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HIGH PRESSURE TURBINE BLADE DOUBLE SCARF CUT

Abstract

A turbine blade includes a root section extending from a bottom side of a platform. The root section includes a first end and a second end aft of the first end. A first plurality of serrations is formed on a pressure side of the root section. A second plurality of serrations is formed on a suction side of the root section. Each serration of the second plurality of serrations extends on the suction side from the first end to the second end of the root section. A first scarf cut is formed on each serration of the second plurality of serrations such that each serration of the second plurality of serrations is tapered at the first end of the root section.

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Background/Summary

BACKGROUND

[0001] The present disclosure relates to gas turbine engines, and in particular, to turbine rotor blades.

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

[0003] The turbine section includes turbine vanes to guide and direct the high-speed exhaust gas flow across turbine rotor blades in the turbine section. As the high-speed exhaust gas flow across the turbine rotor blades, the high-speed exhaust gas flow rotates the rotor blades to power the compressor section and/or the fan section. The turbine rotor blades are generally attached to a disk. The disk includes attachment grooves that each include a fir-tree pattern that is shaped to receive a fir-tree shaped attachment root of a turbine rotor blade. During operation of the turbine section, stress can build up between the attachment roots of the turbine rotor blades and the attachment grooves of the disk, causing wear on the disk and reducing the operation life of the disk.

SUMMARY

[0004] In one example, a turbine blade includes a platform with a top side and a bottom side opposite the top side. An airfoil section extends from the top side of the platform to a tip of the turbine blade. A root section is connected to a bottom side of the platform and includes an attachment body extending from a forward end to an aft end. A first plurality of serrations is formed on a pressure side of the attachment body. Each serration of the first plurality of serrations extends straight on the pressure side of the attachment body from the aft end toward the forward end of the attachment body. A second plurality of serrations is formed on a suction side of the attachment body. Each serration of the second plurality of serrations extends straight in a first direction on the suction side from the aft end toward the forward end of the attachment body. The first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the attachment body. An angled surface is formed on the suction side of the attachment body adjacent to the forward end. The angled surface extends along each serration of the second plurality of serrations and is angled toward the pressure side relative to the first direction as the angled surface extends toward the forward end.

[0005] In another example, a turbine blade includes a platform with a top side and a bottom side opposite the top side. An airfoil section extends from the top side of the platform to a tip of the turbine blade. A root section extends from the bottom side of the platform. The root section includes a first end and a second end aft of the first end relative to a flow direction of the turbine blade. A first plurality of serrations is formed on a pressure side of the root section. Each serration of the first plurality of serrations extends on the pressure side of the root section from the first end to the second end of the root section. A second plurality of serrations is formed on a suction side of the root section. Each serration of the second plurality of serrations extends on the suction side from the first end to the second end of the root section. The first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the root section. A first scarf cut is formed on the suction side of the root section and extends aft from the first end toward the second end of the root section. The first scarf cut is formed on each serration of the second plurality of serrations such that each serration of the second plurality of serrations is tapered at the first end of the root section.

[0006] In yet another example, a turbine blade includes a platform comprising a top side and a bottom side opposite the top side. An airfoil section extends from the top side of the platform to a tip of the turbine blade. A root section is connected to a bottom side of the platform. The root section includes an attachment body extending from a forward end to an aft end. A first plurality of serrations is formed on a pressure side of the attachment body. Each serration of the first plurality of serrations extends on the pressure side of the attachment body from the forward end to the aft end of the attachment body. A second plurality of serrations is formed on a suction side of the

attachment body. Each serration of the second plurality of serrations extends on the suction side from the forward end to the aft end of the attachment body. The first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the attachment body. Each serration of the second plurality of serrations is tapered at the forward end.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a partial cross-sectional view of a gas turbine engine.

[0008] FIG. **2** is a cross-sectional view of a turbine section of the gas turbine engine of FIG. **1**.

[0009] FIG. **3** is a perspective view of a turbine blade from the turbine section of FIG. **2**.

[0010] FIG. **4** is a perspective view of a root section of the turbine blade from FIG. **3**.

[0011] FIG. **5** is another perspective view of the root section of the turbine blade from FIG. **4** with a platform and blade removed.

[0012] FIG. **6** is a front elevation view of the root section of the turbine blade from FIG. **4**.

[0013] FIG. **7**A is a stress diagram of an attachment groove of a rotor disk showing stress concentrations in the rotor disk caused by a root section of a traditional turbine blade.

[0014] FIG. **7**B is a stress diagram of an attachment groove of a rotor disk showing stress concentrations in the rotor disk caused by the root section of the turbine blade of FIG. **6**.

[0015] While the above-identified drawing figures set forth one or more embodiments of the invention, other embodiments are also contemplated. In all cases, this disclosure presents the invention by way of representation and not limitation. It should be understood that numerous other modifications and embodiments can be devised by those skilled in the art, which fall within the scope and spirit of the principles of the invention. The figures may not be drawn to scale, and applications and embodiments of the present invention may include features and components not specifically shown in the drawings. Like reference numerals identify similar structural elements.

DETAILED DESCRIPTION

[0016] This disclosure relates to a turbine blade with a scarf cut formed on a suction side of the root section of the turbine blade adjacent to a forward end of the root section. The root section includes a fir-tree shape profile with a first plurality of serrations on a pressure side of the root section and a second plurality of serrations on the suction side of the root section. The scarf cut creates an angled surface on each serration of the second plurality of serrations that extends aftward on the suction side from the forward end of the root section. The root section of the turbine blade is installed into the attachment grooves of a rotor disk of a gas turbine engine. The scarf cuts on the blade reduce and distribute the contact pressure concentration on the disk that is imparted from the blade at the forward end of the disk attachment, which increases the operational life of the rotor disk. The turbine blade with the scarf cut on the suction side of the root section is discussed below with reference to the figures.

[0017] FIG. **1** is a cross-sectional view that schematically illustrates example gas turbine engine **20** that includes fan section **22**, compressor section **24**, combustor section **26** and turbine section **28**. Fan section **22** drives air along bypass flowpath B while compressor section **24** draws air in along core flowpath C where air is compressed and communicated to combustor section **26**. In combustor section **26**, air is mixed with fuel and ignited to generate a high-pressure exhaust gas stream that expands through turbine section **28** where energy is extracted and utilized to drive fan section **22** and compressor section **24**.

[0018] Although the disclosed non-limiting embodiment depicts a turbofan gas turbine engine, it should be understood that the concepts described herein are not limited to use with turbofans as the teachings may be applied to other types of turbine engines; for example, an industrial gas turbine; a reverse-flow gas turbine engine; and a turbine engine including a three-spool architecture in which three spools concentrically rotate about a common axis and where a low spool enables a low-pressure turbine to drive a fan via a gearbox, an intermediate spool that enables an intermediate pressure turbine to drive a first compressor of the compressor section, and a high spool that enables a high-pressure turbine to drive a high-pressure compressor of the compressor section.

[0019] The example gas turbine engine **20** generally includes low speed spool **30** and high speed spool **32** mounted for rotation about center axis A of gas turbine engine **20** relative to 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.

[0020] Low speed spool **30** generally includes inner shaft **40** that connects fan **42** and low-pressure (or first) compressor section **44** to low-pressure (or first) turbine section **46**. Inner shaft **40** drives fan **42** through a speed change device, such as geared architecture **48**, to drive fan **42** at a lower speed than low speed spool **30**. High-speed spool **32** includes outer shaft **50** that interconnects high-pressure (or second) compressor section **52** and high-pressure (or second) turbine section **54**. Inner shaft **40** and outer shaft **50** are concentric and rotate via bearing systems **38** about center axis A.

[0021] Combustor **56** is arranged between high-pressure compressor **52** and high-pressure turbine section **54**. In one example, high-pressure turbine section **54** includes at least two stages to provide double stage high-pressure turbine section **54**. In another example, high-pressure turbine section **54** includes only a single stage. As used herein, a “high-pressure” compressor or turbine experiences a higher pressure than a corresponding “low-pressure” compressor or turbine. The example low-pressure turbine section **46** has a pressure ratio that is greater than about **5**. The pressure ratio of the example low-pressure turbine section **46** is measured prior to an inlet of low-pressure turbine section **46** as related to the pressure measured at the outlet of low-pressure turbine section **46** prior to an exhaust nozzle.

[0022] Mid-turbine frame **58** of engine static structure **36** can be arranged generally between high-pressure turbine section **54** and low-pressure turbine section **46**. Mid-turbine frame **58** further supports bearing systems **38** in turbine section **28** as well as setting airflow entering the low-pressure turbine section **46**. Mid-turbine frame **58** includes vanes **60**, which are in the core flowpath and function as inlet guide vanes for low-pressure turbine section **46**.

[0023] The gas flow in core flowpath C is compressed first by low-pressure compressor **44** and then by high-pressure compressor **52**. The gas flow in core flowpath C is then mixed with fuel and ignited in combustor **56** to produce high speed exhaust gases that are then expanded through high-pressure turbine section **54** and low-pressure turbine section **46**. As discussed below with reference to FIG. **2**, high-pressure turbine section **54** and low-pressure turbine section **46** include turbine vanes to guide the gas flow through high-pressure turbine section **54** and low-pressure turbine section **46** and include turbine blades that are worked and rotated by the gas flow.

[0024] FIG. **2** is a cross-sectional view of high-pressure turbine section **54** of gas turbine engine **20** of FIG. **1**. As shown in FIG. **2**, high-pressure turbine section **54** includes vane stage **62**, rotor stage **64**, case **66**, and blade outer air seal (BOAS) **68**. Vane stage **62** includes vanes **70**, with each of vanes **70** including airfoil section **72** extending between inner platform **74** and outer platform **76** to define a portion of core flowpath C. Rotor stage **64** includes turbine blades **78** connected to rotor disk **80**. Rotor stage **64** can also include forward retaining plate **81***a* and aft retaining plate **81***b*. Each of turbine blades **78** includes root section **82**, platform **84**, airfoil section **86**, and tip **88**. Rotor disk **80** includes forward side **83**, aft side **85**, forward retaining hook **87**, aft retaining hook **89**, seat **90**, and a plurality of attachment grooves AG (shown in phantom). An axial direction X and a radial direction Y are shown in FIG. **2**. The axial direction X is parallel to center axis A and the radial direction Y extends radially outward from the axial direction X.

[0025] In the example of FIG. **2**, vane stage **62** is axially forward and upstream from rotor stage **64** and guides and conditions the gas flow in core flowpath C before the gas flow reaches rotor stage **64**. The plurality of attachment grooves AG are formed in rotor disk **80** such that the plurality of attachment grooves AG are circumferentially space apart from each about center axis A. Each turbine blade **78** is connected to rotor disk **80** by mating root section **82** with one of attachment grooves AG such that turbine blades **78** are circumferentially arrayed about rotor disk **80** and center axis A. Forward retaining hook **87** is formed on forward side **83** of rotor disk **80**, and aft retaining hook **89** is formed on aft side **85** of rotor disk **80**. The forward retaining plate **81***a* can be mounted into forward retaining hook **87** and seat **90**. Aft retaining plate **81***b* can be mounted into aft retaining hook **89**. Together, forward retaining plate **81***a* and aft retaining plate **81***b* axially lock each turbine blade **78** into one of attachment grooves AG formed in rotor disk **80**. Platform **84** for each turbine blade **78** is connected to root section **82** and forms a radially inner flowpath surface for core flowpath C across rotor stage **64**. Airfoil section **86** on each turbine blade **78** extends radially outward from platform **84** to tip **88**. BOAS **68** is spaced radially outward from tip **88** of each turbine blade **78** and extends circumferentially about rotor stage **64** and center axis A. BOAS **68** forms a radially outer flowpath surface for core flowpath C across rotor stage **64**. Case **66** is a stationary structure that extends circumferentially around vane stage **62** and rotor stage **64** and supports vane stage **62** and BOAS **68**. While high-pressure turbine section **54** is shown in FIG. **2** has having a single vane stage **62** and a single rotor stage **64**, high-pressure turbine section **54** can have multiple rotor stages **64** and multiple vane stages **62**. Low-pressure turbine section **46** can also include multiple rotor stages **64** and multiple vane stages **62**.

[0026] FIG. **3** is a perspective view of turbine blade **78** from rotor stage **64** of FIG. **2**. As previously noted above with reference to FIG. **2**, turbine blade **78** includes root section **82**, platform **84**, airfoil section **86**, and tip **88**. Airfoil section **86** of turbine blade **78** includes leading edge **91**, trailing edge **92**, pressure surface **94**, and suction surface **96**. Root section **82** and/or platform **84** form base **98** of turbine blade **78**. Root section includes forward end **100** and aft end **102**.

[0027] Top side **84***a* of platform **84** forms an inner endwall flow surface of turbine blade **78**. Bottom side **84***b* is opposite top side **84***a* in the radial direction Y and is outside of core flowpath C. Root section **82** is connected to bottom side **84***b* and extends downward from bottom side **84***b* of platform **84**. Root section **82** extends aftward from forward end **100** to aft end **102**. As shown in FIG. **3**, root section **82** can be a fir-tree shaped root for connecting turbine blade **78** to rotor disk **80**. Root section **82** and/or platform **84** can form base **98** of turbine blade **78**.

[0028] Tip **88** of turbine blade **78** is radially outward from base **98** in the radial direction Y. Airfoil section **86** extends from top side **84***a* of platform **84** to tip **88** of turbine blade **78**. Leading edge **91** extends radially outward from top side **84***a* of platform **84** in the radial direction Y to tip **88**. Trailing edge **92** also extends radially outward from top side **84***a* of platform **84** to tip **88** and is aft of leading edge **91** in the axial direction X.

[0029] Pressure side **94** is a generally concave surface of airfoil section **86** that extends from leading edge **91** to trailing edge **92** and also extends from top side **84***a* of platform **84** to tip **88**. Suction side **96** is a generally convex surface of airfoil section **86** that extends from leading edge **91** to the trailing edge **92** and extends from top side **84***a* of platform **84** to tip **88**. Suction side **96** is opposite pressure side **94** in a circumferential direction Z, the circumferential direction Z generally being a direction of rotation of turbine blade **78** about center axis A of gas turbine engine **20** of FIG. **1**.

[0030] FIGS. **4-6** will be discussed concurrently. FIG. **4** is a perspective view of root section **82** of turbine blade **78**. FIG. **5** is another perspective view of root section **82** of turbine blade **78** with platform **84** removed for better viewing of root section **82**. FIG. **6** is a front elevation view of root section **82** of turbine blade **78** that allows a better view of pressure side PS compared to FIGS. **4** and **5**. As shown in FIGS. **4-6**, root section **82** further includes neck **104** and attachment body **106**. Attachment body **106** includes pressure side PS, suction side SS, first edge **108**, second edge **110**, a first plurality of serrations **112**, a second plurality of serrations **114**, first scarf cut **116**, first angled surface **117**, second scarf cut **118**, and second angled surface **119**. As shown best in FIGS. **4** and **5**, attachment body **106** also includes first length L**1**, second length L**2**, third length L**3**, and fourth length L**4**. First direction D**1** is also shown in FIGS. **4-6**. First direction D**1** defines a dimension that is parallel to root section **82** as root section **82** extends from forward end **100** to aft end **102**.

[0031] Attachment body **106** and neck **104** together form root section **82**. Neck **104** connects attachment body **106** to platform **84**. Attachment body **106** extends from forward end **100** to aft end **102** in first direction D**1**. Pressure side PS of attachment body **106** is on a same side of turbine blade **78** as pressure surface **94**. Suction side SS of attachment body **106** is on a same side of turbine blade **78** as suction surface **96**. First edge **108** forms a top edge of attachment body **106** on pressure side PS. Second edge **110** forms a top edge of attachment body **106** on suction side SS. In the example of FIGS. **4-6**, first edge **108** and second edge **110** can both extend parallel to first direction D**1** from aft end **102** toward forward end **100**.

[0032] The first plurality of serrations **112** is formed on pressure side PS of attachment body **106**. Each serration **112** of the first plurality of serrations **112** forms a lobe that extends outward from pressure side PS in a direction or dimension that is transverse to the first direction D**1**. Each serration **112** of the first plurality of serrations **112** also extends from forward end **100** to aft end **102** of attachment body **106**. Together, serrations **112** of the first plurality of serrations **112** form an undulating and wave-like pattern on pressure side PS of attachment body **106** that extends from first edge **108** to a bottom end of attachment body **106**. In the example of FIGS. **4-6**, each serration **112** of the first plurality of serrations **112** extends straight on pressure side PS of attachment body **106** from aft end **102** toward forward end **100**.

[0033] The second plurality of serrations **114** is formed on suction side SS of attachment body **106**. Each serration **114** of the second plurality of serrations **114** forms a lobe that extends outward from suction side SS in a direction or dimension that is transverse to the first direction D**1**. Each serration **114** of the second plurality of serrations **114** also extends from forward end **100** to aft end **102** of attachment body **106**. Together, serrations **114** of the second plurality of serrations **114** form an undulating and wave-like pattern on suction side SS of attachment body **106** that extends from second edge **110** to the bottom end of attachment body **106**. In the example of FIG. **4**, each serration **114** of the second plurality of serrations **114** extends straight on suction side SS of attachment body **106** from aft end **102** toward forward end **100**. The first plurality of serrations **112** and the second plurality of serrations **114** together form a fir-tree shaped profile of attachment body **106** when viewed from forward end **100** or aft end **102**. Each of the attachment grooves AG of rotor disk **80** (shown in FIG. **2**) can also include a fir-tree shaped profile that mates with the fir-tree shaped profile of attachment body **106** when turbine blade **78** is assembled onto rotor disk **80**.

[0034] First scarf cut **116** is formed on suction side SS of attachment body **106** of root section **82** adjacent to forward end **100**. First scarf cut **116** forms first angled surface **117** that extends aft from forward end **100** toward aft end **102**. As shown in FIGS. **4-6**, first scarf cut **116** and first angled surface **117** are formed on each serration **114** of the second plurality of serrations **114** such that each serration **114** of the second plurality of serrations **114** is tapered at forward end **100**. First angled surface **117** of first scarf cut **116** is angled toward pressure side SS relative to the first direction D**1** as first angled surface **117** extends toward forward end **100**.

[0035] As shown best in FIGS. **4** and **5**, each serration **114** of the second plurality of serrations **114** extends straight in the first direction D**1** from aft end **102** to first scarf cut **116**. Suction side SS of attachment body **106** and each serration **114** on suction side SS includes first length L**1**. First length L**1** is the distance suction side SS and serrations **114** extend from forward end **100** to aft end **102** in the first direction D**1**. First angled surface **117** of first scarf cut **116** includes second length L**2**. Second length L**2** is the distance that first angled surface **117** extends in the first direction D**1** from forward end **100** toward aft end **102**. A ratio (L**2**/L**1**) of second length L**2** to first length L**1** is at least 0.05 and no greater than 0.08. In the example of FIGS. **4-6**, first length L**1** is 1.517 inches (3.853 cm), second length L**2** is 0.1 inches (0.254 cm), and the ratio (L**2**/L**1**) of the second length L**2** to the first length L**1** is 0.065.

[0036] As shown in FIG. **5**, first angled surface **117** of first scarf cut **116** is angled toward pressure side PS at a first angle A**1**. First angle A**1** has a value of at least 6 degrees and no greater than 10 degrees relative to the first direction D**1**. In the example of FIGS. **4-6**, first angled surface **117** is angled toward pressure side PS such that first angle A**1** has a value of 8 degrees relative to the first direction D**1**.

[0037] Second scarf cut **118** is formed on pressure side PS of attachment body **106** of root section **82** adjacent to forward end **100**. Second scarf cut **118** forms second angled surface **119** that extends aft from forward end **100** toward aft end **102**. Second scarf cut **118** and second angled surface **119** are formed on each serration **112** of the first plurality of serrations **112** such that each serration **112** of the first plurality of serrations **112** is tapered at forward end **100**. Second angled surface **119** of second scarf cut **118** is angled toward suction side SS relative to the first direction D**1** as second angled surface **119** extends toward forward end **100**.

[0038] Each serration **112** of the first plurality of serrations **112** extends straight in the first direction D**1** from aft end **102** to second scarf cut **118**. Pressure side PS of attachment body **106** and each serration **112** on pressure side PS includes third length L**3**. Third length L**3** is the distance pressure side PS and serrations **112** extend from forward end **100** to aft end **102** in the first direction D**1**. In the example of FIGS. **4-6**, the third length L**3** can be equal in length in the first direction D**1** to first length L**1** of suction side SS. Second angled surface **119** of second scarf cut **118** includes fourth length L**4**. Fourth length L**4** is the distance that second angled surface **119** extends in the first direction D**1** from forward end **100** toward aft end **102**. A ratio (L**4**/L**3**) of fourth length L**4** to third length L**3** is at least 0.05 and no greater than 0.08. In the example of FIGS. **4-6**, third length L**3** is 1.517 inches (3.853 cm), fourth length L**4** is 0.1 inches (0.254 cm), and the ratio (L**4**/L**3**) of the fourth length L**4** to the third length L**3** is 0.065.

[0039] Second angled surface **119** of second scarf cut **118** is angled toward suction side SS at a second angle A**2**. Second angle A**2** has a value of at least 8 degrees and no greater than 10 degrees relative to the first direction D**1**. In the example of FIGS. **4-6**, second angled surface **119** is angled toward suction side SS such that second angle A**2** has a value of 10 degrees relative to the first direction D**1**. As discussed below with reference to FIGS. **7**A and **7**B, the above-described first scarf cut **116** with first angled surface **117** and the above-described second scarf cut **118** with second angled surface **119** helps reduce stress concentrations between each turbine blade **78** and rotor disk **80**, which increases operational life of rotor disk **80**.

[0040] FIG. **7**A is a stress diagram of one of attachment grooves AG of rotor disk **80** showing stress concentrations in rotor disk **80** caused by a root section of a traditional turbine blade. FIG. **7**B is a stress diagram of one of attachment grooves AG of rotor disk **80** showing stress concentrations in rotor disk **80** caused by root section **82** of turbine blade **78** of FIGS. **4-6**. Both FIG. **7**A and **7**B show a side profile of one side of attachment groove AG. As shown in FIGS. **7**A and **7**B, each side of attachment groove AG of rotor **80** includes first lobe **120**A, second lobe **120**B, and third love **120**C. Attachment groove AG also includes first fillet **121**A, second fillet **121**B, and third fillet **121**C. Lobes **120**A-**120**C alternate with fillets **121**A-**121**C to form a fir-tree profile that can mate with attachment body **106** of root section **82** of turbine blade **78**. No turbine blades are shown in FIGS. **7**A and **7**B to allow a clear view of attachment groove AG.

[0041] When a turbine blade without first scarf cut **116** and without second scarf cut **118** is installed in attachment groove AG of rotor disk **80** and rotated by gas flow, centrifugal loads between the turbine blade and rotor disk **80** can cause stress concentration SCI to develop in rotor disk **80** at forward side **83** in second fillet **121**B between second lobe **120**B and third lobe **120**C. Stress concentration SC**1** shown in FIG. **7**A is high enough to reduce the operational life of rotor disk **80**.

[0042] Including first scarf cut **116** and second scarf cut **118** onto attachment body **106** of root section **82** helps reduce stress concentrations in rotor disk **80**, as shown in FIG. **7**B. When attachment body **106** is installed in attachment groove AG of rotor disk **80** and when turbine blade **78** and rotor disk **80** are both rotated by the gas flow passing through high-pressure turbine section

54 (shown in FIG. **1**), centrifugal loads between turbine blade **78** and rotor disk **80** can cause stress concentration SC**2** to develop in rotor disk **80**. The contact between rotor disk **80** and attachment body **106** of turbine blade **78** is completely removed by the first scarf cut **116** and second scarf cut **118** at the forward end of attachment body **106**. The lack of contact due to the scarf cuts helps to redistribute load in attachment groove AG aftward, which helps flatten and decrease stress concentration SCI in comparison to stress concentration SCI shown in FIG. **7**A. Stress concentration SC**2** is sufficiently flattened and distributed in comparison to stress concentration SC**1** of FIG. **7** that the material and geometry of rotor disk **80** can handle stress concentration SC**2** without cracking or wearing prematurely.

Discussion of Possible Embodiments

[0043] The following are non-exclusive descriptions of possible embodiments of the present invention.

[0044] A turbine blade includes a platform with a top side and a bottom side opposite the top side. An airfoil section extends from the top side of the platform to a tip of the turbine blade. A root section is connected to a bottom side of the platform and includes an attachment body extending from a forward end to an aft end. A first plurality of serrations is formed on a pressure side of the attachment body. Each serration of the first plurality of serrations extends straight on the pressure side of the attachment body from the aft end toward the forward end of the attachment body. A second plurality of serrations is formed on a suction side of the attachment body. Each serration of the second plurality of serrations extends straight in a first direction on the suction side from the aft end toward the forward end of the attachment body. The first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the attachment body. An angled surface is formed on the suction side of the attachment body adjacent to the forward end. The angled surface extends along each serration of the second plurality of serrations and is angled toward the pressure side relative to the first direction as the angled surface extends toward the forward end.

[0045] The turbine blade of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components in the paragraphs below.

[0046] In an embodiment of the foregoing turbine blade, the angled surface formed on the suction side of the attachment body is angled toward the pressure side at an angle of at least 6 degrees and no greater than 10 degrees relative to the first direction.

[0047] In an embodiment of the foregoing turbine blade, the angled surface formed on the suction side of the attachment body is angled toward the pressure side at an angle of 8 degrees relative to the first direction.

[0048] In an embodiment of the foregoing turbine blade, the suction side comprises a first length in the first direction and the angled surface comprises a second length in the first direction, wherein a ratio of the second length to the first length is at least 0.05 and no greater than 0.08.

[0049] In an embodiment of the foregoing turbine blade, the ratio of the second length to the first length is 0.065.

[0050] In an embodiment of the foregoing turbine blade, the root section further comprises a second angled surface formed on the pressure side of the attachment body adjacent to the forward end, wherein the second angled surface extends along each serration of the first plurality of serrations, and wherein the second angled surface is angled toward the suction side relative to the first direction as the second angled surface extends toward the forward end.

[0051] In an embodiment of the foregoing turbine blade, the second angled surface formed on the pressure side of the attachment body is angled toward the suction side at an angle of at least 8 degrees and no greater than 10 degrees relative to the first direction.

[0052] In an embodiment of the foregoing turbine blade, the second angled surface formed on the pressure side of the attachment body is angled toward the suction side at an angle of 10 degrees relative to the first direction.

[0053] In an embodiment of the foregoing turbine blade, the pressure side comprises a third length in the first direction and the second angled surface comprises a fourth length in the first direction, wherein a ratio of the fourth length to the third length is at least 0.05 and no greater than 0.08.
[0054] In an embodiment of the foregoing turbine blade, the ratio of the fourth length to the third length is 0.065.
[0055] A turbine blade includes a platform with a top side and a bottom side opposite the top side. An airfoil section extends from the top side of the platform to a tip of the turbine blade. A root section extends from the bottom side of the platform. The root section includes a first end and a second end aft of the first end relative to a flow direction of the turbine blade. A first plurality of serrations is formed on a pressure side of the root section. Each serration of the first plurality of serrations extends on the pressure side of the root section from the first end to the second end of the root section. A second plurality of serrations is formed on a suction side of the root section. Each serration of the second plurality of serrations extends on the suction side from the first end to the second end of the root section. The first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the root section. A first scarf cut is formed on the suction side of the root section and extends aft from the first end toward the second end of the root section. The first scarf cut is formed on each serration of the second plurality of serrations such that each serration of the second plurality of serrations is tapered at the first end of the root section.
[0056] The turbine blade of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components in the paragraphs below.
[0057] In an embodiment of the foregoing turbine blade, each serration of the second plurality of serrations extends straight in a first direction from the second end to the first scarf cut.
[0058] In an embodiment of the foregoing turbine blade, the first scarf cut is angled toward the pressure side at an angle of at least 6 degrees and no greater than 10 degrees relative to the first direction.
[0059] In an embodiment of the foregoing turbine blade, the first scarf cut is angled toward the pressure side at an angle of 8 degrees relative to the first direction.
[0060] In an embodiment of the foregoing turbine blade, the suction side comprises a first length in the first direction and the first scarf cut comprises a second length in the first direction, wherein a ratio of the second length to the first length is at least 0.05 and no greater than 0.08.
[0061] In an embodiment of the foregoing turbine blade, the ratio of the second length to the first length is 0.065.
[0062] In an embodiment of the foregoing turbine blade, the root section further comprises a second scarf cut formed on the pressure side of the root section and extending aft from the first end toward the second end of the root section, wherein the second scarf cut is formed on each serration of the first plurality of serrations such that each serration of the first plurality of serrations is tapered at the first end of the root section.
[0063] In an embodiment of the foregoing turbine blade, each serration of the first plurality of serrations extends straight on the pressure side from the second end to the second scarf cut, and wherein the second scarf cut is angled toward the suction side at an angle of 10 degrees relative to the first direction.
[0064] In an embodiment of the foregoing turbine blade, the pressure side comprises a third length in the first direction and the second angled surface comprises a fourth length in the first direction, wherein a ratio of the fourth length to the third length is 0.065.
[0065] A turbine blade includes a platform comprising a top side and a bottom side opposite the top side. An airfoil section extends from the top side of the platform to a tip of the turbine blade. A root section is connected to a bottom side of the platform. The root section includes an attachment body extending from a forward end to an aft end. A first plurality of serrations is formed on a pressure side of the attachment body. Each serration of the first plurality of serrations extends on the

pressure side of the attachment body from the forward end to the aft end of the attachment body. A second plurality of serrations is formed on a suction side of the attachment body. Each serration of the second plurality of serrations extends on the suction side from the forward end to the aft end of the attachment body. The first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the attachment body. Each serration of the second plurality of serrations is tapered at the forward end.

[0066] While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A turbine blade comprising: a platform comprising a top side and a bottom side opposite the top side; an airfoil section extending from the top side of the platform to a tip of the turbine blade; and a root section connected to a bottom side of the platform, wherein the root section comprises: an attachment body extending from a forward end to an aft end; a first plurality of serrations formed on a pressure side of the attachment body, wherein each serration of the first plurality of serrations extends straight on the pressure side of the attachment body from the aft end toward the forward end of the attachment body; a second plurality of serrations formed on a suction side of the attachment body, wherein each serration of the second plurality of serrations extends straight in a first direction on the suction side from the aft end toward the forward end of the attachment body, wherein the first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the attachment body; and an angled surface formed on the suction side of the attachment body adjacent to the forward end, wherein the angled surface extends along each serration of the second plurality of serrations, and wherein the angled surface is angled toward the pressure side relative to the first direction as the angled surface extends toward the forward end.

2. The turbine blade of claim 1, wherein the angled surface formed on the suction side of the attachment body is angled toward the pressure side at an angle of at least 6 degrees and no greater than 10 degrees relative to the first direction.

3. The turbine blade of claim 2, wherein the angled surface formed on the suction side of the attachment body is angled toward the pressure side at an angle of 8 degrees relative to the first direction.

4. The turbine blade of claim 3, wherein the suction side comprises a first length in the first direction and the angled surface comprises a second length in the first direction, wherein a ratio of the second length to the first length is at least 0.05 and no greater than 0.08.

5. The turbine blade of claim 4, wherein the ratio of the second length to the first length is 0.065.

6. The turbine blade of claim 5, wherein the root section further comprises: a second angled surface formed on the pressure side of the attachment body adjacent to the forward end, wherein the second angled surface extends along each serration of the first plurality of serrations, and wherein the second angled surface is angled toward the suction side relative to the first direction as the second angled surface extends toward the forward end.

7. The turbine blade of claim 6, wherein the second angled surface formed on the pressure side of the attachment body is angled toward the suction side at an angle of at least 8 degrees and no greater than 10 degrees relative to the first direction.

8. The turbine blade of claim 7, wherein the second angled surface formed on the pressure side of the attachment body is angled toward the suction side at an angle of 10 degrees relative to the first direction.

9. The turbine blade of claim 8, wherein the pressure side comprises a third length in the first direction and the second angled surface comprises a fourth length in the first direction, wherein a ratio of the fourth length to the third length is at least 0.05 and no greater than 0.08.

10. The turbine blade of claim 9, wherein the ratio of the fourth length to the third length is 0.065.

11. A turbine blade comprising: a platform comprising a top side and a bottom side opposite the top side; an airfoil section extending from the top side of the platform to a tip of the turbine blade; and a root section extending from the bottom side of the platform, wherein the root section comprises: a first end; a second end aft of the first end relative to a flow direction of the turbine blade; a suction side of the root section extending from the first end to the second end; a pressure side of the root section extending from the first end to the second end of the root section; a first scarf cut formed on the suction side and extending aft from the first end toward the second end of the root section, wherein the first scarf cut is angled toward the pressure side as the first scarf cut extends toward the first end; a second scarf cut formed on the pressure side and extending aft from the first end toward the second end of the root section, wherein the second scarf cut is angled toward the suction side as the second scarf cut extends toward the first end; a first plurality of serrations formed on the pressure side of the root section, wherein each serration of the first plurality of serrations extends on the pressure side of the root section from the first end to the second end of the root section; and a second plurality of serrations formed on the suction side of the root section, wherein each serration of the second plurality of serrations extends on the suction side from the first end to the second end of the root section, and wherein the first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the root section.

12-19. (canceled)

20. A turbine blade comprising: a platform comprising a top side and a bottom side opposite the top side; an airfoil section extending from the top side of the platform to a tip of the turbine blade; and a root section connected to a bottom side of the platform, wherein the root section comprises: an attachment body extending from a forward end to an aft end; a first plurality of serrations formed on a pressure side of the attachment body, wherein each serration of the first plurality of serrations extends on the pressure side of the attachment body from the forward end to the aft end of the attachment body, and wherein each serration of the first plurality of serrations is tapered at the forward end toward a suction side; and a second plurality of serrations formed on the suction side of the attachment body, wherein each serration of the second plurality of serrations extends on the suction side from the forward end to the aft end of the attachment body, wherein the first plurality of serrations and the second plurality of serrations form a fir-tree shaped profile of the attachment body, and wherein each serration of the second plurality of serrations is tapered at the forward end toward the pressure side.

21. The turbine blade of claim 11, wherein the suction side extends straight in a first direction from the second end to the first scarf cut.

22. The turbine blade of claim 21, wherein the first scarf cut is angled toward the pressure side at an angle of at least 6 degrees and no greater than 10 degrees relative to the first direction.

23. The turbine blade of claim 22, wherein the first scarf cut is angled toward the pressure side at an angle of 8 degrees relative to the first direction.

24. The turbine blade of claim 23, wherein the suction side comprises a first length in the first direction and the first scarf cut comprises a second length in the first direction, wherein a ratio of the second length to the first length is at least 0.05 and no greater than 0.08.

25. (canceled)

26. The turbine blade of claim 24, wherein a pressure surface extends straight from the second end to the second scarf cut, and wherein the second scarf cut is angled toward the suction side at an angle of 10 degrees relative to the first direction.

27. The turbine blade of claim 26, wherein the pressure side comprises a third length in the first direction and the second scarf cut comprises a fourth length in the first direction, wherein a ratio of the fourth length to the third length is 0.065.

28. (canceled)