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EXTENDED INNER PROFILE FOR MANDREL FOR USE IN FORMING BRAIDED CMC STRUCTURES

Abstract

A method of forming a gas turbine engine component having an airfoil includes the steps of placing a mandrel into a braiding machine, with the mandrel having a mandrel body, a radially outer tang and a radially inner tang for holding the mandrel relative to the knitting machine. The mandrel extends between a leading edge and a trailing edge and the radially outer tang with a width in a direction between the leading edge and the trailing edge that is smaller than a distance between the leading edge and trailing edge of the mandrel such that there is a ledge leading into the outer tang. The mandrel body has a width in a direction between the leading edge and the trailing edge that transitions into the inner tang beyond a location that will serve as a base for the braided material, and the mandrel body transitions smoothly into the inner tang. Ceramic matrix composite ("CMCs") yarn is braided about a portion of the mandrel which serves as the base for the braided yarn to form a shear tube. A mandrel is also disclosed.

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Background/Summary

BACKGROUND

[0001] This invention relates to a mandrel that is utilized as a base for forming a braided structure from CMC yarn.

[0002] Gas turbine engines are known, and typically include a propulsor delivering air as propulsion. The air is also delivered into a compressor where it is compressed. The compressed air is then delivered into a combustor where it is mixed with fuel and ignited. Products of this combustion pass downstream over turbine rotors, driving them to rotate.

[0003] It is known that the products of combustion are quite hot. Thus, the components in the turbine section must withstand high temperature. It has been proposed to utilize ceramic matrix composites (“CMCs”) to form turbine components. One particular turbine component that may be formed from CMCs is a static vane. The static vane has an airfoil extending between an inner and outer platform. Within the static vane there are typically hollow channels.

[0004] To form the airfoil from CMCs, a mandrel is provided, and CMC yarn is braided around the mandrel. This then serves as a shear tube which is a base for outer CMC fabric layers. The shear tube interior forms a channel in the airfoil.

[0005] During the braiding operation, the mandrel is held within a braiding machine by a radially outer tang and a radially inner tang. The tangs extend beyond the portion of the mandrel which is forming the base for the braiding of yarn.

[0006] As gas turbine engine vanes advance, the size of the channels also becomes more complex. In some vanes the channel might be quite small such that the mandrel is also small.

[0007] In the prior art, the tang has typically been a tab extending away from a platform defining the end of the braiding surface on the mandrel. As the mandrel becomes smaller, the tang may be subject to fracture.

SUMMARY

[0008] In a featured embodiment, a method of forming a gas turbine engine component having an airfoil includes the steps of placing a mandrel into a braiding machine, with the mandrel having a mandrel body, a radially outer tang and a radially inner tang for holding the mandrel relative to the knitting machine. The mandrel extends between a leading edge and a trailing edge and the radially outer tang with a width in a direction between the leading edge and the trailing edge that is smaller than a distance between the leading edge and trailing edge of the mandrel such that there is a ledge leading into the outer tang. The mandrel body has a width in a direction between the leading edge and the trailing edge that transitions into the inner tang beyond a location that will serve as a base for the braided material, and the mandrel body transitions smoothly into the inner tang. Ceramic matrix composite (“CMCs”) yarn is braided about a portion of the mandrel which serves as the base for the braided yarn to form a shear tube.

[0009] In another embodiment according to the previous embodiment, CMC layers are then placed outwardly of the braided shear tube to form an intermediate vane.

[0010] In another embodiment according to any of the previous embodiments, the intermediate vane is then placed into a densifying chamber wherein the CMC materials are densified.

[0011] In another embodiment according to any of the previous embodiments, the inner tang has a locating pin hole that receives a pin from a holding structure such that the intermediate vane is properly positioned within the densifying chamber.

[0012] In another embodiment according to any of the previous embodiments, the braiding machine has a plurality of spools of CMC yarn that are braided onto the outer surface of the

mandrel.
[0013] In another embodiment according to any of the previous embodiments, a plurality of shear tubes are formed by distinct mandrels and then utilized to form the intermediate vane.
[0014] In another embodiment according to any of the previous embodiments, the intermediate vane has a plurality of hollow channels, and the shear tubes define the hollow channels, and serve as a base for the outer CMC fabric layers.
[0015] In another embodiment according to any of the previous embodiments, the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
[0016] In another embodiment according to any of the previous embodiments, the braiding machine has a plurality of spools of CMC yarn that are braided onto the outer surface of the mandrel.
[0017] In another embodiment according to any of the previous embodiments, a plurality of shear tubes are formed by distinct mandrels and then utilized to form the intermediate vane.
[0018] In another embodiment according to any of the previous embodiments, the intermediate vane has a plurality of hollow channels, and the shear tubes define the hollow channels, and serve as a base for the outer CMC fabric layers.
[0019] In another embodiment according to any of the previous embodiments, the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
[0020] In another embodiment according to any of the previous embodiments, the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
[0021] In another embodiment according to any of the previous embodiments, the braiding machine has a plurality of spools of CMC yarn that are braided onto the outer surface of the mandrel.
[0022] In another embodiment according to any of the previous embodiments, a plurality of shear tubes are formed by distinct mandrels and then utilized to form the intermediate vane.
[0023] In another embodiment according to any of the previous embodiments, the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
[0024] In another embodiment according to any of the previous embodiments, the intermediate vane is then placed into a densifying chamber wherein the CMC materials are densified.
[0025] In another featured embodiment, a mandrel to provide a base for braiding yarn includes a mandrel body, a radially outer tang and a radially inner tang for holding the mandrel relative to a knitting machine. The mandrel body extends between a leading edge and a trailing edge and the outer tang has a width in a direction between the leading edge and the trailing edge that is smaller than a distance between the leading edge and trailing edge of the mandrel body such that there is a ledge leading into the outer tang. The mandrel body has a width in a direction between the leading edge and the trailing edge that transitions into the inner tang beyond a location that will serve as a base for the braided material, the mandrel body transitions smoothly into the inner tang.
[0026] In another embodiment according to any of the previous embodiments, the inner tang has a thickness that decreases from the radially outer end to a radially inner end
[0027] In another embodiment according to any of the previous embodiments, the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
[0028] The present disclosure may include any one or more of the individual features disclosed above and/or below alone or in any combination thereof.
[0029] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] FIG. **1** schematically shows a gas turbine engine.

[0031] FIG. **2** schematically shows a turbine section.

[0032] FIG. **3** shows a static vane in a gas turbine engine.

[0033] FIG. **4** is a cross-sectional view through the airfoil of the FIG. **3** vane.

[0034] FIG. **5** schematically shows the formation of interior components within the FIG. **3** vane.

[0035] FIG. **6** shows a mandrel which is utilized to form the interior component.

[0036] FIG. **7** shows the FIG. **6** mandrel receiving braided yarn.

[0037] FIG. **8** shows a step subsequent to the FIG. **7** step.

DETAILED DESCRIPTION

[0038] FIG. **1** schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. The fan section **22** may include a single-stage fan **42** having a plurality of fan blades **43**. The fan blades **43** may have a fixed stagger angle or may have a variable pitch to direct incoming airflow from an engine inlet. The fan **42** drives air along a bypass flow path B in a bypass duct **13** defined within a housing **15** such as a fan case or nacelle, and also drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. A splitter **29** aft of the fan **42** divides the air between the bypass flow path B and the core flow path C. The housing **15** may surround the fan **42** to establish an outer diameter of the bypass duct **13**. The splitter **29** may establish an inner diameter of the bypass duct **13**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures. The engine **20** may incorporate a variable area nozzle for varying an exit area of the bypass flow path B and/or a thrust reverser for generating reverse thrust.

[0039] The exemplary 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, and the location of bearing systems **38** may be varied as appropriate to the application.

[0040] The low speed spool **30** generally includes an inner shaft **40** that interconnects, a first (or low) pressure compressor **44** and a first (or low) pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in the exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive the fan **42** at a lower speed than the low speed spool **30**. The inner shaft **40** may interconnect the low pressure compressor **44** and low pressure turbine **46** such that the low pressure compressor **44** and low pressure turbine **46** are rotatable at a common speed and in a common direction. In other embodiments, the low pressure turbine **46** drives both the fan **42** and low pressure compressor **44** through the geared architecture **48** such that the fan **42** and low pressure compressor **44** are rotatable at a common speed. Although this application discloses geared architecture **48**, its teaching may benefit direct drive engines having no geared architecture. The high speed spool **32** includes an outer shaft **50** that interconnects a second (or high) pressure compressor **52** and a second (or high) pressure turbine **54**. A combustor **56** is arranged in the exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. A mid-turbine frame **57** of the engine static structure **36** may be arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The mid-turbine frame **57** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.

[0041] Airflow in the core flow path C is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded through the high pressure turbine **54** and low pressure turbine **46**. The mid-turbine frame **57** includes airfoils **59** which are in the core flow path C. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of the low pressure compressor, or aft of the combustor section **26** or even aft of turbine section **28**, and fan **42** may be positioned forward or aft of the location of gear system **48**.

[0042] The fan **42** may have at least 10 fan blades **43** but no more than 20 or 24 fan blades **43**. In examples, the fan **42** may have between **12** and **18** fan blades **43**, such as 14 fan blades **43**. An exemplary fan size measurement is a maximum radius between the tips of the fan blades **43** and the engine central longitudinal axis A. The maximum radius of the fan blades **43** can be at least 40 inches, or more narrowly no more than 75 inches. For example, the maximum radius of the fan blades **43** can be between 45 inches and 60 inches, such as between 50 inches and 55 inches. Another exemplary fan size measurement is a hub radius, which is defined as distance between a hub of the fan **42** at a location of the leading edges of the fan blades **43** and the engine central longitudinal axis A. The fan blades **43** may establish a fan hub-to-tip ratio, which is defined as a ratio of the hub radius divided by the maximum radius of the fan **42**. The fan hub-to-tip ratio can be less than or equal to 0.35, or more narrowly greater than or equal to 0.20, such as between 0.25 and 0.30. The combination of fan blade counts and fan hub-to-tip ratios disclosed herein can provide the engine **20** with a relatively compact fan arrangement.

[0043] The low pressure compressor **44**, high pressure compressor **52**, high pressure turbine **54** and low pressure turbine **46** each include one or more stages having a row of rotatable airfoils. Each stage may include a row of vanes adjacent the rotatable airfoils. The rotatable airfoils are schematically indicated at **47**, and the vanes are schematically indicated at **49**.

[0044] The low pressure compressor **44** and low pressure turbine **46** can include an equal number of stages. For example, the engine **20** can include a three-stage low pressure compressor **44**, an eight-stage high pressure compressor **52**, a two-stage high pressure turbine **54**, and a three-stage low pressure turbine **46** to provide a total of sixteen stages. In other examples, the low pressure compressor **44** includes a different (e.g., greater) number of stages than the low pressure turbine **46**. For example, the engine **20** can include a five-stage low pressure compressor **44**, a nine-stage high pressure compressor **52**, a two-stage high pressure turbine **54**, and a four-stage low pressure turbine **46** to provide a total of twenty stages. In other embodiments, the engine **20** includes a four-stage low pressure compressor **44**, a nine-stage high pressure compressor **52**, a two-stage high pressure turbine **54**, and a three-stage low pressure turbine **46** to provide a total of eighteen stages. It should be understood that the engine **20** can incorporate other compressor and turbine stage counts, including any combination of stages disclosed herein.

[0045] The engine **20** may be a high-bypass geared aircraft engine. It should be understood that the teachings disclosed herein may be utilized with various engine architectures, such as low-bypass turbofan engines, prop fan and/or open rotor engines, turboprops, turbojets, etc. The bypass ratio can be greater than or equal to 10.0 and less than or equal to about 18.0, or more narrowly can be less than or equal to 16.0. The geared architecture **48** may be an epicyclic gear train, such as a planetary gear system or a star gear system. The epicyclic gear train may include a sun gear, a ring gear, a plurality of intermediate gears meshing with the sun gear and ring gear, and a carrier that supports the intermediate gears. The sun gear may provide an input to the gear train. The ring gear (e.g., star gear system) or carrier (e.g., planetary gear system) may provide an output of the gear train to drive the fan **42**. A gear reduction ratio may be greater than or equal to 2.3, or more narrowly greater than or equal to 3.0, and in some embodiments the gear reduction ratio is greater than or equal to 3.4. The gear reduction ratio may be less than or equal to 4.0. The fan diameter is significantly larger than that of the low pressure compressor **44**. The low pressure turbine **46** can have a pressure ratio that is greater than or equal to 8.0 and in some embodiments is greater than or equal to 10.0. The low pressure turbine pressure ratio can be less than or equal to 13.0, or more narrowly less than or equal to 12.0. Low pressure turbine **46** pressure ratio is pressure measured prior to an inlet of low pressure turbine **46** as related to the pressure at the outlet of the low pressure turbine **46** prior to an exhaust nozzle. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present invention is applicable to other gas turbine engines including direct drive turbofans. All of these parameters are measured at the cruise condition described below.

[0046] 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 (10,668 meters). The flight condition of 0.8 Mach and 35,000 ft (10,668 meters), with the engine at its best fuel consumption—also known as “bucket cruise Thrust Specific Fuel Consumption (‘TSFC’)”—is the industry standard parameter of lbm of fuel being burned divided by lbf of thrust the engine produces at that minimum point. The engine parameters described above, and those in the next paragraph are measured at this condition unless otherwise specified.

[0047] “Fan pressure ratio” is the pressure ratio across the fan blade **43** alone, without a Fan Exit Guide Vane (“FEGV”) system. A distance is established in a radial direction between the inner and outer diameters of the bypass duct **13** at an axial position corresponding to a leading edge of the splitter **29** relative to the engine central longitudinal axis A. The fan pressure ratio is a spanwise average of the pressure ratios measured across the fan blade **43** alone over radial positions corresponding to the distance. The fan pressure ratio can be less than or equal to 1.45, or more narrowly greater than or equal to 1.25, such as between 1.30 and 1.40. “Corrected fan tip speed” is the actual fan tip speed in ft/sec divided by an industry standard temperature correction of [(Tram ° R)/(518.7 ° R)].sup.0.5. The corrected fan tip speed can be less than or equal to 1150.0 ft/second (350.5 meters/second), and can be greater than or equal to 1000.0 ft/second (304.8 meters/second).

[0048] The fan **42**, low pressure compressor **44** and high pressure compressor **52** can provide different amounts of compression of the incoming airflow that is delivered downstream to the turbine section **28** and cooperate to establish an overall pressure ratio (OPR). The OPR is a product of the fan pressure ratio across a root (i.e., 0% span) of the fan blade **43** alone, a pressure ratio across the low pressure compressor **44** and a pressure ratio across the high pressure compressor **52**. The pressure ratio of the low pressure compressor **44** is measured as the pressure at the exit of the low pressure compressor **44** divided by the pressure at the inlet of the low pressure compressor **44**. In examples, a sum of the pressure ratio of the low pressure compressor **44** and the fan pressure ratio is between 3.0 and 6.0, or more narrowly is between 4.0 and 5.5. The pressure ratio of the high pressure compressor ratio **52** is measured as the pressure at the exit of the high pressure compressor **52** divided by the pressure at the inlet of the high pressure compressor **52**. In examples, the pressure ratio of the high pressure compressor **52** is between 9.0 and 12.0, or more narrowly is between 10.0 and 11.5. The OPR can be equal to or greater than 45.0, and can be less than or equal to 70.0, such as between 50.0 and 60.0. The overall and compressor pressure ratios disclosed herein are measured at the cruise condition described above, and can be utilized in two-spool architectures such as the engine **20** as well as three-spool engine architectures.

[0049] The engine **20** establishes a turbine entry temperature (TET). The TET is defined as a maximum temperature of combustion products communicated to an inlet of the turbine section **28** at a maximum takeoff (MTO) condition. The inlet is established at the leading edges of the axially forwardmost row of airfoils of the turbine section **28**, and MTO is measured at maximum thrust of the engine **20** at static sea-level and 86 degrees Fahrenheit (° F.). The TET may be greater than or equal to 2700.0° F., or more narrowly less than or equal to 3500.0° F., such as between 2750.0° F.

and 3350.0° F. The relatively high TET can be utilized in combination with the other techniques disclosed herein to provide a compact turbine arrangement.

[0050] The engine **20** establishes an exhaust gas temperature (EGT). The EGT is defined as a maximum temperature of combustion products in the core flow path C communicated to at the trailing edges of the axially aftmost row of airfoils of the turbine section **28** at the MTO condition. The EGT may be less than or equal to 1000.0° F., or more narrowly greater than or equal to 800.0° F., such as between 900.0° F. and 975.0° F. The relatively low EGT can be utilized in combination with the other techniques disclosed herein to reduce fuel consumption.

[0051] FIG. **2** schematically shows a turbine section **100**. Rotating turbine blades **102** are spaced by intermediate static vanes **104**. Vanes **104** include an outer platform **106**, an inner platform **108**, and an intermediate connecting airfoil **110**.

[0052] As shown in FIG. **3**, the airfoil **110** extends from a leading edge **112** to a trailing edge **114**. An outer structure **116** of the airfoil **110** is shown. An inner braided structure **118** is also shown, and may be called a shear tube. The shear tube **118** is formed of CMC yarn. A CMC material forming outer airfoil layers **116** is comprised of one or more ceramic fiber plies in a ceramic matrix. Example ceramic matrices are silicon-containing ceramic, such as but not limited to, a silicon carbide (SiC) matrix or a silicon nitride (Si_3N_4) matrix. Example ceramic reinforcement of the CMC are silicon-containing ceramic fibers, such as but not limited to, silicon carbide (SiC) fiber or silicon nitride (Si_3N_4) fibers. The CMC may be, but is not limited to, a SiC/SiC ceramic matrix composite in which SiC fiber plies are disposed within a SiC matrix. A fiber ply has a fiber architecture, which refers to an ordered arrangement of the fiber tows relative to one another, such as a 2D woven ply or a 3D structure. A monolithic ceramic does not contain fibers or reinforcement and is formed of a single material. Example monolithic ceramics include silicon-containing ceramics, such as silicon carbide (SiC) or silicon nitride (Si_3N_4).

[0053] FIG. **4** is a cross-sectional view through the FIG. **3** airfoil. As shown, there are braided CMC yarn shear tubes **118** sitting within outer layers of CMC fabric **116** and defining channels **119**.

[0054] FIG. **5** schematically shows a mandrel **129** which forms the shear tube **118**. The mandrel **129** is as known in the prior art. A mandrel body extends for a first relatively great width. Radially outer tangs **121** and radially inner tangs **119** extend for a width that is less than the width of the mandrel body **129**. In a sense, the tangs extend from a ledge defining an end of the mandrel body **129**. As the vane gets smaller, the inner tang will become smaller, and more subject to fracture.

[0055] As shown in FIG. **6**, a mandrel **120** as disclosed here includes an outer surface **121** with grooves **124**. The mandrel is received within the vane **104** as formed when the CMC materials are “densified.” The grooves **124** assist in movement of the densifying material into the interior of the shear tube **118**.

[0056] As shown, mandrel **120** extends from a leading edge **126** to a trailing edge **128**. A tang **130** extends away from a ledge **131**. Tang **130** is smaller than the ledge **131**. An inner tang **132** extends along the same profile as the mandrel **120** at both the leading edge **126** and trailing edge **128**.

[0057] One can see there is a smooth transition between the end **133** and **135** of where the braided yarn will stop and continuing onto the tang **132**. The tang **132** is also provided with a positioning hole **134** for a reason to be described below.

[0058] The inner tang **132** has a thickness that decreases from the radially outer end to a radially inner end.

[0059] FIG. **7** schematically shows a braiding arrangement **148**. The tang **132** is held in positioning structure **138**. The tang **130** is held in positioning structure **136**. The positioning structure is as known, as is the braiding machine **130**. A plurality of yarn spools **137** are connected through a ring **135**, and braid yarns **160** about the outer surface **121** of the mandrel **120** to form shear tube **118**. Note tang **130** extends beyond an upper end **144** of the braided yarn structure. Similarly, tang **132** extends beyond a lower end **140** of the braided yarn structure.

[0060] Since the inner tang **132** has a greater thickness than in the prior art, it is less subject to fracture, even as size of the overall mandrel **120** becomes smaller.
[0061] In embodiments, the mandrel may be formed with an appropriate graphite material.
[0062] FIG. **8** shows the subsequent step. After formation of the shear tube **118**, the outer fabric layers are laid upon the braided shear tube **118**.
[0063] Then, the intermediate vane **104** is placed in a so-called “clam shell” **150** in which the densifying material is injected into the CMC materials forming the intermediate vane **104**. As shown, the locating hole **134** receives holding structure **152** from the clam shell **150** such that the vane **104** is properly positioned during intensification. Clam shell **150** may be as known.
[0064] In fact, in some embodiments the densification may be a multi-step process. As an example, there may be an initial run which applies an interface coating on the fiber to partially densify the matrix. The mandrel may then be removed, and further densification steps may be performed.
[0065] A method of forming a gas turbine engine component having an airfoil under this disclosure could be said to include the steps of placing a mandrel into a braiding machine. The mandrel has a body, a radially outer tang and a radially inner tang for holding the mandrel relative to the knitting machine. The mandrel extends between a leading edge and a trailing edge. The outer tang has a width in a direction between the leading edge and the trailing edge that is smaller than a distance between the leading edge and trailing edge of the mandrel body such that there is a ledge leading into the outer tang. The mandrel has a width in a direction between the leading edge and the trailing edge that transitions into the inner tang beyond a location that will serve as a base for the braided material and the mandrel body transitions smoothly into the inner tang. Ceramic matrix composite (“CMCs”) yarn is braided about a portion of the mandrel which serves as the base for the braided yarn to form a shear tube.
[0066] A mandrel to provide a base for braiding yarn under this disclosure could be said to include a mandrel having a mandrel body having a radially outer tang and a radially inner tang for holding the mandrel relative to a knitting machine. The mandrel extends between a leading edge and a trailing edge. The radially outer tang has a width in a direction between the leading edge and the trailing edge that is smaller than a distance between the leading edge and trailing edge of the mandrel body such that there is a ledge leading into the outer tang. The mandrel body has a width in a direction between the leading edge and the trailing edge that transitions into the inner tang beyond a location that will serve as a base for the braided material. The mandrel body transitions smoothly into the inner tang.
[0067] Although embodiments of this disclosure have been disclosed, a worker of ordinary skill in this art would recognize that modifications would come within the scope of this disclosure. For that reason, the following claims should be studied to determine the true scope and content of this disclosure.

Claims

1. A method of forming a gas turbine engine component having an airfoil comprising the steps of: placing a mandrel into a braiding machine, with the mandrel having a mandrel body, a radially outer tang and a radially inner tang for holding the mandrel relative to the knitting machine, the mandrel extending between a leading edge and a trailing edge and the radially outer tang with a width in a direction between the leading edge and the trailing edge that is smaller than a distance between the leading edge and trailing edge of the mandrel such that there is a ledge leading into the outer tang; the mandrel body having a width in a direction between the leading edge and the trailing edge that transitions into the inner tang beyond a location that will serve as a base for the braided material, and the mandrel body transitions smoothly into the inner tang; and braiding ceramic matrix composite (“CMCs”) yarn about a portion of the mandrel which serves as the base for the braided yarn to form a shear tube.

2. The method as set forth in claim 1, wherein CMC layers are then placed outwardly of the braided shear tube to form an intermediate vane.
3. The method as set forth in claim 2, wherein the intermediate vane is then placed into a densifying chamber wherein the CMC materials are densified.
4. The method as set forth in claim 3, wherein the inner tang has a locating pin hole that receives a pin from a holding structure such that the intermediate vane is properly positioned within the densifying chamber.
5. The method as set forth in claim 4, wherein the braiding machine has a plurality of spools of CMC yarn that are braided onto the outer surface of the mandrel.
6. The method as set forth in claim 5, wherein a plurality of shear tubes are formed by distinct mandrels and then utilized to form the intermediate vane.
7. The method as set forth in claim 6, wherein the intermediate vane has a plurality of hollow channels, and the shear tubes defining the hollow channels, and serving as a base for the outer CMC fabric layers.
8. The method as set forth in claim 7, wherein the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
9. The method as set forth in claim 2, wherein the braiding machine has a plurality of spools of CMC yarn that are braided onto the outer surface of the mandrel.
10. The method as set forth in claim 9, wherein a plurality of shear tubes are formed by distinct mandrels and then utilized to form the intermediate vane.
11. The method as set forth in claim 10, wherein the intermediate vane has a plurality of hollow channels, and the shear tubes defining the hollow channels, and serving as a base for the outer CMC fabric layers.
12. The method as set forth in claim 11, wherein the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
13. The method as set forth in claim 12, wherein the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
14. The method as set forth in claim 1, wherein the braiding machine has a plurality of spools of CMC yarn that are braided onto the outer surface of the mandrel.
15. The method as set forth in claim 1, wherein a plurality of shear tubes are formed by distinct mandrels and then utilized to form the intermediate vane.
16. The method as set forth in claim 1, wherein the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
17. The method as set forth in claim 1, wherein the intermediate vane is then placed into a densifying chamber wherein the CMC materials are densified.
18. A mandrel to provide a base for braiding yarn comprising: a mandrel body, a radially outer tang and a radially inner tang for holding the mandrel relative to a knitting machine, the mandrel body extending between a leading edge and a trailing edge and the outer tang has a width in a direction between the leading edge and the trailing edge that is smaller than a distance between the leading edge and trailing edge of the mandrel body such that there is a ledge leading into the outer tang; and the mandrel body having a width in a direction between the leading edge and the trailing edge that transitions into the inner tang beyond a location that will serve as a base for the braided material, the mandrel body transitions smoothly into the inner tang.
19. The mandrel as set forth in claim 18, wherein the inner tang has a thickness that decreases from the radially outer end to a radially inner end.
20. The mandrel as set forth in claim 17, wherein the inner tang has a thickness that decreases from the radially outer end to a radially inner end.