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MULTI-PIECE MANDREL FOR BUILDING UP AIRFOIL STRUCTURE

Abstract

A mandrel includes a mandrel body upon which to build ceramic matrix composite (“CMC”) yarns to provide a shear tube for building up an airfoil from CMC fabric layers. The mandrel body formed of at least two mandrel parts interfitting to define a desired shape for the shear tube, and such that after formation of the airfoil the at least two parts of the mandrel body can be separately removed from the shear tube in order to facilitate removal. A method is also disclosed.

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Background/Summary

BACKGROUND

[0001] This application relates to a mandrel for forming a shear tube to use as a base for building an airfoil structure. A method is also disclosed.

[0002] Gas turbine engines are known, and typically include a propulsor delivering air as propulsion air. The air is also delivered into a compressor. 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. As such, it has been proposed to form turbine components from ceramic matrix composites (“CMCs”). In one method of forming ceramic matrix composite airfoils, a mandrel is provided to make a base for a braided tube formed of CMC yarns known as a shear tube. Fabric layers may then be placed outwardly of the shear tube to form a component having an airfoil. The component is then densified.

[0004] After densification the mandrel must be removed from the shear tube. There are some airfoil designs which would raise challenges with removal of the mandrel.

SUMMARY

[0005] In a featured embodiment, a mandrel includes a mandrel body upon which to build ceramic matrix composite (“CMC”) yarns to provide a shear tube for building up an airfoil from CMC fabric layers. The mandrel body formed of at least two mandrel parts interfitting to define a desired shape for the shear tube, and such that after formation of the airfoil the at least two parts of the mandrel body can be separately removed from the shear tube in order to facilitate removal.

[0006] In another embodiment according to the previous embodiment, a first of the two mandrel parts has a bowed profile such that a central portion is spaced closer to a second of the two mandrel parts then are upper and lower areas of the first mandrel part, and the second mandrel part has an outer shape which is closer to straight, such that the second mandrel part can be initially removed from the shear tube. The first mandrel part can be moved away from a bowed surface on an inner periphery of the shear tube such that the first mandrel part can then be removed.

[0007] In another embodiment according to any of the previous embodiments, the mandrel body has grooves on an outer surface to facilitate the movement of gas during a densification process of the CMC yarns and fabric layers.

[0008] In another embodiment according to any of the previous embodiments, the mandrel shape further has a twist along a radial length of the at least two mandrel parts.

[0009] In another embodiment according to any of the previous embodiments, the interfitting of the at least two mandrel parts is provided by a tongue and groove connection between the first and second mandrel parts.

[0010] In another embodiment according to any of the previous embodiments, edges of each of the first and second mandrel parts are formed with chamfers to allow turning of one of the first and second mandrel parts relative to the other to facilitate removal of the one of the first and second mandrel parts.

[0011] In another embodiment according to any of the previous embodiments, the mandrel shape further has a twist along a radial length of the at least two mandrel parts.

[0012] In another embodiment according to any of the previous embodiments, edges of each of the two mandrel parts are formed with chamfers to allow turning of one of the two mandrel parts relative to the other to facilitate removal of the one of the first and second mandrel parts.

[0013] In another featured embodiment, a method of forming a gas turbine engine component having a airfoil includes the steps of providing a mandrel formed of at least two mandrel parts. A shear tube is formed on an outer surface of the at least two parts of the mandrel by placing a ceramic matrix composites (“CMC”) yarn on an outer surface of the at least two mandrel parts. Additional CMC fabric layers are formed on the shear tube to form the airfoil. The CMC fabric layers and yarn then begin to be densified. One of the two mandrel parts is removed. Then the other

of the two mandrel parts is removed.
[0014] In another embodiment according to any of the previous embodiments, a first of the two mandrel parts has a bowed profile such that a central portion is spaced closer to a second of the two mandrel parts then are upper and lower areas of the first mandrel part, and the second mandrel part has an outer shape which is closer to straight, and the second mandrel part being the one initially removed from the shear tube. The first mandrel part is then moved away from a bowed surface on an inner periphery of the shear tube, and the first mandrel part then is the other removed part.
[0015] In another embodiment according to any of the previous embodiments, the mandrel body has grooves on an outer surface to facilitate movement of gas during the densification step of the CMC yarns and fabric layers.
[0016] In another embodiment according to any of the previous embodiments, the mandrel shape further has a twist along a radial length of the at least two mandrel parts.
[0017] In another embodiment according to any of the previous embodiments, the first and second mandrel parts have a tongue and groove connection.
[0018] In another embodiment according to any of the previous embodiments, edges of each of the first and second mandrel parts are formed with chamfers to allow turning of one of the two mandrel parts relative to the other to facilitate removal of the second mandrel part.
[0019] In another embodiment according to any of the previous embodiments, the mandrel body has grooves on an outer surface to facilitate movement of gas during the densification step of the CMC yarns and fabric layers.
[0020] In another embodiment according to any of the previous embodiments, the mandrel shape further has a twist along a radial length of the at least two mandrel parts.
[0021] In another embodiment according to any of the previous embodiments, the at least two mandrel parts have a tongue and groove connection.
[0022] In another embodiment according to any of the previous embodiments, edges of each of the two mandrel parts are formed with chamfers to allow turning of one of the at least two mandrel parts relative to the other to facilitate removal of the one of the two mandrel parts.
[0023] In another embodiment according to any of the previous embodiments, the at least two mandrel parts have a tongue and groove connection.
[0024] In another embodiment according to any of the previous embodiments, edges of each of the at least two mandrel parts formed with chamfers to allow turning of one of the at least two mandrel parts relative to the other to facilitate removal of the one of the two mandrel parts.
[0025] The present disclosure may include any one or more of the individual features disclosed above and/or below alone or in any combination thereof.
[0026] 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
[0027] FIG. **1** schematically shows a gas turbine engine.
[0028] FIG. **2** schematically shows a turbine section.
[0029] FIG. **3**A shows a vane which may be utilized in the turbine section of FIG. **2**.
[0030] FIG. **3**B is a cross-section through the FIG. **3**A vane.
[0031] FIG. **4** shows a mandrel and shear tube.
[0032] FIG. **5**A is a perspective view of a mandrel.
[0033] FIG. **5**B shows a two part mandrel separated.
[0034] FIG. **6**A shows a first step in removing the FIG. **5**A/B mandrel.
[0035] FIG. **6**B shows a feature of the airfoil.

[0036] FIG. **6**C is a step subsequent to FIG. **6**A.
[0037] FIG. **6**D shows a step subsequent to the FIG. **6**C step.
[0038] FIG. **7**A shows another embodiment mandrel.
[0039] FIG. **7**B shows a step in removing the FIG. **7**A mandrel which may be in addition to the steps of FIGS. **6**A-**6**C.

DETAILED DESCRIPTION

[0040] 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.
[0041] 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.
[0042] 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.
[0043] 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**.

[0044] 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.

[0045] 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**.

[0046] 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.

[0047] 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.

[0048] 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 1 bm of fuel being burned divided by 1 bf 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.

[0049] “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).

[0050] 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.

[0051] 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.

[0052] 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.

[0053] FIG. **2** schematically shows a turbine section **100** having a pair of spaced rotating turbine blades **102**. An intermediate static vane **104** is shown having an outer platform **106**, an inner platform **108** and an intermediate airfoil **110**. As known, the airfoil **110** extends between a leading edge **114** and a trailing edge **112**.

[0054] FIG. **3**A is a view of the vane **104**. There is a pressure side and a suction side. The airfoil **110** merges into both of the platforms **106** and **108** along each of the pressure side and the suction side and around the leading edge **114** and the trailing edge **112**. As shown a radially central portion **219** is bowed relative to radially inner and outer areas at the leading edge **114**.

[0055] The vane **104** is formed of layers of ceramic matrix composite fabric plies.

[0056] A CMC material 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 (Si3N4) 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 (Si3N4) 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 (Si3N4).

[0057] This disclosure relates to a method of forming a vane such as vane **104**.

[0058] FIG. **3**B shows the airfoil **110**. The airfoil has a shear tube **124** received in a hollow chamber **117** adjacent leading edge **114**. Another shear tube **124** is in a chamber **119** spaced further from the leading edge **114** than the chamber **117**. Outer fabric layers **118** are positioned outwardly of the shear tubes **124**.

[0059] As shown in FIG. **4** at **120**, a mandrel **122** may be formed of graphite, and provides a shape upon which to form a shear tube **124**. The shear tube **124** may be formed of braided CMC yarn.

[0060] As shown in FIG. **5**A, the mandrel **122** is formed of two parts **126** and **128**. The part **126** has a groove **132** and the part **128** has a tongue **130**. Of course, any number of other interfitting structure may be utilized. Grooves **133** are formed on an outer surface to facilitate densification.

[0061] As shown in FIG. **5**B, the parts **126** and **128** can be separated.

[0062] As shown in FIG. **6**A, the mandrel **122** with parts **126** and **128** is used as a base to form the shear tube **124** with a braided machine. Then, outer structure is formed from fabric layers **118** to form the airfoil. The inner and outer platforms **106**/**108** are also attached of the vane **104**.

[0063] As shown in this Figure, one face **134** of the mandrel, and thus the shear tube **124** has a distinctive curve, bend or bow such that upper **201** and lower ends **200** are spaced further away from a central portion **135** to form central bow **219**. On the other hand, outer face **136** of the half **126** is closer to straight.

[0064] It could be said a first of the two mandrel parts **128** has a bowed profile such that a central portion **135** is spaced closer to a second of the mandrel parts **126** then are upper **201** and lower ends **200** of the first mandrel part **128**. The second mandrel part **126** has an outer shape **136** which is closer to straight, such that the second mandrel part **136** can be initially removed from the shear tube, and the first mandrel part **128** can then be moved away from a bowed surface on an inner periphery of the shear tube **128** such that the first mandrel part can be removed.

[0065] After the formation of the fabric layers **118** on the shear tube **124**, the vane **104** is densified, as known. The grooves **133** facilitate the movement of the densification gasses into an inner surface of the shear tube **124**. The mandrel **122** must then be removed. As can be appreciated, the central portion **135** would raise a challenge with removing the combined mandrel **126**/**128** upwardly or

radially outwardly as shown in this FIG. **6**A.
[0066] 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.
[0067] FIG. **6**B shows that the airfoil outer periphery changes its orientation in a radial distance such as shown at X and Y. This further complicates removal of the mandrel **122**.
[0068] However, due to the two part mandrel **122**, as shown in FIG. **6**C, the mandrel half **126** with the flatter outer face **136** can be simply removed upwardly and out of the shear tube **124**.
[0069] Now, as show in FIG. **6**D, the mandrel half **128** can be moved to the right in this figure and then can then be easily removed. Due to the extra space from the removal of the mandrel half **136** the shape of face **134** does not provide any challenge to the removal.
[0070] As shown in FIG. **7**A, another embodiment mandrel **148** also has two parts **150** and **152**. However, edges of the two parts **150** and **152** are formed as chamfered surfaces **154** and **156**.
[0071] Now, as shown in FIG. **7**B, when removing the mandrel part **152** it can be rocked on the tongue and groove connection **130**/**132** such that one chamfered surface **156** on part **152** moves into a chamfered surface **154** on the part **150**. The other chamfered surface **156** moves away from the other chamfered surface **154** on the part **150**. This may facilitate movement of the part **152** outwardly of the shear tube.
[0072] Chamfered surfaces **154** and **156** also facilitate the movement of densification gases during densification, similar to grooves **133**.
[0073] A mandrel under this disclosure could be said to include a mandrel body upon which to build ceramic matrix composite ("CMC") yarns to provide a shear tube for building up an airfoil from CMC fabric layers. The mandrel body is formed of at least two mandrel parts interfitting to define a desired shape for the shear tube, and such that after formation of the airfoil the at least two parts of the mandrel body can be separately removed from the shear tube in order to facilitate removal.
[0074] A method of forming a gas turbine engine component having an airfoil under this disclosure could be said to include the steps of providing a mandrel formed of at least two mandrel parts. A shear tube is formed on an outer surface of the at least two parts of the mandrel by placing a ceramic matrix composites ("CMC") yarn on an outer surface of the at least two mandrel parts. Additional CMC fabric layers are formed on the shear tube to form the airfoil. The CMC fabric layers and yarn then begin to be densified. One of the two mandrel parts is removed. Then the other of the two mandrel parts is removed.
[0075] 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 mandrel comprising: a mandrel body upon which to build ceramic matrix composite ("CMC") yarns to provide a shear tube for building up an airfoil from CMC fabric layers; and the mandrel body formed of at least two mandrel parts interfitting to define a desired shape for the shear tube, and such that after formation of the airfoil the at least two parts of the mandrel body can be separately removed from the shear tube in order to facilitate removal.
2. The mandrel as set forth in claim 1, wherein a first of the two mandrel parts has a bowed profile such that a central portion is spaced closer to a second of the two mandrel parts then are upper and lower areas of the first mandrel part, and the second mandrel part has an outer shape which is closer to straight, such that the second mandrel part can be initially removed from the shear tube, and the first mandrel part can be moved away from a bowed surface on an inner periphery of the

shear tube such that the first mandrel part can then be removed.
3. The mandrel as set forth in claim 2, wherein the mandrel body having grooves on an outer surface to facilitate the movement of gas during a densification process of the CMC yarns and fabric layers.
4. The mandrel as set forth in claim 2, wherein the mandrel shape further having a twist along a radial length of the at least two mandrel parts.
5. The mandrel as set forth in claim 2, wherein the interfitting of the at least two mandrel parts is provided by a tongue and groove connection between the first and second mandrel parts.
6. The mandrel as set forth in claim 2, wherein edges of each of the first and second mandrel parts formed with chamfers to allow turning of one of the first and second mandrel parts relative to the other to facilitate removal of the one of the first and second mandrel parts.
7. The mandrel as set forth in claim 1, wherein the mandrel shape further having a twist along a radial length of the at least two mandrel parts.
8. The mandrel as set forth in claim 1, wherein edges of each of the two mandrel parts formed with chamfers to allow turning of one of the two mandrel parts relative to the other to facilitate removal of the one of the first and second mandrel parts.
9. A method of forming a gas turbine engine component having a airfoil including the steps of: providing a mandrel formed of at least two mandrel parts; forming a shear tube on an outer surface of the at least two parts of the mandrel by placing a ceramic matrix composites (“CMC”) yarn on an outer surface of the at least two mandrel parts; forming additional CMC fabric layers on the shear tube to form the airfoil; beginning densifying the CMC fabric layers and yarn; removing one of the two mandrel parts; and then removing the other of the two mandrel parts.
10. The method as set forth in claim 9, wherein a first of the two mandrel parts has a bowed profile such that a central portion is spaced closer to a second of the two mandrel parts then are upper and lower areas of the first mandrel part, and the second mandrel part has an outer shape which is closer to straight, and the second mandrel part being the one initially removed from the shear tube, and the first mandrel part then moved away from a bowed surface on an inner periphery of the shear tube, and the first mandrel part then being the other removed part.
11. The method as set forth in claim 10, wherein the mandrel body having grooves on an outer surface to facilitate movement of gas during the densification step of the CMC yarns and fabric layers.
12. The method as set forth in claim 10, wherein the mandrel shape further having a twist along a radial length of the at least two mandrel parts.
13. The method as set forth in claim 10, wherein the first and second mandrel parts have a tongue and groove connection.
14. The method as set forth in claim 10, wherein edges of each of the first and second mandrel parts formed with chamfers to allow turning of one of the two mandrel parts relative to the other to facilitate removal of the second mandrel part.
15. The method as set forth in claim 9, wherein the mandrel body having grooves on an outer surface to facilitate movement of gas during the densification step of the CMC yarns and fabric layers.
16. The method as set forth in claim 9, wherein the mandrel shape further having a twist along a radial length of the at least two mandrel parts.
17. The method as set forth in claim 16, wherein the at least two mandrel parts have a tongue and groove connection.
18. The method as set forth in claim 17, wherein edges of each of the two mandrel parts formed with chamfers to allow turning of one of the at least two mandrel parts relative to the other to facilitate removal of the one of the two mandrel parts.
19. The method as set forth in claim 9, wherein the at least two mandrel parts have a tongue and groove connection.

20. The method as set forth in claim 19, wherein edges of each of the at least two mandrel parts formed with chamfers to allow turning of one of the at least two mandrel parts relative to the other to facilitate removal of the one of the two mandrel parts.