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Green et al.

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(54) **STATOR VANE ARRANGEMENT AND A METHOD OF CASTING A STATOR VANE ARRANGEMENT**

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(57) **ABSTRACT**

A stator vane arrangement for a turbomachine comprises a radially inner annular structure, a radially outer annular structure and a plurality of circumferentially spaced vanes extending radially between the inner annular structure and the outer annular structure. At least one of the vanes has a passage extending from the inner annular structure to the outer annular structure. The inner annular structure has at least one radially inwardly extending boss and each boss has a passage extending there-through. The passage in each boss is aligned with a corresponding passage in a vane. Each boss comprises a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area. The first portion of each boss is positioned between and intercon-

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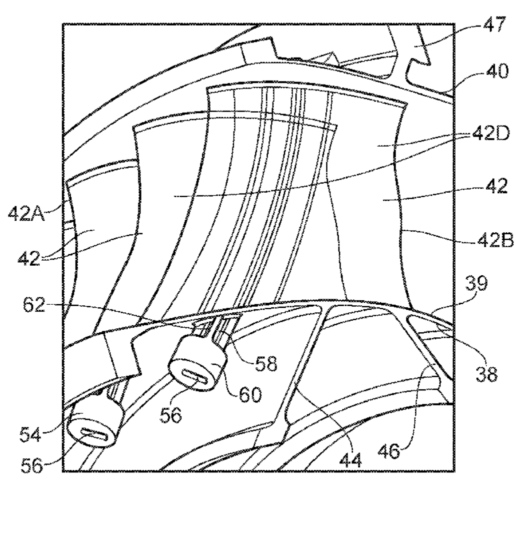

necting the second portion of the boss and the inner annular structure.

20 Claims, 4 Drawing Sheets

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F01D 21/00 (2006.01)
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F01D 25/18 (2006.01)

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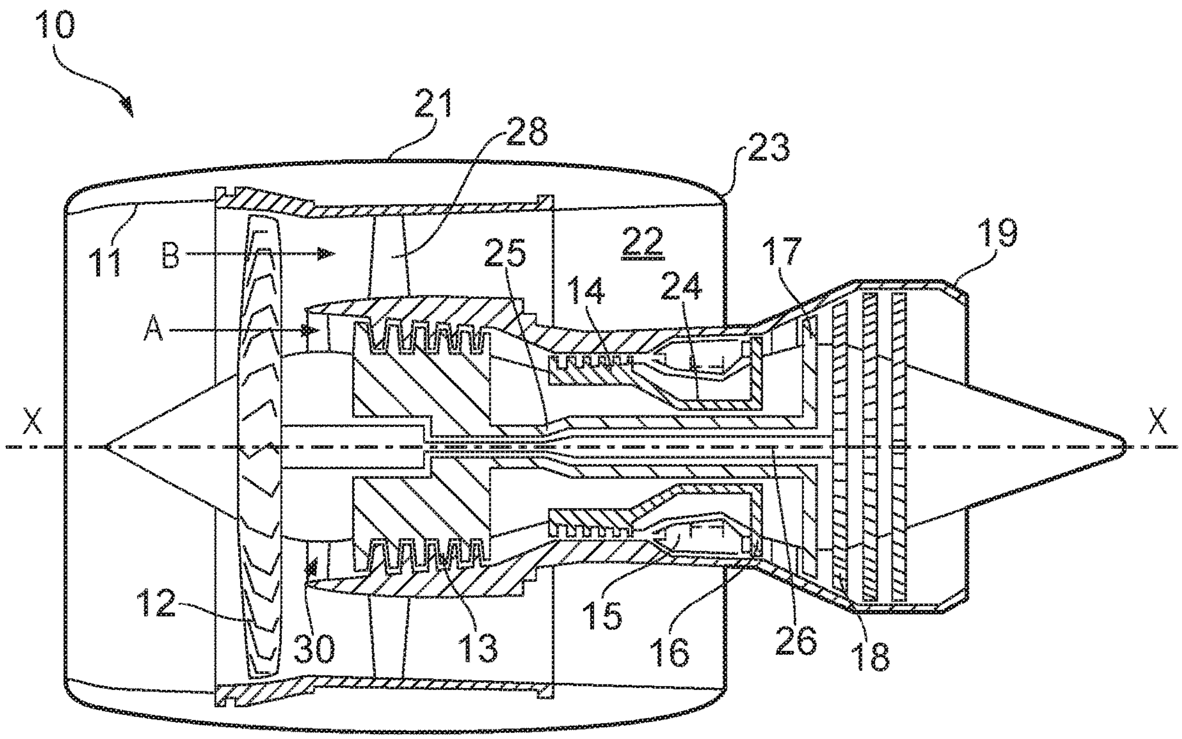
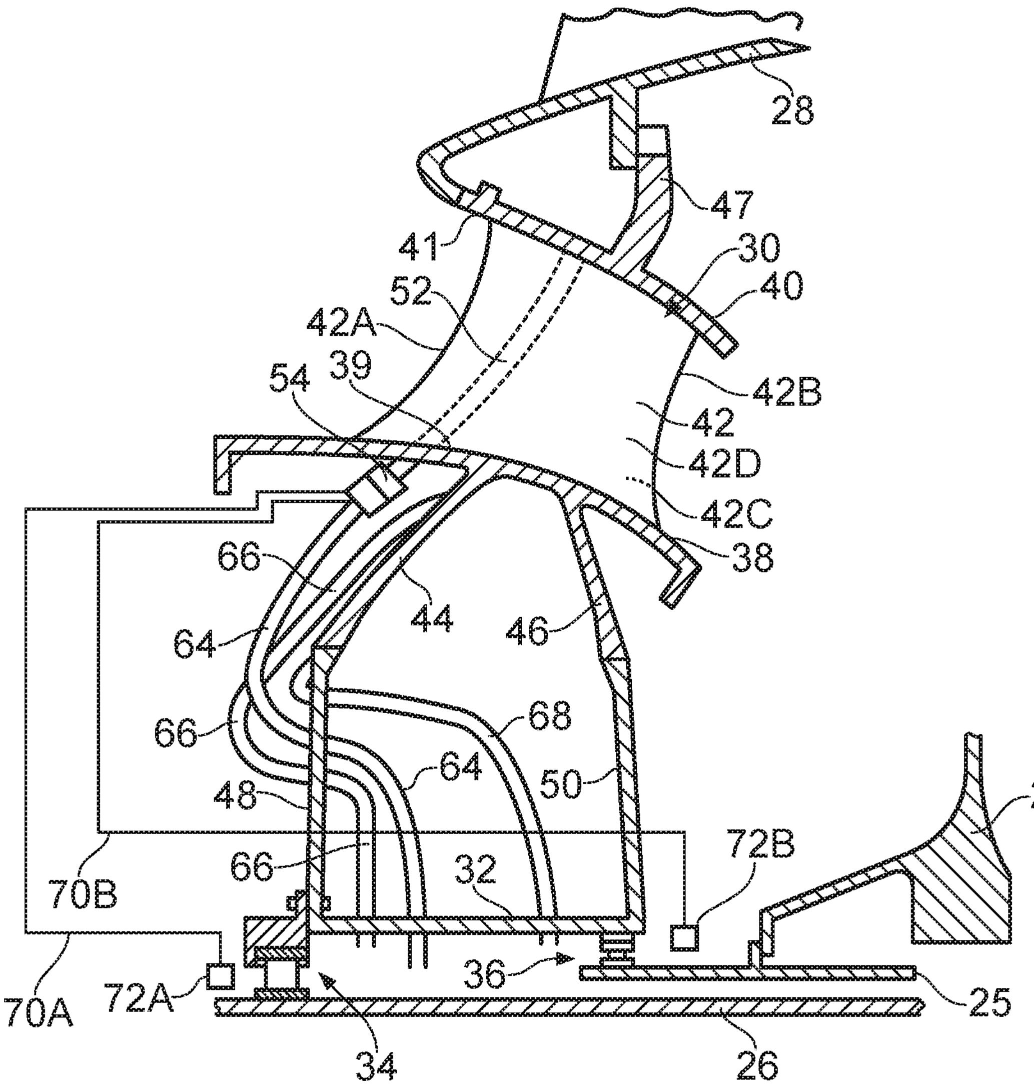


FIG. 1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42A
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42D
42C
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46
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72B
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70B
36
72A
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70A
34
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FIG. 2

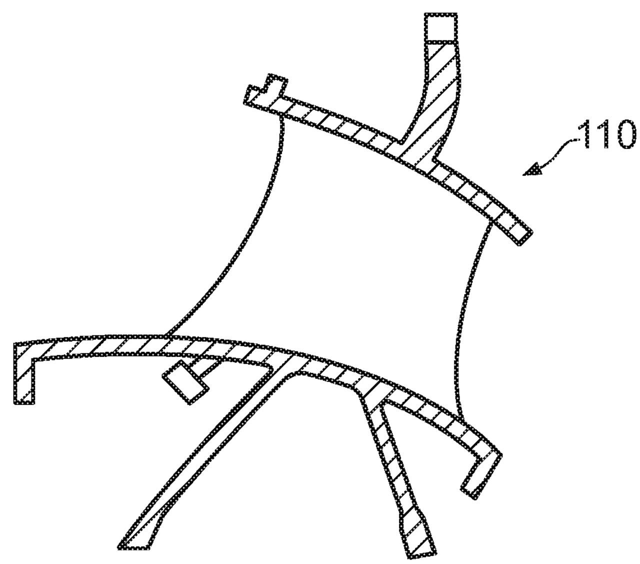
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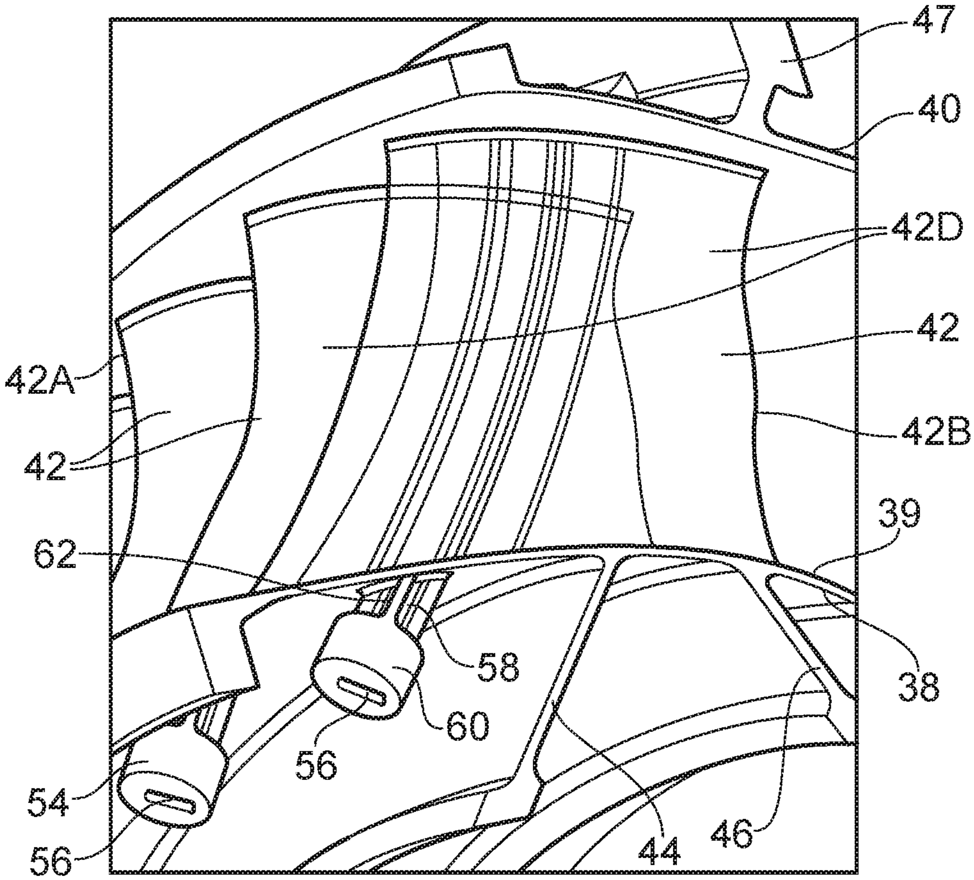
FIG. 9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40
42D
42
42A
42
42B
39
62
58
38
60
56
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56
44
46

FIG. 3

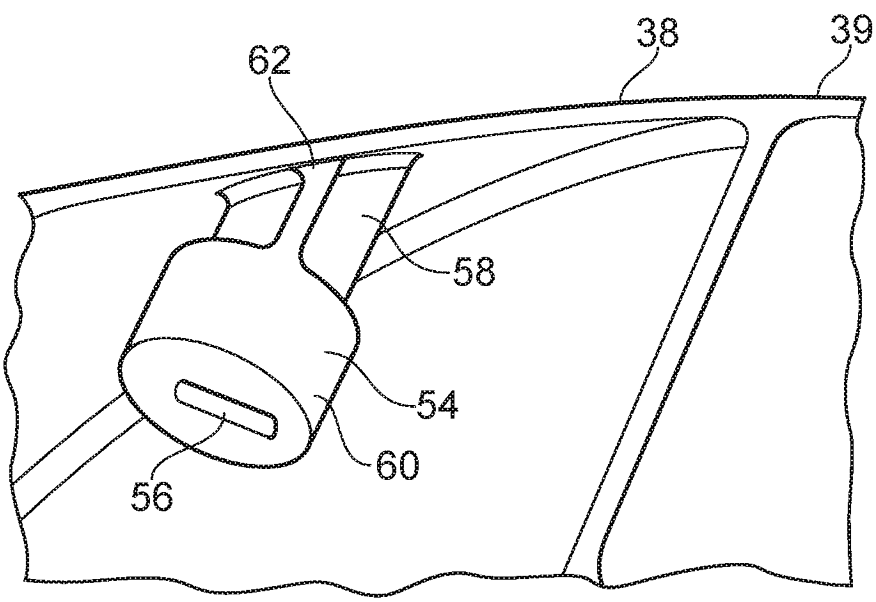
62
38
39
58
54
60
56

FIG. 4

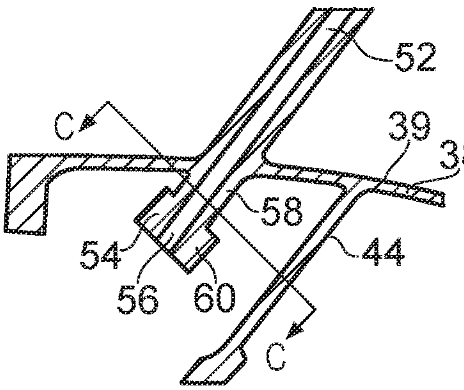

FIG. 5

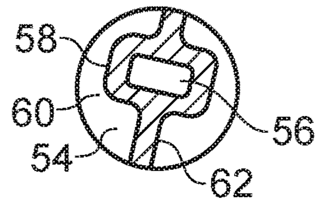

FIG. 6

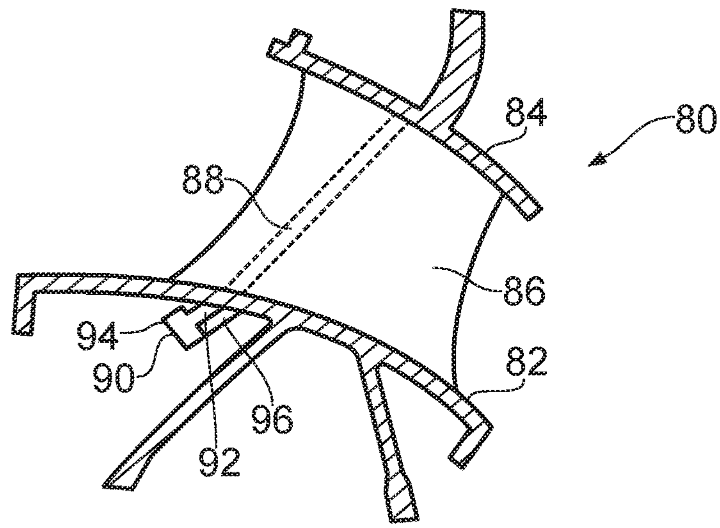

FIG. 7

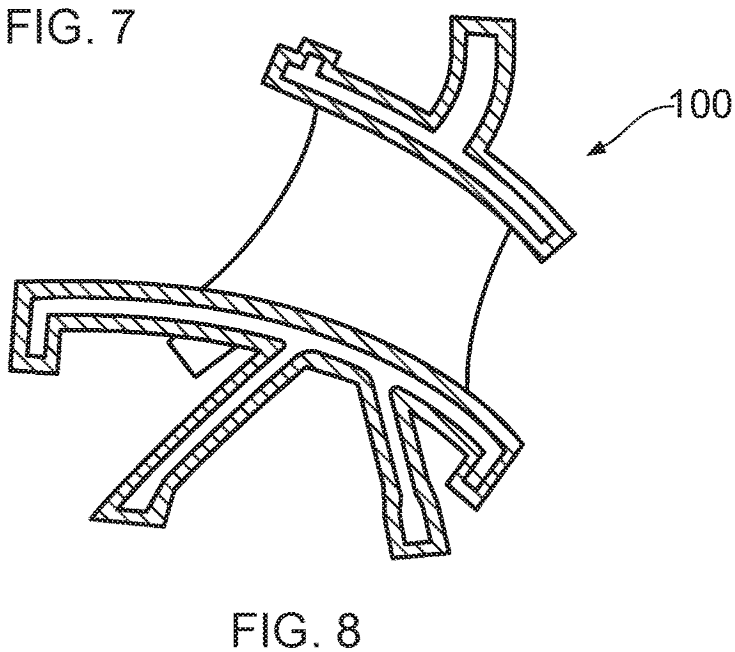

FIG. 8

STATOR VANE ARRANGEMENT AND A METHOD OF CASTING A STATOR VANE ARRANGEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from British Patent Application Number 1611372.2 filed 30 Jun. 2016, the entire contents of which are incorporated by reference.

BACKGROUND

1. Field of Disclosure

The present disclosure concerns a stator vane arrangement and a method of casting a stator vane arrangement and in particular concerns a stator vane arrangement for a turbomachine and a method of casting a stator vane arrangement for a turbomachine.

2. Description of the Related Art

Turbomachines, e.g. gas turbine engines, have one or more stator vane arrangements to support bearing housings and associated bearings of the turbomachine. In a turbofan gas turbine engine one of these stator vane arrangements supports a bearing housing and associated bearings for a fan shaft and/or a compressor shaft of the turbofan gas turbine engine. This stator vane arrangement is sometimes known as an engine section stator. The radially inner annular structure is secured to the bearing housing and the radially outer annular structure is secured to the fan outlet guide vanes and hence to the fan casing. The stator vane arrangement comprises a radially inner annular structure, a radially outer annular structure and a plurality of circumferentially spaced vanes extending radially between the radially inner annular structure and the radially outer annular structure. A radially inner surface of the radially outer annular structure and a radially outer surface of the radially inner annular structure define the flow path from the fan to the compressor, or compressors, of the core engine of the turbofan gas turbine engine.

It is known to produce this stator vane arrangement by individually forging, casting or otherwise forming the vanes and welding the stator vanes together. It is also known to produce this stator vane arrangement by investment casting the stator vane arrangement as a single integral, or monolithic, structure and machining.

A cast stator vane arrangement comprising a single integral structure is cheaper to produce and may have reduced weight.

The stator vane arrangement has hollow vanes which have passages to enable lubricant to be supplied to and removed from the associated bearings in the bearing housing and to enable air to be vented from the associated bearings. Hollow bosses on a radially inner surface of the radially inner annular wall enable pipes to supply lubricant out of, lubricant into or air into the hollow vanes. The hollow vanes are produced using ceramic cores during the investment casting process.

However, the provision of the bosses on the radially inner surface of the radially inner annular wall has several problems. It is difficult to control the positions of the bosses relative to the ceramic cores which may result in reduced thickness of the walls of the bosses around the passage after casting and final machining. There is a difference in the thickness between the majority of the radially inner annular wall and the thickness of the radially inner annular wall in the regions of the bosses. During the solidification of the molten metal during the casting process the molten metal in the thinner regions cools quicker than the molten metal in the thicker regions and hence dimples, a process known as "hip-sinkage", are formed in the radially outer surface of the radially inner annular structure in the regions of the bosses and this requires additional machining to provide the correct shape for the radially outer surface of the radially inner annular structure.

OBJECTS AND SUMMARY

According to a first aspect of the present disclosure there is provided a stator vane arrangement comprising a radially inner annular structure, a radially outer annular structure and a plurality of circumferentially spaced vanes extending radially between the radially inner annular structure and the radially outer annular structure, at least one of the vanes having a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having at least one boss extending radially inwardly there-from, the at least one boss having a passage extending there-through, the passage in the at least one boss being aligned with the passage in the at least one vane, the at least one boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure.

A plurality of vanes may have a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having a plurality of bosses extending radially inwardly there-from, each boss having a passage extending there-through, the passage in each boss being aligned with a passage in a respective one of the vanes, each boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of each boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure.

The or each boss may have at least one support structure to support the boss, the at least one support structure extending radially from the second portion of the boss to the radially inner annular structure and the at least one support structure being connected to the first portion of the boss.

The or each boss may have a plurality of support structures to support the boss, each support structure extending radially from the second portion of the boss to the radially inner annular structure and each support structure being connected to the first portion of the boss.

According to a second aspect of the present discourse there is provided a turbomachine comprising a stator vane arrangement as described in any one of the previous four paragraphs.

The turbomachine may have a bearing housing secured to the radially inner annular structure and at least one bearing being arranged within the bearing housing.

A lubricant supply may be arranged to supply lubricant through the passage through the at least one stator vane from the radially outer annular structure to the radially inner annular structure.

A pipe may be arranged to supply lubricant from the at least one boss to at least one bearing within the bearing housing.

A lubricant collector may be arranged to supply collected lubricant through the passage through the at least one stator vane from the radially inner annular structure to the radially outer annular structure.

A pipe may be arranged to supply lubricant to the at least one boss from at least one bearing within the bearing housing.

An air collector may be arranged to supply collected air through the passage through the at least one stator vane from the radially inner annular structure to the radially outer annular structure.

A pipe may be arranged to supply air to the at least one boss from at least one bearing within the bearing housing.

An electrical cable may extend through the passage through the at least one stator vane from the radially inner annular structure to the radially outer annular structure.

The electrical cable may be arranged to supply an electrical signal from a speed probe.

The at least one bearing may rotatably mount a shaft of the turbomachine.

The turbomachine may be a gas turbine engine.

The gas turbine engine may be an aero gas turbine engine, a marine gas turbine engine, an industrial gas turbine engine or an automotive gas turbine engine. The aero gas turbine engine may be a turbofan gas turbine engine, a turbojet gas turbine engine, a turbo-shaft gas turbine engine or a turbo-propeller gas turbine engine.

The gas turbine engine may be a turbofan gas turbine engine and the shaft is a fan shaft.

According to a third aspect of the present disclosure there is provided a method of casting a stator vane arrangement comprising a radially inner annular structure, a radially outer annular structure and a plurality of circumferentially spaced vanes extending radially between the radially inner annular structure and the radially outer annular structure, at least one of the vanes having a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having at least one boss extending radially inwardly there-from, the at least one boss having a passage extending there-through, the passage in the at least one boss being aligned with the passage in the at least one vane, the at least one boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure, the method comprising producing a wax pattern of the radially inner annular structure, the radially outer annular structure and the plurality of circumferentially spaced vanes, providing a ceramic core in the wax pattern of at least one of the vanes, the ceramic core extending through the wax radially inner annular wall, providing a wax boss on the radially inner end of the ceramic core, the wax boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the wax boss being positioned between and interconnecting the second portion of the wax boss and the wax radially inner annular structure, depositing a ceramic material on the wax pattern to form a ceramic mould, removing the wax from the ceramic mould, pouring molten metal into the ceramic mould, solidifying the molten metal within the ceramic mould to form the stator vane arrangement and removing the ceramic mould and ceramic core from the stator vane arrangement.

The method may comprises providing a ceramic core in the wax pattern of a plurality of vanes, each ceramic core extending through the wax radially inner annular wall, providing a wax boss on the radially inner end of each ceramic core, each wax boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the wax boss being positioned between and interconnecting the second portion of the wax boss and the wax radially inner annular structure, depositing a ceramic material on the wax pattern to form a ceramic mould, removing the wax from the ceramic mould, pouring molten metal into the ceramic mould, solidifying the molten metal within the ceramic mould to form the stator vane arrangement and removing the ceramic mould and the ceramic cores from the stator vane arrangement.

The method may comprise providing at least one wax support structure to support each boss, the at least one wax support structure extending radially from the second portion of the wax boss to the wax radially inner annular structure and the at least one wax support structure being connected to the first portion of the wax boss.

The or each boss may have a plurality of wax support structures to support the wax boss, each wax support structure extending radially from the second portion of the wax boss to the wax radially inner annular structure and each wax support structure being connected to the first portion of the wax boss.

The metal may be a titanium alloy, steel or a nickel alloy.

The skilled person will appreciate that except where mutually exclusive, a feature described in relation to any one of the above aspects of the disclosure may be applied mutatis mutandis to any other aspect of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the disclosure will now be described by way of example only, with reference to the Figures, in which:

FIG. **1** is a cross-sectional view through a turbofan gas turbine engine having a stator vane arrangement according to the present disclosure.

FIG. **2** is an enlarged cross-sectional view of half of an engine section stator, bearings and a bearing housing of the turbofan gas turbine engine shown in FIG. **1** having a stator vane arrangement according to the present disclosure.

FIG. **3** is a further enlarged perspective view of part of the stator vane arrangement shown in FIG. **2**.

FIG. **4** is a further enlarged perspective view of a boss of the stator vane arrangement shown in FIG. **3**.

FIG. **5** is a cross-sectional view a portion of a stator vane and a boss of the stator vane arrangement shown in shown in FIG. **3**.

FIG. **6** is a cross-sectional view in the direction of arrows C-C in FIG. **5**.

FIG. **7** is a cross-sectional view through half of a wax pattern for casting a stator vane arrangement according to the present disclosure.

FIG. **8** is a cross-sectional view through half of a ceramic mould for casting a stator vane arrangement according to the present disclosure.

FIG. **9** is a cross-sectional view through half of a cast stator vane arrangement according to the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

With reference to FIG. **1**, a gas turbine engine is generally indicated at **10**, having a principal and rotational axis X. The engine **10** comprises, in axial flow series, an air intake **11**, a propulsive fan **12**, an intermediate pressure compressor **13**, a high-pressure compressor **14**, combustion equipment **15**, a high-pressure turbine **16**, and intermediate pressure turbine **17**, a low-pressure turbine **18** and an exhaust nozzle **19**. A nacelle **21** generally surrounds the engine **10** and defines the intake **11**, a bypass duct **22** and a bypass exhaust nozzle **23**.

The gas turbine engine **10** works in the conventional manner so that air entering the intake **11** is accelerated by the fan **12** to produce two air flows: a first air flow A into the intermediate pressure compressor **13** and a second air flow B which passes through the bypass duct **22** to provide propulsive thrust. The intermediate pressure compressor **13** compresses the air flow directed into it before delivering that air to the high pressure compressor **14** where further compression takes place. The nacelle **21** is generally supported from the core engine by a plurality of circumferentially spaced radially extending fan outlet guide vanes **28**.

The compressed air exhausted from the high-pressure compressor **14** is directed into the combustion equipment **15** where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive the high, intermediate and low-pressure turbines **16**, **17**, **18** before being exhausted through the nozzle **19** to provide additional propulsive thrust. The high **16**, intermediate **17** and low **18** pressure turbines drive respectively the high pressure compressor **14**, intermediate pressure compressor **13** and fan **12**, each by a suitable interconnecting shaft **24**, **25** and **26** respectively.

The turbofan gas turbine engine **10** also comprises one or more stator vane arrangements to support bearing housings and associated bearings of the turbofan gas turbine engine. The turbofan gas turbine engine **10** has a stator vane arrangement **30** to support a bearing housing **32** which has an associated bearing **34** for the shaft **26** arranged to drive the fan **12** and an associated bearing **36** for the shaft **25** arranged to drive the intermediate pressure compressor **13** of the turbofan gas turbine engine **10**. This stator vane arrangement **30** is sometimes known as an engine section stator. The bearings **34** and **36** may be roller bearings or ball bearings. The shaft **25** is secured to a disc **27** of the intermediate pressure compressor **13**.

The stator vane arrangement **30** is shown more clearly in FIGS. **2** to **6** and comprises a radially inner annular structure **38**, a radially outer annular structure **40** and a plurality of circumferentially spaced vanes **42** extending radially between and secured to the radially inner annular structure **38** and the radially outer annular structure **40**. The radially inner annular structure **38** is secured to the bearing housing **32** and the radially outer annular structure **40** is secured to the fan outlet guide vanes **28** and hence to the nacelle **21**. A radially outer surface **39** of the radially inner annular structure **38** and a radially inner surface **41** of the radially outer annular structure **40** define the flow path for the first air flow A from the fan **12** to the intermediate pressure compressor **13** and thence to the high pressure compressor **14** of the core engine of the turbofan gas turbine engine **10**. The vanes **42** may be aerodynamically shaped to supply the first air flow A to the intermediate pressure compressor **13**. The radially inner annular structure **38** comprises a first frustoconical panel **44** and a second frustoconical panel **46** spaced axially from the first frustoconical panel **44** which extend radially inwardly from the radially inner annular structure **38**. The first frustoconical panel **44** is secured to a first annular panel **48** extending radially outwardly from an axially upstream end of the bearing housing **32** for example by welding, e.g. by electron beam welding in a partial vacuum, and the second frustoconical panel **46** is secured to a second annular panel **50** extending radially outwardly from an axially downstream end of the bearing housing **32** for example by welding, e.g. by electron beam welding in a partial vacuum. The radially outer annular structure **40** comprises an annular flange **47** which extends radially outwardly from the radially outer annular structure **40** and the fan outlet guide vanes **28** are secured to the annular flange **47**. The fan outlet guide vanes **28** are secured to the annular flange **47** by fasteners, e.g. nuts and bolts.

Each vane **42** has a leading edge **42**A, a trailing edge **42**B, a convex suction surface **42**C extending from the leading edge **42**A to the trailing edge **42**B and a concave pressure surface **42**D extending from the leading edge **42**A to the trailing edge **42**B.

A plurality of the vanes **42** each have a passage **52** extending there-through from the radially inner annular surface of the radially inner annular structure **40** to the radially outer surface of the radially outer annular structure **38** and the radially inner annular structure **38** has a plurality of circumferentially spaced bosses **54** extending radially inwardly there-from from the radially inner surface of the radially inner annular structure **38**. Each boss **54** has a passage **56** extending there-through and the passage **56** in each boss **54** is aligned with a passage **52** in a respective one of the vanes **42**. Each boss **54** comprises a first portion **58** which has a first cross-sectional area and a second portion **60** which has a second cross-sectional area which is greater than the first cross-sectional area. The first portion **58** of each boss **54** is positioned between and interconnects the second portion **60** of the boss **54** and the radially inner annular structure **38**. Each boss **54** has at least one support structure **62** to support the boss **54** and the at least one support structure **62** extends radially from the second portion **60** of the boss **54** to the radially inner annular structure **38** and the at least one support structure **62** is connected to the first portion **58** of the boss **54**. In this particular example each boss **54** has a plurality of support structures **62** to support the boss **54** and each support structure **62** extends radially from the second portion **60** of the boss **54** to the radially inner annular structure **38** and each support structure **62** is connected to the first portion **58** of the boss **54**. The first portion **58** of each boss **54** forms a first section of a wall around the passage **56** through the boss **54** and the second portion **60** of each boss **54** forms a second section of the wall around the passage **56** though the boss **54** and the second section of the wall around the passage **56** is thicker than the first section of the wall around the passage **56** as shown in FIG. **6**. The second portion **60** of each boss **54** is generally annular in cross-section and the first portion **58** of each boss **54** has a generally annular cross-sectional shape to correspond with the shape of the ceramic core **52**. The first portion **58** has a cross-sectional shape with generally rectangular inner and outer surfaces with rounded corners, as shown in FIG. **6**, to correspond with the shape of the ceramic core **52**. The second portion **60** of each boss **54** has a cross-sectional shape with a circular outer surface and a generally rectangular inner surface with rounded corners, as shown in FIGS. **3** and **4**, to correspond with the shape of the ceramic core **52**. However, the first portion **58** of each boss **54** may have a cross-sectional shape with circular inner and outer surfaces to correspond with a circular cross-section ceramic core **52** and the second portion **60** of each boss **54** may have a cross-sectional shape with circular inner and outer surfaces to correspond with a circular cross-section ceramic core **52**.

A lubricant supply (not shown) is arranged to supply lubricant through the passage **52** through at least one of the stator vanes **42** from the radially outer annular structure **40** to the radially inner annular structure **40**. The lubricant then flows through the passage **56** within the associated boss **54**. A pipe **64** is arranged to supply lubricant from the passage **56** within the associated boss **54** to the bearings **34** and **36** within the bearing housing **32**. In one particular example lubricant is supplied through the passage **52** through two of the stator vanes **42** from the radially outer annular structure **40** to the radially inner annular structure **40**. The lubricant then flows through the passage **56** within the associated bosses **54**. Two pipes **64** are arranged to supply lubricant from the passages **56** within the associated bosses **54** to the bearings **34** and **36** within the bearing housing **32**.

A lubricant collector (not shown) within the bearing housing **32** is arranged to supply collected lubricant through the passage **52** through at least one of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40**. A pipe **66** is arranged to supply lubricant collected from the bearings **34** and **36** within the bearing housing **32** from the lubricant collector to at least one boss **54**. The lubricant then flows through the passage **56** within the at least one boss **54** and then through the passage **52** through at least one of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40** and the lubricant is returned to the lubricant supply. In one particular example two pipes **66** are arranged to supply lubricant collected from the bearings **34** and **36** within the bearing housing **32** from the lubricant collector to two bosses **54**. The lubricant then flows through the passage **56** within the two bosses **54** and then through the passages **52** through two of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40** and the lubricant is returned to the lubricant supply.

An air collector (not shown) within the bearing housing **32** is arranged to supply collected air through the passage **52** through the at least one stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40**. A pipe **68** is arranged to supply air collected from the bearings **34** and **36** within the bearing housing **32** to at least one boss **54**. The air then flows through the passage **56** within the at least one boss **54** and then through the passage **52** through at least one of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40** to allow excess pressure in the bearing chamber, e.g. air, to be vented overboard via an oil air separator. In one particular example three pipes **68** are arranged to supply air from the bearings **34** and **36** within the bearing housing **32** to three bosses **54**. The air then flows through the passage **56** within the three bosses **54** and then through the passages **52** through three of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40** to allow excess pressure in the bearing chamber, e.g. air, to be vented overboard via an oil air separator.

An electrical cable **70**A, **70**B extends through the passage **52** through at least one of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40**. The electrical cable **70**A, **70**B is arranged to supply an electrical signal from a speed probe **72**A, **72**B, which is arranged to measure the speed of rotation of the shaft **26** or the shaft **25**. The electrical cable **70**A, **70**B extends through the passage **56** within at least one boss **54** and then through the passage **52** through at least one of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40** and the electrical cable **70**A, **70**B is connected to an engine control unit. In one particular example two speed probes **72**A (Only one shown) measure the speed of the shaft **26** and two speed probes **72**B (Only one shown) measure the speed of the shaft **25**. Two electrical cables **70**A extends through the passages **56** within two bosses **54** and then through the passages **52** through two of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40** and the electrical cables **70**A are connected to the engine control unit and two electrical cables **70**B extends through the passages **56** within two bosses **54** and then through the passages **52** through two of the stator vanes **42** from the radially inner annular structure **38** to the radially outer annular structure **40** and the electrical cables **70**B are connected to the engine control unit.

The circumferential dimension of the second portion of each boss is greater than that circumferential dimension of the vanes at the radially inner annular structure.

It is to be noted that the stator vane arrangement **30** is an integral structure, a single piece structure or a monolithic structure, e.g. the radially inner annular structure **38**, the radially outer annular structure **40**, the plurality of circumferentially spaced vanes **42** extending radially between and secured to the radially inner annular structure **38** and the radially outer annular structure **40** and the bosses **54** is an integral structure, a single piece structure or a monolithic structure. The stator vane arrangement **30** is formed by casting.

The advantage of the present disclosure is that the thickness of the radially inner annular structure in the region of each boss has been reduced due to each boss having a first portion with a smaller cross-sectional area. This reduces the weight of the stator vane arrangement. The diameter of the second portion of each boss may be easily adjusted, increased or decreased, to suit the particular application. The angle of each boss relative to the radially inner annular structure may be adjusted. More than one passage, e.g. two or three passages, may be provided in one or more of the vanes and a boss of this type may be provided for each of these passages. The length of the first portion of each boss may be easily adjusted, increased or decreased, to suit the particular application. The thickness of the first portion of each boss may be easily adjusted, increased or decreased, to suit the particular application. The support structures support the bosses to minimise stresses in the bosses and to reduce "chattering" of the machine tool during machining of the bosses. The thickness of each support structures may be easily adjusted, increased or decreased, to vary the amount of support. The number of support structures on each boss may be easily adjusted, increased or decreased, to vary the amount of support.

Although the present disclosure has been described with reference to a stator vane arrangement supporting a bearing housing and associated bearings for a fan shaft and/or a compressor shaft it is equally applicable to a stator vane arrangement supporting a bearing housing and associated bearings for one or more compressor shafts or one or more turbine shafts.

Although the present disclosure has been described with reference to a turbofan gas turbine engine it is equally applicable to a turbojet gas turbine engine, a turbo-shaft gas turbine engine, a turbo-propeller gas turbine engine or other aero gas turbine engine.

Although the present disclosure has been described with reference to an aero gas turbine engine it is equally applicable to a marine gas turbine engine, an industrial gas turbine engine or an automotive gas turbine engine.

Although the present disclosure has been described with reference to a gas turbine engine it is equally applicable to other turbomachines comprising a stator vane arrangement as mentioned above, e.g. steam turbine.

Although the present disclosure has referred to a stator vane arrangement with a plurality of vanes having a passage extending there-through it is equally applicable to a stator vane arrangement in which at least one of the vanes having a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having at least one boss extending radially inwardly there-from, the at least one boss having a passage extending there-through, the passage in the at least one boss being aligned with the passage in the at least one vane, the at least one boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure.

FIGS. **7** to **9** show a method of casting a stator vane arrangement **30** shown in FIGS. **2** to **6**. The method comprising producing a wax pattern of the stator vane arrangement **80**, the wax pattern comprises a wax radially inner annular structure **82**, a wax radially outer annular structure **84** and a plurality of circumferentially spaced wax vanes **86**, as shown in FIG. **7**. A ceramic core **86** is provided in the wax pattern of a plurality of the wax vanes **86** and each ceramic core **86** extends through the wax radially inner annular structure **82**. A wax boss **90** is provided on the radially inner end of each ceramic core **88**. Each wax boss **90** comprises a first portion **92** having a first cross-sectional area and a second portion **94** having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion **92** of the wax boss **90** is positioned between and interconnecting the second portion **94** of the wax boss **90** and the wax radially inner annular structure **82**. A ceramic material is deposited on the wax pattern of the stator vane arrangement **80** to form a ceramic mould **100**, as shown in FIG. **8**. The wax is then removed from the ceramic mould **100** for example by heating the mould to melt the wax and by pouring the molten wax out of the ceramic mould **100**. Molten metal is supplied, poured, into the ceramic mould **100** and the molten metal is solidified within the ceramic mould **100** to form a cast stator vane arrangement **110** as shown in FIG. **9** and then the ceramic mould **100** and the ceramic cores **88** are removed from the cast stator vane arrangement **110** to form the stator vane arrangement **30** as shown in FIG. **2**.

The stator vane arrangement is used as cast. However, it may be necessary for the stator vane arrangement to be finish machined to final shape. The radially outer surface of the radially inner annular structure, the radially inner surface of the radially outer annular structure and the leading edges, trailing edges and the concave and convex surfaces of the vanes may be milled using a six axis milling machine, by milling using other suitable milling machine and/or by mechanical polishing, e.g. grinding and sanding. The surfaces of the passages within the stator vanes and bosses may be aggregate flow polished, also known as abrasive flow machining, by passing an abrasive laden fluid through the passages.

The method comprises providing at least one wax support structure **96** to support each wax boss **90**, the at least one wax support structure **96** extends radially from the second portion **94** of the wax boss **90** to the wax radially inner annular structure **82** and the at least one wax support structure **96** is connected to the first portion **92** of the wax boss **90**. The or each wax boss **90** has a plurality of wax support structures **96** to support the wax boss **90**, each wax support structure **96** extends radially from the second portion of the wax boss **90** to the wax radially inner annular structure **82** and each wax support structure **96** is connected to the first portion **92** of the wax boss **90**.

Each wax vane **86** which is to be provided with a passage is provided with a ceramic core **88** which extends through the wax vane **86** from the radially outer end of the wax vane **86** to the radially inner end of the wax vane **86**. Each ceramic core **88** extends out of and beyond the radially inner end of the corresponding wax vane **86**. The radially inner end of each ceramic core **88** protrudes from the corresponding wax vane **86**. A wax wall is wrapped around each ceramic core **88** protruding from a wax vane **86** and the wax wall is wax welded to the wax radially inner annular structure **82** to form the first portion **92** of the wax boss **90**. A preformed wax boss is placed around the remaining portion of the radially inner end of each ceramic core **88** and adjacent to the wax wall and each preformed wax boss is wax welded to the wax wall to form the second portion **94** of each wax boss **90**. The wax welding may comprise heating the mating surfaces of both of the wax parts and joining the wax parts by holding them together while the wax sets or by inserting a heated metal strip between the mating surfaces of both of the wax parts to melt the mating surfaces and then removing the metal strip to allow the wax to set or other suitable method known to those skilled in the art. The wax weld or wax joint is then smoothed.

The metal used to make the stator vane arrangement **30** may be a titanium alloy, steel or a nickel alloy.

The advantage of the present disclosure is that by positioning, e.g. building up, each wax boss on the respective ceramic core the positions of the wax bosses relative to the ceramic cores is controlled and hence any movement of a ceramic cores will result in a corresponding movement of the corresponding wax boss. Hence, the movement of the ceramic core does not result in a reduced thickness of the walls of the bosses around the passage after casting and final machining. Also, it enables the use of a ceramic core with a larger cross-sectional area and hence produces a passage within the vane with a greater cross-sectional area and thus provides a greater flow area for lubricant or air.

Although the present disclosure has referred to providing a ceramic core in a plurality of wax vanes it is equally possible to provide a ceramic core in at least one of the wax vanes, the ceramic core extending through the wax radially inner annular structure, providing a wax boss on the radially inner end of the ceramic core, the wax boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the wax boss being positioned between and interconnecting the second portion of the wax boss and the wax radially inner annular structure, depositing a ceramic material on the wax pattern to form a ceramic mould, removing the wax from the ceramic mould, pouring molten metal into the ceramic mould, solidifying the molten metal within the ceramic mould to form the cast stator vane arrangement and removing the ceramic mould and ceramic core from the cast stator vane arrangement to form the stator vane arrangement.

It will be understood that the invention is not limited to the embodiments above-described and various modifications and improvements can be made without departing from the concepts described herein. Except where mutually exclusive, any of the features may be employed separately or in combination with any other features and the disclosure extends to and includes all combinations and sub-combinations of one or more features described herein.

We claim:

1. A stator vane arrangement comprising a radially inner annular structure, a radially outer annular structure and a plurality of circumferentially spaced vanes extending radially between the radially inner annular structure and the radially outer annular structure, at least one of the vanes having a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having at least one boss extending radially inwardly there-from, the at least one boss having a passage extending there-through, the passage in the at least one boss being aligned with the passage in the at least one vane, the at least one boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, the first portion of the boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure, and the radially inner annular structure, the radially outer annular structure, the plurality of circumferentially spaced vanes extending radially between and secured to the radially inner annular structure and the radially outer annular structure and the at least one boss comprising a monolithic structure, wherein the or each boss having at least one support structure to support the boss, the at least one support structure extending radially from the second portion of the boss to the radially inner annular structure and the at least one support structure being connected to the first portion of the boss.

2. A stator vane arrangement as claimed in claim **1** wherein a plurality of vanes have a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having a plurality of bosses extending radially inwardly there-from, each boss having a passage extending there-through, the passage in each boss being aligned with a passage in a respective one of the vanes, each boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of each boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure, the radially inner annular structure, the radially outer annular structure, the plurality of circumferentially spaced vanes extending radially between and secured to the radially inner annular structure and the radially outer annular structure and the plurality of bosses comprising a monolithic structure.

3. A stator vane arrangement as claimed in claim **1** wherein the or each boss having a plurality of support structures to support the boss, each support structure extending radially from the second portion of the boss to the radially inner annular structure and each support structure being connected to the first portion of the boss.

4. A turbomachine comprising a stator vane arrangement, the stator vane arrangement comprising a radially inner annular structure, a radially outer annular structure and a plurality of circumferentially spaced vanes extending radially between the radially inner annular structure and the radially outer annular structure, at least one of the vanes having a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having at least one boss extending radially inwardly there-from, the at least one boss having a passage extending there-through, the passage in the at least one boss being aligned with the passage in the at least one vane, the at least one boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, the first portion of the boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure, and the radially inner annular structure, the radially outer annular structure, the plurality of circumferentially spaced vanes extending radially between and secured to the radially inner annular structure and the radially outer annular structure and the at least one boss comprising a monolithic structure, wherein the or each boss having at least one support structure to support the boss, the at least one support structure extending radially from the second portion of the boss to the radially inner annular structure and the at least one support structure being connected to the first portion of the boss.

5. A turbomachine as claimed in claim **4** wherein a bearing housing being secured to the radially inner annular structure and at least one bearing being arranged within the bearing housing.

6. A turbomachine as claimed in claim **5** wherein a lubricant supply is arranged to supply lubricant through the passage through the at least one of the stator vanes from the radially outer annular structure to the radially inner annular structure.

7. A turbomachine as claimed in claim **6** wherein a pipe is arranged to supply lubricant from the at least one boss to at least one bearing within the bearing housing.

8. A turbomachine as claimed in claim **5** wherein a lubricant collector is arranged to supply collected lubricant through the passage through the at least one of the stator vanes from the radially inner annular structure to the radially outer annular structure.

9. A turbomachine as claimed in claim **8** wherein a pipe is arranged to supply lubricant to the at least one boss from at least one bearing within the bearing housing.

10. A turbomachine as claimed in claim **5** wherein an air collector is arranged to supply collected air through the passage through the at least one of the stator vanes from the radially inner annular structure to the radially outer annular structure.

11. A turbomachine as claimed in claim **10** wherein a pipe is arranged to supply air to the at least one boss from at least one bearing within the bearing housing.

12. A turbomachine as claimed in claim **4** wherein an electrical cable extends through the passage through the at least one of the stator vanes from the radially inner annular structure to the radially outer annular structure.

13. A turbomachine as claimed in claim **12** wherein the electrical cable is arranged to supply an electrical signal from a speed probe.

14. A turbomachine as claimed in claim **5** wherein the at least one bearing rotatably mounting a shaft of the turbomachine.

15. A turbomachine as claimed in claim **14** wherein the turbomachine is a gas turbine engine.

16. A method of casting a stator vane arrangement comprising a radially inner annular structure, a radially outer annular structure and a plurality of circumferentially spaced vanes extending radially between the radially inner annular structure and the radially outer annular structure, at least one of the vanes having a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having at least one boss extending radially inwardly there-from, the at least one boss having a passage extending there-through, the passage in the at least one boss being aligned with the passage in the at least one vane, the at least one boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure, the radially inner annular structure, the radially outer annular structure, the plurality of circumferentially spaced vanes extending radially between and secured to the radially inner annular structure and the radially outer annular structure and the at least one boss comprising a monolithic structure, the method comprising producing a wax pattern of the radially inner annular structure, the radially outer annular structure and the plurality of circumferentially spaced vanes, providing a ceramic core in the wax pattern of at least one of the vanes, the ceramic core extending through a radially inner annular wall of the wax pattern, providing a wax boss on a radially inner end of the ceramic core, the wax boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the wax boss being positioned between and interconnecting the second portion of the wax boss and the wax radially inner annular structure, depositing a ceramic material on the wax pattern to form a ceramic mould, removing the wax pattern from the ceramic mould, pouring molten metal into the ceramic mould, solidifying the molten metal within the ceramic mould to form the stator vane arrangement and removing the ceramic mould and ceramic core from the stator vane arrangement.

17. A method as claimed in claim **16** the radially inner annular structure, the radially outer annular structure, the plurality of circumferentially spaced vanes extending radially between and secured to the radially inner annular structure and the radially outer annular structure and a plurality of bosses of the stator vane arrangement comprising a monolithic structure, the method comprising providing a ceramic core in the wax pattern of a plurality of vanes, each ceramic core extending through a wax radially inner annular wall, providing a wax boss on a radially inner end of each ceramic core, each wax boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, and the first portion of the wax boss being positioned between and interconnecting the second portion of the wax boss and the wax radially inner annular structure, depositing a ceramic material on the wax pattern to form a ceramic mould, removing a wax from the ceramic mould, pouring molten metal into the ceramic mould, solidifying the molten metal within the ceramic mould to form the stator vane arrangement and removing the ceramic mould and the ceramic cores from the stator vane arrangement.

18. A method as claimed in claim **16** comprising providing at least one wax support structure to support the boss, the at least one wax support structure extending radially from the second portion of the wax boss to a wax radially inner annular structure and the at least one wax support structure being connected to the first portion of the wax boss.

19. A method as claimed in claim **18** wherein the boss having a plurality of wax support structures to support the wax boss, each wax support structure extending radially from the second portion of the wax boss to a wax radially inner annular structure and each wax support structure being connected to the first portion of the wax boss.

20. A stator vane arrangement comprising a radially inner annular structure, a radially outer annular structure and a vane extending radially between the radially inner annular structure and the radially outer annular structure, the vane having a passage extending there-through from the radially inner annular structure to the radially outer annular structure, the radially inner annular structure having a boss extending radially inwardly there-from, the boss having a passage extending there-through, the passage in the boss being aligned with the passage in the vane, the boss comprising a first portion having a first cross-sectional area and a second portion having a second cross-sectional area which is greater than the first cross-sectional area, the first portion of the boss being positioned between and interconnecting the second portion of the boss and the radially inner annular structure, and the second portion of the at least one boss having a circular cross section taken normal to the direction of the passage extending through the boss and defining the passage having an elongated cross sectional shape taken normal to the direction of the passage, wherein the or each boss having at least one support structure to support the boss, the at least one support structure extending radially from the second portion of the boss to the radially inner annular structure and the at least one support structure being connected to the first portion of the boss.

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