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(54) **MODULAR TURBINE BLADE WITH SEPARATE PLATFORM SUPPORT SYSTEM**

(71) Applicant: **Siemens Energy, Inc.**, Orlando, FL (US)

(72) Inventors: **Samuel R. Miller, JR.**, Port St. Lucie, FL (US); **Darryl Eng**, Stuart, FL (US); **Christian Xavier Campbell**, Charlotte, NC (US)

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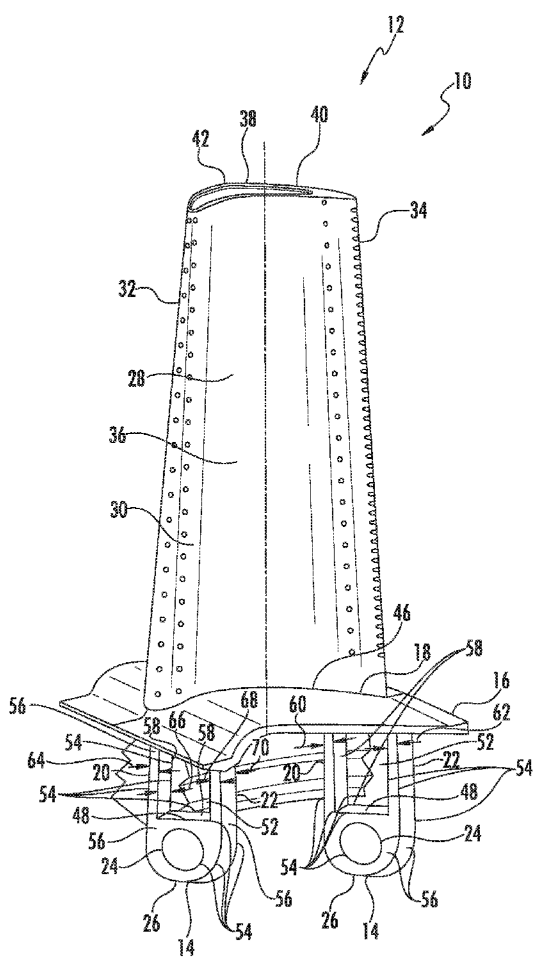
(57) **ABSTRACT**

A modular turbine blade assembly (**10**) usable in a gas turbine engine (**12**) and formed from an airfoil (**28**) and an independent, modular platform (**16**) supported by one or more clevis arm supports (**14**) extending radially inward from the modular platform (**16**) to a disk is disclosed. The clevis arm support may support the modular platform while a separate dovetail attachment supports the generally hollow airfoil. The clevis arm support (**14**) may be formed from at least two arms (**20**, **22**) designed to reduce stress from a pin receiving orifice (**24**) at a distal end (**26**) of the two arms (**20**, **22**) to the platform (**16**). The independent arms (**20**, **22**) minimize stress concentrations caused by centrifugal loading in the support. The arms (**20**, **22**) may be modified independently of each other, such as thickness and support angle. The clevis arm support (**14**) enables use of a modular platform system for the modular turbine blade (**10**).



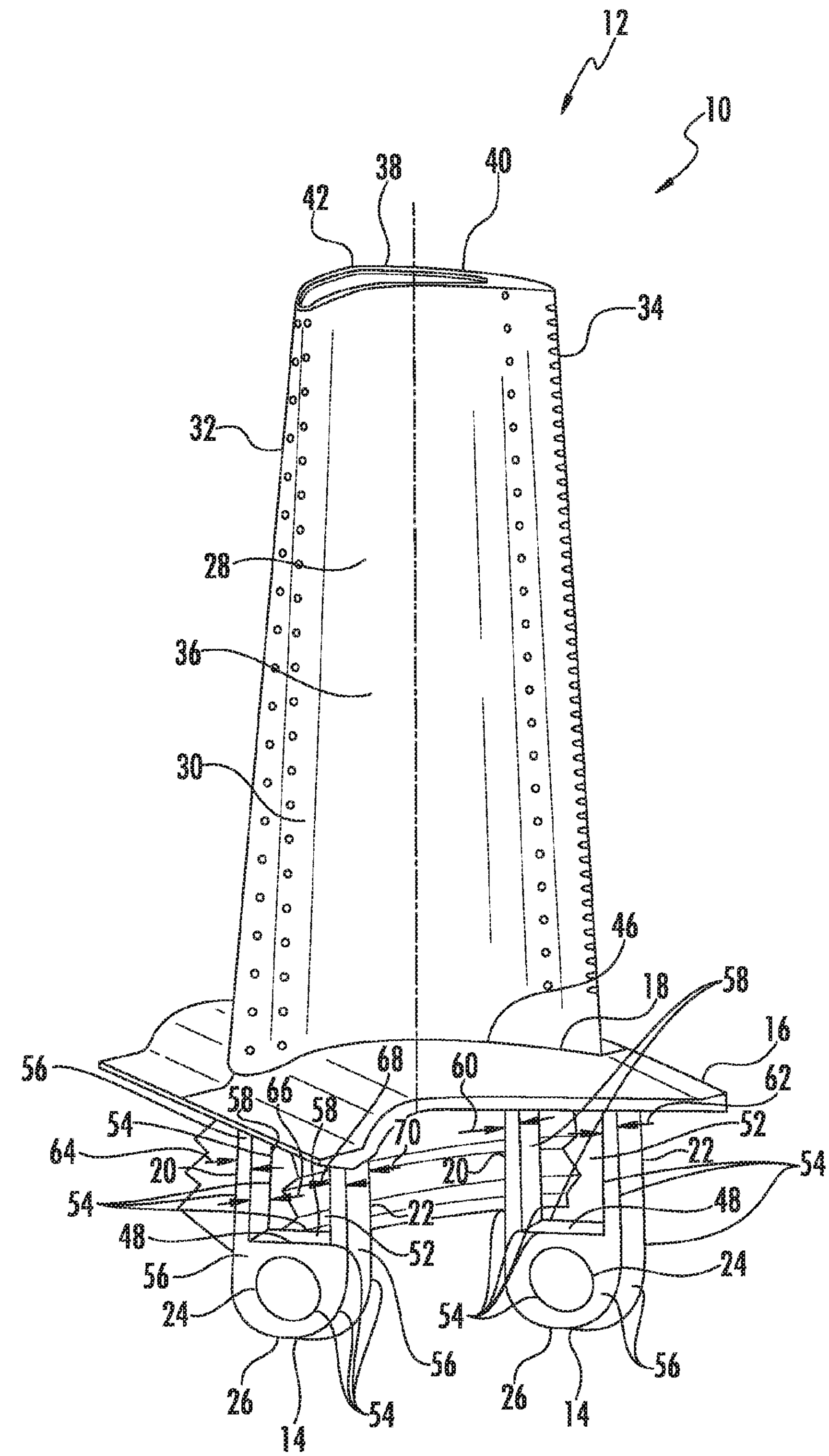

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FIG. 1

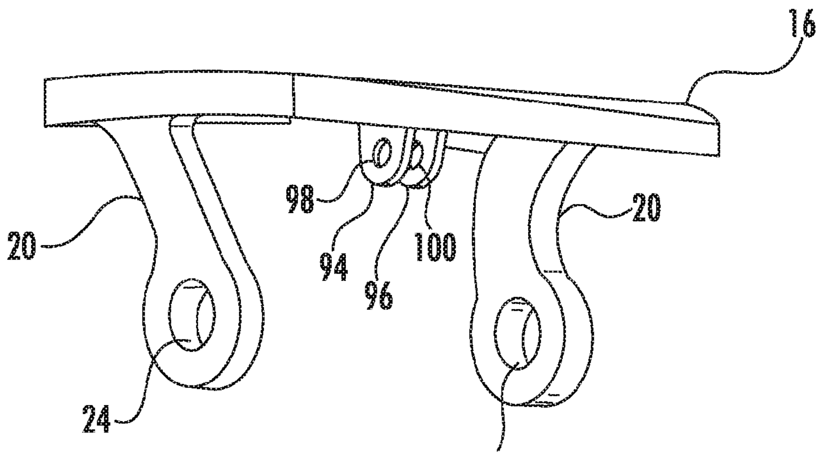
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FIG. 2

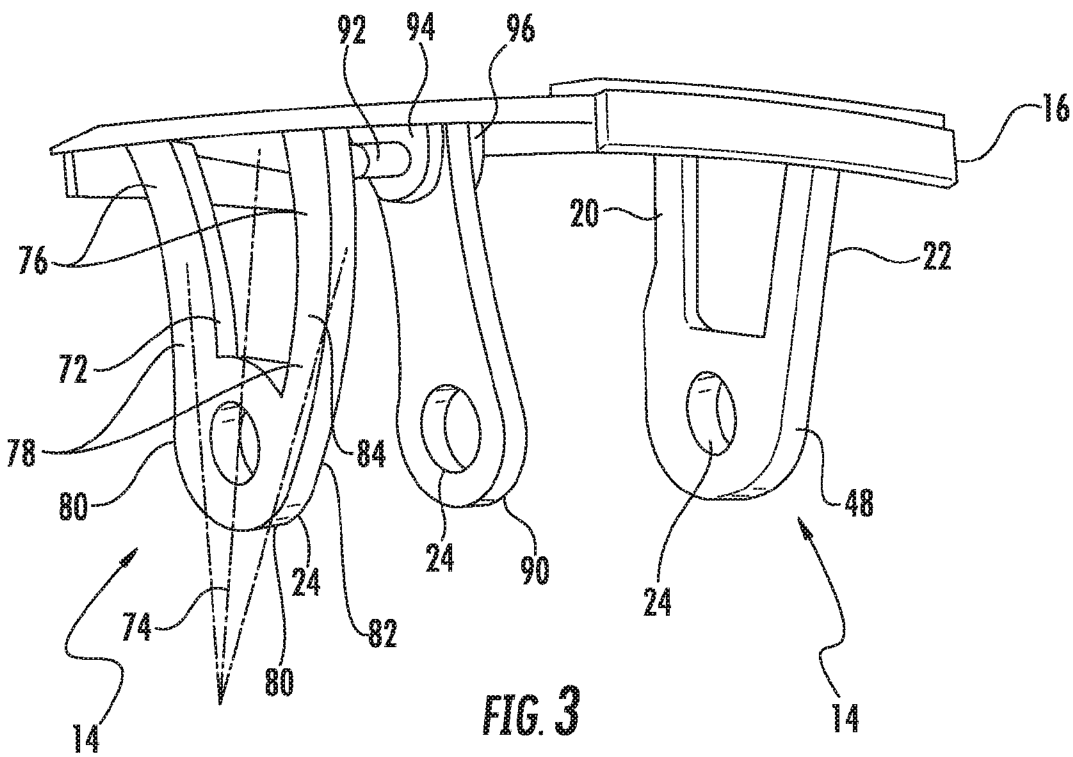
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FIG. 3

MODULAR TURBINE BLADE WITH SEPARATE PLATFORM SUPPORT SYSTEM

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0001] Development of this invention was supported in part by the United States Department of Energy, Advanced Turbine Development Program, Contract No. DE-FC26-05NT42644. Accordingly, the United States Government may have certain rights in this invention.

FIELD OF THE INVENTION

[0002] This invention is directed generally to turbine airfoils, and more particularly to support systems in turbine airfoils in gas turbine engines.

BACKGROUND

[0003] Typically, gas turbine engines include a compressor for compressing air, a combustor for mixing the compressed air with fuel and igniting the mixture, and a turbine blade assembly for producing power. Combustors often operate at high temperatures that may exceed 2,240 degrees Fahrenheit. Typical turbine combustor configurations expose turbine blade assemblies to these high temperatures. As a result, turbine blades must be made of materials capable of withstanding such high temperatures. In addition, turbine blades often contain cooling systems for prolonging the life of the blades and reducing the likelihood of failure as a result of excessive temperatures.

[0004] Typically, turbine blades are formed from a root portion having a platform at one end and an elongated portion forming a blade that extends outwardly from the platform coupled to the root portion. The blade is ordinarily composed of a tip opposite the root section, a leading edge, and a trailing edge. The inner aspects of most turbine blades typically contain an intricate maze of cooling channels forming a cooling system. Turbine airfoils are often supported via a root having multiple dovetail projections extending therefrom for attachment to a rotor. Alternative configurations of a support and connection system have been employed.

SUMMARY OF THE INVENTION

[0005] A modular turbine blade assembly usable in a gas turbine engine and formed from an airfoil and an independent, modular platform supported by one or more clevis arm supports extending radially inward from the modular platform to a disk is disclosed. The clevis arm support may support the modular platform while a separate dovetail attachment supports the generally hollow airfoil. The clevis arm support may be formed from one or more arms, such as, but not limited to, two arms, a first and second arm, that may be independently modified to reduce stress at an attachment device at a distal end of the two arms. In at least one embodiment, the attachment device may be a pin receiving orifice. The independent arms may be contoured for assembly between blades and designed to minimize stresses along clevis arm features. At attachment locations, one or more pin receiving orifices may be included at distal ends of the two arms.

[0006] The modular turbine blade for a gas turbine engine may be formed from a generally elongated hollow airfoil formed from an outer wall, and having a leading edge, a trailing edge, a pressure side, a suction side, and a tip at a first end of the airfoil. The clevis arm support may support the modular platform while a separate dovetail attachment supports the generally hollow airfoil. The modular turbine blade may also include one or more modular platforms attached to a disc via clevis arm supports extending radially inward from the modular platform. The clevis arm support may be formed from a first arm and a second arm extending from the modular platform into contact with each other radially inward of the modular platform. A cross member may extend between the first and second arms forming an attachment device, such as, but not limited to, a pin receiving orifice radially inward of the cross member and between the first and second arms and forming a void between the cross member, the first arm, the second arm and the modular platform. In at least one embodiment, inner surfaces of the first arm, the second arm and the cross member may be planar inner surfaces.

[0007] The first and second arms may reduce stress at the pin receiving orifice at a distal end of the two arms. The clevis arm support may reduce stress in a number of ways. In particular, the first and second arms may be nonorthogonal and nonparallel to each other. The first arm may be positioned at a different angle relative to a longitudinal axis of the at least one clevis arm support than the second arm. One or more intersections of two or more sides forming the cross member, the first arm, and the second arm may be rounded. In another embodiment, each of the intersections of two or more sides forming the cross member, the first arm, and the second arm may be rounded. A thickness of the first arm may differ from a thickness of the second arm. The first arm may have a cross-sectional area with a width that is greater than a length, and the second arm may have a cross-sectional area with a width that is greater than a length. The first ends of the first and second arms closest to the generally elongated hollow airfoil may be further apart than second ends of the first and second arms at the cross member. A distal end of the cross member may be curved from a first side aligned with the first arm to a second side aligned with the second arm.

[0008] During assembly, the center link may be pinned at the platform and may be rotated around and between the airfoil into the disk, which helps facilitate the installation and alignment with the pin, pin receiving orifices and disk holes. During operation, the first and second clevis arms and pin inherently provide the ability to rotate along the pin axis through the pin receiving orifices to load the modular platform against the pressure side of the generally elongated hollow airfoil for sealing and vibratory dampening. For servicing or assembly, or both, the modular turbine blade assembly provides a configuration that makes the option of removing or replacing the platform, or both, while the blade remains attached in place in turbine engine possible. This feature is very beneficial in that the modular turbine blade assembly provides a lower cost replacement in contrast to repairing and replacing a full blade during service intervals.

[0009] An advantage of the modular platform is the ability to improve the castability of the airfoil by minimizing overhang features, which is primarily for single crystal airfoils. The platform can utilize a less challenging casting method such as directional/non directional solidification or single crystal if warranted.

[0010] Another advantage of the modular turbine blade assembly is that the pin and clevis hole arrangement provides the ability to be sized to achieve sufficient pin and clevis arm bearing area while minimizing stress within the hole. The features of the modular turbine blade assembly can be easily controlled during the manufacturing process to create close tolerances between the pin and holes in the clevis arms.

[0011] Yet another advantage of this the clevis arm support is that the clevis arm support may be formed from at least two arms, a first and second arm, that may be independently modified to reduce stress at a pin receiving orifice at a distal end of the two arms.

[0012] Another advantage of the clevis arm support is that the independent arms minimize stress concentrations caused by centrifugal loading through the support.

[0013] Still another advantage of the clevis arm support is that the support enables mass reduction to be achieved through use of the first and second arms of the clevis arm support relative to conventional attachments.

[0014] These and other embodiments are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The accompanying drawings, which are incorporated in and form a part of the specification, illustrate embodiments of the presently disclosed invention and, together with the description, disclose the principles of the invention.

[0016] FIG. **1** is a perspective view of a modular turbine blade having features according to the instant invention.

[0017] FIG. **2** is a perspective view of the clevis arm support of the modular turbine blade.

[0018] FIG. **3** is a perspective view of the clevis arm support of the modular turbine blade.

DETAILED DESCRIPTION OF THE INVENTION

[0019] As shown in FIGS. **1-3**, a modular turbine blade assembly **10** usable in a gas turbine engine **12** and formed from an airfoil **28** and an independent, modular platform **16** supported by one or more clevis arm supports **14** extending radially inward from the modular platform **16** to a disk is disclosed. The clevis arm support **14** may support the modular platform **16** while a separate dovetail attachment supports the generally hollow airfoil **28**. The clevis arm support **14** may be formed from one or more arms, such as, but not limited to, two arms, a first arm **20** and second arm **22**, that may be independently modified to reduce stress at an attachment device **24** at a distal end **26** of the two arms **20**, **22**. The independent arms **20**, **22** may be contoured for assembly between blades **28** and designed to minimize stresses along clevis arm **20**, **22** features. The independent arms **20**, **22** minimize stress concentrations caused by centrifugal loading through the support **14**. The arms **20**, **22** may be modified independently of each other, by modifying elements such as thickness and support angle. With the airfoil **28** being attached to a disc separately from the modular platform **16**, the modular platform **16** may be removed and replaced without removing the airfoil **28**.

[0020] In at least one embodiment, as shown in FIG. **1**, the modular turbine blade **10** may be formed from a generally elongated hollow airfoil **28** formed from an outer wall **30**, and having a leading edge **32**, a trailing edge **34**, a pressure side **36**, a suction side **38** and a tip **40** at a first end **42** of the airfoil **28**. The clevis arm support **14** may support the modular platform **16** while a separate dovetail attachment supports the generally hollow airfoil **28**. A modular platform **16** may be positioned at a second end **46** opposite to the first end **42** and may be supported by one or more clevis arm supports **14**, as shown in FIGS. **1-3**, extending radially inward from the modular platform **16**. In at least one embodiment, as shown in FIG. **2**, each clevis arm support **14** may include a first arm **20** sized to support the attachment device **24**, which, in at least one embodiment, may be a pin receiving orifice **24**. The first arm **20** may be formed from any appropriate configuration such as, but not limited to, an "I" beam profile. The pin receiving orifice **24** may have any appropriate size and configuration, such as, but not limited to, tubular.

[0021] In at least one embodiment, as shown in FIG. **3**, the modular turbine blade **10** may include two clevis arm supports **14** per modular platform **16**. The clevis arm support **14** may be formed from a first arm **20** and a second arm **22** extending from the modular platform **16** into contact with each other radially inward of the modular platform **16**. The clevis arm support **14** may be formed from any appropriate material capable of adequately supporting the modular platform **16** and withstanding the high temperatures, vibrations and other elements. A cross member **48** may extend between the first and second arms **20**, **22** forming a pin receiving orifice **24** radially inward of the cross member **48** and between the first and second arms **20**, **22** forming a void **52** between the cross member **48**, the first arm **20**, the second arm **22** and the modular platform **16**. The inner surfaces **58** of the first arm **20**, the second arm **22** and the cross member **48** may be planar inner surfaces **58**. In at least one embodiment, the first ends **76** of the first and second arms **20**, **22** closest to the generally elongated hollow airfoil **28** may be further apart than second ends **78** of the first and second arms **20**, **22** at the cross member **48**. A distal end **80** of the cross member **48** may be curved from a first side **80** aligned with the first arm **20** to a second side **82** aligned with the second arm **22**.

[0022] The first and second arm **20**, **22**, may reduce stress at the pin receiving orifice **24** at a distal end **26** of the two arms **20**, **22**. The clevis arm support **14** may reduce stress in a number of ways. In at least one embodiment, one or more intersections **54** of two or more sides **56** forming the cross member **48**, the first arm **20**, and the second arm **22** is rounded. In another embodiment, each of the intersections **54** of two or more sides **56** forming the cross member **48**, the first arm **20**, and the second arm **22** is rounded.

[0023] The first and second arm **20**, **22**, may also reduce stress at the pin receiving orifice **24** at a distal end **26** of the two arms **20**, **22** in other ways. In particular, a thickness **60** of the first arm **20** may differ from a thickness **62** of the second arm **22**. The length of the first and second arms **20** and **22** may be varied as well to reduce stress and to enable proper positioning of the pin receiving orifice **24**. The first arm **20** may have a cross-sectional area with a width **64** that is greater than a length **66**, and the second arm **22** may have a cross-sectional area with a width **68** that is greater than a length **70**. The first and second arms **20**, **22** may be nonorthogonal and nonparallel to each other. In particular, the first arm **20** may be positioned at a different angle **72** relative to a longitudinal axis **74** of the clevis arm support **14** than an angle **84** of the second arm **22** relative to the longitudinal axis **74**.

[0024] The modular platform **16** may also include a center link **90** extending radially inward. The center link **90** may include one or more pin receiving orifices **24**, one of which may be positioned near a distal end **26**. The center link **90** may be positioned between the first and second arms **20**, **22**. The center link **90** may be coupled to the modular platform **16** via a pivot connection. The center link **90** may be attached to the modular platform **16** via a pivot connection formed from a pin **92** extending through a hole in the center link **90** and attached to arms **94**, **96** via holes **98**, **100** therein. The pin **92** enables the center link **90** to pivot around the blade **28** during installation and removal and enable minor platform circumferential differences. The center link **90** may be used for assembly and support of the center of the modular platform **16** from centrifugal loading. The center link **90** may assist in minimizing platform deflections between the first and second clevis arms **20**, **22** to enable the center link **90** to fit around the airfoil contour because the center of the modular platform **16** is near the blade mid-chord, which limits clevis access.

[0025] During assembly, the center link **90** may be pinned at the platform and may be rotated around and between the airfoil **28** into the disk, which helps facilitate the installation and alignment with the pin, pin receiving orifices **24** and disk holes. During operation, the first and second clevis arms **20**, **22** and pin inherently provide the ability to rotate along the pin axis through the pin receiving orifices **24** to load the modular platform **16** against the pressure side **36** of the generally elongated hollow airfoil **28** for sealing and vibratory dampening. For servicing or assembly, or both, the modular turbine blade assembly **10** provides a configuration that makes the option of removing or replacing the platform, or both, while the blade remains attached in place in turbine engine possible. This feature is very beneficial in that the modular turbine blade assembly **10** provides a lower cost replacement in contrast to repairing and replacing a full blade during service intervals.

[0026] The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of this invention. Modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of this invention.

1. A modular turbine blade (**10**) of a gas turbine engine comprising:

a generally elongated hollow airfoil formed from an outer wall, and having a leading edge, a trailing edge, a pressure side, a suction side, and a tip at a first end of the airfoil; and

a modular platform attached to a disc via at least one clevis arm support extending radially inward from the modular platform, wherein the at least one clevis arm support is formed from a first arm and a second arm extending from the modular platform into contact with each other radially inward of the modular platform, wherein a cross member extends between the first and second arms forming an attachment device radially inward of the cross member and between the first and second arms and forming a void between the cross member, the first arm, the second arm and the modular platform.

2. The modular turbine blade of claim **1**, wherein the attachment device is a pin receiving orifice.

3. The modular turbine blade of claim **1**, wherein at least one intersection of two or more sides forming the cross member, the first arm, and the second arm is rounded.

4. The modular turbine blade of claim **1**, wherein inner surfaces of the first arm, the second arm and the cross member are planar inner surfaces.

5. The modular turbine blade of claim **1**, wherein a thickness of the first arm differs from a thickness of the second arm.

6. The modular turbine blade of claim **1**, wherein the first arm has a cross-sectional area with a width that is greater than a length, and the second arm has a cross-sectional area with a width that is greater than a length.

7. The modular turbine blade of claim **1**, wherein the first and second arms are nonorthogonal and nonparallel to each other.

8. The modular turbine blade of claim **7**, wherein the first arm is positioned at a different angle relative to a longitudinal axis of the at least one clevis arm support than the second arm.

9. The modular turbine blade of claim **1**, wherein first ends of the first and second arms closest to the generally elongated hollow airfoil are further apart than second ends of the first and second arms at the cross member.

10. The modular turbine blade of claim **1**, wherein a distal end of the cross member is curved from a first side aligned with the first arm to a second side aligned with the second arm.

11. The modular turbine blade of claim **1**, further wherein a center link extending radially inward from the modular platform and positioned between the first and second arms.

12. The modular turbine blade of claim **11**, wherein the center link is coupled to the modular platform via a pivot connection.

* * * * *