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(54) Vane assembly and method of assembling a vane assembly for a variable-nozzle turbocharger

(57) A vane assembly includes vanes each having an axle and an arm immovably connected with the vane prior to assembling the vane assembly. The vane, axle, and can be an integral one-piece structure formed by casting, machining, or metal injection molding. The axles engage apertures in a nozzle ring are rotatable in the apertures about axes of the vanes. An actuator ring is assembled with the nozzle ring and is rotatable relative thereto. The actuator ring defines connecting elements that connect with cooperative connecting elements on the vane arms. Rotation of the actuator ring causes the vanes to rotate for adjusting the angles of the vanes. During assembly, the motion of inserting the axles into the apertures is also effective for placing the in position for connection with the actuator ring.

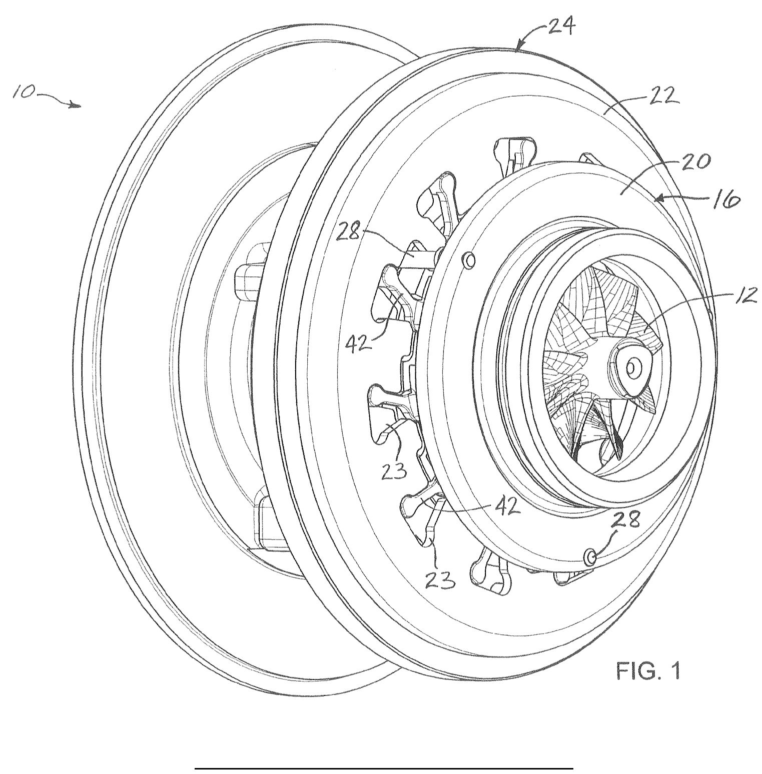

FIG. 1

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to turbochargers having a variable-nozzle turbine in which movable vanes are disposed in the nozzle of the turbine for regulating exhaust gas flow into the turbine.

[0002] An exhaust gas-driven turbocharger is a device used in conjunction with an internal combustion engine for increasing the power output of the engine by compressing the air that is delivered to the air intake of the engine to be mixed with and burned in the engine. A turbocharger comprises a compressor wheel mounted on one end of a shaft in a compressor housing and a turbine wheel mounted on the other end of the shaft in a turbine housing. Typically the turbine housing is formed separately from the compressor housing, and there is yet another center housing connected between the turbine and compressor housings for containing bearings for the shaft. The turbine housing defines a generally annular chamber that surrounds the turbine wheel and that receives exhaust gas from an engine. The turbine assembly includes a nozzle that leads from the chamber into the turbine wheel. The exhaust gas flows from the chamber through the nozzle to the turbine wheel and the turbine wheel is driven by the exhaust gas. The turbine thus extracts power from the exhaust gas and drives the compressor. The compressor receives ambient air through an inlet of the compressor housing and the air is compressed by the compressor wheel and is then discharged from the housing to the engine air intake.

[0003] One of the challenges in boosting engine performance with a turbocharger is achieving a desired amount of engine power output throughout the entire operating range of the engine. It has been found that this objective often is not readily attainable with a fixed-geometry turbocharger, and hence variable-geometry turbochargers have been developed with the objective of providing a greater degree of control over the amount of boost provided by the turbocharger. One type of variable-geometry turbocharger is the variable-nozzle turbocharger (VNT), which includes an array of variable vanes in the turbine nozzle. The vanes are pivotally mounted in the nozzle and are connected to a mechanism that enables the setting angles of the vanes to be varied. Changing the setting angles of the vanes has the effect of changing the effective flow area in the turbine nozzle, and thus the flow of exhaust gas to the turbine wheel can be regulated by controlling the vane positions. In this manner, the power output of the turbine can be regulated, which allows engine power output to be controlled to a greater extent than is generally possible with a fixed-geometry turbocharger.

[0004] Existing variable vane mechanisms tend to be made up of a relatively large number of separate parts and thus are complicated and present a challenge in terms of manufacture and assembly. It would be desirable to improve upon the ease of manufacture and assembly of a variable vane mechanism.

BRIEF SUMMARY OF THE INVENTION

[0005] The present invention addresses the above needs and achieves other advantages by providing a variable vane assembly for a variable-nozzle turbine having a reduced parts count and therefore reduced complexity of manufacture and assembly relative to some existing variable vane assemblies. In accordance with one embodiment of the invention, a variable vane assembly includes a fixed nozzle ring defining a plurality of circumferentially spaced apertures, and a ring of circumferentially spaced vanes each comprising an airfoil portion that extends axially from a first end proximate the nozzle ring to an opposite second end. Each vane has an axle immovably connected with the first end of the airfoil portion and extending axially therefrom in a direction away from the second end, the axle defining a rotation axis of the vane. The axles of the vanes are inserted in the apertures of the nozzle ring such that the axles are rotatable in the apertures.

[0006] An actuator ring is disposed adjacent to and concentric with the nozzle ring, the actuator ring being rotatable about an axis relative to the nozzle ring. In some embodiments, the actuator ring can concentrically surround a portion of the nozzle ring such that the actuator ring and the portion of the nozzle ring occupy the same plane. The actuator ring defines a plurality of circumferentially spaced first connecting elements.

[0007] Each vane further includes an arm having a proximal end immovably connected with the vane proximate the first end of the airfoil portion. A distal end of the is offset from the rotation axis of the vane and defines a second connecting element configured to connect with one of the first connecting elements of the actuator ring. Insertion of the axle of each vane into one of the apertures in the nozzle ring is also effective to connect the second connecting element of the vane with one of the first connecting elements of the actuator ring, thereby connecting the arm of the vane to the actuator ring. Thus, rotation of the actuator ring moves the arms and thereby causes the vanes to rotate about the rotation axes thereof for adjusting a rotational orientation of the vanes.

[0008] In some embodiments, each vane and its associated axle and arm comprise an integral one-piece structure. The structure can be formed by casting, by machining a single piece of starting material, by metal injection molding (MIM), or any other suitable technique.

[0009] Accordingly, the variable vane mechanism has a relatively simple construction. In particular, in some embodiments all, of the vanes are identical to one another, and therefore the entire assembly encompasses only three part configurations: (1) the nozzle ring, (2) the actuator ring, and (3) the vanes. The parts count is also significantly reduced in comparison with prior vane assemblies in which the vanes and the arms are separate until the time of assembly. The process of assembly is considerably simplified because there is no need to weld or otherwise attach the arms to the vanes during assembly.

[0010] In accordance with another aspect of the invention, a method for assembling a vane assembly comprises the steps of: (1) providing a nozzle ring encircling an axis, the nozzle ring having an annular surface generally perpendicular to the axis and defining a plurality of circumferentially spaced apertures extending through the annular surface; (2) assembling an actuator ring with the nozzle ring such that the actuator ring is adjacent to and concentric with the nozzle ring, the actuator ring defining a plurality of circumferentially spaced first connecting elements and being rotatable relative to the nozzle ring; (3) providing a plurality of vanes each having an airfoil portion that extends axially from a first end to an opposite second end, and an axle immovably connected with the first end of the airfoil portion and extending axially therefrom in a direction away from the second the axle defining a rotation axis of the vane, each vane further comprising an having a proximal immovably connected with the vane proximate the first end of the airfoil portion, a distal end of the arm being offset from the rotation axis of the vane and defining a second connecting element configured to connect with one of the first connecting elements of the actuator ring; and (4) inserting the axle of each of the vanes into one of the apertures in the nozzle ring, the motion of inserting the axle being effective also to place the second connecting element of the vane in position for connection with one of the first connecting elements of the actuator ring.

BRIEF OF THE SEVERAL VIEWS OF THE DRAWING (S)

[0011] Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

[0012] FIG. 1 is a perspective view of a partial assembly of a turbocharger including a variable vane assembly in accordance with an embodiment of the invention;

[0013] FIG. 2 is an exploded view of the partial assembly of FIG. 1;

[0014] FIG. 3 is a perspective view of a vane with integral arm in accordance with an embodiment of the invention;

[0015] FIG. 4 is another perspective view of the vane;

[0016] FIG. 5 is a perspective view of the variable vane assembly in accordance with an embodiment of the invention; and

[0017] FIG. 6 is a perspective view of the partial assembly of FIG. 1, partly in section.

DETAILED OF THE INVENTION

[0018] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the inventions are shown. Indeed, these inventions may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

[0019] A partial assembly **10** of a turbocharger in accordance with an embodiment of the invention is shown in perspective view in FIG. 1, in exploded view in FIG. 2, and in a partially sectioned perspective view in FIG. 6. The partial assembly includes a turbine wheel **12** mounted on one end of a shaft **14**. The turbine wheel is part of a turbine that includes a turbine housing assembly surrounding the turbine wheel. The turbine housing assembly includes a turbine housing **15** and an insert **16** having a generally tubular portion **18** that is inserted into a generally cylindrical bore in the turbine housing and forms a part of a flow path for exhaust gas through the turbine wheel. The tubular portion **18** of the insert **16** is joined to a generally annular portion **20** that extends radially outwardly from the end of the tubular portion. The annular portion **20** forms one wall of a nozzle that directs exhaust gas from a generally annular chamber defined in the turbine housing **15** radially inwardly into the turbine wheel **12**.

[0020] The opposite wall of the nozzle is formed in part by a generally annular cover or plate **22** that is affixed to a center housing **24** of the partial assembly **10.** The cover **22** has a generally cylindrical flange at its outer diameter that engages the radially outer surface of a generally cylindrical flange on the center housing. The center housing houses a bearing **25** for the shaft **14** passing through the center housing. The end of the shaft **14** opposite from the turbine wheel 12 is connected to a compressor wheel (not shown) driven by the turbine wheel **12.**

[0021] With reference to FIG. 2, the opposite wall of the nozzle from the annular portion **20** of the insert **16** is also formed in part by a nozzle ring **26.** The nozzle ring **26** is connected to the annular portion **20** by a plurality of spacers **28** that are spaced apart about the circumference of the nozzle ring. The spacers **28** keep the nozzle ring **26** and the annular portion **20** a substantially constant axial distance apart from each other. The nozzle ring **26** also engages a shroud **30** and a locator ring **31** affixed to the center housing **24** for ensuring that the nozzle ring is substantially coaxial with respect to the center housing. The shroud **31** also serves as a heat shield for shielding the center housing from the hot exhaust gas passing through the turbine.

[0022] The nozzle ring **26** supports a plurality of adjustable vanes **32** that are disposed in the nozzle between the wall formed by the nozzle ring **26** and plate **22** and the opposite wall formed by the annular portion **20** of the insert **16.** The vanes **32** are circumferentially spaced apart about the circumference of the nozzle ring. With reference to FIGS. 3 and 4, each vane **32** includes an airfoil portion **34** that is wetted by the exhaust gas flowing through the nozzle into the turbine wheel and acts in cooperation with adjacent vanes to determine or influence the flow direction of the exhaust gas flowing through the passages between the vanes. At a proximal end of the airfoil portion **34**, an axle **36** is immovably connected with the airfoil portion to form an airfoil/axle assembly. The nozzle ring defines a plurality of apertures **38** circumferentially spaced apart about its circumference. Each aperture **38** receives the axle **36** of one of the vanes. The axles **36** are rotatable in the apertures **38** about the axes of the axles for adjusting the setting angles of the airfoil portions **34.** The apertures **38** extend through a generally annular surface **40** of the nozzle ring that is generally perpendicular to the central axis of the nozzle ring and that faces the annular portion **20** of the insert **16.** The airfoil portion **34** of each vane **32** extends axially from the proximal end of the airfoil portion adjacent the annular surface **40** to an opposite distal end. The distal end of the airfoil portion **34** can be a free end as shown, or alternatively the distal end can include an axle engaging an aperture in the annular portion **20** of the insert **16**. The proximal ends of the airfoil portions **34** advantageously are closely adjacent the annular surface **40** of the nozzle ring **26** and the distal ends of the airfoil portions **34** advantageously are closely adjacent the annular portion **20** so the exhaust gas flowing through the nozzle is substantially prevented from leaking between the ends of the airfoil portions and the adjacent walls of the nozzle.

[0023] Each vane **32** further includes an arm **42** immovably connected with the airfoil/axle assembly. The arm **42** is connected at a location intermediate the distal end of the airfoil portion **34** and the distal end of the axle **36,** contrary to prior-art vanes in which the arm is connected to the distal end of the axle. The arm advantageously is connected proximate the proximal end of the airfoil portion **34.** The arm **42** extends perpendicular to the axis of the axle **36** and terminates in a distal end **44.** The distal end includes a projection **46** that extends axially away from the proximal end of the airfoil portion **34,** in the same direction as the axle **36.** The vane **32** with its associated axle **36** and arm **42** is a one-piece integral structure. The structure can be formed by manufacturing the airfoil portion **34** and axle **36** together as a single part (e.g., by casting or machining), manufacturing the arm **42** as a separate part, and then joining the two parts together by welding or the like. Alternatively, however, the entire vane structure can be formed as a single part by casting, by machining, by metal injection molding (MIM), or by any other suitable technique.

[0024] With reference to FIG. 5, a variable vane assembly is illustrated in isolation, forming a portion of the partial assembly **10** depicted in FIGS. I and 2. The variable vane assembly includes the nozzle ring **26,** the vanes **32,** and an actuator ring **48.** The actuator ring surrounds the portion of the nozzle ring **26** having the apertures **38** for the vane axles. More particularly, the nozzle ring **26** is of a stepped configuration having a larger-diameter portion joined to a smaller-diameter portion. The actuator ring surrounds the smaller-diameter portion, and the iarger-diarneter portion is disposed axially adjacent the actuator ring. The actuator ring is rotatable about the axis of the nozzle ring. The actuator ring engages the arms **42** of the vanes **32** such that rotation of the actuator ring causes the vanes to be rotated about the axes of the axles **36.** The actuator ring **48** and the vane arms **42** are on the front or "flow" side of the nozzle ring **26**.

[0025] More specifically, the distal end of each vane arm **42** defines a connecting element that connects with a cooperative connecting element defined by the actuator ring **48**. In the illustrated embodiment, the connecting of the actuator ring **48** comprise receptacles **50** defined in the actuator ring, and the connecting elements of the vane arms comprise the projections **46** that are received in the receptacles **50**. Alternatively, the actuator ring could define projections received in receptacles defined in the vane arms, or the connection between the vane arms and actuator ring could be accomplished in another way.

[0026] In preferred embodiments, such as the illustrated embodiment, the variable vane assembly is configured to ease the assembly of the parts. In particular, during assembly the actuator ring **48** is assembled to the nozzle ring **26** and is rotatably positioned with respect to the nozzle ring so that a receptacle **50** is generally aligned with each aperture **38** in the nozzle ring. The axles **36** of the vanes are inserted into the apertures **38** in the nozzle ring in such an orientation that the projections **46** on the vane arms **42** are received in the receptacles **50.** Each aperture **38** in the nozzle ring has a relatively small-diameter portion that receives one of the axles **36** and forms a bearing surface therefor, and a relatively larger-diameter countersunk portion surrounding the small-diameter portion at the annular surface **40** of the nozzle ring. A lengthwise portion of the arm **42** of each vane adjacent the proximal end of the arm is accommodated in the countersunk portion of the respective aperture. The motion of inserting the axle **36** into an aperture **38** substantially concurrently connects the vane arm projection **46** with the cooperating connecting element (i.e., the receptacle **50**) of the actuator ring, or at least places the projection **46** in a position to be connected with the actuator ring. Thus, the one-piece vanes and the arrangement for connecting the vane arms with the actuator ring in accordance with the invention avoid the need for welding of vane parts during assembly. This is in contrast to some prior variable vane assemblies in which each vane is formed in two separate parts that must be welded together during the assembly process.

[0027] With primary reference to FIG. 2, the actuator ring defines a recess or slot **52** (FIG. 5) for receiving a tab **54** on a crank arm **56** disposed on one side of the center housing **24,** on the opposite side of the nozzle ring **26** from the actuator ring **48**. The crank arm **56** is immovably connected with a shaft **58** of another crank arm **60** disposed on the opposite side of the center housing **24.**

The shaft **58** extends through a bushing **62** that passes through the center housing **24,** and the end of the shaft **58** is immovably connected with the crank arm **56.** The crank arm **60** is rotated by an actuator (not shown), which causes the crank arm **56** to be rotated such that the tab **54** rotates the actuator ring **48.** In this manner, the setting angles of the vanes **32** can be adjusted to any desired angle for regulating the exhaust gas flow into the turbine wheel **12.**

[0028] In the illustrative embodiment shown and described herein, the actuator ring **48** has receptacles **50** for the vane arms **42** that are formed by recesses in the radially inner surface of the actuator ring. Alternatively, however, it is possible for the receptacles to be formed by recesses in the radially outer surface of the actuator ring. In the illustrative embodiment, the cover **22** also defines recesses **23** (FIG. 1) to accommodate the vane arms **42.** The recesses **23** are circumferentially elongated to accommodate the extent of the circumferential movement of the vane arms **42.**

[0029] The apertures **38** in the nozzle ring that form bearing surfaces for the vane axles **36** can be either blind holes or can extend entirely through the nozzle ring to its back side. Blind holes offer the advantage that exhaust gas cannot leak through the holes to the back side of the nozzle ring, but the length of the bearing surfaces cannot be as great with blind holes as it can be with through holes unless the axial thickness of the nozzle ring is increased.

[0030] In the illustrative embodiment, the vane arms **42** are connected to the axles **36** adjacent the proximal ends of the airfoil portions **34,** and hence the arms **42** do not project into the stream of exhaust gas flowing through the nozzle, or at least the extent of their projection into the stream is minimal. Alternatively, however, the arms **42** could attach to the airfoil portions **34**, although this is not preferred because the arms would be in the exhaust gas stream and thus would cause aerodynamic losses that would impair the efficiency of the turbine.

[0031] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

A vane assembly includes vanes each having an axle and an arm immovably connected with the vane prior to assembling the vane assembly. The vane, axle, and arm can be an integral one-piece structure formed by casting, machining, or metal injection molding. The axles engage apertures in a nozzle ring and are rotatable in the apertures about axes of the vanes. An actuator ring is assembled with the nozzle ring and is rotatable relative thereto. The actuator ring defines connecting elements that connect with cooperative connecting elements on the vane arms. Rotation of the actuator ring causes the vanes to rotate for adjusting the angles of the vanes. During assembly, the motion of inserting the axles into the apertures is also effective for placing the arms in position for connection with the actuator ring.

Claims

1. A variable-nozzle turbine, comprising:

a turbine wheel connected with a shaft for rotation therewith;

a turbine housing enclosing the turbine wheel, the turbine housing defining a generally annular chamber surrounding the turbine wheel for receiving exhaust gas, and comprising a nozzle defining a flow path for passage of exhaust gas from the chamber radially inwardly to the turbine wheel, the flow path being defined between axially spaced and second walls;

a fixed nozzle ring encircling an axis, the nozzle ring having a flow side and an opposite back side, the flow side defining an annular surface that is generally perpendicular to the axis and at least partly forms the first wall, the nozzle ring defining a plurality of circumferentially spaced apertures extending axially through said annular surface;

an actuator ring disposed adjacent to the flow side of and concentric with the nozzle ring, the actuator ring being rotatable about said axis relative to the nozzle ring; the actuator ring defining a plurality of circumferentially spaced first connecting elements;

a ring of circumferentially spaced vanes each comprising an airfoil portion that extends axially from a end proximate the annular surface of the nozzle ring to an opposite second end, and an axle immovably connected with the first end of the airfoil portion and extending axially therefrom in a direction away from the second end, the axle defining a rotation axis of the vane, the axles of the vanes being disposed in the apertures of the nozzle ring such the axles are rotatable in the apertures; and

each vane further including an arm having a proximal end immovably connected with the vane proximate the first end of the airfoil portion, a distal end of the arm being offset from the rotation axis of the vane and defining a second connecting element removably connected with one of the first connecting elements of the actuator ring, the arms of the vanes being on the flow side of the nozzle ring.

2. The variable-nozzle turbine of claim 1, wherein the arm of each vane is immovably connected with the axle proximate the first end of the airfoil portion of the vane.

3. The variable-nozzle turbine of claim 1, wherein the arm of each vane is immovably connected with the airfoil portion of the vane.

4. The variable-nozzle turbine of claim 1, wherein each vane and associated axle and arm comprise an integral one-piece structure.

5. The variable-nozzle turbine of claim 1, wherein the actuator ring surrounds a portion of the nozzle ring, and the actuator ring and nozzle ring collectively form at least part of the first wall of the nozzle.

6. The variable-nozzle turbine of claim 5, wherein respective surfaces of the actuator ring and the portion of the nozzle ring that form at least part of the first wall of the nozzle are substantially flush with each other.

7. The variable-nozzle turbine of claim 1, wherein the first connecting elements of the actuator ring comprise female connecting elements, and the distal end of the arm of each vane defines a male connecting element that is engaged in one of the female connecting elements for connecting the arm to the actuator ring.

8. The variable-nozzle turbine of claim 7, wherein the female connecting elements of the actuator ring comprise recesses in a radially inner surface of the actuator ring.

9. The variable-nozzle turbine of claim 7, wherein the female connecting elements of the actuator ring comprise recesses in a radially outer surface of the actuator ring.

10. The variable-nozzle turbine of claim 1, wherein the nozzle ring is of stepped configuration having a larger-diameter portion joined to a smaller-diameter portion, the actuator ring surrounding the smaller-diameter portion, the larger-diameter portion being disposed axially adjacent the actuator ring.

11. The variable-nozzle turbine of claim 1, further comprising a plurality of spacers connected between the nozzle ring and the second wall of the nozzle.

12. A variable vane assembly for a nozzle, comprising:

a fixed nozzle ring encircling an axis, the nozzle having a flow and an opposite back side, the flow defining an annular surface that is generally perpendicular to the axis and at least partly forms the first wall, the nozzle ring defining a plurality of circumferentially spaced apertures extending axially through said annular surface;

an actuator ring disposed adjacent to the flow side of and concentric with the nozzle ring, the actuator ring being rotatable about said axis relative to the nozzle ring, the actuator ring defining a plurality of circumferentially spaced first connecting elements;

a of circumferentially spaced vanes each an airfoil portion that extends axially from a first end proximate the annular surface of the nozzle ring to an opposite second end, and an axle immovably connected with the first of the airfoil portion and extending axially therefrom in a direction away from the second end, the axle defining a rotation axis of the vane, the axles of the vanes being disposed in the apertures of the nozzle ring such that the axles are rotatable in the apertures; and

each vane further including an arm having a proximal end immovably connected with the vane proximate the first end of the airfoil portion, a distal end of the arm being offset from the rotation axis of the vane and defining a second connecting element removably connected with one of the first connecting elements of the actuator ring, the arms of the vanes being on the flow side of the nozzle ring.

13. The variable vane assembly of claim 12, wherein the arm of each vane is immovably connected with the axle proximate the first end of the airfoil portion of the vane.

14. The variable vane assembly of claim 12, wherein the of each vane is immovably connected with the airfoil portion of the vane.

15. The variable vane assembly of claim 12, wherein each vane and associated axle and arm comprise an integral one-piece structure.

16. The variable vane assembly of claim 12, wherein the apertures in the nozzle ring comprise blind holes.

17. The variable vane assembly of claim 12, wherein each aperture in the nozzle ring has a relatively small-diameter portion that receives one of the axles and forms a bearing surface therefor, and a relatively larger-diameter countersunk portion surrounding, the small-diameter portion at the annular surface of the nozzle ring, a lengthwise portion of the arm of each vane adjacent the proximal end of the arm being accommodated in the countersunk portion of the respective aperture.

18. A method for assembling a variable vane assembly for a variable-nozzle turbine, comprising the steps of:

providing a nozzle ring encircling an axis, the nozzle ring having a flow side an annular surface generally perpendicular to the axis and defining plurality of circumferentially spaced apertures extending through the annular surface;
assembling an actuator ring with the nozzle ring such that the actuator ring is to the flow side of and concentric with the nozzle ring, the actuator ring defining a plurality of circumferentially spaced first connecting elements and being rotatable relative to the nozzle ring;
providing a plurality of vanes each having an airfoil portion that extends axially from a first end to an opposite second end, and an axle immovably connected with the first end of the airfoil portion and extending axially therefrom in a direction away from the second end, the axle defining a rotation axis of the vane, each vane further comprising an arm having a proximal end immovably connected with the vane proximate the first end of the airfoil portion, a distal end of the arm being offset from the rotation axis of the vane and defining a second connecting element configured to connect with one of the first connecting elements of the actuator ring; and
inserting the axle of each of the vanes into one of the apertures in the nozzle ring, the motion of inserting the axle being effective also to place the second connecting of the vane in position for connection with one of the first connecting elements of the actuator ring.

19. The method of claim 18, wherein the actuator ring is assembled with the nozzle ring prior to inserting the axles into the apertures, and the motion of inserting the axles is also effective to connect the second connecting elements of the vanes with the first connecting elements of the actuator ring.

20. A vane for a variable nozzle of a turbocharger, comprising:

an airfoil portion having a proximal end and an opposite distal end;
an axle having a proximal end connected to the proximal end of the airfoil portion so as to form an airfoil/axle assembly, the axle having an opposite distal the the axle defining a rotation axis for the vane; and
an arm connected to the airfoil/axle assembly intermediate the distal end of the airfoil portion and the distal end of the axle, the arm extending outward from the axle for engaging an actuator for rotating the vane about the rotation axis.

21. The vane of claim 20, wherein the arm is connected to the axle proximate the proximal end thereof.

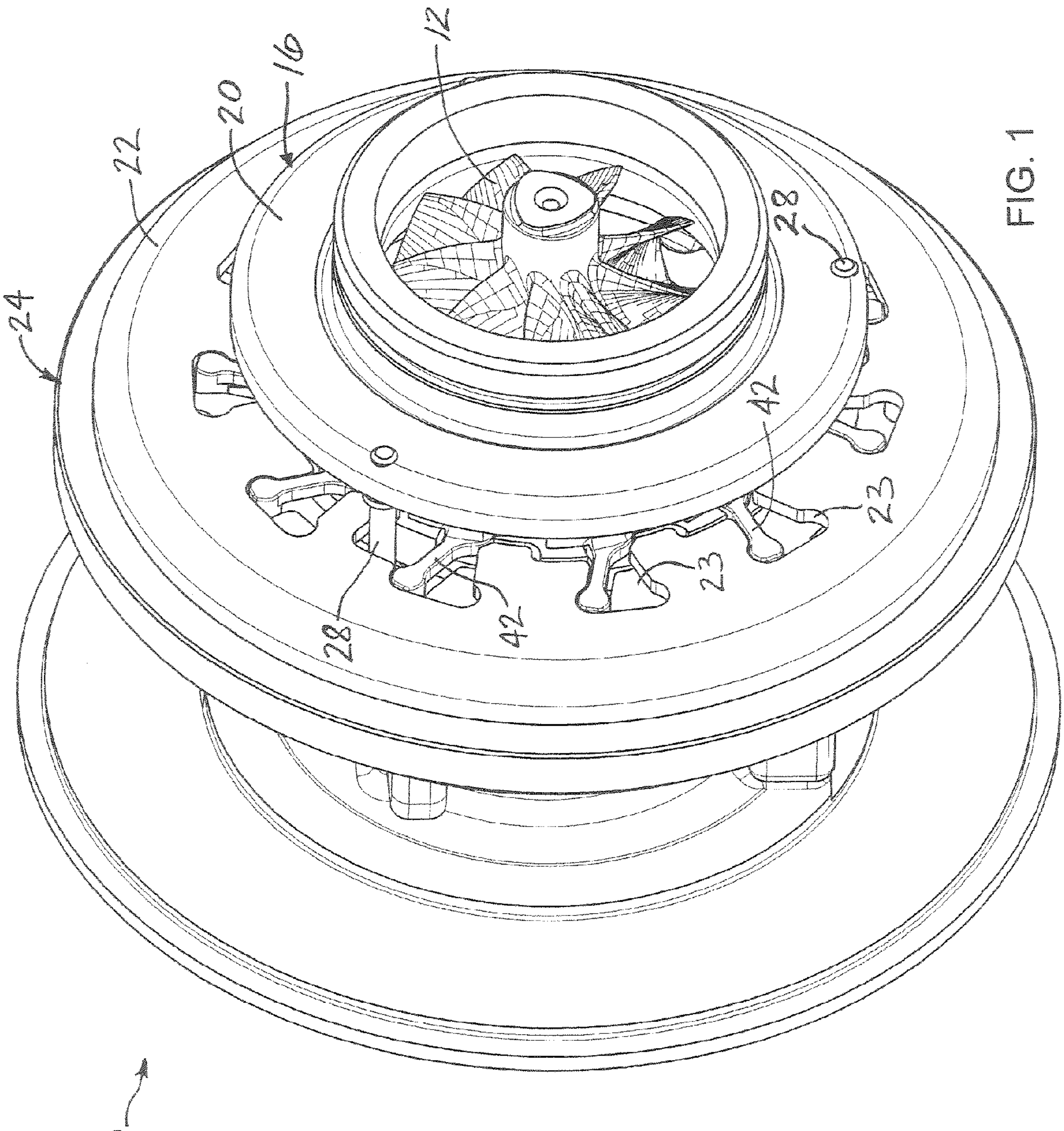

FIG. 1

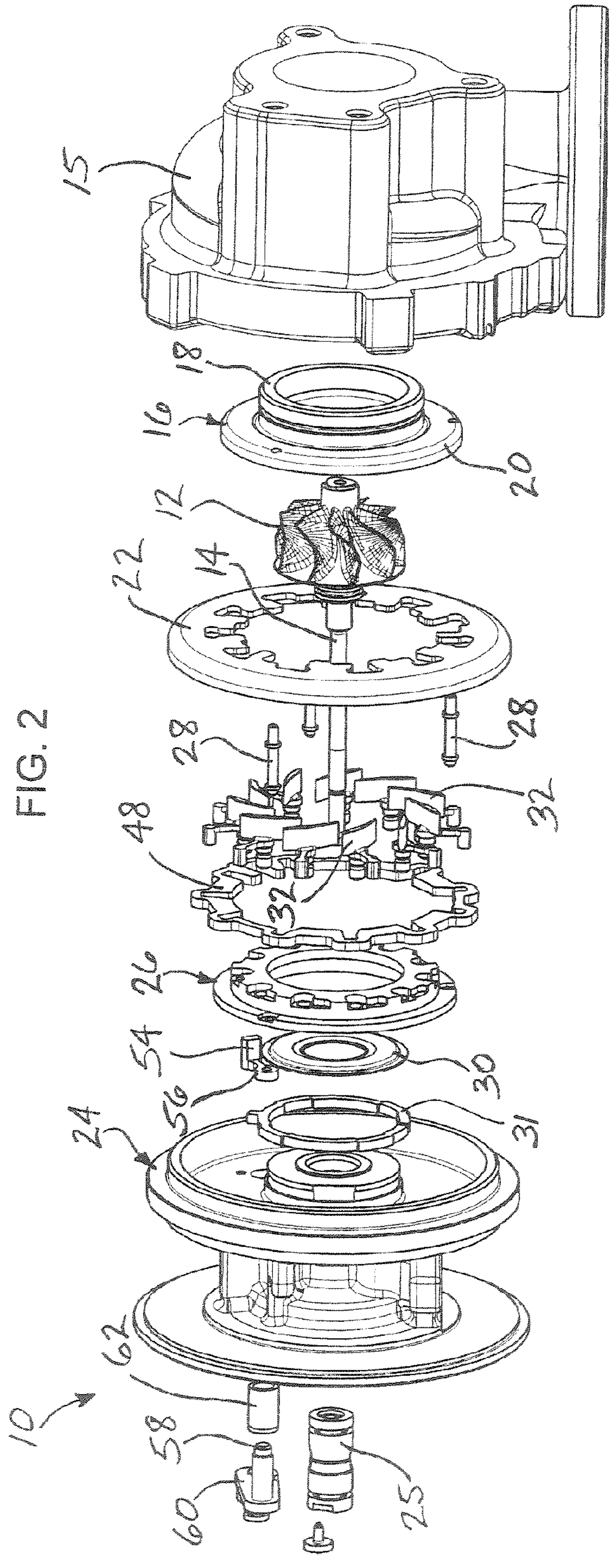

FIG. 2

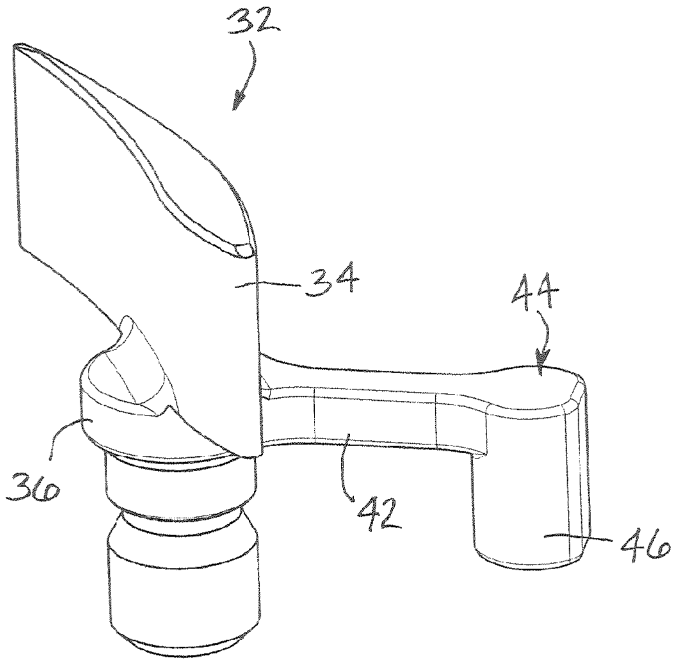

FIG. 3

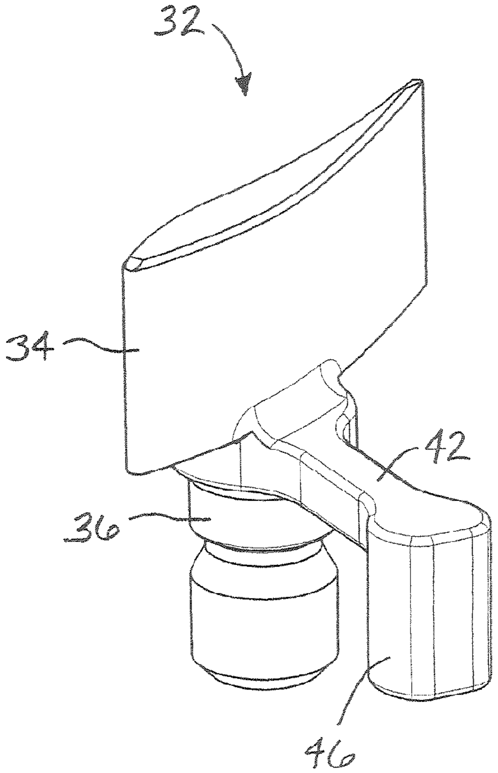

FIG. 4

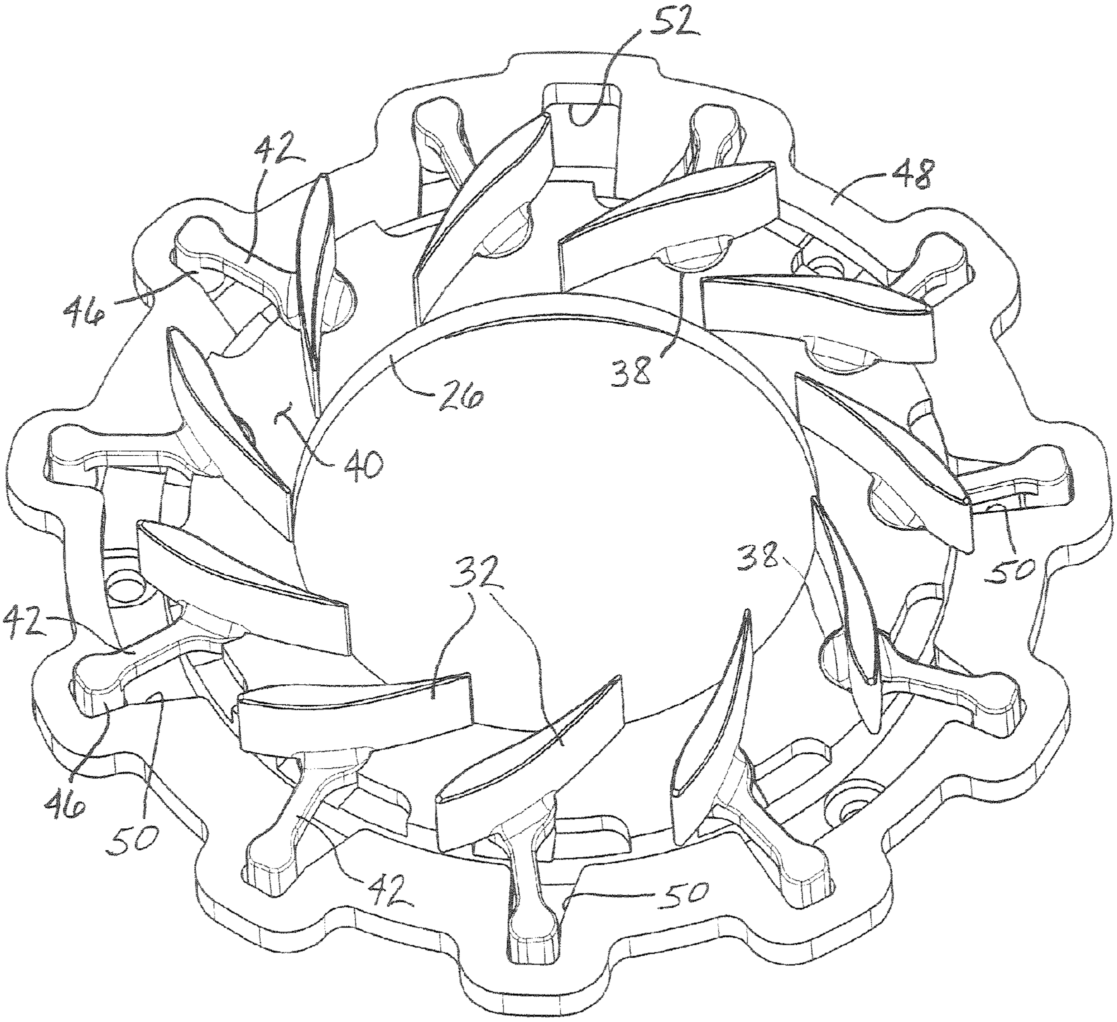

FIG. 5

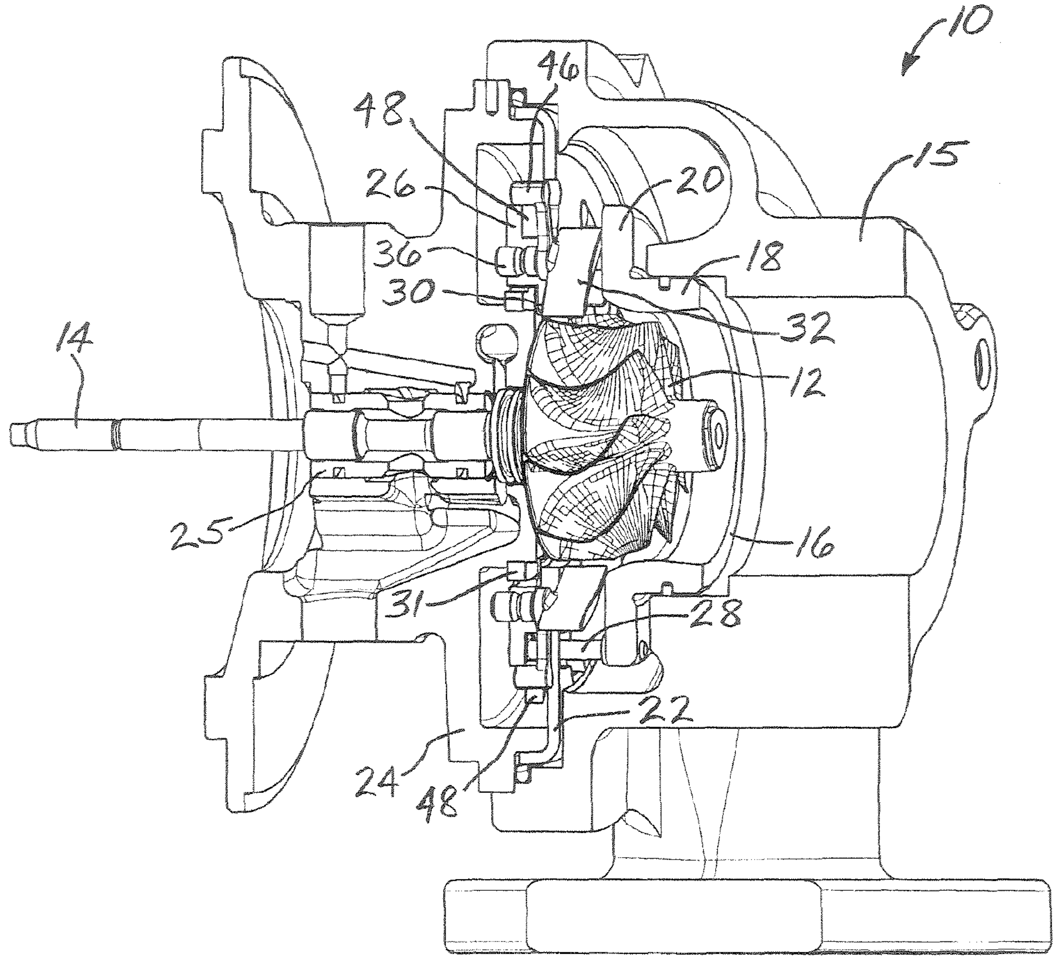

FIG. 6