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(54) FABRICATED TURBINE AIRFOIL

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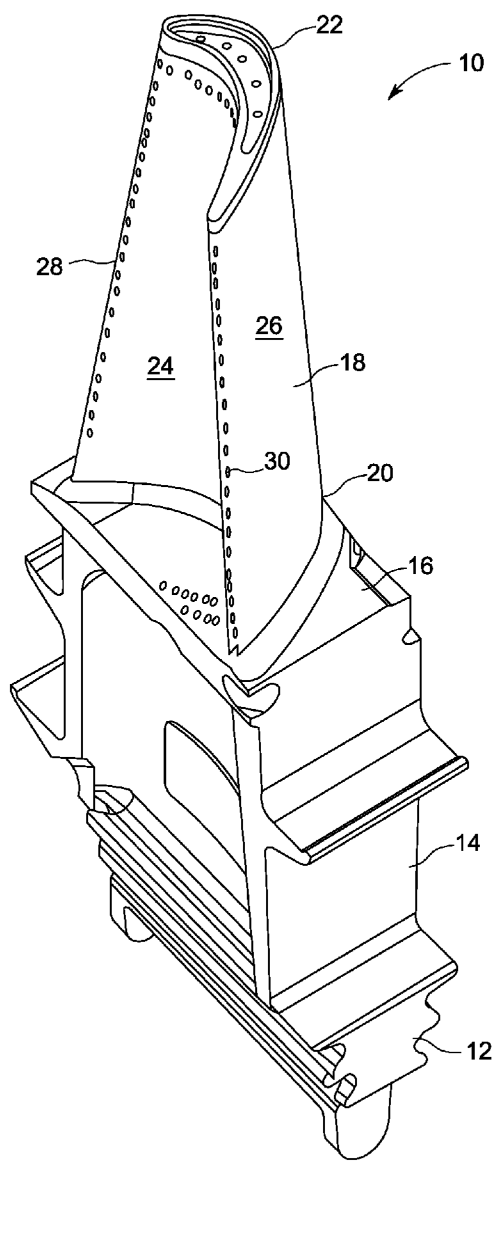
(57) ABSTRACT

The invention provides an apparatus and method for combining materials having different thermal and mechanical properties into an article, such as a gas turbine bucket, which includes a first section, a second section, and a third section; wherein the first section provides structural support for the remaining sections, the second section is integrally joined with the first section, and the third section connects the first and second sections.



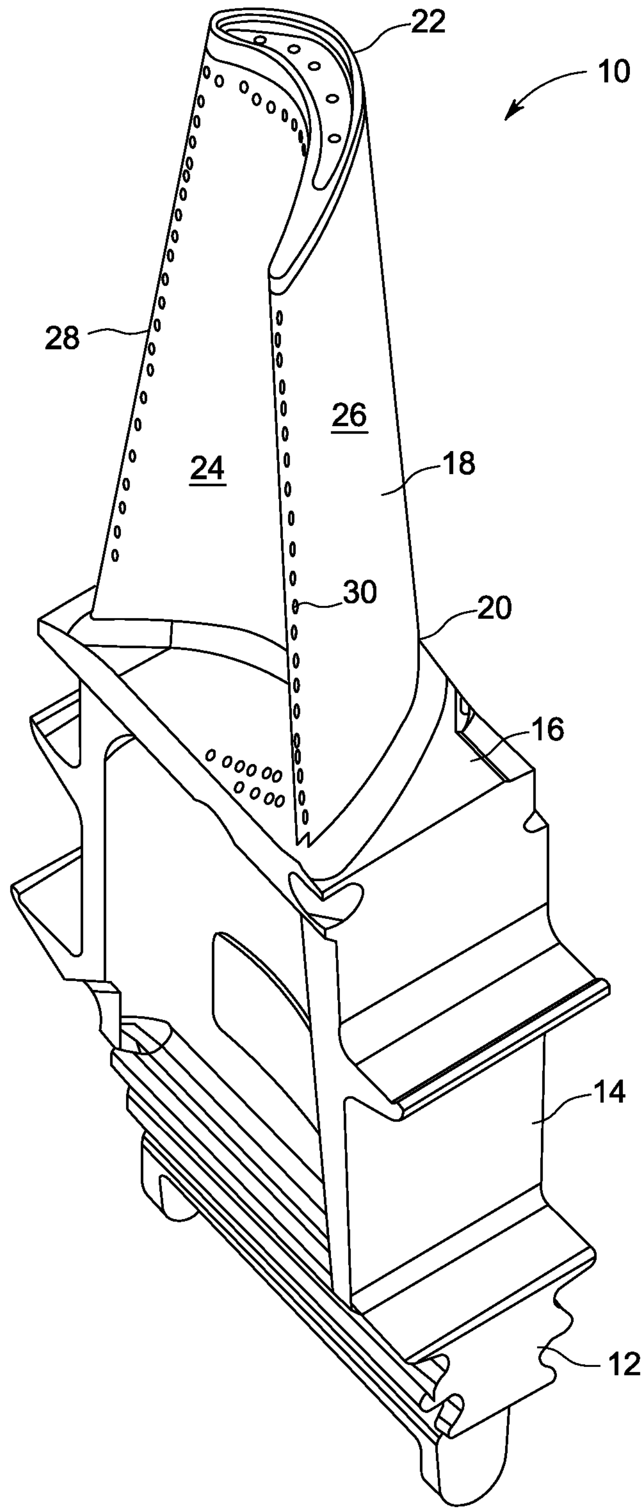



FIG. 1

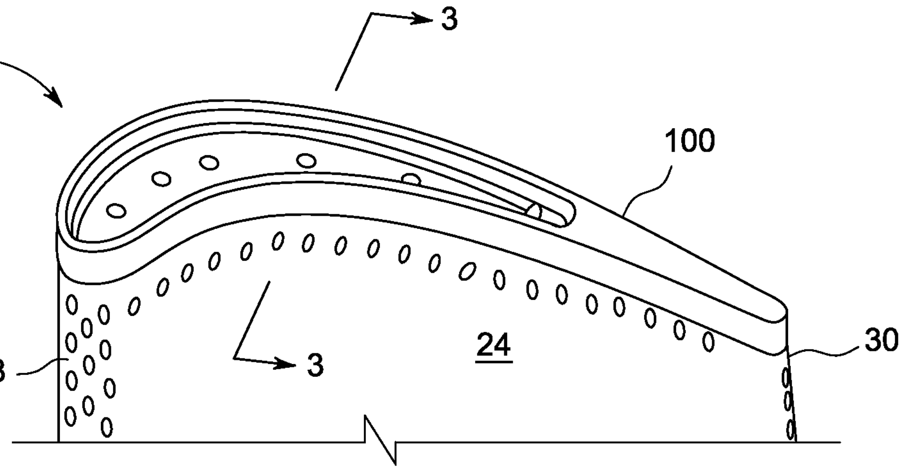



FIG. 2

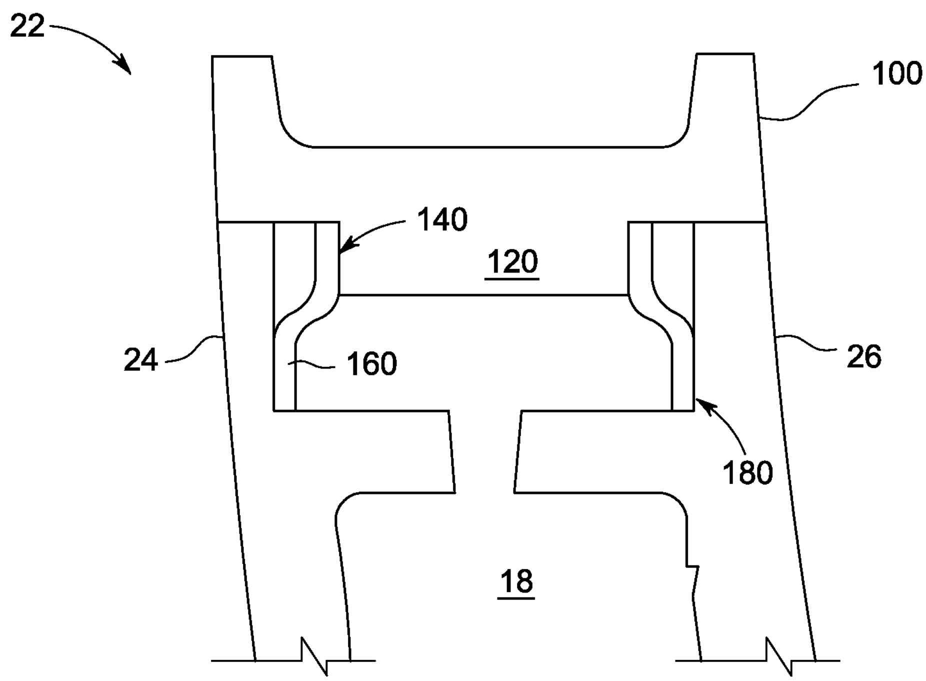



FIG. 3

# FABRICATED TURBINE AIRFOIL

## BACKGROUND OF THE INVENTION

**[0001]** The present invention relates generally to a turbine airfoil formed as a fabricated article; and, more particularly, to an apparatus and method for providing a fabricated gas turbine bucket; wherein the radially outermost portion is protected from exposure to elevated temperatures, high velocity gases, or an otherwise degrading environment.

**[0002]** In a gas turbine, pressurized air from a compressor is mixed with fuel and ignited in a combustor to generate hot pressurized gases. The hot pressurized gases flow from the combustor to one or more fixed and rotating turbine stages. Each rotating turbine stage includes a plurality of airfoils, or buckets, which are radially disposed about a rotating element, such as a disk. A stationary element, such as a shroud, is radially disposed about the rotating airfoils, thereby forming an annular flowpath. Energy is imparted from the hot pressurized gases to the rotating airfoils, causing rotation of the rotating element, thereby converting the thermal and kinetic energy from the hot pressurized gases to mechanical torque. Some of the mechanical torque is typically used to drive the compressor, and the remaining torque is typically used to drive a generator or other rotating machine.

**[0003]** Each gas turbine bucket generally includes an airfoil extending radially outwardly from a shank that is connected with and imparts mechanical energy to the rotating element. The airfoil is typically hollow or contains a plurality of internal passages through which a pressurized fluid, such as compressed air, is caused to flow for the purpose of cooling the airfoil material. Additionally, a tip may be provided to protect and impart structural integrity to the radially outermost portion of the airfoil. The tip must be capable of withstanding highly degrading environmental conditions, including elevated temperatures and high velocity gases; as well as have sufficient mechanical strength and stiffness to maintain the aerodynamic shape of the airfoil, contain the pressurized internal cooling fluid, and withstand high speed rubbing in the event that the tip contacts the stationary shroud.

**[0004]** It is often advantageous to form the tip from a different material than the remainder of the airfoil. This combination may provide multiple benefits; including tailoring the thermal and mechanical properties of the tip to satisfy the particular requirements stated above, reducing the overall weight of the bucket, and facilitating repair of the bucket. However, the thermal and mechanical loads acting on the airfoil may cause the material combination to be substantially weaker and less durable than a monolithic airfoil. This problem is particularly acute when materials having different thermal and mechanical properties; such as coefficient of thermal expansion, thermal conductivity, or modulus of elasticity; are combined.

## BRIEF DESCRIPTION OF THE INVENTION

**[0005]** The present invention provides an apparatus and method for combining materials having different thermal and mechanical properties into an article, such as a gas turbine bucket. The invention also provides means for protecting the radially outermost portion of a gas turbine bucket from exposure to elevated temperatures, high velocity gases, or an otherwise degrading environment. Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

**[0006]** In one embodiment, a fabricated turbine airfoil includes a first section, a second section, and a third section; wherein the first section provides structural support for the remaining sections, the second section is integrally joined with the first section, and the third section connects the first and second sections.

**[0007]** In another embodiment, a method of manufacturing a fabricated turbine airfoil includes the steps of forming a first section including a load bearing member, a first end, and a second end; forming a second section; forming a third section; attaching the third section to the second end of the first section; and attaching the second section to the third section in such a manner that the second section is integrally joined with the first section and the first section provides structural support for the remaining sections.

**[0008]** Other objects and advantages of the present invention will be better appreciated from the following detailed description.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** Non-limiting and non-exhaustive embodiments are described with reference to the following figures, wherein like reference numerals refer to like parts throughout the various views unless otherwise specified.

**[0010]** FIG. **1** is a perspective view of an embodiment of a gas turbine bucket formed as a fabricated article in accordance with aspects of the present invention.

**[0011]** FIG. **2** is an enlarged perspective view of the tip region of the gas turbine bucket shown in FIG. **1** viewed circumferentially.

**[0012]** FIG. **3** is a cross-sectional view of the tip region of the gas turbine bucket shown in FIGS. **1** and **2** viewed along line **3-3**.

## DETAILED DESCRIPTION OF THE INVENTION

**[0013]** Referring now to the drawings, FIG. **1** illustrates an exemplary embodiment of a gas turbine bucket **10** formed as a fabricated article in accordance with aspects of the present invention. The bucket **10** may include a dovetail **12** that attaches to a rotor disk (not shown). A shank **14** extends radially outwardly from the dovetail **12** and terminates in a platform **16** that projects radially outwardly from and surrounds the shank **14**.

**[0014]** A first section in the form of an airfoil **18** extends radially outwardly from the platform **16**. The airfoil **18** has a root **20** at the junction with the platform **16** and a tip **22** at its radially outer end. The airfoil **18** has a concave pressure sidewall **24** and a convex suction sidewall **26** joined together at a leading edge **28** and a trailing edge **30**. The airfoil **18** may take any configuration suitable for extracting energy from the hot gas stream and causing rotation of the rotor. This results in a substantial mechanical load on the airfoil caused by the difference in gas pressure between the pressure sidewall **24** and the suction sidewall **26**. The airfoil **18** may be hollow or contain a plurality of internal passages through which a pressurized fluid, such as compressed air, is caused to flow for the purpose of cooling the airfoil material. The shank **14** and platform **16** may be similarly cooled. The airfoil **18**, shank **14**, and platform **16** are typically formed from a cast high strength nickel-based superalloy, but may be formed using any suitable process and from any suitable material for performing the functions described herein.

**[0015]** FIG. **2** illustrates the tip **22** in greater detail. A second section **100** is integrally joined to and closes off the tip **22** in a manner such that the aerodynamic and structural continuity of the airfoil pressure sidewall **24**, suction sidewall **26**, leading edge **28**, and trailing edge **30** is maintained. The second section **100** may take any configuration suitable for maintaining the aerodynamic shape and efficiency of the bucket **10**, and may be formed using any suitable process and from any suitable material for imparting structural integrity to and providing environmental protection for the tip **22**. It will be appreciated that the second section **100** may extend radially inwardly to any suitable location on the radial span of the airfoil **18**, so long as the airfoil **18** structurally supports the second section **100** as the bucket **10** rotates or when it is stationary.

**[0016]** The second section **100** may be formed from a different material than the airfoil **18**; such as a refractory metal or metallic composite, intermetallic compound, ceramic, or ceramic composite. In an exemplary embodiment, the second section **100** is formed from a ceramic material by first forming a near net "green" shape using an isostatic pressing process, followed by an intermediate firing step to strengthen the green shape, followed by a machining step to achieve the desired shape, followed by a firing step to achieve the final dimensions and properties of the second section **100**. It will be appreciated that these process steps are not exhaustive, and that any suitable process and sequence of process steps may be used, depending upon the material forming the second section **100**; and the final dimensional tolerance, surface finish, and mechanical properties desired.

**[0017]** FIG. **3** illustrates a cross-section of the tip **22** viewed along line **3-3**. The second section **100** includes a neck **120** forming a radially inward facing surface **140**. A third section in the form of a sleeve **160** is disposed between the radially inward facing surface **140** and a radially outward facing surface **180** of the airfoil **18** in such a manner that the sleeve **160** nests within the airfoil pressure sidewall **24** and suction sidewall **26** and the majority of centrifugal load is taken in the shear direction. It will be appreciated that the radially inward facing surface **140** and the radially outward facing surface **180** may be disposed in any suitable manner for providing mechanical integrity to the assembly. The sleeve **160** may be either continuous or discontinuous, and may be formed using any suitable process and from any suitable material for providing mechanical integrity to the assembly and resistance to thermal distortion. In an exemplary embodiment, the sleeve **160** is formed from a nickel-based superalloy using a stamping or extrusion process followed by machining to the final shape, dimensions, and surface finish desired.

**[0018]** The sleeve **160** may be bonded to the radially inward facing surface **140** using a brazing process. In an exemplary embodiment, a braze alloy such as Palniro™-1 (50% gold, 25% nickel, 25% palladium) may be used with a suitable heat treatment to achieve high mechanical integrity of the resulting joint. It will be appreciated that mechanical features may be added to the sleeve **160** and the radially inward facing surface **140** in order to improve the mechanical strength of the bond, particularly in the shear direction.

**[0019]** The sleeve **160** may be attached to the radially outward facing surface **180** using any suitable method; such as brazing, welding, mechanical attachment, or a combination thereof; in order to achieve high mechanical integrity of the resulting joint, particularly in the shear direction, as well as provide means for removal of the sleeve **160** and second section **100** assembly during repair and refurbishment of the bucket **10**.

**[0020]** Summarizing, the present invention contemplates a fabricated airfoil; wherein the radially outermost portion is protected from exposure to elevated temperatures, high velocity gases, or an otherwise degrading environment. Exemplary embodiments of the fabricated airfoil are described in detail above.

**[0021]** Although the apparatus and methods described herein are described in the context of creating a turbine airfoil, it is understood that the apparatus and methods are not limited to turbomachinery applications. Furthermore, although the foregoing description contains many specifics, these should not be construed as limiting the scope of the present invention, but merely as providing illustrations of some of the presently preferred embodiments. Similarly, other embodiments of the invention may be devised which do not depart from the spirit or scope of the present invention. Features from different embodiments may be employed in combination. The scope of the invention is, therefore, indicated and limited only by the appended claims and their legal equivalents, rather than by the foregoing description. All additions, deletions and modifications to the invention as disclosed herein which fall within the meaning and scope of the claims are to be embraced thereby.

**[0022]** As used herein, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural elements or steps, unless such exclusion is explicitly recited. Furthermore, references to "one embodiment" of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

**[0023]** This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

**1**. A fabricated turbine airfoil comprising a first section, a second section, and a third section; wherein the first section provides structural support for the remaining sections, the second section is integrally joined with the first section, and the third section connects the first and second sections.

**2**. The airfoil of claim **1**, wherein the first section comprises an aerodynamically shaped load bearing member, a first end, and a second end.

**3**. The airfoil of claim **2**, wherein the first end is integral with or attached to a rotor.

**4**. The airfoil of claim **2**, wherein the second end is exposed to elevated temperatures, high velocity gases, or an otherwise degrading environment.

**5**. The airfoil of claim **4**, wherein the second section protects the second end from the degrading environment.

**6**. The airfoil of claim **1**, wherein the second section is comprised of a different material than the first and third sections.

**7**. The airfoil of claim **1**, wherein the third section comprises a sleeve.

**8**. The airfoil of claim **1**, wherein the second section is bonded to the third section.

**9**. The airfoil of claim **8**, wherein the bond between the second section and the third section is formed using a braze alloy.

**10**. The airfoil of claim **2**, wherein the third section is attached to the second end of the first section.

**11**. A fabricated turbine bucket comprising a first section, a second section, and a third section; wherein the first section provides structural support for the remaining sections and comprises a load bearing member, a first end, and a second end exposed to elevated temperatures, high velocity gases, or an otherwise degrading environment; the second section protects the second end from the degrading environment and is integrally joined with the first section, and the third section connects the first and second sections.

**12**. The bucket of claim **11**, wherein the first section comprises an airfoil.

**13**. The bucket of claim **11**, wherein the first end is integral with or attached to a rotor.

**14**. The bucket of claim **11**, wherein the second section is comprised of a different material than the first and third sections.

**15**. The bucket of claim **11**, wherein the third section comprises a sleeve.

**16**. The bucket of claim **11**, wherein the second section is bonded to the third section.

**17**. The bucket of claim **16**, wherein the bond between the second section and the third section is formed using a braze alloy.

**18**. The bucket of claim **11**, wherein the third section is attached to the second end of the first section using any suitable method resulting in a joint having high mechanical integrity.

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