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(54) **BEARING SUPPORT STIFFNESS CONTROL**

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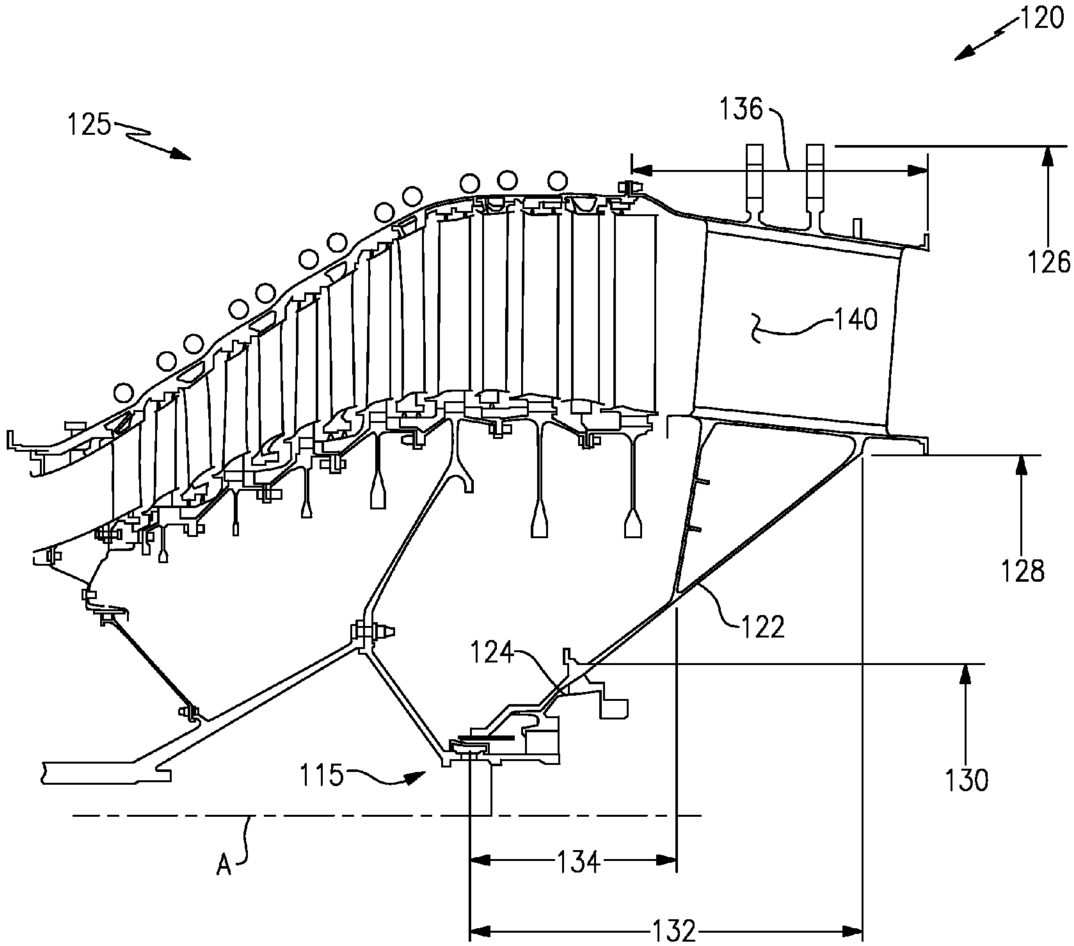
(57) **ABSTRACT**

A bearing support bracket for supporting the bearing assembly includes individually adjustable features for defining and enabling a desired stiffness.



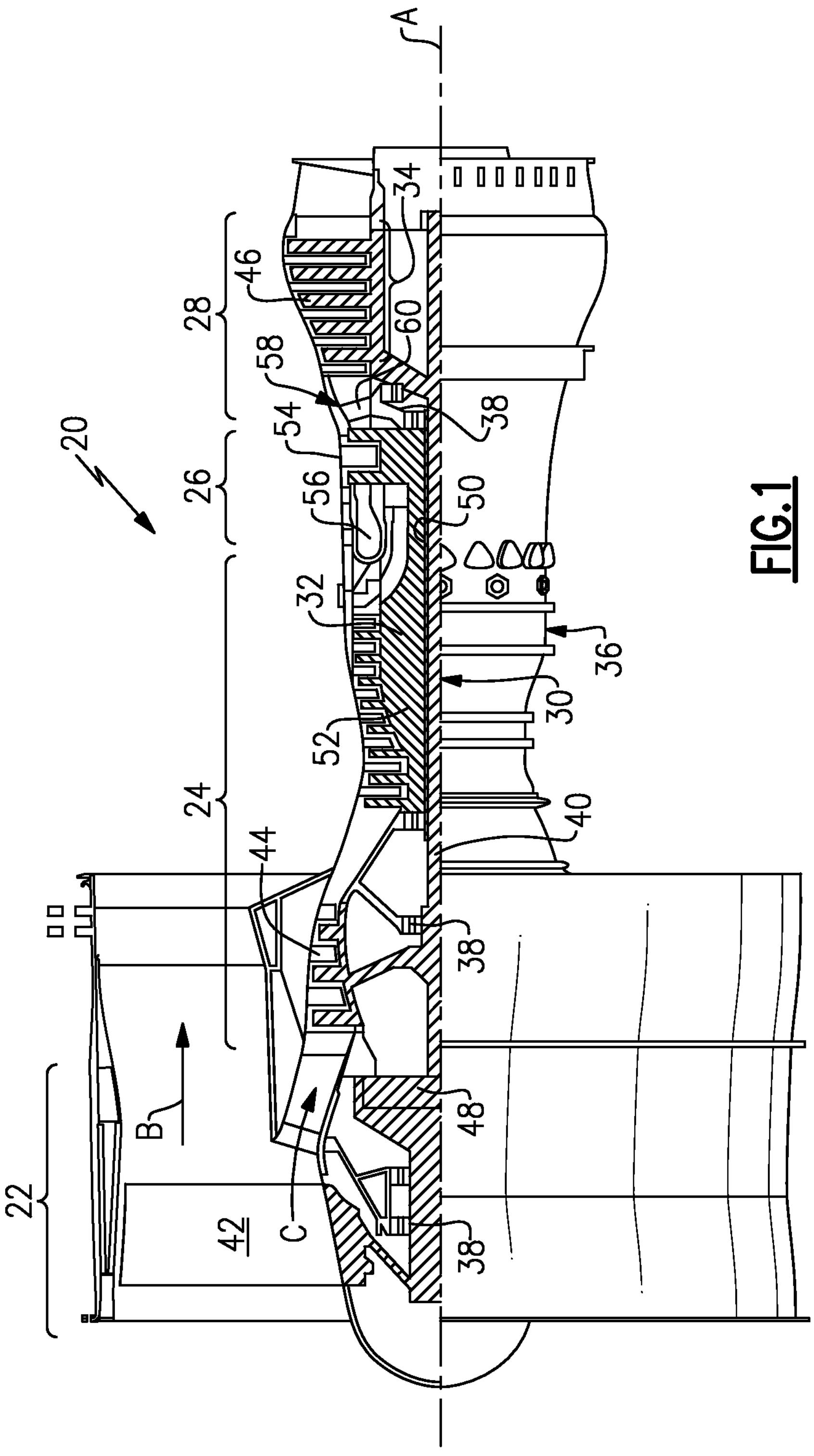


FIG.1

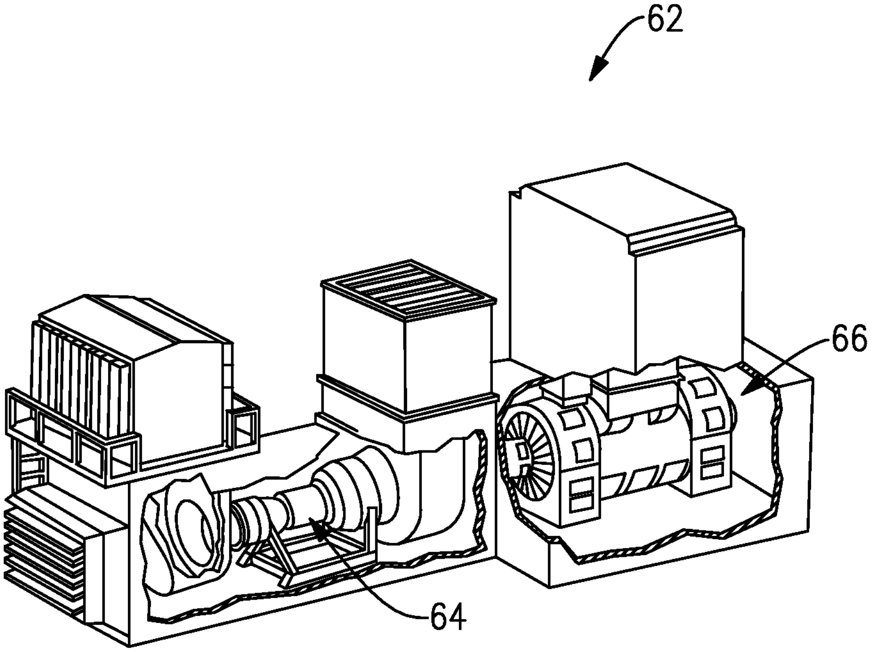


FIG.2

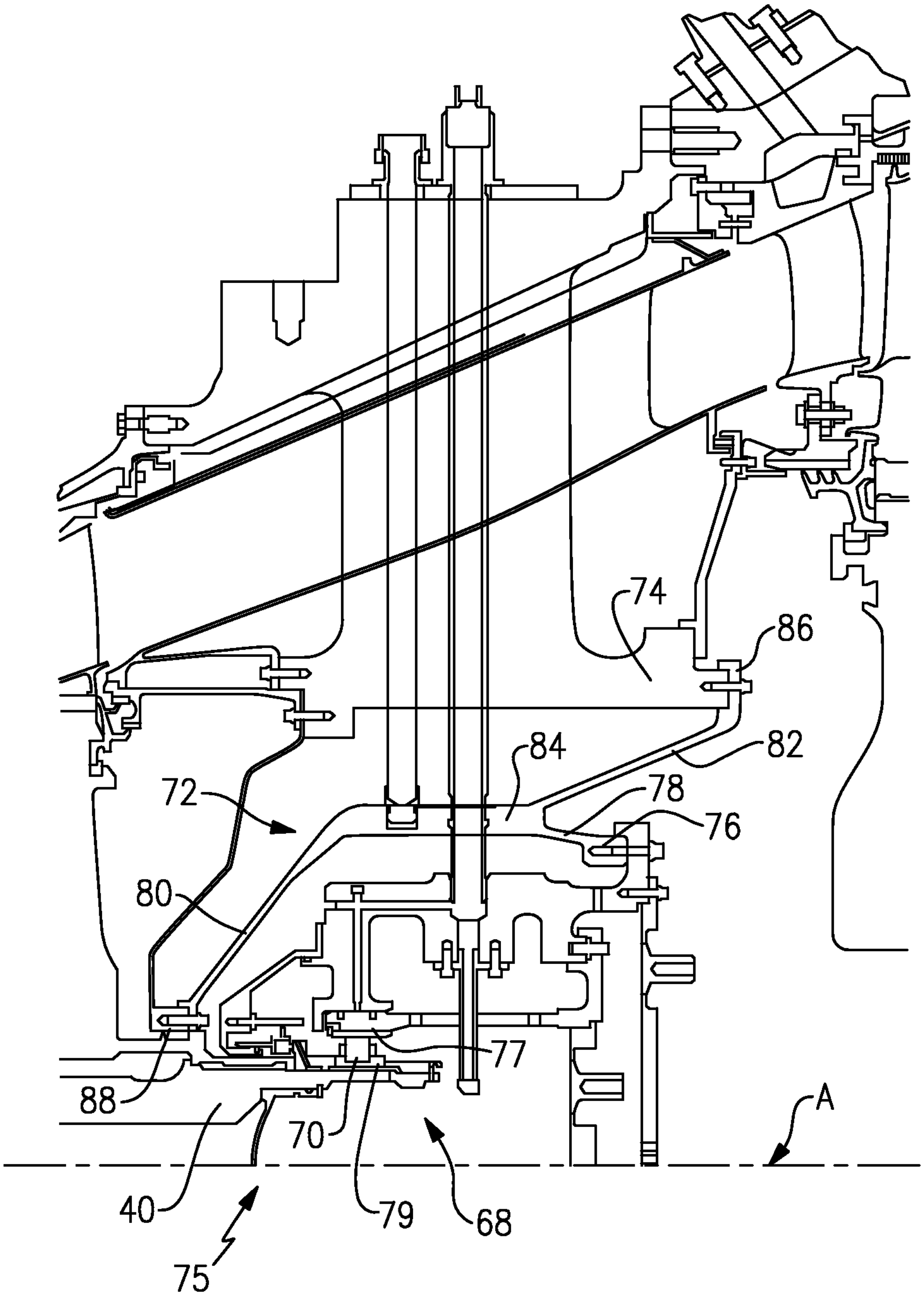
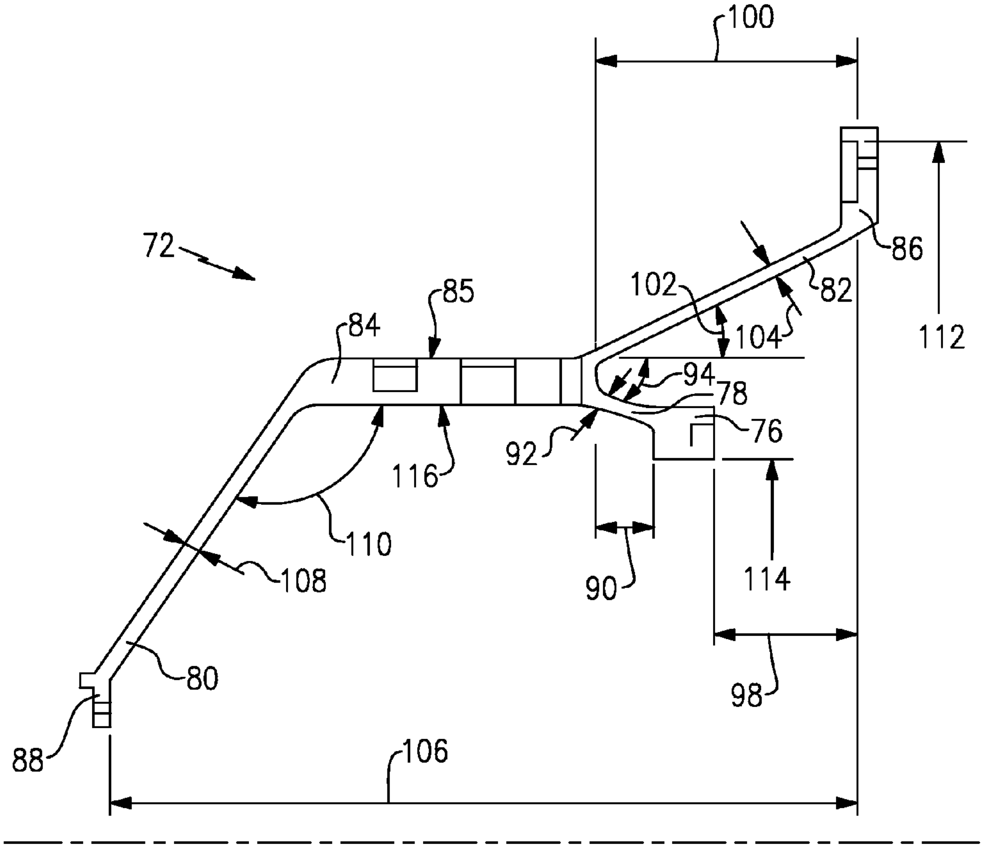


FIG.3


100
72
86
102
82
104
112
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76
92
116
110
108
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114
98
80
88
106

FIG.4

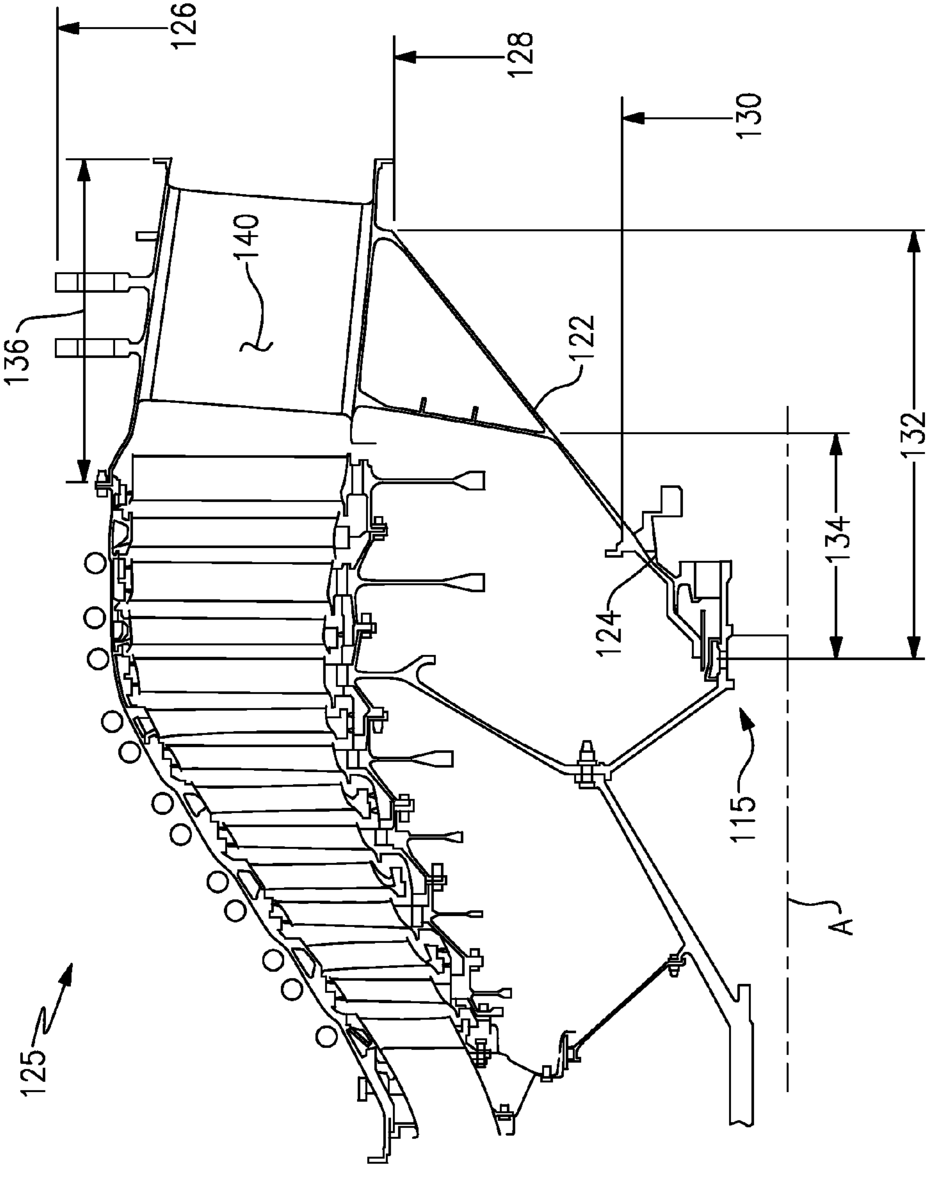

FIG.5

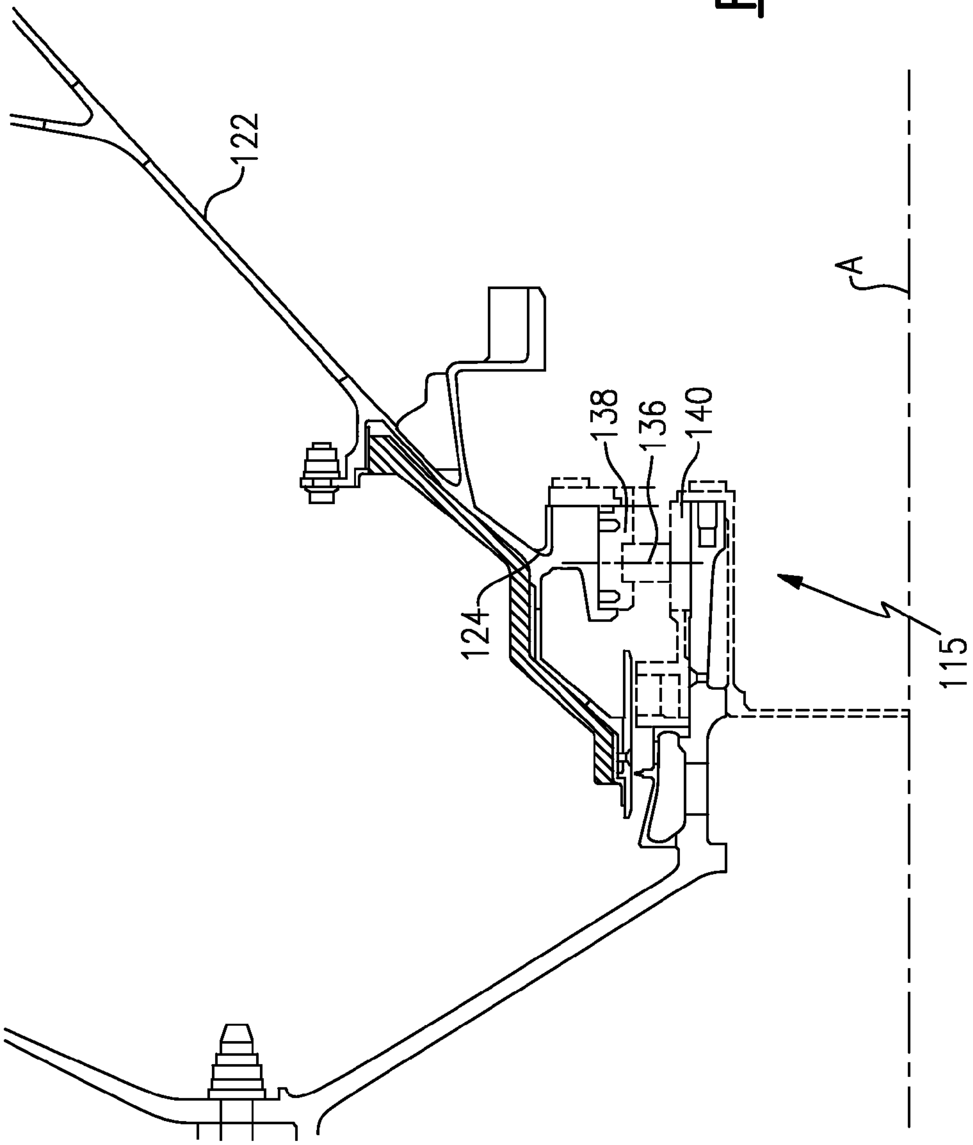

FIG.6

BEARING SUPPORT STIFFNESS CONTROL

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application No. 61/711,423 filed on Oct. 9, 2012.

BACKGROUND

[0002] A gas turbine engine typically includes a fan section, a compressor section, a combustor section and a turbine section. Air entering the compressor section is compressed and delivered into the combustion section where it is mixed with fuel and ignited to generate a high-speed exhaust gas flow. The high-speed exhaust gas flow expands through the turbine section to drive the compressor and the fan section. The compressor section typically includes low and high pressure compressors, and the turbine section includes low and high pressure turbines.

[0003] A static structure supporting engine rotating components is required to provide a module stiffness determined to handle dynamic loads. Engine static structure components can include complex shapes that are difficult to modify to obtain desired module stiffness while maintaining structural rigidity. Engine manufacturers are continually seeking methods and features that simplify design and assembly and therefore it is desirable to develop support structures that are easily tailored to meet structural demands.

SUMMARY

[0004] A gas turbine engine according to an exemplary embodiment of this disclosure, among other possible things includes a compressor section disposed about an axis, a combustor in fluid communication with the compressor section, a turbine section in fluid communication with the combustor, a shaft rotating about an the axis and driven by the turbine section for driving the compressor section, a bearing assembly supporting rotation of the shaft, and a bearing support supporting the bearing assembly and including an aft flange supported on an aft cone having a first length and first thickness and a support flange supported on a support cone having a second length and a second thickness defined separate from the first thickness and the first length to define a desired stiffness of the bearing assembly.

[0005] In a further embodiment of the foregoing gas turbine engine, the first length is related to the first thickness by a ratio between about 18.0 and about 22.0 to define the desired stiffness of the bearing assembly.

[0006] In a further embodiment of any of the foregoing gas turbine engines, the second length and the second thickness are related according to a ratio between about 3.0 and about 4.25 to further define the desired stiffness of the bearing assembly.

[0007] In a further embodiment of any of the foregoing gas turbine engines, the bearing support includes a body portion with the aft cone and the support cone extends from the body portion.

[0008] In a further embodiment of any of the foregoing gas turbine engines, the body portion includes a surface substantially parallel to the axis and the aft cone extends from the body portion at a first angle related to the first length according to a ratio between about 0.23 and about 0.25.

[0009] In a further embodiment of any of the foregoing gas turbine engines, the body portion includes a surface substantially parallel to the axis and the support cone extends from the body portion at a second angle related to the second length according to a ratio between about 0.130 and about 0.135.

[0010] In a further embodiment of any of the foregoing gas turbine engines, the aft flange includes a first diameter related to the first length according to a ratio between about 5.85 and about 6.15.

[0011] In a further embodiment of any of the foregoing gas turbine engines, the support flange includes a second diameter related to the second length according to a ratio between about 16.85 and about 17.15.

[0012] In a further embodiment of any of the foregoing gas turbine engines, the bearing support includes an overall length related to the first length according to a ratio between about 5.90 and 6.10.

[0013] A bearing assembly for a gas turbine engine according to an exemplary embodiment of this disclosure, among other possible things includes a bearing support including an aft flange supported on an aft cone mounted to a fixed structure of the gas turbine engine and a support flange supported on support cone, and a bearing disposed between a first race supported on the support flange and a second race fixed to a rotating shaft. The aft cone includes a first length and first thickness and the support cone includes a second length and a second thickness separately defined from the first thickness and the first length to define a desired stiffness of the bearing assembly.

[0014] In a further embodiment of the foregoing bearing assembly, the bearing support includes a body portion with the aft cone and the support cone extending from the body portion.

[0015] In a further embodiment of any of the foregoing bearing assemblies, the bearing support at least partially defines a cavity within which is supported the bearing.

[0016] In a further embodiment of any of the foregoing bearing assemblies, the body portion includes a surface substantially parallel to the axis and the aft cone extends from the body portion at an angle related to the first length according to a ratio between about 0.25 and about 0.23.

[0017] In a further embodiment of any of the foregoing bearing assemblies, the body portion includes a surface substantially parallel to the axis and the support cone extends from the body portion at an angle related to the second length according to a ratio between about 0.130 and about 0.135.

[0018] In a further embodiment of any of the foregoing bearing assemblies, the first thickness is related to the first length by a ratio between about 18.0 and about 22.0 to define further define the desired stiffness of the bearing assembly.

[0019] In a further embodiment of any of the foregoing bearing assemblies, the second length and the second thickness are related according to a ratio between about 3.0 and about 4.25 to further define the desired stiffness of the bearing assembly.

[0020] A method of defining bearing assembly stiffness for a gas turbine engine according to an exemplary embodiment of this disclosure, among other possible things includes attaching an aft flange to a fixed support structure and supporting the aft flange on an aft cone extending from a body portion a first length, attaching a bearing support member to a support flange extending from the body portion a second length less than the first length, and adjusting a first thickness of the first length of the aft cone and a second thickness of the second length of the support cone to define the desired stiffness of the bearing assembly.

[0021] In a further embodiment of the foregoing method, includes adjusting the first thickness in relation to the first length according to a ratio between about 18.0 and about 22.0, and adjusting the second thickness in relation to the second length according to a ratio between about 3.0 and about 4.25.

[0022] In a further embodiment of any of the foregoing methods, includes extending the aft cone from the body portion at first angle related to the first length according to a ratio between about 0.25 and about 0.23 and extending the support cone from the body portion at a second angle relative to the second length according to a ratio between about 0.130 and 0.135.

[0023] Although the different examples have the specific components shown in the illustrations, embodiments of this disclosure are not limited to those particular combinations. It is possible to use some of the components or features from one of the examples in combination with features or components from another one of the examples.

[0024] These and other features disclosed herein can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. **1** is a schematic view of an example gas turbine engine.

[0026] FIG. **2** is a schematic view of an example industrial gas turbine engine.

[0027] FIG. **3** is a cross-section of an a portion of an example gas turbine engine.

[0028] FIG. **4** is a cross-section of an example bearing support bracket.

[0029] FIG. **5** is a cross-section another example bearing support bracket.

[0030] FIG. **6** is an enlarged view of the example bearing support bracket shown in FIG. **5**.

DESCRIPTION

[0031] FIG. **1** schematically illustrates an example gas turbine engine **20** that includes a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. Alternative engines might include an augmenter section (not shown) among other systems or features. The fan section **22** drives air along a bypass flow path B while the compressor section **24** draws air in along a core flow path C where air is compressed and communicated to a combustor section **26**. In the combustor section **26**, air is mixed with fuel and ignited to generate a high pressure exhaust gas stream that expands through the turbine section **28** where energy is extracted and utilized to drive the fan section **22** and the compressor section **24**.

[0032] Although the disclosed non-limiting embodiment depicts a turbofan gas turbine engine, it should be understood that the concepts described herein are not limited to use with turbofans as the teachings may be applied to other types of turbine engines; for example a turbine engine including a three-spool architecture in which three spools concentrically rotate about a common axis and where a low spool enables a low pressure turbine to drive a fan via a gearbox, an intermediate spool that enables an intermediate pressure turbine to drive a first compressor of the compressor section, and a high spool that enables a high pressure turbine to drive a high pressure compressor of the compressor section.

[0033] The example engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided.

[0034] The low speed spool **30** generally includes an inner shaft **40** that connects a fan **42** and a low pressure (or first) compressor section **44** to a low pressure (or first) turbine section **46**. The inner shaft **40** drives the fan **42** through a speed change device, such as a geared architecture **48**, to drive the fan **42** at a lower speed than the low speed spool **30**. The high-speed spool **32** includes an outer shaft **50** that interconnects a high pressure (or second) compressor section **52** and a high pressure (or second) turbine section **54**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via the bearing systems **38** about the engine central longitudinal axis A.

[0035] A combustor **56** is arranged between the high pressure compressor **52** and the high pressure turbine **54**. In one example, the high pressure turbine **54** includes at least two stages to provide a double stage high pressure turbine **54**. In another example, the high pressure turbine **54** includes only a single stage. As used herein, a “high pressure” compressor or turbine experiences a higher pressure than a corresponding “low pressure” compressor or turbine.

[0036] The example low pressure turbine **46** has a pressure ratio that is greater than about 5. The pressure ratio of the example low pressure turbine **46** is measured prior to an inlet of the low pressure turbine **46** as related to the pressure measured at the outlet of the low pressure turbine **46** prior to an exhaust nozzle.

[0037] A mid-turbine frame **58** of the engine static structure **36** is arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The mid-turbine frame **58** further supports bearing systems **38** in the turbine section **28** as well as setting airflow entering the low pressure turbine **46**.

[0038] Airflow through the core flow path C is compressed by the low pressure compressor **44** then by the high pressure compressor **52** mixed with fuel and ignited in the combustor **56** to produce high speed exhaust gases that are then expanded through the high pressure turbine **54** and low pressure turbine **46**. The mid-turbine frame **58** includes vanes **60**, which are in the core airflow path and function as an inlet guide vane for the low pressure turbine **46**. Utilizing the vane **60** of the mid-turbine frame **58** as the inlet guide vane for low pressure turbine **46** decreases the length of the low pressure turbine **46** without increasing the axial length of the mid-turbine frame **58**. Reducing or eliminating the number of vanes in the low pressure turbine **46** shortens the axial length of the turbine section **28**. Thus, the compactness of the gas turbine engine **20** is increased and a higher power density may be achieved.

[0039] The disclosed gas turbine engine **20** in one example is a high-bypass geared aircraft engine. In a further example, the gas turbine engine **20** includes a bypass ratio greater than about six (6), with an example embodiment being greater than about ten (10). The example geared architecture **48** is an epicyclical gear train, such as a planetary gear system, star gear system or other known gear system, with a gear reduction ratio of greater than about 2.3.

[0040] In one disclosed embodiment, the gas turbine engine **20** includes a bypass ratio greater than about ten (10:1) and the fan diameter is significantly larger than an outer diameter of the low pressure compressor **44**. It should be understood, however, that the above parameters are only exemplary of one embodiment of a gas turbine engine including a geared architecture and that the present disclosure is applicable to other gas turbine engines.

[0041] A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio. The fan section **22** of the engine **20** is designed for a particular flight condition—typically cruise at about 0.8 Mach and about **35,000** feet. The flight condition of 0.8 Mach and 35,000 ft., with the engine at its best fuel consumption—also known as "bucket cruise Thrust Specific Fuel Consumption ('TSFC')"—is the industry standard parameter of pound-mass (1 bm) of fuel per hour being burned divided by pound-force (1 bf) of thrust the engine produces at that minimum point.

[0042] "Low fan pressure ratio" is the pressure ratio across the fan blade alone, without a Fan Exit Guide Vane ("FEGV") system. The low fan pressure ratio as disclosed herein according to one non-limiting embodiment is less than about 1.50. In another non-limiting embodiment the low fan pressure ratio is less than about 1.45.

[0043] "Low corrected fan tip speed" is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of $[(\text{Tram}\ ^\circ \text{R})/(518.7^\circ \text{R}]^{0.5}$. The "Low corrected fan tip speed", as disclosed herein according to one non-limiting embodiment, is less than about 1150 ft/second.

[0044] The example gas turbine engine includes the fan **42** that comprises in one non-limiting embodiment less than about 26 fan blades. In another non-limiting embodiment, the fan section **22** includes less than about 20 fan blades. Moreover, in one disclosed embodiment the low pressure turbine **46** includes no more than about 6 turbine rotors schematically indicated at **34**. In another non-limiting example embodiment the low pressure turbine **46** includes about 3 turbine rotors. A ratio between the number of fan blades **42** and the number of low pressure turbine rotors is between about 3.3 and about 8.6. The example low pressure turbine **46** provides the driving power to rotate the fan section **22** and therefore the relationship between the number of turbine rotors **34** in the low pressure turbine **46** and the number of blades **42** in the fan section **22** disclose an example gas turbine engine **20** with increased power transfer efficiency.

[0045] Referring to FIG. **2**, an example industrial gas turbine engine assembly **62** includes a gas turbine engine **64** that is mounted to a structural land based frame to drive a generator **66**. The example gas turbine engine **64** includes many of the same features described in the gas turbine engine **20** illustrated in FIG. **1** and operates in much the same way. The land based industrial gas turbine engine **62**, however, may include additional features such as a shaft and/or exhaust flow path to drive the generator **66** and is not constrained by the same weight restrictions that apply to an aircraft mounted gas turbine engine. As appreciated, many of the parts that are utilized in an aircraft and land based gas turbine engine are common and therefore both aircraft based and land based gas turbine engines are within the contemplation of this disclosure.

[0046] Referring to FIGS. **3** and **4**, with continued reference to FIGS. **1** and **2**, a bearing assembly **75** supports rotation of an aft portion of the low pressure turbine shaft **40**. The bearing assembly **75** includes a roller bearing **70** disposed within a bearing compartment **68** defined within a bearing support bracket **72**. The roller bearing **70** is supported between a first race **77** and a second race **79**. The first race **77** is attached to the support bracket **72** and the second race **79** is supported on the shaft **40**. The bearing support bracket **72** is attached to a portion of the engine static structure **74**.

[0047] A desired module stiffness is utilized that enable an engine to handle dynamic loads such as rotation of the shaft **40**. The stiffness of the bearing **70** supporting rotation of the shaft **40** results from the structure supporting the bearing **70**. The example bearing support bracket **72** includes features for tailoring support of the bearing **70** to provide the desired structural required for supporting rotation of the shaft **40**.

[0048] The bearing support bracket **72** includes a body portion **84** defining a surface **85** substantially parallel to the axis A. An aft cone **82** extends radially outward and aft of the body portion **84** and supports an aft flange **86** spaced axially apart from the body portion **84**.

[0049] A support cone **78** also extends aft of the body portion **84** to support a support flange **76**. The aft flange **86** is attached to the static structure **74** and the first race **77** is attached to the support flange **76**. The support bracket **72** includes a forward cone **80** that extends forward of the body portion **84** and is angled according to angle **110** radially inward toward the axis A to support a forward flange **88**. The forward cone **80** can be adjusted to change the stiffness of the part and to provide for a desired path for a secondary airflow.

[0050] The figures illustrate a cross section of the bearing support bracket **72** about the axis A. Accordingly, the features of the support bracket **72** shown in cross-section represent annular structures about the axis A. Each structure and portion of the bearing support **72** is tunable to tailor module stiffness to provide the desired engine dynamics.

[0051] The aft cone **82** includes a first length **100**, a first thickness **104** and is disposed at a first angle **102** relative to the surface **85** of the body portion **84**. Each of the first length **100**, first thickness **104** and first angle **102** are tunable to enable adjustment of the stiffness of the roller bearing **70**. Moreover, the stiffness of the aft cone **82** is separately adjustable from the support cone **78** to further enable adjustment of module stiffness supporting the bearing **70**.

[0052] In one disclosed example embodiment, the aft cone **82** provides a desired stiffness by including a ratio of the first length **100** to the first thickness **104** that is between about 18.0 and about 22.0. Another tunable feature is represented in a ratio of an overall length **106** as it relates to the length **100** that is between about 2.50 and about 3.50.

[0053] Moreover, the aft cone **82** may be further tailored to provide a desired stiffness by modification of the first angle **102**. In one example disclosed embodiment, the first length **100** is related to the first angle **102** according to a ratio between about 0.23 and about 0.25.

[0054] The support cone **78** further includes tunable features that are defined separate from the first thickness **104**, first length **100** and first angle **102** of the aft cone **82**. The support cone **78** includes a second length **90**, a second thickness **92**, and a second angle **94** that are tunable to enable adjustment of the stiffness of the roller bearing **70** in support of the shaft **40**. In one disclosed example embodiment the tunable features of the support cone **78** are defined as a ratio of the second arm length **90** to the second thickness **92** that is between about 3.0 and 4.25.

[0055] The support cone **78** extends from the body portion at the second angle **94** that provides a further tunable feature to define the overall structural stiffness encountered by the bearing **70** that is provided to support the shaft **40**. In one disclosed embodiment, the second angle **94** is defined according to a relationship to the second length **90** to provide a desired stiffness according to a ratio between about 0.130 and about 0.135.

[0056] It should be understood that each of the aft cone **82**, arm **78** and forward cone **80** can be tuned separately or in concert with each other to provide the desired overall module stiffness of the support bracket **72** and thereby support of the shaft **40**.

[0057] The example bearing support **72** includes an aft diameter **112** that corresponds to the aft flange **86** and a mount diameter **114** that corresponds to the support flange **76**. The example aft diameter **112** is provided in relation to the first length **100** to enable a desired stiffness according to a ratio of the first diameter **112** and the first length **100** that is between about 5.85 and about 6.15.

[0058] The support flange **76** is disposed at a second diameter **114**. The example support flange **76** is defined to provide a desired stiffness at least partially by providing a relationship between the second length **90** and the second diameter according to a ratio between about 16.85 and about 17.15. The example bearing support **72** further defines the overall desired thickness at least in part by providing the first length **100** as a portion of the overall length **106** according to a ratio between about 5.90 and 6.10.

[0059] A load path is defined from the bearing assembly **75** from the support flange **76** through to the aft flange **86**. The support flange **76** is the anchor point and stiffness can be tuned by adjusting the lengths **98** and **100**.

[0060] A further dimensional embodiment that defines an example desired overall stiffness of the bracket **72** relates the first diameter **112** to the second diameter **114**. As appreciated, the relationship between the first diameter **112** and the second diameter **114** provides the bracket with a desired range of stiffness to support and balance operational requirements of supporting the shaft **40**. In one example embodiment this relationship is defined by a ratio of the first diameter **112** to the second diameter that is within a range of between about 1.4 and about 1.90. It should be understood that each feature of the example bearing support is tunable in concert with other features to provide and tailor an overall stiffness.

[0061] Referring to FIGS. **5** and **6**, another example bearing assembly **115** is disclosed and supported by a support bracket **124** disposed at an aft portion **120** of a turbine section **125**. The support bracket **124** is an integral portion of the exhaust case **122**. In this example the bracket **124** and case **122** include tunable features to adjust overall module stiffness of the bearing assembly **115**. The example bearing assembly **115** includes a roller bearing **138** supported between an outer race **138** attached to the support bracket **124** and an inner race **140** supported on a rotating part of the turbine section **125**.

[0062] In the disclosed example an outermost diameter **126** is defined at an outer flange of the exhaust case **122**. An intermediate diameter **128** is defined at an inner surface of the exhaust gas flow path **140** and is related to a first length **132**. The first length **132** extends from a forward most end of the support bracket **124** to an aft end of the exhaust case **122**. The stiffness at the bearing assembly is determined as a factor of the tunable features defined in the support bracket **124** and exhaust case **122**. In this example, the stiffness is provided in the support bracket **124** according to a relationship between the diameter **128** and the length **132**. In one disclosed example, a ratio of the diameter **128** to the length **132** is between about 1.7 and about 2.0. Another diameter **130** is defined at a length **134** from the forward portion of the support bracket **124** and is a further tunable feature. In this example a ratio of the diameter **130** to the length **134** is between about 1.25 and 1.75.

[0063] Accordingly, the example support brackets include individually tunable features that are adjustable in combination and/or separately to enable a specific stiffness required to support bearing assemblies and thereby rotating engine components.

[0064] Although an example embodiment has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this disclosure. For that reason, the following claims should be studied to determine the scope and content of this disclosure.

What is claimed is:

1. A gas turbine engine comprising:

a compressor section disposed about an axis;

a combustor in fluid communication with the compressor section;

a turbine section in fluid communication with the combustor;

a shaft rotating about an the axis and driven by the turbine section for driving the compressor section;

a bearing assembly supporting rotation of the shaft; and

a bearing support supporting the bearing assembly and including an aft flange supported on an aft cone having a first length and first thickness and a support flange supported on a support cone having a second length and a second thickness defined separate from the first thickness and the first length to define a desired stiffness of the bearing assembly.

2. The gas turbine engine as recited in claim **1**, wherein the first length is related to the first thickness by a ratio between about 18.0 and about 22.0 to define the desired stiffness of the bearing assembly.

3. The gas turbine engine as recited in claim **1**, wherein the second length and the second thickness are related according to a ratio between about 3.0 and about 4.25 to further define the desired stiffness of the bearing assembly.

4. The gas turbine engine as recited in claim **1**, wherein the bearing support includes a body portion with the aft cone and the support cone extending from the body portion.

5. The gas turbine engine as recited in claim **4**, wherein the body portion includes a surface substantially parallel to the axis and the aft cone extends from the body portion at a first angle related to the first length according to a ratio between about 0.23 and about 0.25.

6. The gas turbine engine as recited in claim **4**, wherein the body portion includes a surface substantially parallel to the axis and the support cone extends from the body portion at a second angle related to the second length according to a ratio between about 0.130 and about 0.135.

7. The gas turbine engine as recited in claim **1**, wherein the aft flange includes a first diameter related to the first length according to a ratio between about 5.85 and 6.15.

8. The gas turbine engine as recited in claim **2**, wherein the support flange includes a second diameter related to the second length according to a ratio between about 16.85 and about 17.15.

9. The gas turbine engine as recited in claim **1**, wherein the bearing support includes an overall length related to the first length according to a ratio between about 5.90 and 6.10.

10. A bearing assembly for a gas turbine engine comprising:

a bearing support including an aft flange supported on an aft cone mounted to a fixed structure of the gas turbine engine and a support flange supported on support cone; and

a bearing disposed between a first race supported on the support flange and a second race fixed to a rotating shaft, wherein the aft cone includes a first length and first thickness and the support cone includes a second length and a second thickness separately defined from the first thickness and the first length to define a desired stiffness of the bearing assembly.

11. The bearing assembly as recited in claim **10**, wherein the bearing support includes a body portion with the aft cone and the support cone extending from the body portion.

12. The bearing assembly as recited in claim **10**, wherein the bearing support at least partially defines a cavity within which is supported the bearing.

13. The bearing assembly as recited in claim **11**, wherein the body portion includes a surface substantially parallel to the axis and the aft cone extends from the body portion at an angle related to the first length according to a ratio between about 0.25 and about 0.23.

14. The bearing assembly as recited in claim **11**, wherein the body portion includes a surface substantially parallel to the axis and the support cone extends from the body portion at an angle related to the second length according to a ratio between about 0.130 and about 0.135.

15. The bearing assembly as recited in claim **10**, wherein the first thickness is related to the first length by a ratio between about 18.0 and about 22.0 to define further define the desired stiffness of the bearing assembly.

16. The bearing assembly as recited in claim **10**, wherein the second length and the second thickness are related according to a ratio between about 3.0 and about 4.25 to further define the desired stiffness of the bearing assembly.

17. A method of defining bearing assembly stiffness for a gas turbine engine comprising:

attaching an aft flange to a fixed support structure and supporting the aft flange on an aft cone extending from a body portion a first length;

attaching a bearing support member to a support flange extending from the body portion a second length less than the first length; and

adjusting a first thickness of the first length of the aft cone and a second thickness of the second length of the support cone to define the desired stiffness of the bearing assembly.

18. The method as recited in claim **17**, including adjusting the first thickness in relation to the first length according to a ratio between about 18.0 and about 22.0, and adjusting the second thickness in relation to the second length according to a ratio between about 3.0 and about 4.25.

19. The method as recited in claim **17**, including extending the aft cone from the body portion at first angle related to the first length according to a ratio between about 0.25 and about 0.23 and extending the support cone from the body portion at a second angle relative to the second length according to a ratio between about 0.130 and 0.135.

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