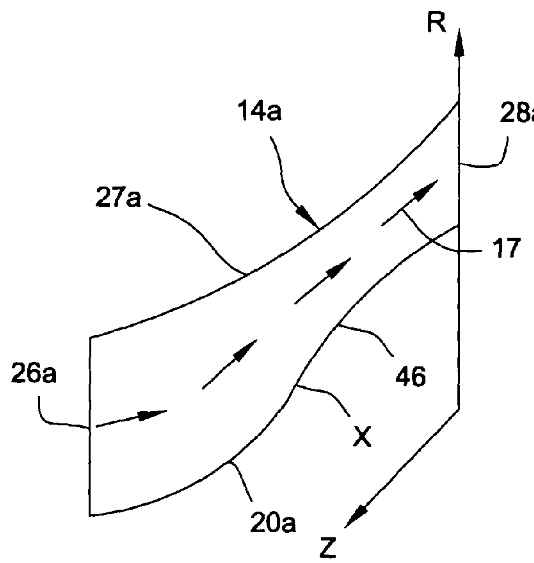

FIG 7

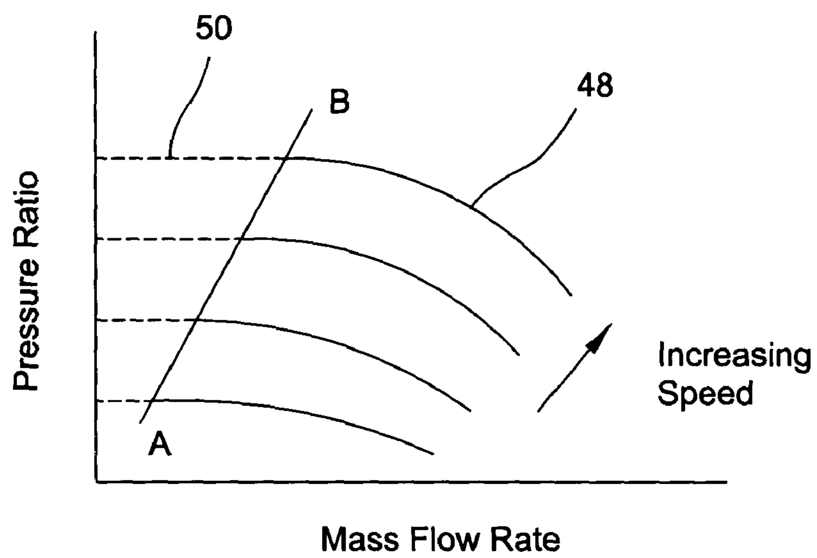
50
B
48
Pressure Ratio
Increasing Speed
A
Mass Flow Rate

FIG 8

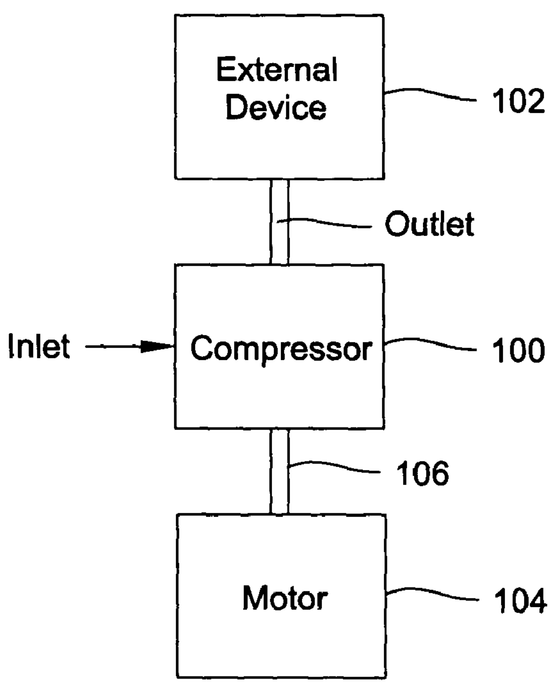
External Device
102
Outlet
Inlet
Compressor
100
106
Motor
104

FIG 9

COMPRESSOR SURGE PREVENTION VIA DISTINCT BLADE SHAPES

FIELD OF THE INVENTION

[0001] The present invention relates to impellers for compressors and pumps and the like, and more particularly, to an improved blade design for an impeller.

BACKGROUND OF THE INVENTION

[0002] Impellers are widely used in a variety of applications to compress a fluid. For example, impellers are often used in air compressor applications for use in generating compressed air to power pneumatic tools and the like. Alternatively, impellers are used to compress a fluid for use in a pressurized system such as in supplying a pressurized fluid stream for use on a fire truck or pumping station. Further yet, such impellers are commonly used in the design and operation of aircraft engines, whereby a compressed fluid stream is provided via an impeller to propel an airplane in a desired direction. In any of the foregoing applications, it is desirable to provide an impeller capable of operating under varying flow conditions to provide a continuous supply of pressurized fluid, regardless of external forces.

[0003] As can be appreciated from the foregoing discussion, impellers are operable to compress a fluid stream for use in a plurality of applications. As previously discussed, one such application is an air compressor. Conventional compressors typically include an impeller, a diffuser, and a volute, whereby the diffuser is in fluid communication with both the impeller and the volute and is operable to transfer a compressed air stream from the impeller to the volute for use in an external system. The impeller commonly includes a plurality of blades that are operable to receive and compress an external air stream between a hub of the impeller and a stationary shroud. Specifically, the impeller captures the external air stream at an inducer disposed proximate to a leading edge of each blade such that the captured mass air flow is forced between the hub and the stationary shroud through rotation of the impeller. The inducer is generally operable to capture the external air stream and force it between the hub and the stationary shroud as the impeller is rotated due to the generally curved or arcuate shape of the leading edge of each blade.

[0004] As can be appreciated, as the air stream travels between each of the blades, the shape of the shroud and hub are such that the air stream is compressed prior to reaching the volute. The compressed air stream is received into the volute for distribution into an external application such as a pneumatic tool or a vehicle engine or a fuel cell power module. The diffuser commonly includes a plurality of stationary vanes which are operable to diffuse the air stream and, thus, increase the static pressure of the compressed air. Such increases in static pressure generally increase the pressure of the air stream, thereby providing a desired output of pressurized air from the compressor. The stream is then collected and delivered to the exhaust system, via the volute.

[0005] In compressor design, it is increasingly important to deliver a constant stream of pressurized air to ensure proper operation of an external device. As can be appreciated, interruption of a compressor can cause external devices, such as pneumatic tools, to seize and abruptly stop working. A common occurrence of such compressor failure is caused by surge. Surge is a term which generally refers to a condition caused by a significant reduction in pressure of an inlet air stream to an impeller. More particularly, surge is caused by flow separation at a suction side of each blade, generally near the leading edge. Such flow separation occurs at reduced flows when the incidence angle is large and the mass flow rate of air is reduced. Under such conditions, flow separation of the inlet air stream can cause a stalled flow to be received by the impeller, thereby causing the impeller to stall or fail.

[0006] In one application, an impeller is used with a compressor to deliver a constant supply of compressed hydrogen and oxygen to a vehicle engine to thereby power the engine. As can be appreciated, different operating conditions of the vehicle may cause varying inlet flow conditions. For example, the vehicle system may require more or less flow under different operating conditions such as weather changes, elevational changes, or system loads. In such an application, prevention of surge provides the vehicle with the ability to operate under such varying conditions, regardless of the varying inlet flow conditions.

[0007] Conventional systems attempt to treat surge by providing mechanisms operable to detect a reduced flow such that the system may stall or hinder the impending surge. Such conventional systems include positive displacement compressors with low performance and high noise levels, compressors with modified casings or housings operable to delay the onset of stall, and variable geometry inlet guide vanes. In each of the foregoing systems, a significant amount of power is wasted driving a very unsteady or stalled flow without actually preventing surge. In this manner, conventional systems suffer from the disadvantage of requiring multiple systems to delay the onslaught of surge, thereby increasing the complexity and cost of the overall system without actually preventing surge. Additionally, because conventional systems merely delay the onslaught of surge, such conventional systems are unable to provide a constant stream of pressurized fluid as such systems are unable to perform under reduced flow conditions.

[0008] Therefore, an impeller which is capable of performing under reduced flow conditions, even as a net mass inlet flow is approaching zero, is desirable in the industry. Additionally, an impeller having a plurality of blades that are able to organize a would be stalled flow into a cohesive flow, while concurrently providing a blade structure that is readily and easily manufactured with a minimal number of components, is also desirable.

SUMMARY OF THE INVENTION

[0009] Accordingly, the present invention provides a compressor including a vaneless diffuser, a volute in fluid communication with the diffuser, and an impeller operable to compress a fluid stream and direct the fluid stream to the diffuser. The impeller includes a hub having an axis of rotation and a plurality of blades extending therefrom. The blades include a surface defined by an axial direction (Z), a radius (R) defined from the axis of rotation, and a polar angle (⊖), whereby ⊖ is substantially defined by the following equation:

$$\ominus = a^*[\text{natural logarithm of } (R)] + b.$$

[0010] The impeller is operable to capture an air stream near a leading edge of each blade and compress the air stream for use in an external system. By defining each blade shape as a function of (R) only, the impeller is capable of functioning under conditions where inlet mass flow is at, or approaching, zero, and is therefore operable to prevent surge.

[0011] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0013] **FIG. 1** is a perspective view of an impeller in accordance with the principals of the present invention;

[0014] **FIG. 2** is a cross-sectional view of the impeller of **FIG. 1**;

[0015] **FIG. 3** is a more detailed cross-sectional view of the impeller of **FIG. 1**;

[0016] **FIG. 4** is a partial perspective view of the impeller of **FIG. 1** showing a meridional profile of an impeller blade;

[0017] **FIG. 5** shows the impeller of FIG.**1** incorporated into a collecting assembly;

[0018] **FIG. 6** is a meridional view of an impeller blade for use with a radial impeller;

[0019] **FIG. 7** is a meridional view of an impeller blade for use with a mixed-flow impeller;

[0020] **FIG. 8** is a graphical representation of a compressor performance map showing a classical surge line; and

[0021] **FIG. 9** is a schematic diagram showing a compressor in accordance with the principals of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0023] With reference to the figures, an impeller **10** is provided and includes a hub **12** and a plurality of blades **14** radially extending therefrom. The impeller **10** is operable to capture an air flow through cooperation between the plurality of blades **14** and the hub **12** to compress the air flow and deliver a pressurized air stream as the impeller **10** rotates about a central axis of rotation **16**.

[0024] With reference to **FIG. 1**, the impeller **10** is shown to include a generally circular shape having the hub **12** disposed coaxially with the axis of rotation **16**. The hub **12** includes a tip **18** and a hub contour **20** formed proximate each blade **14**, as best shown in **FIGS. 2 and 3**. The hub tip **18** includes a generally arcuate surface **22** for distributing a received air flow to each of the plurality of blades **14**.

[0025] With reference to **FIG. 4**, the blades are shown to include a generally sweeping arcuate surface extending radially and axially from the hub **12**. As can be appreciated, the sweeping nature of the arcuate surface **24** further provides each blade with an angular component Θ, generally referred to as the polar angle. In this manner, the overall shape and contour of each blade **14** is defined as a function of an axial direction (Z), a radius (R), and the polar angle (Θ). The axial direction (Z) generally dictates the overall height of each blade **14** and extends in a direction generally perpendicular to the axis of rotation **16** of the hub **12**. The radial direction, or radius (R), extends outwardly from the central axis of rotation **16** to generally define a length of each blade **14**. In this manner, each blade **14** includes a leading edge **26** extending along the axial direction (Z) and a trailing edge **28** formed generally at a distal end of each blade **14** along the radial direction (R), as best shown in the meridional projection of **FIG. 4**. Additionally, each blade **14** includes a tip contour **27** extending between the leading edge **26** and the trailing edge **28** for interaction with an air stream, as will be discussed further below.

[0026] As previously discussed, each blade **14** includes a sweeping arcuate surface **24** generally defined by an axial direction (Z), a radial direction (R), and an angular direction or polar angle (Θ). As can be appreciated, as each blade **14** moves away from the hub **12**, the angular position at any given radial value (R) will vary. In other words, the angular position, or polar angle (Θ), is defined as a function of the radius (R) by the following equation:

$$\Theta=a*[\text{natural logarithm of }(R)]+b.$$

[0027] The "a" and "b" terms in the above equation are constants and depend on a required flow that the impeller **10** must capture at a given rotational speed. Such constants are generally governed by the overall requirements of the impeller **10** and are often dictated by the particular application in which the impeller **10** is used. In this manner, regardless of impeller **10** rotational speed, mass air flow, or pressure rise through the impeller **10**, the blade polar angle (Θ) is only determined as a function of the radius (R). Each blade **14** includes a generally constant shape extending in the axial direction (Z) due to the polar angle being formed as a function of radius (R), as best shown in **FIGS. 1 and 4**.

[0028] By way of example, **FIG. 4** depicts a blade having a shape according to the principles of the present invention. The location of points A_1 and A_2 along the blade **14** are defined by the polar angles Θ_1 and Θ_2, respectively and radii R_1 and R_2, respectively. As described, the particular location of Θ_1 is generally defined as Θ_1=a*[natural logarithm of (R_1)]+b while Θ_2 is generally defined as Θ_2=a*[natural logarithm of (R_2)]+b. In this regard, the overall blade shape is defined as a function of the polar angle (Θ) along the length of the blade **14** at a particular radial (R) position. While two angular positions (i.e. Θ_1 and Θ_2) are depicted, it should be understood the overall blade shape could be defined by an infinite number of polar angles extending between the leading edge **26** and the trailing edge **28** at respective radial positions, and should be considered within the scope of the present invention. Such a relationship provides for improved manufacturability as upper and lower die molds may be quickly separated upon forming the impeller **10**. As can be appreciated, a blade **14** defining a surface as both a function of (R) and (Z) increases manufacturing complexity as part removal from the die is restricted by the extension of the blade **14** in both the radial (R) and axial (Z) directions. Furthermore, by defining blade shape as a function of only radius (R), impeller **10** performance is greatly improved as inlet mass flow and pressure are reduced, as will be discussed further below.

[**0029**] With reference to **FIG. 5**, the impeller **10** is shown incorporated into a collecting assembly **30** which includes a vaneless diffuser **34** and a volute **32**. The vaneless diffuser **34** radially surrounds the impeller **10** and defines a generally open space **38** disposed proximate the volute **32**. The volute **32** radially surrounds an outer diameter of the diffuser **34** and similarly includes an open space **36**. The open space **36** of the volute **32** is in fluid communication with the open space **38** of the vaneless diffuser **34**. In this manner, the impeller **10** is operable to transmit a compressed fluid to the volute **32** via the open space **38** of the diffuser **34**.

[**0030**] In operation, the impeller **10** receives a mass flow of air at an inlet or inducer generally proximate the leading edge **26** of each blade **14**. As the leading edge **26** captures the air flow through rotation of the impeller **10** about the central axis **16**, the air is redirected into the impeller **10** by leading edge **26** and contour of each blade **14**. Once the air flow is captured by the blades **14**, the air is forced to travel along the arcuate surface **24** and tip contour **27** of each blade **14**, generally between the hub contour **12** and an external structure such as a stationary shroud **40** (best seen in **FIGS. 2 and 3**). Movement of the air along the blades **14** from the leading edge **26** to the trailing edge **28** causes the air stream to increase pressure due to the overall shape of each blade **14**, confined space between each blade **14** and stationary shroud **40**, and the overall rotational speed of the impeller **10**.

[**0031**] Once sufficient pressure is achieved, the air stream is released into the open space **38** of the vaneless diffuser **34** for collection. As can be appreciated, each impeller blade **14** forms an opening **42** between each pair of respective blades **14** for interaction with the diffuser **34**. Specifically, the openings **42** are in fluid communication with the open space **38** of the diffuser **34** and serve to deliver the compressed air stream to the open space **38** for collection and distribution to the volute **32**. Upon receiving the compressed air stream, the volute **32** distributes the fluid stream to an external source such as a vehicle engine, fuel cell, or pneumatic tool (neither shown) via an outlet **44**.

[**0032**] In one embodiment, the impeller **10** is a radial impeller, whereby a mass flow of air received at the leading edge **26** of each blade **14** travels along the blade **14** between the leading edge **26** and the trailing edge **28** for compression, as previously discussed. Such an arrangement serves to compress air through a centrifugal method, whereby the air stream is captured by the inducer at the leading edge **26** generally in the axial direction (Z) of each blade **14**. Once captured, the air flow is caused to travel along the arcuate surface **24** of each blade generally in the radial (R) direction through rotation of the impeller **10**, as best shown in **FIG. 6** and indicated by a plurality of arrows **15**. In such a relationship, high pressure air flow can be achieved, as the full force of the air is directed in a single direction (R).

[**0033**] In such a radial impeller **10**, the length of the inducer, or height of the leading edge **26** in the axial direction (Z), should be within 5 to 7% of the outer diameter of the impeller **10** for optimum impeller performance, as will be discussed further below.

[**0034**] In an alternate embodiment, the impeller **10** is a mixed-flow impeller, as shown in **FIG. 7**. In view of the similarity between the radial impeller **10** and the mixed-flow impeller, like reference numerals are used hereinafter and in the drawings to identify like components while like reference numerals containing letter extensions are used to identify those components that have been modified.

[**0035**] In a mixed-flow impeller, an entering air flow enters along the axial direction (Z), but does not exit the impeller **10** solely in the radial direction (R). Rather, in a mixed-flow impeller application, a compressed air stream exits the impeller in both the axial (Z) and radial (R) directions, as best shown in **FIG. 7** and indicated by a plurality of arrows **17**. In such systems, the impeller includes a plurality of blades **14*a*** having a leading edge **26*a***, a trailing edge **28*a***, and a blade contour **27*a*** extending therebetween, as best shown in the meridional view of **FIG. 7**. Additionally, such blades **14*a*** further include a hub contour **20*a*** having a rapid area reduction **46** disposed generally ⅓ the overall length of the blade **14*a*** from the leading edge **26*a***, whereby the overall length of the blade **14*a*** is measured between the leading edge **26*a*** and the trailing edge **28*a***, as best shown in **FIG. 7**.

[**0036**] The rapid area reduction **46** is formed as a function of the overall area of the leading edge **26*a***. Specifically, the reduced area **46** in the axial direction (Z) should be within ⅔ to ¾ of the area of the leading edge **26*a*** for optimum performance, as will be discussed further below. In this manner, the rapid area reduction **46** includes a starting point at a distance "X" away from the leading edge **26*a*** and extends from such point to the trailing edge **28*a*** of each blade **14*a***, as shown in **FIG. 7**. As previously discussed, the distance "X" is roughly equal to the following equation: X=⅓*(the total length of the blade).

[**0037**] In any of the foregoing embodiments, proper operation of the impeller **10** hinges on the ability of the impeller **10** to receive an air stream and compress such air stream to consistently deliver a predetermined fluid pressure for use in an external system. In this manner, the impeller **10** must be able to consistently compress a fluid stream, regardless of the condition of the input fluid stream. In doing so, the impeller **10** must be able to function under minimal input flow characteristics to avoid the onslaught of surge.

[**0038**] As previously discussed, surge is caused by flow separation on a suction surface, or near the leading edge **26**, of the impeller blades **14** and occurs at reduced flow when the incidence angle is large. Surge can cause failure of the impeller **10** as such flow separation produces a "stalled" or separated flow. **FIG. 8** is a graphical representation of a surge line indicating a point at which a stalled flow is experienced at a given rotational speed.

[**0039**] As mass flow rate and pressure of a received air stream are reduced, an impeller **10** is likely to experience surge. Speed curves **48**, indicated in **FIG. 8**, can be drawn for varying rotational speeds of the impeller **10**, whereby each speed curve **48** intersects a surge line (A-B) at a point at which a stalled flow occurs. The point at which the speed curve **48** contacts the surge line (A-B), is the point at which the impeller **10** will experience surge for a given rotational speed. As can be appreciated, as the pressure ratio and mass flow rate of an input fluid stream are reduced, the likelihood of surge is increased.

[0040] With continued reference to **FIG. 8**, it is shown that surge can be prevented if the surge line (A-B) is coaxially aligned with the vertical axis such that the pressure ratio is finite and mass flow rate is zero, thereby preventing surge. Such a relationship is graphically indicated in **FIG. 8** by extending the speed lines to the vertical axis using dashed lines **50** and coaxially aligning the surge line (A-B) with the vertical axis. By doing so, the impeller **10** may operate under a condition where the pressure ratio is finite and mass flow rate is zero, thereby preventing the occurrence of surge.

[0041] In operation, the impeller **10** of the present invention is operable to prevent surge by re-attaching the separated flow and allowing a useable input fluid stream. In other words, the blade shape is designed to stabilize the "would be stalled" flow such that the flow remains attached to the blade surface **24** at all flows, even under conditions where the flow is reduced to zero.

[0042] To ensure that a received fluid stream remains attached to the impeller blades **14** under any input flow condition, three elements must be met. First, the shape of the blade **14** must only be a function of the radius (R). In sum, the polar angle (⊖) should substantially satisfy the following equation: ⊖=a*[the natural logarithm of (R)]+b, as previously discussed. By generally meeting the above equation, it should be understood that it is intended that minor variations would similarly eliminate surge.

[0043] A second requirement to achieve surge prevention is that a vaneless diffuser **34** should be used in conjunction with the impeller **10**. In other words, a diffuser **34** having an open space **38** should be used in conjunction with the impeller **10** and should not include a plurality of fixed vanes.

[0044] For a radial impeller **10**, the third requirement in the prevention of surge is that the length of the inducer, or height of the leading edge **26** in the axial direction (Z), should be within 5% to 7% of the outer diameter of the impeller **10** for optimum performance, as previously discussed and best shown in **FIG. 6**.

[0045] In the case of a mixed-flow impeller, the third requirement to prevent surge is that the area of the rapid area reduction **46** in the axial direction (Z) should be within ⅔ to ¾ of the area of the leading edge **26*a***. In this manner, the reduced area **46** begins at a distance "X" away from the leading edge **26*a*** of the blade **14*a*** and extends from such beginning point to the trailing edge **28*a*** of each blade **14*a***, as previously discussed and shown in **FIG. 7**.

[0046] With reference to **FIG. 9**, a compressor **100** is provided and is operable to compress an air stream for use in an external system **102**. The compressor **100** is rotatably driven by a motor **104**, having a shaft **106** extending therebetween. The impeller **10** is disposed within the compressor **100** and is operably engaged with the shaft **106**. Specifically, the shaft **106** is operably connected to the hub **12** of the impeller **10** such that rotation of the shaft **106** concurrently rotates the impeller **10**. As previously discussed, rotation of the impeller **10** causes the leading edge **26** of each blade **14** to capture an inlet air flow and deliver a compressed air stream to the collecting assembly **30**. Upon sufficient compression, the collecting assembly **30** is operable to deliver the compressed fluid to the external system **102** via outlet **44**, as previously discussed.

[0047] As can be appreciated, such a relationship between a vanelss diffuser **34** and an impeller blade **14**, having a surface defined only as a function of radius (R), can be applied to any range of applications and is not merely limited to a compressor. Furthermore, such an impeller **10** is not limited to compression of air and my be applied in any system requiring a compressed fluid such as, but not limited to, a compressed stream of water or hydrogen. In any of the foregoing applications, prevention of surge provides the particular application with the ability to consistently produce and maintain a stream of pressurized fluid under any external or input flow conditions.

[0048] The description of the invention is merely exemplary in nature and, thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A compressor comprising:

a diffuser;

a volute defining an open space in fluid communication with said diffuser; and

an impeller operable to compress a fluid stream and direct said fluid stream to said volute, said impeller including:

a hub having an axis of rotation; and

a plurality of blades extending from said hub, said blades having a surface defined by an axial direction (Z), a radius (R) defined from said axis of rotation of said hub, and a polar angle (⊖), whereby the polar angle (⊖) is substantially defined by the equation: ⊖=a*[natural logarithm of (R)]+b.

2. The compressor of claim 1, wherein each of said blades includes a leading edge and a trailing edge, said leading edge formed proximate said hub and said trailing edge formed proximate said volute.

3. The compressor of claim 2, wherein a and b are constants determined from a blade angle of said leading edge, said leading edge blade angle generally determined by output requirements of the compressor.

4. The compressor of claim 1, wherein said diffuser is vaneless, said vaneless diffuser including a generally open space in fluid communication with said open space of said volute.

5. The compressor of claim 1, wherein said impeller is a radial impeller, said radial impeller including an inducer formed proximate a leading edge of each blade.

6. The compressor of claim 5, wherein said inducer includes a height component in said axial direction (Z) which is 5-7% of an outer diameter of said impeller.

7. The compressor of claim 1, wherein said impeller is a mixed-flow impeller.

8. The compressor of claim 7, further comprising an area reduction formed along each of said blades between a leading edge and a trailing edge.

9. The compressor of claim 8, wherein said area reduction includes an area being between ⅔ and ¾ an area of said leading edge of each blade.

10. The compressor of claim 8, wherein said area reduction is formed along each of said blades a distance X from said leading edge, said distance X approximately equal to ⅓ of a total blade length as measured along said radius (R).

11. An impeller comprising:

a hub having an axis of rotation; and

a plurality of blades extending from said hub, said blades having a surface defined by an axial direction (Z), a radius (R) defined from said axis of rotation of said hub, and a polar angle (⊖), whereby the polar angle (⊖) is substantially defined by the equation: ⊖=a*[natural logarithm of (R)]+b.

12. The impeller of claim 11, wherein each of said blades includes a leading edge and a trailing edge.

13. The impeller of claim 12, wherein a and b are constants determined from a blade angle of said leading edge, said leading edge blade angle generally determined by output requirements of the compressor.

14. The impeller of claim 11, wherein said impeller is a radial impeller, said radial impeller including an inducer formed proximate a leading edge of each blade.

15. The compressor of claim 14, wherein said inducer includes a height component in said axial direction (Z) which is 5-7% of an outer diameter of said impeller.

16. The compressor of claim 11, wherein said impeller is a mixed-flow impeller.

17. The compressor of claim 16, further comprising an area reduction along each of said blades between a leading edge and a trailing edge.

18. The compressor of claim 17, wherein said area reduction includes an area being between ⅔ and ¾ an area of a leading edge of each blade.

19. The compressor of claim 17, wherein said area reduction is formed along each of said blades a distance X from said leading edge, said distance X approximately equal to ⅓ of a total blade length as measured along said radius (R).

20. A compressor comprising:

a vaneless diffuser;

a volute in fluid communication with said vaneless diffuser; and

a radial impeller operable to compress a fluid stream and direct said fluid stream to said volute, said radial impeller including:

a hub having an axis of rotation; and

a plurality of blades extending from said hub, said blades having a surface defined by an axial direction (Z), a radius (R) defined from said axis of rotation of said hub, and a polar angle (⊖), whereby the polar angle (⊖) is substantially defined by the equation: ⊖=a*[natural logarithm of (R)]+b; and

an inducer formed proximate a leading edge of said blades, said inducer having a height as a function of said axial direction (Z), said height being 5-7% of an outer diameter of said radial impeller.

21. A compressor comprising:

a vaneless diffuser;

a volute in fluid communication with said vaneless diffuser; and

a mixed-flow impeller operable to compress a fluid stream and direct said fluid stream to said volute, said mixed-flow impeller including:

a hub having an axis of rotation; and

a plurality of blades extending from said hub, said blades having a surface defined by an axial direction (Z), a radius (R) defined from said axis of rotation of said hub, and a polar angle (⊖), whereby the polar angle (⊖) is substantially defined by the equation: ⊖=a*[natural logarithm of (R)]+b; and

wherein each of said blades includes a leading edge and a trailing edge, said trailing edge having an area at or between ⅔ to ¾ an area of said leading edge.

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