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(54) **HOUSING ASSEMBLY FOR A TURBOCHARGER**

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(57) **ABSTRACT**

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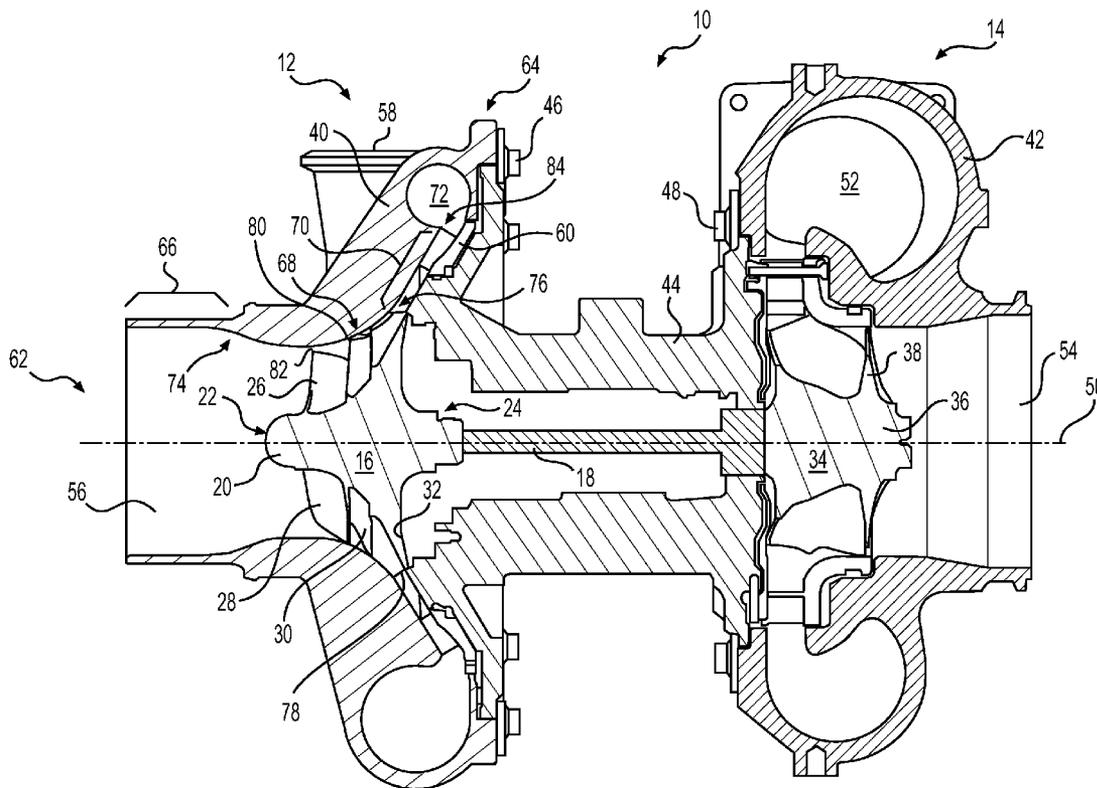
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A compressor housing assembly is disclosed. The compressor housing assembly includes a compressor housing including a compressor housing flange. The compressor housing assembly may include a bearing housing. The bearing housing may include a body portion and a web. The web may extend outward from the body portion to a web end. The bearing housing may also include a bearing housing flange extending radially outward from the web. The compressor housing assembly may also include a clamping plate having a generally annular shape. The clamping plate may abut on the compressor housing flange and the bearing housing flange. In addition, the compressor housing assembly may include a fastener configured to attach the clamping plate to the compressor housing flange and the bearing housing flange.

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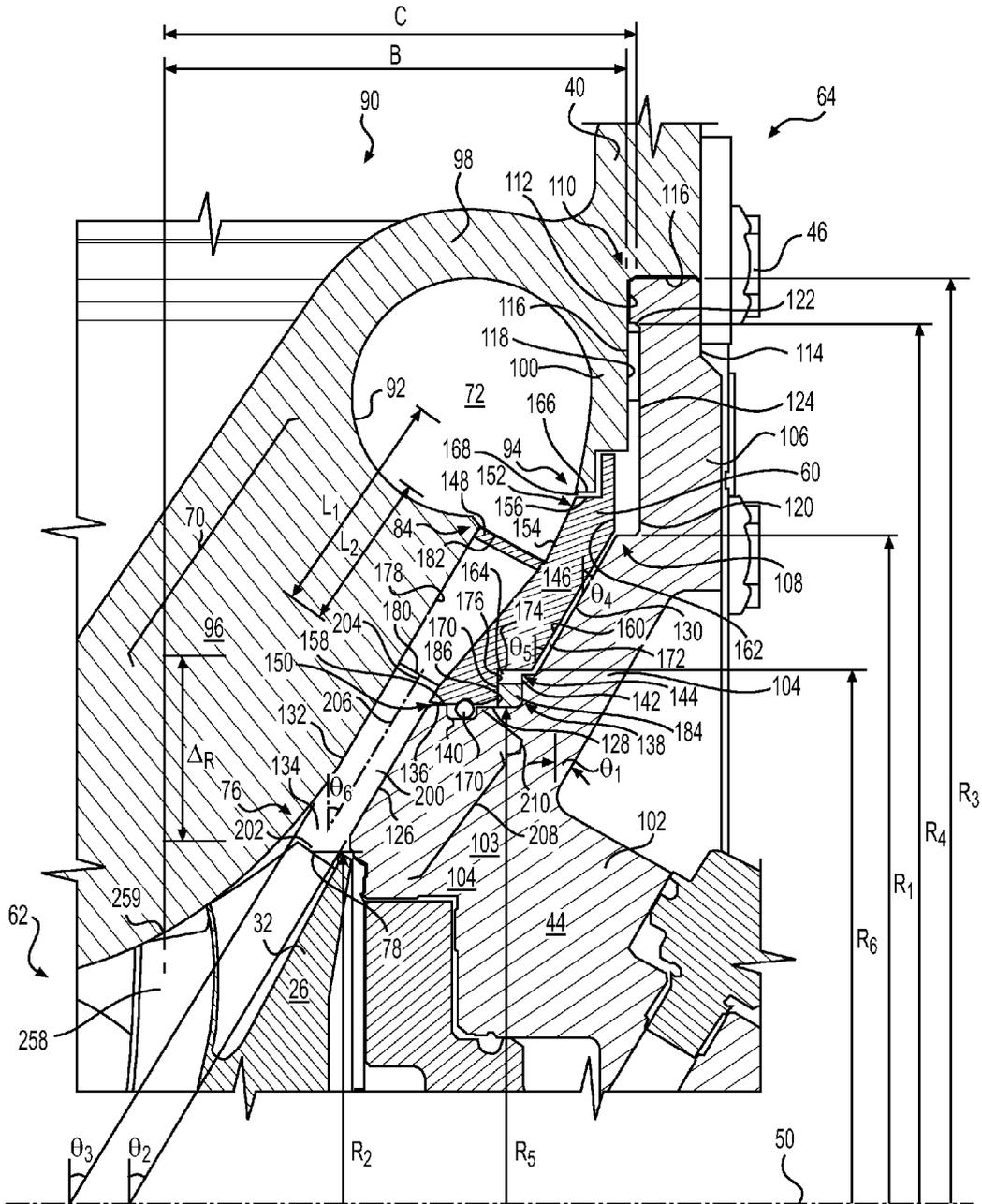


FIG. 2

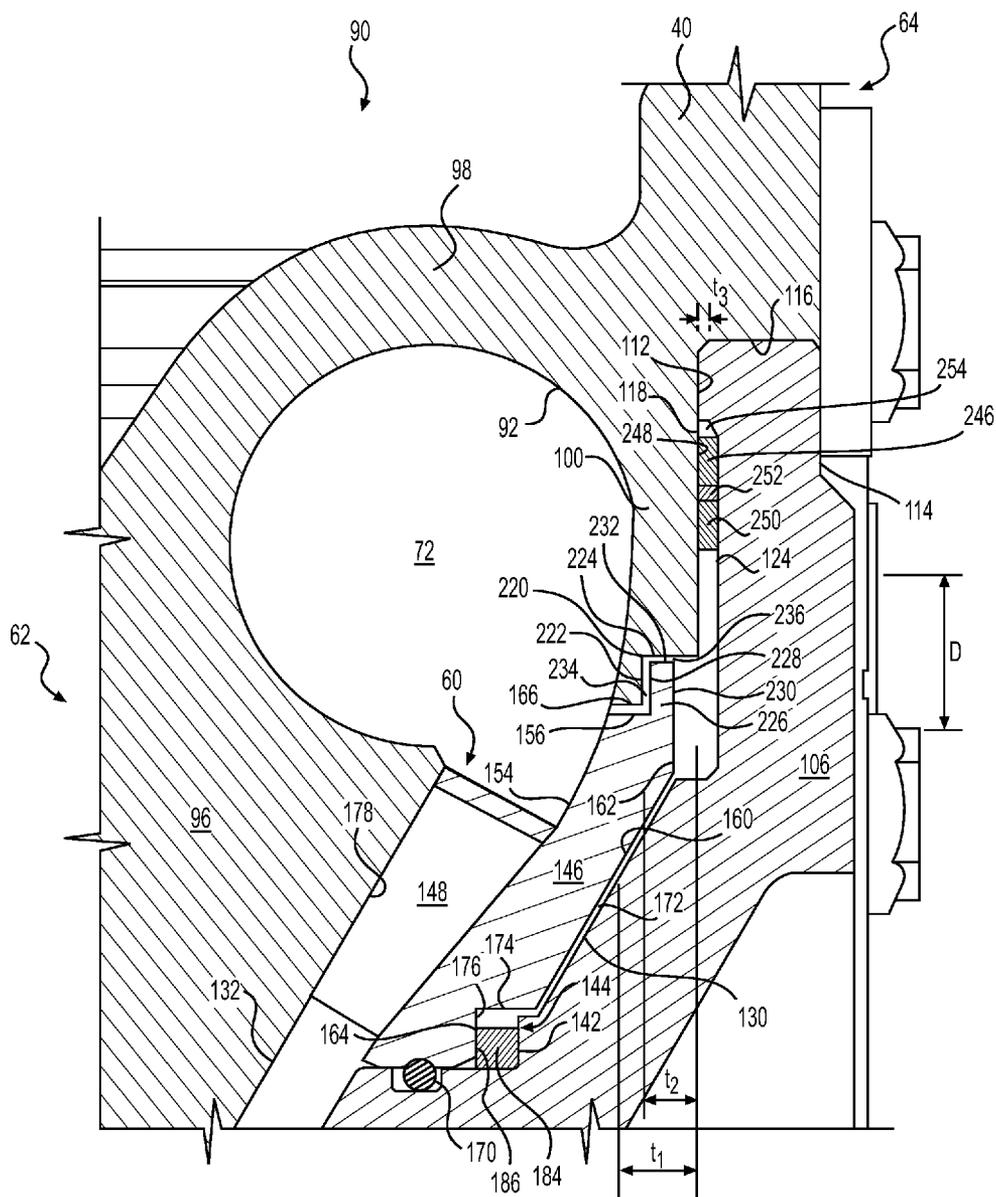


FIG. 3

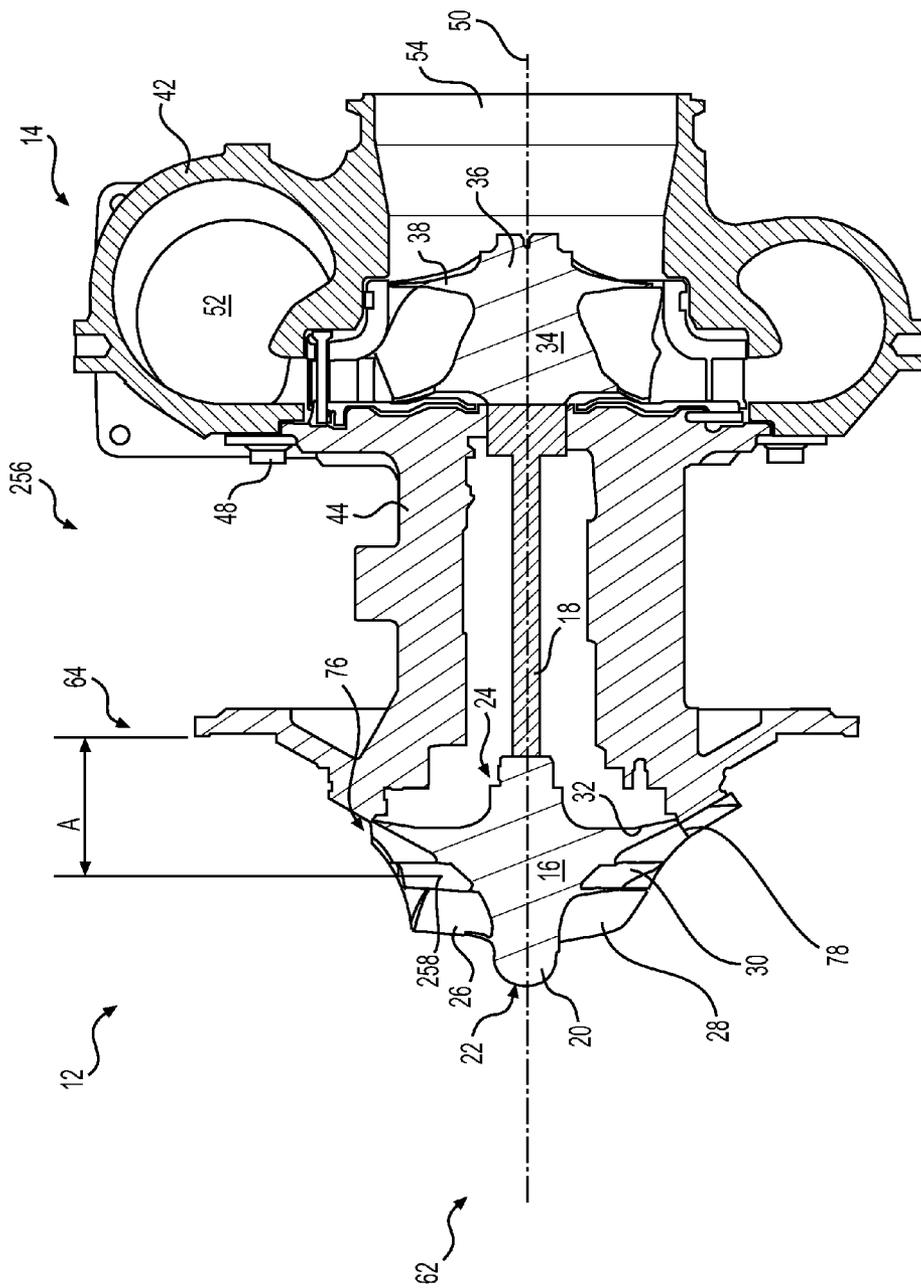


FIG. 5

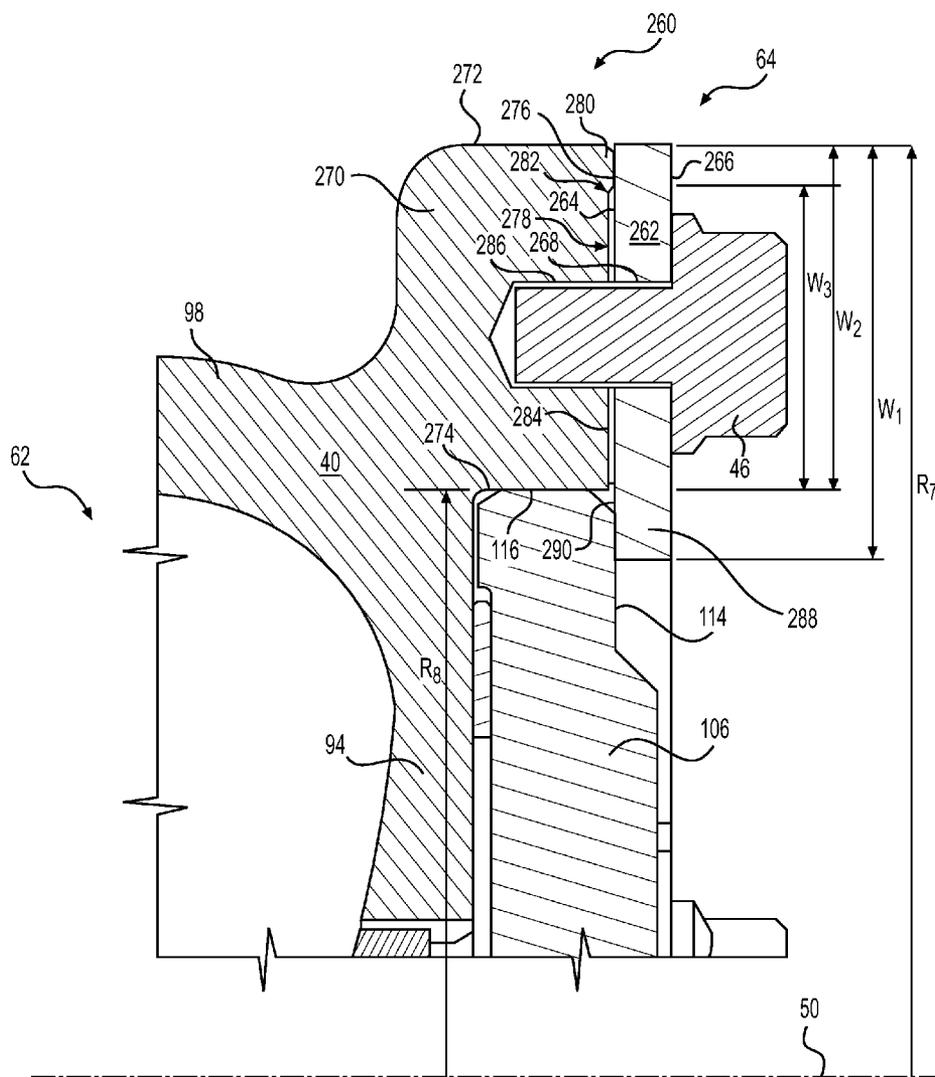


FIG. 6

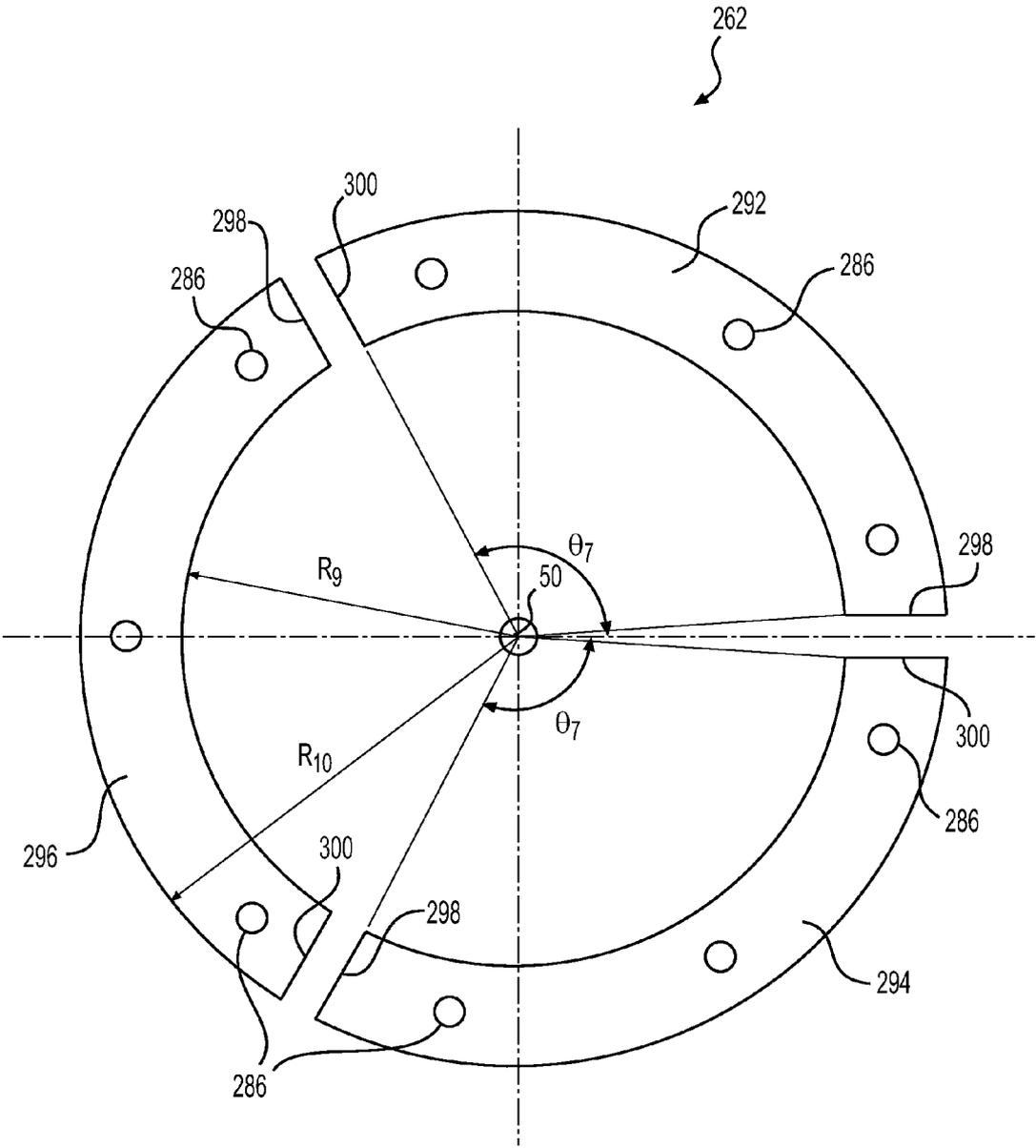


FIG. 7

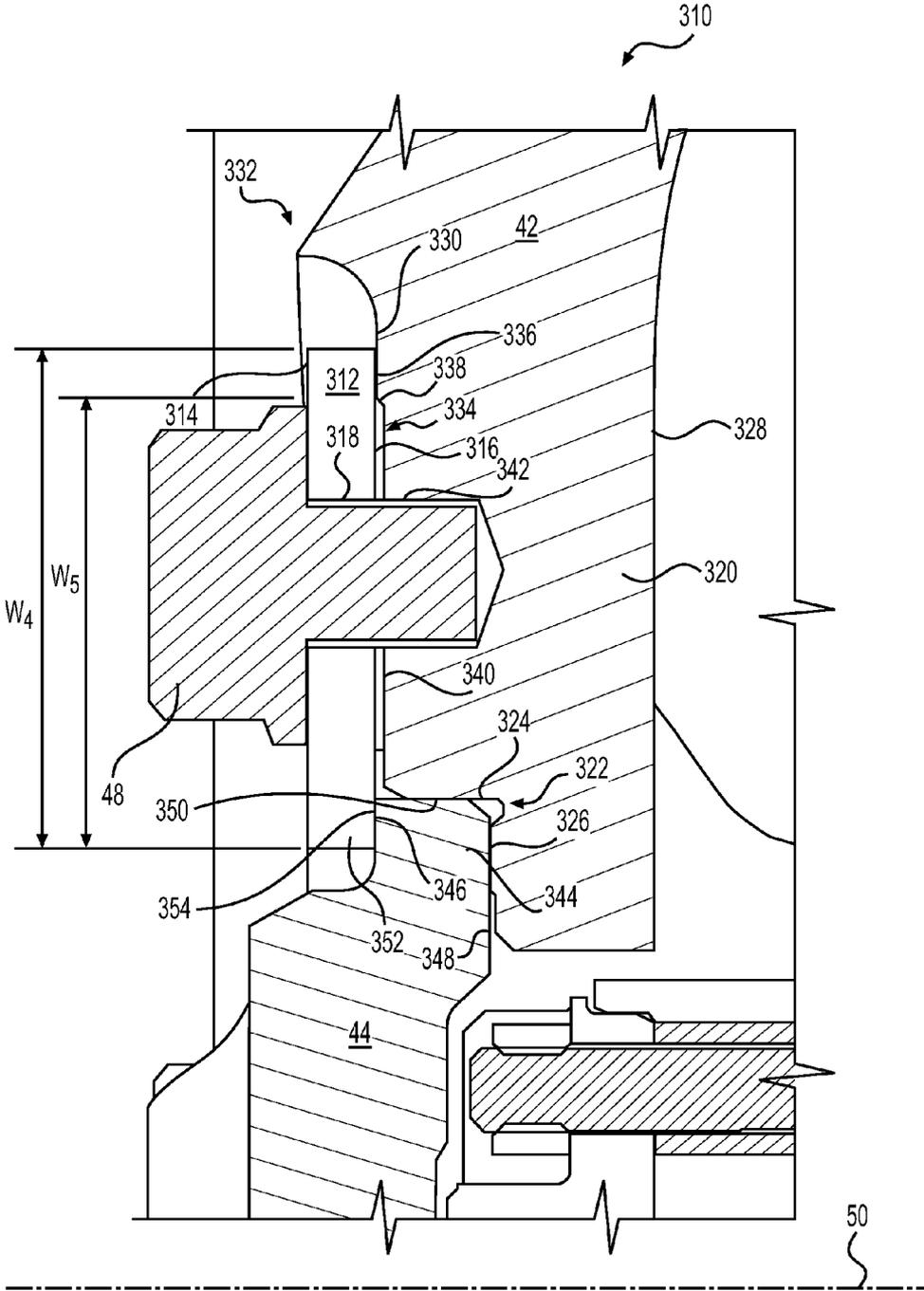


FIG. 8

HOUSING ASSEMBLY FOR A TURBOCHARGER

TECHNICAL FIELD

[0001] The present disclosure relates generally to a housing assembly and, more particularly, to a housing assembly for a turbocharger.

BACKGROUND

[0002] Internal combustion engines, for example, diesel engines, gasoline engines, or natural gas engines employ turbochargers to deliver compressed air for combustion in the engine. A turbocharger compresses air flowing into the engine, helping to force more air into combustion chambers of the engine. The increased supply of air allows for increased fuel combustion in the combustion chambers, resulting in increased power output from the engine.

[0003] A typical turbocharger includes a shaft, a turbine wheel connected to one end of the shaft, a compressor wheel connected to the other end of the shaft, and bearings to support the shaft. Often a turbine housing surrounds the turbine wheel and a separate compressor housing surrounds the compressor impeller. In addition, the turbocharger may include a bearing housing that surrounds the bearings and includes features that help prevent leakage of bearing lubrication oil into the turbine housing or the compressor housing. The turbine housing, the compressor housing, and the bearing housing are attached to each other via fasteners or other clamping mechanisms.

[0004] Hot exhaust from the engine flows through the turbine housing and expands over the turbine wheel, rotating the turbine wheel and the shaft connected to the turbine wheel. The shaft in turn rotates the compressor impeller. Relatively cool air from the ambient flows through the compressor housing where the compressor impeller compresses the air and drives the compressed air into the combustion chambers of the engine. Because the exhaust from the engine is significantly hotter than the ambient air, the turbine housing can experience temperatures significantly higher than the compressor housing. The bearing housing, lying between the turbine housing and the compressor housing, experiences temperatures relatively lower than that of the turbine housing and relatively higher than that of the compressor housing. Because of the different temperatures of the turbine housing, the compressor housing, and the bearing housing, these components may experience different amounts of thermal expansion. The differential thermal expansion causes relative motion between the turbine housing, the compressor housing, and the bearing housing, making it difficult to keep these components securely fastened to each other during operation of the turbocharger. Moreover, the relative motion may also induce mechanical fatigue in the connecting fasteners, reducing the useful life of the fasteners.

[0005] U.S. Patent Application Publication No. 2013/0259661 of Shudo et al. that published on Oct. 3, 2013 (“the ’661 publication”) discloses a sealing structure for sealing joint surfaces of a turbine housing and a bearing housing of a turbocharger. In particular, the ’661 publication discloses a turbine housing that has an end face including an inner end face that makes contact with a bearing housing. The ’661 publication discloses that the bearing housing has a flange that has a height difference relative to the end face of the turbine housing. The ’661 publication also discloses that a

flanged bolt engages with the turbine housing to connect the bearing housing and the turbine housing such that a flange of the bearing housing is sandwiched between the flange portion of the bolt and the inner end face of the turbine housing. The ’661 publication also discloses an embodiment which uses a washer abutting on the turbine housing and bearing housing surfaces. A flanged bolt passes through the washer to engage with the turbine housing such that the bearing housing is sandwiched between the flange portion of the bolt and the inner end face of the turbine housing. Although the ’661 publication discloses a flanged bolt with or without a washer to attach a turbine housing and a bearing housing of a turbocharger, the disclosed method of assembly may still not be optimal. For example, both the flange portion of the bolt and the washer may induce bending loads on the bolt, which in turn may cause failure in the bolt.

[0006] The housing assembly of the present disclosure solves one or more of the problems set forth above and/or other problems of the prior art.

SUMMARY

[0007] In one aspect, the present disclosure is directed to a compressor housing assembly. The compressor housing assembly includes a compressor housing including a compressor housing flange. The compressor housing assembly may include a bearing housing. The bearing housing may include a body portion and a web. The web may extend outward from the body portion to a web end. The bearing housing may also include a bearing housing flange extending radially outward from the web. The compressor housing assembly may also include a clamping plate having a generally annular shape. The clamping plate may abut on the compressor housing flange and the bearing housing flange. In addition, the compressor housing assembly may include a fastener configured to attach the clamping plate to the compressor housing flange and the bearing housing flange.

[0008] In another aspect, the present disclosure is directed to a turbine housing assembly. The turbine housing assembly may include a turbine housing wall. The turbine housing assembly may also include a bearing housing including a bearing housing flange. The turbine housing assembly may further include a clamping plate having a generally annular shape. The clamping plate may abut on the turbine housing wall and the bearing housing flange. In addition, the turbine housing assembly may include at least one fastener configured to attach the clamping plate to the turbine housing wall and the bearing housing flange.

[0009] In yet another aspect, the present disclosure is directed to a turbocharger. The turbocharger may include a turbine housing including a turbine housing wall. The turbocharger may also include a turbine wheel disposed within the turbine housing and configured to be driven by exhaust received from an engine. Further, the turbocharger may include a compressor housing including a compressor housing flange. The turbocharger may also include a compressor impeller disposed within the compressor housing. The turbocharger may include a shaft connecting the turbine wheel and the compressor impeller. In addition, the turbocharger may include a bearing housing. The bearing housing may include a first bearing housing flange configured to be attached to the compressor housing flange. The bearing housing may also include a second bearing housing flange configured to be attached to the turbine housing wall. The turbocharger may include a first clamping plate having a generally annular

shape. The first clamping plate may abut on the compressor housing flange and the first bearing housing flange. The turbocharger may also include a second clamping plate having a generally annular shape. The second clamping plate may abut on the turbine housing wall and the second bearing housing flange. The turbocharger may further include a first fastener configured to attach the first clamping plate to the compressor housing flange and the first bearing housing flange. In addition, the turbocharger may include a second fastener configured to attach the second clamping plate to the turbine housing wall and the second bearing housing flange.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a cut-away view of an exemplary disclosed turbocharger;

[0011] FIG. 2 is a cut-away view of an exemplary disclosed compressor assembly for the turbocharger of FIG. 1;

[0012] FIG. 3 is another cut-away view of the exemplary disclosed compressor assembly for the turbocharger of FIG. 1;

[0013] FIG. 4 is a pictorial view of a portion of the exemplary disclosed compressor assembly of FIG. 2;

[0014] FIG. 5 is a cut-away view of an exemplary disclosed turbocharger cartridge for the turbocharger of FIG. 1;

[0015] FIG. 6 is a cut-away view of an exemplary disclosed compressor housing assembly for the turbocharger of FIG. 1;

[0016] FIG. 7 is a pictorial illustration of an exemplary disclosed clamping plate for the compressor housing assembly of FIG. 6 or the turbine housing assembly of FIG. 8; and

[0017] FIG. 8 is a cut-away view of an exemplary disclosed turbine housing assembly for the turbocharger of FIG. 1.

DETAILED DESCRIPTION

[0018] FIG. 1 illustrates an exemplary embodiment of a turbocharger 10. Turbocharger 10 may be used with an engine (not shown) of a machine that performs some type of operation associated with an industry such as mining, construction, farming, railroad, marine, power generation, or another industry known in the art. As shown in FIG. 1, turbocharger 10 may include compressor stage 12 and turbine stage 14. Compressor stage 12 may embody a fixed geometry compressor impeller 16 attached to a shaft 18. Compressor impeller 16 may include compressor hub 20 that may extend from hub front end 22 to hub rear end 24. Compressor blades 26 may be disposed on compressor hub 20 between hub front end 22 and hub rear end 24 in one or more rows. In one exemplary embodiment as illustrated in FIG. 1, compressor impeller 16 may include first row 28, second row 30, and third row 32 of compressor blades 26. First row 28 of compressor blades 26 may be disposed adjacent hub front end 22. Third row 32 of compressor blades 26 may be disposed adjacent hub rear end 24. Second row 30 of compressor blades 26 may be disposed in between first and third rows 28, 32 of compressor blades 26. Third row 32 of compressor blades 26 may be a rear-most row 32, which may be located closest to hub rear end 24 as compared to first row 30 or second row 32. Although FIG. 1 illustrates only three rows (first row 28, second row 30, and third row 32) of compressor blades 26, it is contemplated that compressor impeller 16 may include any number of rows 28, 30 of compressor blades 26. Turbine stage 14 may include a turbine wheel 34, which may also be attached to shaft 18. Turbine wheel 34 may include turbine hub 36 and turbine blades 38 disposed around turbine hub 36.

[0019] Compressor stage 12 may be enclosed by compressor housing 40. Turbine stage 14 may be enclosed by turbine housing 42. Bearing housing 44 may enclose bearings (not shown) that may support shaft 18. Bearing housing 44 may be attached to compressor housing 40 via bolts 46. Likewise, bearing housing 44 may be attached to turbine housing 42 via bolts 48. Compressor impeller 16, shaft 18, turbine wheel 34, compressor housing 40, turbine housing 42, and bearing housing 44 may be disposed around rotational axis 50 of turbocharger 10.

[0020] Exhaust gases exiting the engine (not shown) may enter turbine housing 42 via turbine inlet 52 and exit turbine housing 42 via turbine outlet 54. The hot exhaust gases may move through turbine housing 42, expanding against turbine blades 38, rotating turbine wheel 34. Rotation of turbine wheel 34 may rotate shaft 18, which in turn may rotate compressor impeller 16. Air may enter compressor housing 40 via compressor inlet 56 and exit compressor housing 40 via compressor outlet 58. As air moves through compressor stage 12, compressor impeller 16 may spin and accelerate the air. Compressor stage 12 may include diffuser ring 60, which may help slow down the air, causing an increase in the pressure of the air within compressor stage 12. Compressed air from compressor stage 12 may be directed into the engine.

[0021] As further illustrated in FIG. 1, compressor housing 40 may extend from compressor front end 62 to compressor rear end 64. Compressor housing 40 may include intake portion 66, transition portion 68, diffuser portion 70, and volute 72. Intake portion 66 may extend from adjacent compressor front end 62 to first distal end 74 disposed between compressor front end 62 and compressor rear end 64. In one exemplary embodiment as illustrated in FIG. 1, first distal end 74 may be disposed adjacent hub front end 22 of compressor impeller 16. Intake portion 66 may have a generally frusto-conical shape, which may help direct air from the ambient into compressor housing 40. It is contemplated, however, that intake portion 66 may have a generally cylindrical or any other type of shape known in the art. Transition portion 68 of compressor housing 40 may extend from first distal end 74 to second distal end 76 disposed between first distal end 74 and compressor rear end 64. In one exemplary embodiment as illustrated in FIG. 1, second distal end 76 may be disposed adjacent outer edge 78 of third row 32 of compressor blades 26. As illustrated in FIG. 1, transition portion 68 may have an inner surface 80 that may be radially separated from outer edges 78 of compressor blades 26 in first, second, and third rows 28, 30, 32 by a radial gap 82. Diffuser portion 70 may extend from second distal end 76 to third distal end 84, which may be disposed adjacent volute 72. Volute 72 may have a generally toroidal shape and may be disposed around rotational axis 50. Volute 72 may be connected to diffuser portion 70 at third distal end 84. Intake portion 66, transition portion 68, and diffuser portion 70 may help direct air from compressor inlet 56 to volute 72 during operation of turbocharger 10.

[0022] FIG. 2 illustrates a cut-away view of an exemplary embodiment of compressor assembly 90 of turbocharger 10. As illustrated in FIG. 2, volute 72 may have a volute inner surface 92 that may extend from third distal end 84 to fourth distal end 94. In one exemplary embodiment as illustrated in FIG. 2, volute inner surface 92 may have a generally circular cross-section. Fourth distal end 94 may be axially spaced apart from third distal end 84 in a direction towards compressor rear end 64. Volute 72 may be bounded by diffuser portion wall 96, volute top wall 98, and volute rear wall 100. Volute

rear wall **100** may be axially separated from diffuser portion wall **96**. Volute top wall **98** may connect diffuser portion wall **96** and volute rear wall **100** to form a continuous and smooth volute inner surface **92**.

[0023] As also illustrated in FIG. 2, bearing housing **44** may include body portion **102**, web **104**, and bearing housing flange **106**. Body portion **102** of bearing housing **44** may be disposed symmetrically around rotational axis **50**. Web **104** may extend outward from body portion **102** to web end **108**. In one exemplary embodiment as illustrated in FIG. 2, web end **108** may be disposed adjacent fourth distal end **94** and volute rear wall **100**. Web end **108** may have a radius “ R_1 ,” which may be larger than a radius “ R_2 ” of outer edge **78** of third row **32** of compressor blades **26**. As also illustrated in FIG. 2, for example, web **104** may be generally inclined at an angle θ_1 relative to an axial plane disposed generally orthogonal to rotational axis **50**. One of ordinary skill in the art would recognize that surfaces inclined at an angle relative to an axial plane disposed generally orthogonal to rotational axis **50** would correspondingly be inclined relative to rotational axis **50**.

[0024] Bearing housing flange **106** may extend radially outward from web end **108** to bearing housing flange end **110**. In one exemplary embodiment as illustrated in FIG. 2, bearing housing flange **106** may be disposed generally orthogonal to rotational axis **50**. Bearing housing flange **106** may have flange front face **112** and a flange rear face **114** disposed opposite to flange front face **112**. Bearing housing flange **106** may also have a generally cylindrical flange outer surface **116**, which may have a radius “ R_3 ,” which may be larger than radius R_1 of web end **108**. Flange front face **112** may be disposed adjacent to and may abut on rear face **118** of volute rear wall **100**.

[0025] Bearing housing flange **106** may also include a flange recess **120**, which may extend axially inwards from flange front face **112** towards flange rear face **114**. Flange recess **120** may extend radially from adjacent web end **108** to recess outer edge **122**. In one exemplary embodiment as illustrated in FIG. 2, recess outer edge **122** may have a radius “ R_4 ,” smaller than radius R_3 of flange outer surface **116**. Flange recess **120** may have a recess seating surface **124** disposed axially spaced apart from flange front face **112** and rear face **118** of volute rear wall **100**. Recess seating surface **124** may have a generally annular shape and may extend from adjacent web end **108** to adjacent recess outer edge **122**. Bearing housing flange **106** may be attached to volute rear wall **100** of compressor housing **40** via one or more bolts **46**.

[0026] Web **104** may include a first web face **126**, ledge **128**, and second web face **130**. First web face **126** may extend outward from adjacent outer edge **78** of third row **32** to ledge **128** disposed between outer edge **78** and web end **108**. First web face **126** may be inclined at an angle “ θ_2 ” relative to an axial plane disposed generally orthogonal to rotational axis **50**. First web face **126** may be disposed opposite to and axially spaced apart from inner wall **132** of diffuser portion **70** of compressor housing **40**. Inner wall **132** may be inclined at an angle “ θ_3 ” relative to an axial plane disposed generally orthogonal to rotational axis **50**. First web face **126** and inner wall **132** may form passageway **134**. First web face **126** and inner wall **132** may have a smooth shape that may help ensure that air can travel from outer edges **78** of compressor blades **26** through passageway **134** without significantly altering a velocity or direction of the air. In one exemplary embodiment, first web face **126** may have a smooth curvilinear shape that

may conform to a shape of compressor blades **26**. Likewise, inner wall **132** may have a smooth curvilinear shape that may conform to a surface defined by outer edges **78** of compressor blades **26** in first, second, and third rows **28**, **30**, **32**.

[0027] Ledge **128** may have a generally cylindrical ledge outer surface **136**, which may have a radius “ R_5 ” relative to rotational axis **50**. Ledge outer surface **136** may extend axially from first web face **126** to ledge end **138** disposed between first web face **126** and compressor rear end **64**. Radius R_5 of ledge outer surface **136** may be larger than a radius “ R_2 ” of outer edges **78** of compressor blades **26** in third row **32**. Ledge outer surface **136** may also include a generally annular groove **140**. Ledge **128** may include ledge axial face **142** that may be axially spaced apart from first web face **126**. Ledge axial face **142** may be disposed at ledge end **138**. Ledge axial face **142** may extend radially outward from ledge outer surface **136** to second web face **130**. In one exemplary embodiment as illustrated in FIG. 2, ledge axial face **142** may intersect second web face **130** at ledge axial face end **144**. In one exemplary embodiment as illustrated in FIG. 2, ledge axial face **142** may be disposed generally orthogonal to rotational axis **50**. Second web face **130** may extend from ledge axial face end **144** to web end **108**. Second web face **130** may be inclined at an angle “ θ_4 ” relative to an axial plane disposed generally orthogonal to rotational axis **50**.

[0028] Diffuser ring **60** may be disposed between inner wall **132** of compressor housing **40** and second web face **130** of bearing housing **44**. Diffuser ring **60** may include back plate **146** and one or more vanes **148**. In one exemplary embodiment as illustrated in FIG. 2, back plate **146** may extend from back plate leading edge **150** to back plate trailing edge **152**. Back plate **146** may have a generally annular shape. In one exemplary embodiment as illustrated in FIG. 2, back plate leading edge **150** may be disposed adjacent ledge outer surface **136** and back plate trailing edge **152** may be disposed adjacent fourth distal end **94**. Back plate **146** may include front face **154**, top face **156**, bottom face **158**, inclined rear face **160**, axial rear face **162**, and recess **164**. Front face **154** of back plate **146** may extend from back plate leading edge **150** to back plate trailing edge **152**. Front face **154** may have a generally curvilinear and smooth shape and may be disposed opposite to and axially spaced apart from inner wall **132** of compressor housing **40**. Front face **154** may be shaped to help ensure air from passageway **134** may smoothly flow over front face **154**.

[0029] Top face **156** of back plate **146** may extend axially from front face **154** to axial rear face **162** disposed adjacent recess seating surface **124**. Top face **156** may have a generally cylindrical shape. Top face **156** may be disposed adjacent inner face **166** of volute rear wall **100**. Inner face **166** of volute rear wall **100** may also have a generally cylindrical shape. Top face **156** of back plate **146** may be radially separated from inner face **166** by a radial gap **168**. Bottom face **158** of back plate **146** may extend axially from front face **154** towards inclined rear face **160** disposed adjacent second web face **130**. Bottom face **158** may abut on ledge outer surface **136**. Bottom face **158** may have a generally cylindrical shape. It is contemplated, however, that bottom face **158** may have a non-cylindrical shape. Seal member **170** may be disposed in groove **140** between ledge outer surface **136** and bottom face **158**. In one exemplary embodiment as illustrated in FIG. 2, seal member **170** may be an O-ring. It is contemplated, however, that seal member **170** may be a gasket or any other type

of sealing element known in the art. Seal member 170 may prevent recirculation of air around back plate 146.

[0030] Axial rear face 162 of back plate 146 may be axially separated from front face 154 of back plate 146. Axial rear face 162 may extend radially inward from top face 156 to adjacent web end 108. Axial rear face 162 may connect top face 156 with inclined rear face 160. In one exemplary embodiment as shown in FIG. 2, axial rear face 162 may be disposed generally orthogonal to rotational axis 50. Inclined rear face 160 may extend from axial rear face 162 adjacent web end 108 to adjacent ledge axial face end 144. Inclined rear face 160 may be inclined at an angle " θ_5 " relative to a plane disposed generally orthogonal to rotational axis 50. One of ordinary skill in the art would recognize that inclined rear face 160 would be inclined relative to top face 156 and axial rear face 162. Inclined rear face 160 may be axially separated from front face 154 of back plate 146. Inclined rear face 160 may be disposed adjacent second web face 130. In one exemplary embodiment as illustrated in FIG. 2, inclined rear face 160 may be axially separated from second web face 130 by cavity 172. Seal member 170 may prevent a flow of air from volute 72 to passageway 134 via cavity 172.

[0031] Recess 164 may be disposed adjacent bottom face 158 and between bottom face 158 and inclined rear face 160. Recess 164 may include recess upper face 174 and recess side face 176. Recess upper face 174 may have a generally cylindrical shape and may extend axially from inclined rear face 160 towards front face 154. Recess upper face 174 may be radially separated from ledge outer surface 136. In one exemplary embodiment as illustrated in FIG. 2, recess upper face 174 may have a radius " R_6 " relative to rotational axis 50. Radius R_6 may be larger than radius R_5 of ledge outer surface 136. Recess side face 176 may extend radially inward from recess upper face 174 to bottom face 158. In one exemplary embodiment, recess side face 176 may have a generally annular shape, which may be disposed generally orthogonal to rotational axis 50. Recess side face 176 may be axially disposed between ledge axial face 142 and front face 154. Recess side face 176 may be axially separated from ledge axial face 142.

[0032] Vane 148 may extend radially and axially outward from front face 154 of back plate 146 to vane tip 178. In one exemplary embodiment as illustrated in FIG. 2, vane tip 178 may abut on inner wall 132 of compressor housing 40. Vane 148 may extend from a vane leading edge 180 to a vane trailing edge 182. Vane leading edge 180 may be disposed adjacent back plate leading edge 150. Vane leading edge 180 may intersect front face 154 of back plate 146 at a location which may be offset from back plate leading edge 150. For example, as illustrated in FIG. 2, vane leading edge 180 may intersect front face 154 of back plate 146 at a location disposed between back plate leading edge 150 and back plate trailing edge 152. As illustrated in FIG. 2, vane 148 may extend over a portion of front face 154 of back plate 146 so that vane trailing edge 182 may be offset from back plate trailing edge 152. Thus, for example, a length " L_1 " of front face 154 may be larger than a length " L_2 " of vane 148. Air from passageway 134 may flow between vanes 148 and enter volute 72. A shape of each vane 148 and a circumferential spacing between vanes 148 may be selected so that vanes 148 may help reduce a speed of the air flowing between vanes 148, thereby helping to increase a pressure of the air in volute 72.

[0033] Wave spring 184 may be disposed in recess 164 between ledge axial face 142 and recess side face 176 of

recess 164 in back plate 146. Wave spring 184 may have a generally annular shape having an inner radius, which may be larger than a radius R_5 of ledge outer surface 136. Wave spring 184 may include a plurality of waves on axial face 186 of wave spring 184. In one exemplary embodiment, wave spring 184 may have about 11 waves. Wave spring 184 may have an axial thickness ranging from 2 mm to 4 mm. In an assembled configuration as illustrated in the exemplary embodiment of FIG. 2, wave spring 184 may have a thickness ranging from about 1.5 mm to about 2.5 mm. Wave spring 184 may have a spring constant ranging from about 20 to 30 N/mm (Newtons per mm). Wave spring 184 may apply an axial load on back plate 146 to urge vane tips 178 to firmly abut on and remain in contact with inner wall 132 of compressor housing 40. By helping to keep vane tips 178 firmly in contact with inner wall 132, wave spring 184 may help ensure that no appreciable amount of air can leak from passageway 134 into volute 72 via gaps between vane tips 178 and inner wall 132 of compressor housing 40.

[0034] As also illustrated in FIG. 2, vanes 148 may be disposed nearer to volute 72 as compared to outer edges 78 of compressor blades 26 so as to define a vaneless space 200. Vaneless space 200 may extend within passageway 134 from outer edges 78 of compressor blades 26 in third row 32 to vane leading edges 180. Vaneless space 200 may have a generally annular shape extending between inner wall 132 of compressor housing 40 and first web face 126 of bearing housing 44. In one exemplary embodiment, a radial extent "AR" of vaneless space 200 between midpoints 202 and 204 may range from about 20% to 40% of a maximum radius R_2 of compressor blades 26.

[0035] Vaneless space 200 may be inclined at an angle " θ_6 " relative to an axial plane disposed generally orthogonal to rotational axis 50. Angle θ_6 may be measured between an axis 206 of vaneless space 200 and an axial plane disposed generally orthogonal to rotational axis 50. For example, axis 206 of vaneless space 200 may be defined as a line connecting midpoints 202 and 204 of passageway 134. Midpoint 202 may be disposed adjacent an outer edge 78 of compressor blades 26. Midpoint 204 may be disposed adjacent a vane leading edge 180. As used in this disclosure midpoint 202 may be disposed within passageway 134 halfway between inner wall 132 and second web face 130. Similarly, midpoint 204 may be disposed within passageway 134 halfway between inner wall 132 and front face 154 of back plate 146. One of ordinary skill in the art would recognize that axis 206 may not always be disposed parallel to inner wall 132 and/or second web face 130. As also illustrated in FIG. 2, a portion 208 of vaneless space 200 may be disposed between inner wall 132 and second web face 130. A remaining portion 210 of vaneless space 200 may be disposed between inner wall 132 and front face 154 of back plate 146.

[0036] The above description refers to angles θ_1 , θ_2 , θ_3 , θ_4 , θ_5 , and θ_6 . It is contemplated that angles θ_1 , θ_2 , θ_3 , θ_4 , θ_5 , and θ_6 may be equal or unequal. In one exemplary embodiment, each of angles θ_1 , θ_2 , θ_3 , θ_4 , θ_5 , or θ_6 may range from about 0° to about 45°.

[0037] FIG. 3 illustrates another cut-away view of an exemplary embodiment of compressor assembly 90 of turbo-charger 10. As illustrated in FIG. 3, volute rear wall 100 may include recess 220, which may extend axially from rear face 118 of volute rear wall 100 towards volute inner surface 92. Volute rear wall 100 may have a thickness " t_1 ." Recess 220 may have a depth " t_2 ," which may be smaller than thickness

t_1 . Recess 220 may include recess rear face 222, which may be disposed generally orthogonal to rotational axis 50. Recess rear face 222 may be disposed generally parallel to axial rear face 162 of back plate 146 of diffuser ring 60. Recess 220 may also include recess side surface 224, which may extend axially from rear face 118 of volute rear wall 100 to recess rear face 222.

[0038] As illustrated in FIG. 3, back plate 146 of diffuser ring 60 may include one or more tabs 226 disposed circumferentially around back plate 146. A circumferential spacing between tabs 226 may be uniform or non-uniform. Tab 226 may extend radially outward from top face 156. Tab 226 may have a tab front face 228 and a tab rear face 230 disposed opposite tab front face 228. Tab 226 may also have tab side surface 232 extending between tab front face 228 and tab rear face 230. Tab front face 228 may be disposed adjacent to and axially separated from recess rear face 222 by an axial gap 234. Tab side surface 232 may be radially separated from recess side surface 224 by a radial gap 236.

[0039] FIG. 4 illustrates a pictorial view of an exemplary embodiment of compressor assembly 90. As illustrated in FIG. 4, tab 226 may span a circumferential angle " ϕ ." In one exemplary embodiment, angle ϕ may range from about 5° to 10° . As illustrated in FIG. 4, a first tab 226 may be disposed about a first diametrical axis 237 and a second tab 226 may be disposed about a second diametrical axis 238. In one exemplary embodiment as illustrated in FIG. 4, first diametrical axis 237 may be disposed generally orthogonal to second diametrical axis 238. It is contemplated, however, that first diametrical axis 237 may be disposed at any angle relative to second diametrical axis 238. Further, as illustrated in the exemplary embodiment of FIG. 4, back plate 146 may have about 4 tabs 226. It is contemplated, however, that back plate 146 may have any number of tabs 226. Tabs 226 may engage with recesses 220 in volute rear wall 100. Tabs 226 may be configured to act as anti-rotational features that prevent rotation of back plate 146 around rotational axis 50.

[0040] As further illustrated in FIG. 4, volute rear wall 100 may include one or more recesses 239. Recess 239 may have a depth, which may be smaller than depth t_2 of recess 220. Recess 239 may include a hole 240, which may be threaded. Back plate 146 may be attached to volute rear wall 100 by a fastener 242. Fastener 242 may pass through washer 244 and threadingly engage with threads in hole 240. Washer 244 may abut on volute rear wall 100 and axial rear face 162 of diffuser ring 60 to attach diffuser ring 60 to volute rear wall 100. Depths of recesses 220 and 239 may be selected such that tab front face 228 may remain axially separated from recess rear face 222 of volute rear wall 100. In one exemplary embodiment as illustrated in FIG. 4, back plate 146 of diffuser ring 60 may include about four tabs 226. As also illustrated in the exemplary embodiment of FIG. 4, diffuser ring 60 may be attached to volute rear wall 100 using about three washers 244 and three fasteners 242. It is contemplated, however, that any number of washers 244 and fasteners 242 may be used to attach volute rear wall 100 and diffuser ring 60.

[0041] Returning to FIG. 3, compressor stage 12 may include shim 246. Shim 246 may have a generally annular shape and may be disposed around rotational axis 50. Shim 246 may have a shim front face 248 disposed adjacent to and abutting on rear face 118 of volute rear wall 100. Shim 246 may also have a shim rear face 250 disposed opposite shim front face 248. Shim rear face 250 may be disposed adjacent to and may abut on recess seating surface 124. In one exem-

plary embodiment as illustrated in FIG. 3, shim 246 may be attached to bearing housing flange 106 using one or more rivets 252. Rivets 252 may be circumferentially spaced from each other. A circumferential spacing between rivets 252 may be uniform or non-uniform. In one exemplary embodiment a number of rivets 252 may range from about 6 to 12. Although the above description refers to rivets 252, it is contemplated that bolts, screws, or any other types of fasteners known in the art may be used to attach shim 246 to bearing housing flange 106. Shim 246 may be configured to define a space 254 between shim front face 248 and recess seating surface 124. Shim 246 and consequently space 254 may have a thickness " t_3 ," which may be selected so that gaps between vane tips 178 and inner wall 132 of compressor housing 40 can be reduced or eliminated after assembly of compressor housing 40 with bearing housing 44.

[0042] FIG. 5 illustrates a pictorial view of an exemplary embodiment of turbocharger cartridge 256. As illustrated in FIG. 5, turbocharger cartridge 256 may include compressor impeller 16, shaft 18, turbine wheel 34, turbine housing 42, and bearing housing 44. Dimensional measurements of turbocharger cartridge 256 combined with dimensional tolerances on compressor housing 40 may be used to determine a maximum required thickness t_3 of shim 246. These dimensional measurements and dimensional tolerances may be used to select thickness t_3 of shim 246 so that vane tips 178 may be firmly in contact with inner wall 132 of compressor housing 40 without introducing a gap between vane tips 178 and inner wall 132. Thus, shim 246 and turbocharger cartridge 256 may constitute a matched set. By selecting thickness t_3 of shim 246 in this manner, gaps between vane tips 178 and inner wall 132 may depend only on the dimensional tolerances of compressor housing. In one exemplary embodiment, thickness t_3 may be selected as a maximum thickness that may be required to ensure that vane tips 178 come into contact with inner wall 132 based on the dimensional tolerances of compressor housing 40. In particular, an axial load may be applied to shaft 18, pushing compressor impeller 16 away from turbine housing 42 and towards compressor front end 62. An axial distance "A" between recess seating surface 124 and a gage location 258, on compressor impeller 16, may be measured.

[0043] An axial distance "B" (see FIG. 2) may be measured between rear face 118 of volute rear wall 100 and a gage location 259 on inner wall 132 of compressor housing 40. Gage location 259 may be a predetermined location on inner wall 132 of compressor housing 40. In one exemplary embodiment as illustrated in FIG. 2, gage location 259 may be disposed adjacent to gage location 258. Further, a variation in distance B may be determined based on known manufacturing tolerances. Additionally or alternatively, the variation in distance B may be determined based on measurements of distance B on a plurality of compressor housings 40. A maximum thickness t_3 may be determined based on distance A, distance B, and the variation of distance B, so that that vane tips 178 may remain in contact with inner wall 132 of compressor housing 40. For example, thickness t_3 may be selected so that a distance "C" between recess seating surface 124 of bearing housing flange 106 and gage location 259 may be greater than or equal to a sum of thickness t_3 (see FIG. 3) and a maximum value of distance B determined based on the variation in distance B. Shim 246 having the maximum required thickness t_3 may be attached to bearing housing flange 106 of bearing housing 44 in turbocharger cartridge

256. In one exemplary embodiment thickness t_3 of shim **246** may range from about 1.5 mm to about 2.5 mm.

[0044] FIG. 6 illustrates a cut-away view of an exemplary embodiment of compressor housing assembly **260** for compressor assembly **90** of turbocharger **10**. Compressor housing assembly **260** includes one or more clamping plates **262** and one or more bolts **46** that cooperate to connect compressor housing **40** with bearing housing flange **106** of bearing housing **44**. Clamping plate **262** may abut on compressor housing **40** and bearing housing flange **106**. In one exemplary embodiment, clamping plate **262** may be a single generally annular plate disposed around rotational axis **50**. Clamping plate **262** may have a front face **264** and a rear face **266** disposed opposite to and axially spaced apart from front face **264**. A plurality of holes **268** may be disposed on clamping plate **262**. Holes **268** may be circumferentially spaced from each other. A circumferential spacing between holes **268** may be uniform or non-uniform. Holes **268** may be through holes that may extend from front face **264** to rear face **266**. In some exemplary embodiments, holes **268** may have threads. Clamping plate **262** may have a radial width " W_1 ."

[0045] Compressor housing **40** may have a compressor housing flange **270** attached to volute top wall **98** and volute rear wall **100**. Compressor housing flange **270** may have a generally cylindrical flange outer surface **272**. Flange outer surface **272** may have a radius " R_7 " relative to rotational axis **50**. Compressor housing flange **270** may also include flange inner surface **274**, which may have a radius " R_8 " relative to rotational axis **50**. Radius R_8 may be larger than or about equal to radius R_3 of flange outer surface **116** of bearing housing flange **106**. Radius R_8 may also be smaller than radius R_7 . Flange inner surface **274** may be disposed adjacent to and may abut on flange outer surface **116** of bearing housing flange **106** of bearing housing **44**. Compressor housing flange **270** may include a clamping face **276**, which may extend radially from flange inner surface **274** at radius R_8 to flange outer surface **272** at radius R_7 . Clamping face **276** may have a radial width " W_2 ," which may be smaller than a width W_1 of clamping plate **262**.

[0046] Clamping face **276** of compressor housing flange **270** may include compressor flange recess **278** and compressor flange lip **280**. Compressor flange recess **278** may extend axially inwards from clamping face **276** towards compressor front end **62** forming compressor flange lip **280** on clamping face **276**. Compressor flange recess **278** may extend radially outward from flange inner surface **274** to recess outer edge **282** disposed between flange inner surface **274** and flange outer surface **272**. Compressor flange recess **278** may have a radial width " W_3 ," which may be smaller than a radial width W_2 of clamping face **276**. In one exemplary embodiment width W_3 may range from about 70% to about 90% of width W_2 . As illustrated in FIG. 6, compressor flange recess **278** may include a recess surface **284** axially spaced apart from clamping face **276** of clamping plate **262**. In one exemplary embodiment, an axial spacing of recess surface **284** from clamping face **276** may range from about 0.8 mm to about 1.4 mm. Recess surface **284** may extend radially outward from flange inner surface **274** to recess outer edge **282**. Compressor flange lip **280** may be disposed adjacent recess outer edge **282** of compressor flange recess **278**. Compressor flange lip **280** may extend radially outward from recess outer edge **282** to flange outer surface **272**. As also illustrated in FIG. 6, front face **264** of clamping plate **262** may abut on compressor flange lip **280**.

[0047] Recess surface **284** of compressor housing flange **270** may include a plurality of holes **286**. Like holes **268**, holes **286** may be circumferentially spaced from each other. A circumferential spacing between holes **286** may be uniform or non-uniform. Holes **286** may be arranged so as to align with holes **268**. Holes **286** may also be threaded. Bolts **46** may pass through holes **268** and may be threadingly received in holes **286** to help connect clamping plate **262** with compressor housing flange **270**. In some exemplary embodiments, bolts **46** may be also threadingly received in holes **268**. Although FIG. 6 illustrates bolts **46** being assembled with holes **268** and/or holes **286**, it is contemplated that threaded studs (not shown) may be threadingly assembled into holes **286** and nuts (not shown) abutting on rear face **266** of clamping plate **262** may be attached to the studs to connect clamping plate **262** to compressor housing flange **270**.

[0048] Clamping plate **262** may include clamping plate overhang portion **288**, which may extend radially inward from adjacent flange inner surface **274**. Overhang portion **288** may include a front face portion **290** that may abut on flange rear surface **114** of bearing housing flange **106**. As illustrated in FIG. 6, clamping face **276** of compressor housing flange **270** may be disposed generally coplanar with flange rear surface **114** of bearing housing flange **106**. As also illustrated in FIG. 6, clamping plate **262** may extend over compressor flange recess **278** and abut on compressor flange lip **280** and flange rear face **114** of bearing housing flange **106**. Supporting clamping plate **262** at two radial locations in this manner may help minimize and/or eliminate bending loads transferred by clamping plate **262** to bolts **46**. Further, compressor flange recess **278** may permit clamping plate **262** to bend in compressor flange recess **278** between compressor flange lip **280** and bearing housing flange **106**, when bolts **46** are turned, helping to generate tensile loads in bolts **46**. Tensile loads generated in bolts **46** may in turn help to firmly attach clamping plate **262** to compressor housing flange **270** and bearing housing flange **106**.

[0049] FIG. 7 illustrates another exemplary embodiment of clamping plate **262**, which may have one or more segments. FIG. 7 illustrates a view of clamping plate **262** on a plane disposed generally orthogonal to rotational axis **50**. As illustrated in FIG. 7, clamping plate **262** may include first clamping plate segment **292**, second clamping plate segment **294**, and third clamping plate segment **296**. Each of first second and third clamping plate segments **292**, **294**, **296** may be an annular arc-shaped plates having one or more holes **286**. As illustrated in FIG. 7, first, second, and third clamping plate segments **292**, **294**, **296** may be circumferentially disposed so as to circumscribe rotational axis **50** so that holes **286** may also be circumferentially disposed around rotational axis **50**. In one exemplary embodiment as illustrated in FIG. 7, each of first second and third clamping plate segments **292**, **294**, **296** may include three holes **286** circumferentially spaced equidistant from each other. It is contemplated, however, that each of first second and third clamping plate segments **292**, **294**, **296** may include any number of holes **286**, which may or may not be disposed circumferentially equidistant from each other. Each of first, second, and third clamping plate segments **292**, **294**, **296** may have an inner radius " R_9 " and an outer radius " R_{10} " greater than R_9 . It is contemplated, however, that first, second, and third clamping plate segments **292**, **294**, **296** may have the same or different radii R_9 and R_{10} . Each of first, second, and third clamping plate segments **292**, **294**, **296** may span a circumferential angle " θ_7 ." For example, circumferen-

tial angle θ_7 may be an angle between leading edge 298 to trailing edge 300 of first, second, and third clamping segments 292, 294, 296. It is contemplated, however, that first, second, and third clamping plate segments 292, 294, 296 may span the same or different circumferential angles θ_7 . Although three clamping plate segments have been illustrated in FIG. 7, it is contemplated that clamping plate 262 may have any number of arc-shaped clamping plate segments 292, 294, 296.

[0050] FIG. 8 illustrates a cut-away view of an exemplary embodiment of turbine housing assembly 310 for turbine stage 14 of turbocharger 10. Turbine housing assembly 310 includes one or more clamping plates 312 and one or more bolts 48 that cooperate to connect turbine housing 42 and bearing housing 44. Clamping plate 312 may abut on turbine housing 42 and bearing housing 44. In one exemplary embodiment, clamping plate 312 may be a single generally annular plate disposed around rotational axis 50. It is contemplated, however, that like clamping plate 262, clamping plate 312 may also have one or more segments similar to first clamping plate segment 292, second clamping plate segment 294, and third clamping plate segment 296. It is also contemplated that clamping plate 262 may have a first plurality of clamping plate segments and clamping plate 312 may have a second plurality of clamping plate segments. It is further contemplated that a number of clamping plate segments of clamping plate 262 may be the same as or different from a number of clamping plate segments of clamping plate 312. In addition, it is contemplated that clamping plate 312 may have a thickness, which may be the same as or different from a thickness of clamping plate 262. Clamping plate 312 may have a front face 314 and a rear face 316 disposed opposite to and axially spaced apart from front face 314. A plurality of holes 318 may be disposed on clamping plate 312. Holes 318 may be circumferentially spaced from each other. A circumferential spacing between holes 318 may be uniform or non-uniform. Holes 318 may be through holes that may extend from front face 314 to rear face 316. In some exemplary embodiments, holes 318 may have threads. Clamping plate 312 may have a radial width " W_4 ."

[0051] Turbine housing 42 may have a turbine housing wall 320. Turbine housing wall 320 may include a notch 322. Notch 322 may have a notch inner surface 324 and a notch rear wall 326. Notch inner surface 324 may have a generally cylindrical shape disposed around rotational axis 50. Notch rear wall 326 may extend radially inward from notch inner surface 324 and may be disposed generally orthogonal to rotational axis 50. Turbine housing wall 320 may also include turbine inner surface 328, which may enclose turbine wheel 34 (see FIG. 1). In addition, turbine housing wall may include clamping face 330 disposed opposite the turbine inner surface 328. Clamping face 330 may extend radially outward from notch inner surface 324 to turbine wall outer end 332.

[0052] Clamping face 330 of turbine housing wall 320 may include turbine flange recess 334 and turbine wall lip 336. Turbine flange recess 334 may extend axially inwards from clamping face 330 towards turbine inner surface 328 forming turbine wall lip 336. Turbine flange recess 334 may extend radially outward from notch inner surface 324 to recess outer edge 338 disposed between notch inner surface 324 and turbine wall outer end 332. Turbine flange recess 334 may have a radial width " W_5 ," which may be smaller than a radial width W_4 of clamping plate 312. In one exemplary embodiment radial width W_5 may range from about 70% to about 90% of

width W_4 . As illustrated in FIG. 8, turbine flange recess 334 may include a recess surface 340 axially spaced apart from clamping face 330 of turbine housing wall 320. In one exemplary embodiment, an axial spacing of recess surface 340 from clamping face 330 may range from about 0.8 mm to about 1.4 mm. Recess surface 340 may extend radially outward from notch inner surface 324 to recess outer edge 338. Turbine wall lip 336 may be disposed adjacent recess outer edge 338 of turbine flange recess 334. Turbine wall lip 336 may extend radially outward from recess outer edge 338 to turbine wall outer end 332. As also illustrated in FIG. 8, rear face 316 of clamping plate 312 may abut on turbine wall lip 336. Recess surface 340 of turbine housing wall 320 may include a plurality of holes 342. Like holes 318, holes 342 may be circumferentially spaced from each other. A circumferential spacing between holes 342 may be uniform or non-uniform. Holes 342 may be arranged so as to align with holes 318. Holes 342 may also be threaded.

[0053] Bearing housing 44 may include a bearing housing flange 344. Bearing housing flange 344 may have front face 346, rear face 348 disposed opposite front face 346, and bearing flange outer surface 350. Bearing housing flange 344 may abut on notch rear wall 326 of turbine housing wall 320 such that bearing flange outer surface 350 may be disposed adjacent to and may abut on notch inner surface 324. Clamping plate 312 may include an overhang portion 352, which may extend radially inward from holes 318. Overhang portion 352 may include a rear face portion 354 that may abut on front face 346 of bearing housing flange 344. As illustrated in FIG. 8, clamping face 330 of turbine housing wall 320 may be disposed generally coplanar with front face 346 of bearing housing flange 344.

[0054] Bolts 48 may pass through holes 318 and may be threadingly received in holes 342 to help connect clamping plate 312 with turbine housing wall 320 and bearing housing flange 344. In some exemplary embodiments, bolts 48 may be also threadingly received in holes 318. Although FIG. 8 illustrates bolts 48 being assembled with holes 318 and/or holes 342, it is contemplated that threaded studs (not shown) may be threadingly assembled into holes 342 and nuts (not shown) abutting on front face 314 of clamping plate 312 may be attached to the studs to connect clamping plate 312 to turbine housing wall 320. As illustrated in FIG. 8, clamping plate 312 may extend over turbine flange recess 334 and abut on turbine wall lip 336 on turbine housing 42 and front face 346 of bearing housing flange 344. Supporting clamping plate 312 at two radial locations in this manner may help minimize and/or eliminate bending loads transferred by clamping plate 312 on bolts 48. Further, clamping plate 312 may bend within turbine flange recess 334 when bolts 48 are turned, helping to generate tensile load in bolts 48. Tensile loading in bolts 48 may in turn help to firmly attach clamping plate 312 to turbine housing wall 320 and bearing housing flange 344.

INDUSTRIAL APPLICABILITY

[0055] The disclosed compressor assembly 90 may be implemented to help reduce or eliminate leakage of air through gaps between vane tips 178 of compressor diffuser ring 60 and inner wall 132 of compressor housing 40. Compressor assembly 90 may also be implemented to help improve an efficiency of compressor stage 12 by using shim 246 dimensionally matched to turbocharger cartridge 256 to help reduce or eliminate gaps between vane tips 178 and inner wall 132.

[0056] Additionally, compressor assembly 90 may be implemented to reduce or eliminate failure of compressor blades induced by excitation of compressor blades 26 caused by pressure wakes generated by vanes 148 in diffuser ring 60. Further, compressor assembly 90 may be implemented to help ensure that compressor housing 40, bearing housing 44, and turbine housing 42 may be assembled without inducing bending loads on bolts 46, 48. The disclosed compressor assembly 90 may also be implemented help reduce wear on internal components of compressor assembly 90 caused by thermally induced relative movement between the components.

[0057] Referring to FIGS. 1 and 2, during operation of turbocharger 10, exhaust gases from the engine (not shown) may enter turbine housing 42 via turbine inlet 52, expand against turbine blades 38, rotating turbine wheel 34. Rotation of turbine wheel 34 may rotate shaft 18, which in turn may rotate compressor impeller 16. Air may enter compressor housing 40 via compressor inlet 56 and exit compressor housing 40 via compressor outlet 58. As air moves through compressor stage 12, the rotating compressor impeller 16 may accelerate the air. Air leaving outer edges 78 of compressor blades 26 may be decelerated as the air flows between vanes 148 of diffuser ring 60. Deceleration of air in diffuser ring 60 may increase a pressure of the air in volute 72 of compressor stage 12. Air compressed by the pressure generated in compressor stage 12 may be forced into the combustions chambers of the engine for combustion of fuel. Air flowing in gaps between inner wall 132 and vane tips 178 can bypass the deceleration induced by diffuser ring 60, reducing the ability of diffuser ring 60 to convert the kinetic energy of the air into pressure in volute 72. Reduced pressure in volute 72 may adversely affect performance of the engine.

[0058] Compressor assembly 90 may include numerous features that help to reduce or eliminate gaps between vane tips 178 and inner wall 132 of compressor housing 40. For example, compressor assembly 90 may include a wave spring 184 disposed between second web face 130 and back plate 146 of diffuser ring 60. Wave spring 184 may exert an axial force on back plate 146 forcing diffuser ring 60 to move towards compressor front end 62 and pushing vane tips 178 to firmly come into contact with inner wall 132 of compressor housing 40. By forcing vane tips 178 to firmly abut on inner wall 132, wave spring 184 may help reduce or eliminate gaps between vane tips 178 and inner wall 132 at all operating conditions of turbocharger 10. Wave spring 184 may also help reduce or eliminate damage caused to vanes 148 when the turbocharger is not operational by helping to urge vane tips 178 to come into contact with inner wall 132. Allowing vane tips 178 to remain in contact with inner wall 132 in this manner may help prevent excessive vibration of vanes 148, which in turn may help reduce or eliminate damage to vanes 148.

[0059] Furthermore, during operation of turbocharger 10, high pressure air from volute 72 may bleed through radial gap 168 into cavity 172. The high pressure air may help push back plate 146 away from second web face 130 toward compressor front end 62, which in turn may urge vane tips 178 to firmly come into contact with inner wall 132 of compressor housing 40. By forcing vane tips 178 to firmly abut on inner wall 132, bleed air in cavity 172 may help reduce or eliminate gaps between vane tips 178 and inner wall 132 during high pressure operation of compressor stage 12.

[0060] Radial gap 168 and seal member 170 may also help back plate 146 of diffuser ring 60 to freely expand thermally during operation of compressor stage 12. For example, diffuser ring 60 may be made of aluminum, aluminum alloy, or other alloys, which has a relatively high coefficient of thermal expansion compared to compressor housing 40 and bearing housing 44, both of which may be made of an iron alloy or other alloys. The radial gap 168 and the compressive nature of seal member 170 may allow back plate 146 to expand without coming into contact with or interfering with inner face 166 of volute rear wall 100 of bearing housing 44. Moreover, because seal member 170 is disposed on ledge outer surface 136, which is disposed generally orthogonal to wave spring 184, the axial force exerted by wave spring 184 may not diminish the compressive forces generated in seal member 170. As a result operation of wave spring 184 may not diminish the strength of the seal generated by seal member 170 between ledge outer surface 136 and bottom face 158 of back plate 146. Consequently, seal member 170 may be able to maintain a very effective seal, preventing recirculation of air from volute 72 through cavity 172 and into passageway 134 during the entire range of operation of turbocharger 10, helping to improve the efficiency of compressor stage 12.

[0061] Referring to FIGS. 1-4, compressor assembly 90 may also help reduce or eliminate gaps between vane tips 178 and inner wall 132 of compressor housing 40 by reducing the dimensional mismatch between compressor impeller 16, shaft 18, turbine wheel 34, compressor housing 40, turbine housing 42 and bearing housing 44. In particular, dimensions of turbocharger cartridge 256 may be measured after assembling compressor impeller 16, shaft 18, turbine wheel 34, turbine housing 42, and bearing housing 44. A maximum thickness t_3 of shim 246 may be selected based on the measured dimensions of turbocharger cartridge 256 and dimensional tolerances associated with compressor housing 40. In particular, an axial load may be applied to shaft 18, pushing compressor impeller 16 away from turbine housing 42 and towards compressor front end 62. An axial distance "A" between recess seating surface 124 and a gage location 258, on compressor impeller 16, may be measured. Gage location 258 may be a predetermined location on compressor impeller 16. Further, an axial distance "B" may be measured between rear face 118 of volute rear wall 100 and a gage location 259 on inner wall 132 of compressor housing 40. In addition, a variation of distance B may be determined based on known manufacturing tolerances. Additionally or alternatively, the variation may be determined based on measurements of distance B on a plurality of compressor housings 40. A maximum thickness t_3 may be determined based on distance A, distance B, and the variation of distance B, so that that vane tips 178 may remain in contact with inner wall 132 of compressor housing 40. For example, thickness t_3 may be selected so that a distance "C" between recess seating surface 124 of bearing housing flange 106 and gage location 259 may be greater than or equal to a sum of thickness t_3 and a maximum value of distance B determined based on the variation in distance B. Shim 246 with the selected thickness t_3 may be fixedly attached to bearing housing flange 106. Matching thickness t_3 of shim 246 to turbocharger cartridge 256 in this manner may help ensure that vane tips 178 may firmly abut on inner wall 132 of compressor housing 40 regardless of the dimensional tolerance variations expected in compressor housing 40. Thus, selecting a thickness t_3 for shim 246

matched to turbocharger cartridge 256 may help reduce or eliminate gaps between vane tips 178 and inner wall 132 of compressor housing 40.

[0062] Referring to FIG. 2, compressor assembly 90 may include vaneless space 200 extending from outer edges 78 of a rearmost row 32 of compressor blades 26 and vane leading edges 180. A radial extent AR of vaneless space 200 may be selected so that high frequency vibration of vanes 148 caused by pressure wakes generated at vane leading edges 180 may be reduced or eliminated. In particular, the radial extent AR may be selected to be at least 20% of a maximum radius R_2 of compressor blades 26 in rearmost row 32 of compressor impeller 16 to reduce or eliminate high frequency vibrations in compressor blades 26. A larger value of AR may be advantageously selected to further reduce the effect of pressure wakes generated at vane leading edges 180 on compressor blades 26. To minimize an overall volume of compressor stage 12, however, radial extent AR may be selected to range from about 20% to 40% of radius R_2 . Selecting the radial extent of vaneless space 200 in this manner may help to reduce or eliminate fatigue failures of compressor blades 26 caused by vibrations induced in compressor blades 26 by pressure wakes generated at vane leading edges 180. Reducing or eliminating the fatigue failures of compressor blades 26 may help extend a useful life of compressor assembly 90.

[0063] Referring to FIGS. 3 and 4, tabs 226 may help to prevent rotation of diffuser ring 60 relative to rotational axis 50. Further, washers 244 and fasteners 242 may help attach diffuser ring 60 to volute rear wall 100 of compressor housing 40. Depths of recesses 220 and 239 may be selected so as to maintain an axial gap 234 between tab front face 228 and recess rear face 222 of volute rear wall 100. Axial gaps 234 and radial gaps 236 between tab side surface 232 and recess side surface 224 of recess 220 may help ensure that diffuser ring 60 and tabs 226 may freely expand relative to compressor housing 40 without significantly wearing out tab front face 228, tab rear face 230, and tab side surface 232 during operation of turbocharger 10. In some exemplary embodiments, tabs 226 and diffuser ring 60 may be made out of aluminum, aluminum alloy, or other alloys, which may have a relatively high coefficient of thermal expansion relative to compressor housing 40, which may be made of an iron alloy or other alloys. During operation of turbocharger 10, a temperature of diffuser ring 60 and compressor housing 40 may increase. Diffuser ring 60 and tabs 226 may expand radially and axially to a much larger extent than volute rear wall 100 of compressor housing 40. Thus, tabs 226 may move radially and axially relative to compressor housing 40 numerous times. For example, in one exemplary embodiment, tabs 226 may move radially and axially relative to compressor housing 40 many thousands of times during operation of turbocharger 10. Radial gap 236 may allow tabs 226 to expand freely without interfering with recess side surface 224. Further, axial gap 234 may allow tabs 226 to move relative to recess rear face 222 without causing excessive wear of tabs 226. Thus, tabs 226 may allow diffuser ring 60 to be firmly attached to compressor housing 40, while still allowing relative movement between tabs 226 and recess rear face 222 of recess 220 in volute rear wall 100 caused by differential thermal expansion of diffuser ring 60 and compressor housing 40.

[0064] Additionally, when turbocharger 10 with four tabs 226 is mounted on a horizontal surface with the gravitational direction being generally orthogonal to the horizontal surface, first and second diametrical axes 237 and 238 may be

positioned symmetrically about the gravitational direction. Positioning first and second diametrical axes 237, 238 in this manner may allow an entire weight of turbocharger 10 to be about equally distributed on each of the four tabs 226. Furthermore, such an arrangement may also allow additional radial loads generated by the operation of turbocharger 10 to be distributed about equally between the four tabs 226.

[0065] Referring to FIG. 6, compressor housing assembly 260 may help ensure that bolts 46 are not subjected to bending loads when used to assemble compressor housing 40 and bearing housing 44. As illustrated in FIG. 6, clamping plate 262 may be supported at radial locations by compressor flange lip 280 and flange rear face 114 of bearing housing flange 106. Clamping plate 262 may span compressor flange recess 278. Supporting clamping plate 262 at radially separated locations may allow clamping plate 262 to maintain compressor housing 40 and bearing housing 44 in an assembled configuration even when compressor housing 40 and bearing housing 44 undergo different amounts of axial thermal expansion. Supporting clamping plate 262 on compressor flange lip 280 and bearing housing flange 106 may also allow clamping plate 262 to bend into compressor flange recess 278 as bolts 46 are turned. Bending of clamping plate 262 may help ensure tensile load is generated along a longitudinal axis of bolts 46 while reducing bending loads on bolts 46. Moreover, the tensile load generated in bolts 46 because of bending of clamping plate 262 may help maintain assembly of compressor housing 40 with bearing housing 44 even if bolts become loose during operation of turbocharger 10. Furthermore, because clamping plate 262 applies an axial load to maintain assembly of compressor housing 40 and bearing housing 44, clamping plate 262 may allow compressor flange lip 280 and bearing housing flange 106 to undergo different amounts of radial expansion while still maintaining a clamping load induced by bolts 46.

[0066] Referring to FIG. 8, turbine housing assembly 310 may help ensure that bolts 48 are not subjected to bending loads when used to assemble turbine housing 42 and bearing housing 44. As illustrated in FIG. 8, clamping plate 312 may be supported at radial locations by turbine wall lip 336 and bearing housing flange 344. Clamping plate 312 may span turbine flange recess 334. Supporting clamping plate 312 at radially separated locations may allow clamping plate 312 to maintain turbine housing 42 and bearing housing 44 in an assembled configuration even when turbine housing 42 and bearing housing 44 undergo different amounts of axial thermal expansion. Supporting clamping plate 312 on turbine wall lip 336 and bearing housing flange 344 may also allow clamping plate 312 to bend into turbine flange recess 334 as bolts 48 are turned. Bending of clamping plate 312 may help ensure tensile load is generated along a longitudinal axis of bolts 48 while reducing bending loads on bolts 48. Moreover, the tensile load generated in bolts 48 because of bending of clamping plate 312 may help maintain assembly of turbine housing 42 with bearing housing 44 even if bolts become loose during operation of turbocharger 10. Furthermore, because clamping plate 312 applies an axial load to maintain assembly of turbine housing 42 and bearing housing 44, clamping plate 312 may allow turbine wall lip 336 and bearing housing flange 344 to undergo different amounts of radial expansion while still maintaining a clamping load induced by bolts 48.

[0067] It will be apparent to those skilled in the art that various modifications and variations can be made to the dis-

closed compressor assembly. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed compressor assembly. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

What is claimed is:

1. A compressor housing assembly, comprising:
 - a compressor housing including a compressor housing flange;
 - a bearing housing, including:
 - a body portion;
 - a web extending outward from the body portion to a web end, the web; and
 - a bearing housing flange extending radially outward from the web;
 - a clamping plate having a generally annular shape abutting on the compressor housing flange and the bearing housing flange; and
 - a fastener configured to attach the clamping plate to the compressor housing flange and the bearing housing flange.
2. The compressor housing assembly of claim 1, wherein the compressor housing flange includes a threaded hole, and the fastener includes threads that engage with the threaded hole.
3. The compressor housing assembly of claim 1, wherein the compressor housing flange includes:
 - a generally cylindrical flange inner surface;
 - a generally cylindrical flange outer surface; and
 - a clamping face extending radially from the flange inner surface to the flange outer surface,
 the bearing housing flange includes a flange rear surface, and the clamping face is disposed generally coplanar with the flange rear surface.
4. The compressor housing assembly of claim 3, wherein the clamping face includes:
 - a compressor flange recess extending radially outward from the flange inner surface to a recess outer edge disposed between the flange inner surface and the flange outer surface; and
 - a compressor flange lip extending radially from the recess outer edge to the flange outer surface, and
 the clamping plate is configured to abut on the compressor flange lip and the flange rear surface.
5. The compressor housing assembly of claim 1, wherein the clamping plate includes a plurality of clamping plate segments disposed circumferentially relative to a rotational axis of the compressor housing assembly.
6. The compressor housing assembly of claim 5, wherein a number of the clamping plate segments is 3.
7. The compressor housing assembly of claim 1, wherein the clamping plate segments include:
 - a first clamping plate segment spanning over a first circumferential angle;
 - a second clamping plate segment spanning over a second circumferential angle; and
 - a third clamping plate segment spanning over a third circumferential angle.
8. The compressor housing assembly of claim 7, wherein the first circumferential angle is about equal to the second circumferential angle.

9. The compressor housing assembly of claim 7, wherein the first clamping plate segment has a first thickness, and the second clamping plate segment has a second thickness different from the first thickness.

10. A turbine housing assembly, comprising:

- a turbine housing including a turbine housing wall;
- a bearing housing, including a bearing housing flange;
- a clamping plate having a generally annular shape abutting on the turbine housing wall and the bearing housing flange; and
- at least one fastener configured to attach the clamping plate to the turbine housing wall and the bearing housing flange.

11. The turbine housing assembly of claim 10, wherein the turbine housing wall includes:

- a turbine inner surface configured to enclose a turbine wheel; and
- a clamping face disposed opposite the turbine inner surface,

the bearing housing flange includes:

- a front face;
- a rear face disposed opposite the front face; and
- a bearing flange outer surface, and

the clamping face is disposed generally coplanar with the front face.

12. The turbine housing assembly of claim 11, wherein the clamping face includes:

- a turbine flange recess extending axially inward from the clamping face towards the turbine inner surface; and
- a turbine wall lip disposed adjacent the turbine flange recess, and

the clamping plate is configured to abut on the turbine wall lip and the front face of the bearing housing flange.

13. The turbine housing assembly of claim 12 further including a plurality of fasteners, wherein the turbine flange recess includes a plurality of circumferentially spaced holes, and the fasteners are configured to be threadingly received in the holes.

14. The turbine housing assembly of claim 13, wherein a circumferential spacing between the holes is non-uniform.

15. The turbine housing assembly of claim 10, wherein the clamping plate includes a plurality of clamping plate segments disposed circumferentially relative to a rotational axis of the turbine housing assembly.

16. A turbocharger, comprising:

- a turbine housing including a turbine housing wall;
- a turbine wheel disposed within the turbine housing and configured to be driven by exhaust received from an engine;
- a compressor housing including a compressor housing flange;
- a compressor impeller disposed within the compressor housing;
- a shaft connecting the turbine wheel and the compressor impeller;
- a bearing housing, including:
 - a first bearing housing flange configured to be attached to the compressor housing flange;
 - a second bearing housing flange configured to be attached to the turbine housing wall;

a first clamping plate having a generally annular shape abutting on the compressor housing flange and the first bearing housing flange;

a second clamping plate having a generally annular shape abutting on the turbine housing wall and the second bearing housing flange;

a first fastener configured to attach the first clamping plate to the compressor housing flange and the first bearing housing flange; and

a second fastener configured to attach the second clamping plate to the turbine housing wall and the second bearing housing flange.

17. The turbocharger of claim **16**, wherein

the first clamping plate has a first thickness, and

the second clamping plate has a second thickness different from the first thickness.

18. The turbocharger of claim **17**, wherein the compressor housing flange includes:

a compressor flange recess; and
a compressor flange lip disposed adjacent the compressor flange recess, and

the first clamping plate abuts on the compressor flange lip and the first bearing housing flange.

19. The turbocharger of claim **17**, wherein the turbine housing wall includes:

a turbine flange recess; and
a turbine wall lip disposed adjacent the turbine flange recess, and

the second clamping plate abuts on the turbine wall lip and the second bearing housing flange.

20. The turbocharger of claim **19**, wherein

the first clamping plate includes a first plurality of clamping plate segments, and

the second clamping plate includes a second plurality of clamping plate segments.

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