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Inventor(s)	Oras; Zachary et al.

Additively manufactured protective cover for gas turbine components

Abstract

A cover is provided for covering at least a portion of a component for finishing. The cover has a top portion, a bottom portion, and at least one wall extending from the top portion to the bottom portion. The cover includes a chamber accessible via the bottom portion. The chamber is configured to retain the component such that at least a portion of the component is protected by the cover. The chamber includes a first stop and a second stop each extending into the chamber. The first stop and the second stop are disposed in different vertical planes. The cover is additively manufactured using an elastomeric material.

Inventors: **Oras; Zachary (Riverview, FL), Mitchell; Logan (Tampa, FL), Ezzo; Zachary (Tampa, FL), Hopkins; Zachary (San Diego, CA)**

Applicant: **Chromalloy Gas Turbine LLC** (Palm Beach Gardens, FL)

Family ID: **1000008767058**

Assignee: **Chromalloy Gas Turbine LLC (Palm Beach Gardens, FL)**

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Primary Examiner: Sehn; Michael L

Attorney, Agent or Firm: AVEK IP, LLC

Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) None.

FIELD OF THE DISCLOSURE

(2) The disclosure relates generally to the field of protective covers. More specifically, the disclosure relates to an additively manufactured cover for protecting a gas turbine component.

SUMMARY

(3) The following presents a simplified summary of the invention in order to provide a basic understanding of some aspects of the invention. This summary is not an extensive overview of the invention. It is not intended to identify critical elements of the invention or to delineate the scope of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is presented elsewhere herein.
(4) In an aspect of the disclosure, a cover for a component is disclosed. The cover includes a top portion, a bottom portion, and at least one wall extending from the top portion to the bottom portion. The cover includes a chamber accessible via the bottom portion. The chamber is configured to retain the component such that at least a part of the component is protected by the cover. The chamber includes a first stop and a second stop each extending into the chamber. The first stop and the second stop are disposed in different vertical planes. The cover includes an elastomeric material.
(5) In an aspect, according to any one of the preceding aspects, each of the first stop and the second stop are disposed on the bottom portion.
(6) In an aspect, according to any one of the preceding aspects, the first stop includes a first lower stop and a second lower stop. The first lower stop faces the second lower stop.
(7) In an aspect, according to any one of the preceding aspects, the second stop includes a first upper stop and a second upper stop. The first upper stop faces the second upper stop.
(8) In an aspect, according to any one of the preceding aspects, the at least one wall includes a plurality of walls. Each of the first lower stop, the second lower stop, the first upper stop, and the second upper stop are disposed on a different one of the plurality of walls.
(9) In an aspect, according to any one of the preceding aspects, the first stop is configured to contact the component to preclude the component from falling out of the cover.
(10) In an aspect, according to any one of the preceding aspects, the second stop is configured to contact the component to maintain a distance between the component and the top portion.
(11) In an aspect, according to any one of the preceding aspects, the component is a gas turbine component and the cover is additively manufactured.
(12) In an aspect, according to any one of the preceding aspects, the gas turbine component is one of a blade and a vane.
(13) In an aspect, according to any one of the preceding aspects, the at least one wall includes four walls.
(14) In an aspect, according to any one of the preceding aspects, the top portion includes a first section, a second section, and a recessed portion between the first section and the second section.
(15) In an aspect, according to any one of the preceding aspects, the recessed portion includes a cutout and at least one of the first section and the second section is frusto-ovalur.
(16) In an aspect, according to any one of the preceding aspects, the bottom portion includes a parallelogram configuration.
(17) In an aspect, according to any one of the preceding aspects, the at least one wall includes ribbing.
(18) In an aspect, an additively manufactured cover for a blade of a gas turbine is provided. The cover includes a top portion corresponding to the tip of the blade, a bottom portion, and at least one wall extending from the top portion to the bottom portion. The cover has a chamber accessible via the bottom portion. The chamber is configured to retain the blade such that at least a part of the blade is protected by the cover. The cover has a first stop and a second stop each extending into the chamber. The first stop and the second stop are disposed in different vertical planes.
(19) In an aspect, according to any one of the preceding aspects, the at least a part of the blade protected by the cover includes an airfoil and a gas path surface of a platform of the blade.
(20) In an aspect, according to any one of the preceding aspects, the first stop includes a first lower stop and a second lower stop. The first lower stop facing the second lower stop.
(21) In an aspect, according to any one of the preceding aspects, the second stop is configured to

maintain a distance between the tip of the blade and the top portion.
(22) In an aspect, according to any one of the preceding aspects, when the blade is retained in the chamber, a dovetail of the blade is exposed.
(23) In an aspect, a cover for a gas turbine component includes a top portion having a first section, a second section, and a recessed portion. The cover includes a bottom portion and a plurality of walls extending at an angle from the top portion to the bottom portion. The cover includes a chamber accessible via the bottom portion. The chamber is configured to retain the gas turbine component such that a first part of the component is shielded by the cover and a second part of the component is exposed. The cover includes an elastomeric material.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) Illustrative embodiments of the present disclosure are described in detail below with reference to the attached drawing figures and wherein:
(2) FIG. **1** is a perspective view of a turbine blade.
(3) FIG. **2** is a schematic showing a portion of a blade being covered by a protective cover, according to an aspect of the disclosure.
(4) FIGS. **3**A through **3**D are perspective views of the cover of FIG. **2** with a top portion thereof facing in an upward direction.
(5) FIGS. **4**A through **4**D are perspective views of the cover of FIG. **2** with a top portion thereof facing in a downward direction.
(6) FIGS. **5**A and **5**B are bottom view of the cover of FIG. **2**.
(7) FIGS. **6**A and **6**B are top views of the cover of FIG. **2**.
(8) FIGS. **7**A and **7**B are cross-sectional views of the cover of FIG. **2**.
(9) FIGS. **8**A and **8**B are schematics showing a blade being retained in the cover of FIG. **2**.
(10) FIG. **9** is a perspective view of a cover, according to an aspect of the disclosure.
(11) FIG. **10** is a flowchart illustrating a method of making and using the cover of FIG. **2** and FIG. **9**.
DETAILED DESCRIPTION
(12) A gas turbine engine typically includes a multi-stage compressor coupled to a multi-stage turbine via an axial shaft. Air enters the gas turbine engine through the compressor where its temperature and pressure are increased as it passes through subsequent stages of the compressor. The compressed air is then directed to one or more combustors where it is mixed with a fuel source to create a combustible mixture. This mixture is ignited in the combustors to create a flow of hot combustion gases. These gases are directed into the turbine causing the turbine to rotate, thereby driving the compressor. The output of the gas turbine engine can be mechanical thrust via exhaust from the turbine or shaft power from the rotation of an axial shaft, where the axial shaft can drive a generator to produce electricity.
(13) The compressor and turbine each include a plurality of rotating blades and stationary vanes having an airfoil extending into the flow of compressed air or flow of hot combustion gases. Each blade or vane has a particular set of design criteria which must be met to provide the necessary work to the flow passing through the compressor and the turbine. However, due to the severe nature of the operating environment, especially in the turbine, it is often necessary to cool these blades and vanes. The blades and vanes often utilize complex internal cooling passageways in order to maximize the efficiency of cooling fluid passing therethrough.
(14) FIG. **1** shows a gas turbine component, such as a gas turbine blade **10**. The turbine blade **10** generally includes an airfoil **12** extending from a top or gas path side surface **14** of a platform **16** and a root fixing portion or “dovetail” **18** depending from an undersurface **20** of the platform **16**.

The dovetail **18** may include one or more serrations or tangs **22** that extend laterally from one side **23**A of the dovetail **18** to an opposing side **23**B of the dovetail **18**. The dovetail **18** may terminate at a terminal or bottom wall **25** that may span between the dovetail sides **23**A and **23**B. The dovetail **18**, including the tangs **22** and the bottom wall **25** thereof, may be adapted for interlocking engagement in a corresponding slot defined in the periphery of a hub of a turbine rotor. The bottom wall **25** may be part of a metering plate **35** that is brazed or otherwise secured to the dovetail **18**.
(15) The airfoil **12** may have a pressure side **26**, a suction side **27** opposite the pressure side **26**, a tip **28**, a leading edge **29**, and a trailing edge **31**. The tip **28** may include or may be configured to interact with a shroud. The shroud may be provided at the tip **28** of each blade **10**, or may be a stationary ring including one or more circumferentially extending sections each connected to the gas turbine casing. The shroud(s) may be configured to seal the gap between the tip **28** of the blade **10** and stationary components (e.g., stators) of the turbine, and thereby, may reduce leakage flow between the rotating and stationary components. The airfoil **12**, e.g., the pressure side **26** thereof, may come into contact with combustion gases that are at an extremely high temperature. The airfoil **12** or portions thereof may therefore be coated with heat-resistant, wear-resistant, and/or other coatings. During operation, the tip **28** may rub against the tip shroud, and the tip **28** may therefore additionally or alternately be coated with wear-resistant coatings. In like fashion, one or more other portions of the blade **10** may be coated with different materials depending on the environment in which these portions are located and the stresses encountered thereby.
(16) The bottom wall **25** of the dovetail **18** may include one or more air inlet apertures **30**. Further, one or more portions of the blade **10** may include cooling holes **32** for cooling the blade **10** during operation. The cooling holes **32** may be provided on one or more surfaces of the airfoil **12**, such as the pressure side **26**, the suction side **27**, the tip **28**, the leading edge **29**, the trailing edge **31**, or a combination thereof. The cooling holes **32** may be circular cooling holes, diffused (e.g., angled) cooling holes, cooling slots, or take on one or more other regular or irregular shapes. Cooling gas may pass through internal cooling channels (not illustrated for ease of description) in the blade **10** and emerge from the cooling holes **32** to create a blanket of thin film over the outer surface of the airfoil **12**, thus preventing direct contact of the hot gases and the surfaces of the blade **10**. For example, the illustrated blade **10** has air inlet apertures **30** in the bottom wall **25** of the dovetail **18** and cooling holes **32** on the pressure side **26** of the airfoil **12**. The blade **10**, including the airfoil **12** thereof, may include hollow interior passages for the passage of cooling air, for example, but not limited to, from air inlet apertures **30** to cooling holes **32**. Thus, cooling air may be bled from the compressor and channeled into the air inlet apertures **30**. This air may exit out the cooling holes **32** to cool one or more portions of the blade **10** during operation. One having skill in the art will understand that different blades may have differing cooling schemes and that the inlet apertures **30** and cooling holes **32** in FIG. **1** are merely exemplary and not intended to be independently limiting.
(17) A gas turbine blade, such as the blade **10**, may be manufactured using investment casting, also referred to in the art as lost-wax processing. The investment casting process may involve making a precise negative die of the blade shape that is filled with wax to form the blade shape. If the blade, such as the blade **10**, is hollow and has interior cooling passages, a ceramic core in the shape of the cooling passages may be inserted into the middle. The wax blade may be coated with a heat-resistant material to make a shell, and then that shell may be filled with the blade alloy.
(18) Once cast, the blade **10** may undergo one or more finishing processes to prepare the blade **10** for operation. The finishing processes may ensure that the blade **10** has the required aerodynamic profile, as such may impact engine efficiency and fuel consumption. The finishing processes may also make the blade **10** more resistant to fatigue, and thereby increase the lifespan of the blade **10**. Some finishing processes may reduce the maintenance requirements associated with the blade **10**.
(19) Finishing the blade **10** may include coating one or more surfaces of the blade **10**. For example, one or more surfaces of the blade **10** may be blasted with abrasive media to configure these surfaces to accept coatings, and thereafter, heat-resistant, wear-resistant, and/or other coatings may

be applied to these surfaces of the blade **10**. Finishing the blade **10** may also include deburring and breaking sharp edges, polishing one or more surfaces of the blade **10** to remove excess material, welding, brazing or otherwise associating a feature (e.g., the metering plate **35**) with the blade **10**, machining one or more surfaces of the blade **10**, and so on. The term “finishing” and the phrase “surface finishing”, as used herein, includes any one of the one or more processes that may be used to alter a manufactured component to cause it to achieve a certain property. For example, finishing the blade **10** includes the one or more processes undergone by the blade **10** (e.g., media blasting, brazing, coating, machining, et cetera) after it is cast to prepare the blade **10** for operation in a gas turbine.

(20) To finish a gas turbine component after it is manufactured, e.g., to finish the blade **10** after it is cast, the component may be transported to one or more locations (e.g., one or more locations in the manufacturing facility). For example, the blade **10** may be transported by an operator or via one or more mechanized systems such as a conveyer belt from one finishing station to another. For instance, the blade **10**, after it is cast, may be taken to a first station for media blasting, to a second station for applying a coating to the pressure side **26**, to a third station for applying a coating to the tip **28**, to a fourth station for machining, to a fifth station for brazing the metering plate **35** onto the blade **10**, and so on. These stations may be in the same facility or in different facilities. After the blade **10** is finished, it may be transported to yet another station or location for packaging and shipping. It may be prudent to exercise care as the component (e.g., the blade **10**) is taken from one location to another location (e.g., from one station to another station). If the blade **10** is damaged while it is being handled during a finishing process and/or transported from one location to another (hereinafter “handling damage”), the blade **10** may have to be repaired, and in some cases, the blade **10** may have to be scrapped.

(21) In addition to handling damage, a component, such as a blade **10**, may incur damage from foreign material contamination. For example, braze material being used to braze the metering plate **35** onto the dovetail **18** of the blade **10** may accidentally contact a surface of the platform **16** or the airfoil **12** and cause damage to the blade **10**. Or, for instance, a coating to be applied only to the tip **28** of the blade **10** may accidentally contact the pressure side **26** or the suction side **27** of the airfoil **12**. Like handling damage, damage to the component due to foreign material contamination may require that the component be repaired prior to use or scrapped entirely. The requirement to repair or replace a component due to such inadvertent damage (e.g., handling damage, foreign contamination damage, or other such damage) may be time consuming, laborious, and expensive. It may be beneficial to preclude or minimize the likelihood of damaging a component after one or more initial manufacturing steps have been completed and before the component is finished. Aspects of the present disclosure may provide a cover for protecting the component from damage during finishing.

(22) Focus is directed to FIG. **2**, which shows a protective cover (or mask, sheath, or jacket, hereinafter “cover”) **100**, according to an aspect of the disclosure. The cover **100** may cover (e.g., envelope) one or more portions of the blade **10** and protect the blade **10** from incurring damage, such as during finishing thereof. In the embodiment illustrated in FIG. **2**, the cover **100** is shown covering and protecting the airfoil **12** (i.e., each of the pressure side **26**, suction side **27**, tip **28**, leading edge **29**, and trailing edge **31**) and the gas path side surface **14** of the platform **16**. In other examples of the disclosure, a cover may protect one or more other surfaces of the blade **10** or another component (such as a gas turbine vane or other component).

(23) In an embodiment, the cover **100** may be additively manufactured. Additive manufacturing, also referred to as 3D printing, may be performed by dividing the shape of a three-dimensional object, i.e., the cover **100** in this example, into a number of two-dimensional cross sections having a uniform or variable thickness, and forming the two-dimensional cross sections to be stacked one by one. There are several known additive printing methods such as a material extrusion method, a material jetting method, a binder jetting method, a sheet lamination method, a vat photo-

polymerization method, a powder bed fusion method, a directed energy deposition (DED) method, et cetera. Any one or more of these methods, or any other additive manufacturing method, now known or hereinafter developed, may be employed to manufacture cover **100**.

(24) In some non-limiting examples, cover **100** may be manufactured using vat photo-polymerization. Vat photopolymerization, such as stereolithography, direct light processing, continuous liquid interface production, solid ground curing, et cetera, is a category of additive manufacturing processes that create three dimensional objects by selectively curing material (e.g., resin or other photopolymers) through targeted light-activated polymerization. When exposed to certain wavelengths of light, the liquid photopolymers' molecules may rapidly bind together and cure into a solid state through a process called photopolymerization. The liquid photopolymer(s) may be held in a container or vat with the build platform partially submerged near the surface of the liquid. Using the information supplied by a CAD or other design file, the printer may direct a light source to selectively cure the liquid photopolymer into a solid layer. Then the build platform may then be re-submerged into the remaining resin and the process may be repeated for the next layers until the cover **100** has been fully printed.

(25) FIGS. **3**A through **3**D and **4**A through **4**D show the cover **100** in more detail. In some examples of the disclosure, the cover **100** may have a first wall **102**, a second wall **104**, a third wall **106**, a fourth wall **108**, a bottom portion **110**, and a top portion **112** (see also FIG. **6**). Each of the first wall **102**, the second wall **104**, the third wall **106**, and the fourth wall **108** may extend from the bottom portion **110** to the top portion **112**. The first wall **102** may be disposed at one side of the second wall **104** and the third wall **106** may be disposed on the other side of the second wall **104**. Similarly, the first wall **102** may be disposed at one side of the fourth wall **108** and the third wall **106** may be disposed on the other side of the fourth wall **108**.

(26) In some examples of the disclosure, one or more of the first wall **102**, the second wall **104**, the third wall **106**, and the fourth wall **108** may extend from the bottom portion **110** to the top portion **112** at an angle (e.g., an acute angle as shown or an obtuse angle). In aspects of the disclosure, the first wall **102**, the second wall **104**, the third wall **106**, and the fourth wall **108** may collectively be generally frusto-pyramidal. The angle at which the first wall **102**, the second wall **104**, the third wall **106**, and the fourth wall **108** extend from the bottom portion **110** to the top portion **112** may generally depend on the geometry of the part for which the cover **100** is intended. Further, cover **100** with walls **102**, **104**, **106**, and **108** that extend from the bottom portion **110** to the top portion **112** at an angle (e.g., an acute angle) may require less material to manufacture relative to a cover where the walls vertically extend from the bottom portion to the top portion.

(27) Each of the first wall **102**, the second wall **104**, the third wall **106**, and the fourth wall **108** may have an exterior or outer surface **102**E, **104**E, **106**E, and **108**E, respectively. Each of the first wall **102**, the second wall **104**, the third wall **106**, and the fourth wall **108** may likewise have an interior or inner surface **1021**, **104**I, **106**I, and **108**I, respectively. The exterior surfaces **102**E, **104**E, **106**E, and **108**E may respectively oppose the interior surfaces **1021**, **104**I, **106**I, and **108**I.

(28) In some examples, the top portion **112** may have a first section **114** and a second section **116** with a recessed portion **118** therebetween. The first section **114**, the second section **116**, and the recessed portion **118** may each have an exterior surface **114**E, **116**E, and **118**E, and an interior surface **114**I, **116**I, and **118**I, respectively. In some examples, each of the first section **114** and the second section **116** may be generally frusto-ovalur. In other embodiments, the first section **114** and/or the second section **116** may be pyramidal, spherical, or take on other regular or irregular shapes. In some examples, the first section **114** and/or the second section **116** may be curved such that the first section **114**, the second section **116**, and the recessed portion **118** collectively generally correspond to the shape of the tip **28** of the blade **10**.

(29) In some examples of the disclosure, the recessed portion **118** of the top portion **112** may have a generally concave shape. In other examples, the recessed portion **118** may take on other regular or irregular shapes. The recessed portion **118** may have cutout or opening **120**. The recessed portion

118, including the cutout **120** thereof, may reduce the total material required to additively manufacture the cover **100**. Further, the recessed portion **118** may facilitate printing of the cover **100**, e.g., using vat photopolymerization. Specifically, the recessed portion **118** and the cutout **120** may reduce the likelihood of formation of suction cups that may otherwise form when additively manufacturing the cover **100** using vat photopolymerization. These suction cups, if formed, may impede flow of material during the additive manufacturing process and may cause the walls of the cover **100** to cavitate during the additive manufacturing process. The recessed portion **118**, including the cutout **120** therein, may preclude the formation of these suction cups and may allow liquid to flow freely during the vat photopolymerization process, thereby facilitating additive printability.

(30) The bottom portion **110**, in some examples of the disclosure, may be generally a parallelogram. In other examples, the bottom portion **110** may be generally rectangular, triangular, or take on other regular or irregular shapes. In the illustrated example, the bottom portion **110** has four walls **122**, **124**, **126**, and **128**. Bottom portion wall **122** may extend from and below first wall **102**, bottom portion wall **124** may extend from and below second wall **104**, bottom portion wall **126** may extend from and below third wall **106**, and bottom portion wall **128** may extend from and below fourth wall **108**. Each bottom portion wall **122**, **124**, **126**, and **128** may have an interior surface **122**I, **124**I, **126**I, and **128**I, and an exterior surface **122**E, **124**E, **126**E, and **128**E, respectively. The exterior surfaces **122**E, **124**E, **126**E, and **128**E of the bottom portion walls may respectively oppose the interior surfaces **122**I, **124**I, **126**I, and **128**I thereof.

(31) The first wall, **102**, the second wall **104**, the third wall **106**, the fourth wall **108**, the bottom portion **110**, and the top portion **112**, may collectively define a chamber **130** (FIG. **5**). Specifically, the interior surfaces **1021**, **104**I, **106**I, and **108**I, of the first wall **102**, the second wall **104**, the third wall **106**, the fourth wall **108**, the interior surfaces of the top portion **112** (i.e., the interior surfaces **114**I, **116**I, and **118**I of the first section **114**, the second section **116**, and the recessed portion **118**), and the interior surfaces **122**I, **124**I, **126**I, and **128**I of the walls **122**, **124**, **126**, and **128** of the bottom portion **110**, may collectively define the chamber **130**. In some examples, the shape of the chamber **130** may be generally frusto-pyramidal. In other examples, the chamber **130** may generally be spherical, cylindrical, cuboidal, or take on other symmetrical or non-symmetrical shapes. In some examples, the shape of the chamber **130** may loosely correspond to the shape of the portion of the component (the airfoil **12** of the blade **10** in this example) to be protected by the cover **100**. The interior surfaces **122**I, **124**I, **126**I, and **128**I of the walls **122**, **124**, **126**, and **128** of the bottom portion **110** may define an entryway **132** via which the chamber **130** may be accessed.

(32) In an aspect of the disclosure, the interior surfaces **122**I, **124**I, **126**I, and **128**I of the bottom portion **110** may include two pairs of stops or shelves. Specifically, the interior surface **124**I of the bottom portion wall **124** may have a lower stop **134**A (FIG. **4**B) and the interior surface **128**I of the bottom portion wall **128** may have a lower stop **134**B (FIG. **4**D). The lower stops **134**A and **134**B may also be referred to herein as a “release prevention stops” **134**A and **134**B. The lower stop **134**A may face and be coplanar with the lower stop **134**B.

(33) The interior surface **122**I of the bottom portion wall **122** may have an upper stop **136**A (FIG. **4**A) and the interior surface **126**I of the bottom portion wall **126** may have an upper stop **136**B (FIG. **4**B). The upper stops **136**A and **136**B may also be referred to herein as “over-insertion prevention stops” **136**A and **136**B. The upper stop **136**A may face and be coplanar with the upper stop **136**B.

(34) In an embodiment, the lower stops **134**A and **134**B may be at or proximate the lowermost portion of the bottom portion **110** and the upper stops **136**A and **136**B may be at or proximate the uppermost portion of the bottom portion **110** (i.e., the upper stops **136**A and **136**B may be in a different vertical plane relative to the lower stops **134**A and **134**B). Thus, the lower stops **134**A and **134**B may be proximate the entryway **132** relative to the upper stops **136**A and **136**B (FIGS. **7**A-**7**B). For example, there may be a vertical distance D between the lower stops **134**A, **134**B and the

upper stops **136**A, **136**B.

(35) In some examples, the lower stops **134**A and **134**B may be generally rectangular and may be identical. In other examples, the lower stop **134**A may be disparate from lower stop **134**B and these stops may take on any regular or irregular shape. The upper stops **136**A and **136**B may likewise be generally rectangular and may be identical. In other examples, the upper stop **136**A may be disparate from upper stop **136**B and these stops may take on any regular or irregular shape. Each of the lower stops **134**A and **134**B and the upper stops **136**A and **136**B may extend into the chamber **130** generally laterally from the respective bottom portion wall with which the stops are associated. In some examples, instead of a pair of lower stops **134**A and **134**B and a pair of upper stops **136**A and **136**B, a solitary lower stop and/or a solitary upper stop may be provided. In other examples, instead of a pair of lower stops **134**A and **134**B and a pair of upper stops **136**A and **136**B, the cover **100** may have a different number of stops, such as 3 stops, 4 stops, 5 stops to N stops.

(36) In some examples of the disclosure, the cover **100** may be formed from elastomeric material. In certain aspects of the embodiments, cover **100** may be additively manufactured using elastomeric material. Additively manufacturing the cover **100** using elastomeric material may provide one or more benefits over manufacturing the cover **100** using conventional techniques (e.g., molding, which requires the manufacture of a tool prior to manufacturing the part). Additively manufacturing the cover **100** using elastomeric material may ensure that the cover **100** is flexible and conforms to the surfaces of the blade **10** being protected by the cover **100**. Due to its elastomeric material construction, the bottom portion **110** of cover **100** may be stretched to allow the airfoil **12** to be inserted into the chamber **130**. Further, cover **100** manufactured using elastomeric material may be far less likely to damage the blade **10** when it contacts the blade **10** relative to a stiff or abrasive material.

(37) In an example of the disclosure, cover **100** may be additively manufactured using silicone elastomers having a shore hardness in a range between about 50 and about 90 A. In some examples, IND402 from Loctite® may be used to additively manufacture cover **100**. In other examples, elastomeric three-dimensional printable polymers (e.g., resins, pellets, filaments, powders, and similar materials) that provide a minimum shore hardness of about 75 A and a minimum tear strength of about 28 kN/m may be used to additively manufacture the cover **100**. Using elastomers with a shore hardness between in a range between about 50 and about 90 A and a minimum tear strength of about 28 kN/m may ensure that the cover **100** is suitably flexible to accept the airfoil **12** of the blade **10** without undue effort and is durable enough to withstand forces and materials that would have otherwise caused damage to the airfoil **12**. Further, the relatively higher rebound characteristics of such elastomers may allow for these elastomers to readily withstand externally applied shock (e.g., from a tool or the surface of a station) that may otherwise have transferred to and damaged the blade **10**.

(38) Another benefit of additively manufacturing the cover **100** using elastomeric material may be that the cover **100** may be secured to the blade **10** without screws, nuts and bolts, or other such fasteners that require tools (such as screw drivers or pliers) for fastening. Covers that require tools, including, but not limited to, screws, nuts and bolts, or other such fasteners (collectively, screws) have a high likelihood of being damaged if the screws are over-tightened, and conversely, may not effectively cover the blade **10** if the screws are not appropriately tightened. The cover **100** as embodied by the disclosure is a “toolless” cover **100**, because of its design and elastomeric construction, may provide a conformal boot for selectively and effectively covering one or more portions of the blade **10**.

(39) Focus is directed to FIG. **2**. Once the cover **100** is manufactured, e.g., using additive manufacturing techniques, it may be used to protect the blade **10** during finishing. Specifically, the tip **28** of the airfoil **12** of the blade **10** may be pushed into the chamber **130** of the cover **100** in a direction A towards the top portion **112** of the cover **100** such that the tip **28** is proximate and adjacent the interior surfaces of the top portion **112** (i.e., the interior surfaces **114**I, **116**I, and **118**I

of the first section **114**, the second section **116**, and the recessed portion **118**). When so positioned, the pressure side **26** and suction side **27** of the airfoil **12** may be adjacent one or more of the interior surfaces **1021**, **104**I, **106**I, and **108**I of the walls **102**, **104**, **106**, and **108**.
(40) The upper stops **136**A and **136**B may function to prevent over-insertion of blade **10** into cover **100**. Stops **136**A and **136**B may ensure that the tip **28** of the blade **10** is spaced apart from and does not contact the interior surfaces of the top portion **112**, thus interior surfaces **114**I, **116**I, and **118**I of first section **114**, second section **116**, and recessed portion **118** are not in contact with tip **28** of blade **10**. FIG. **8**A is a schematic illustration and shows the blade **10** being inserted into the chamber **130**. As can be seen, as the blade **10** is inserted into the chamber **130** in direction A, the upper stops **136**A (and **136**B, which is not visible in FIG. **8**A) may abut the gas path side surface **14** of the platform **16** and preclude the blade **10** from being further into the chamber **130**. In certain aspects of the embodiments, either blade **10** or cover **100** may be moved with respect to each other. In some examples, the upper stops **136**A and **136**B (**136**B not illustrated for ease of illustration in FIG. **8**A) may therefore ensure that the tip **28** of the blade **10** is at least a distance E**1** from interior surfaces of the top portion **112** of cover **100**. Spacing E**1** between the tip **28** of the blade **10** and the top portion **112** of the cover **100** may ensure that an inadvertent force applied to the top portion **112** (e.g., in case the top portion **112** of the cover **100** is inadvertently struck by an object, or where the cover **100** is dropped such that the top portion **112** hits the floor) is not readily transmitted to the tip **28** of the blade **10** and causes damage thereto.
(41) The lower stops **134**A and **134**B, conversely, may function to prevent unintentional release of the blade **10** from the cover **100** and may ensure that the blade **10**, once it is inserted into the cover **100**, does not inadvertently fall out of the cover **100** or otherwise disassociate therefrom. Specifically, as shown in FIG. **8**B, as gravity or other forces pull the blade **10** inside the cover **100** in direction B, the undersurface **20** of the platform may abut the lower stops **134**A and **134**B. Accordingly, blade **10** may be precluded from falling out of the cover **100**. Thus, the blade **10** may only be disassociated from the cover **100** intentionally (e.g., the blade **10** may manually be pulled out of the cover **100** after stretching open the bottom portion **110**) but may not unintentionally disassociate from cover **100**. Such may ensure that the cover **100** continues to protect the blade **10** as intended during the finishing processes. Further, because of the elastomeric construction of the upper stops **134**A and **134**B, and lower stops **136**A and **136**B, these stops **134**A, **134**B, **136**A, and/or **136**B may not impede the airfoil **12** from being pushed into the chamber **130**. That is, if the stops **134**A, **134**B, **136**A, and/or **136**B come in contact with the airfoil **12** when the blade **10** is being pushed into the cover **100**, stops **134**A, **134**B, **136**A, and/or **136**B may be pushed aside by the airfoil **12** and may thereafter return to or towards their original position.
(42) Once the blade **10** is inserted into the cover **100**, the airfoil **12** and the gas path surface **14** of the platform **16** retained within cover **100** may be protected from damage (e.g., handling damage, foreign contamination damage, et cetera). Because cover **100** does not cover the dovetail **18**, an operator may finish (e.g., coat, braze, machine, peen, and otherwise further process) the exposed dovetail **18** while the airfoil **12** and the gas path surface **14** of the platform **16** are protected. As noted, in other embodiments, cover **100** may cover a portion of or the entire the dovetail **18**, while another portion or portions of the blade **10** may be exposed for finishing. As illustrated in FIG. **2**, the cover **100** may be of unitary construction. In other examples, the cover **100** may include two or more separate or separable portions configured to protect different parts of a component (such as a gas turbine component). In some examples, cover **100** may have one or more windows to allow one or more portions of the blade **10** to be accessed through the cover **100** for finishing.
(43) FIG. **9** shows a cover **200** in another aspect of the disclosure. The cover **200** may be similar to cover **100**, except as noted. Corresponding parts may be denoted with corresponding reference numerals, though with any noted deviations.
(44) As noted, the cover **100** may be additively manufactured. The cover **200** may likewise be additively manufactured, e.g., using vat photopolymerization or other additive manufacturing

process now known or hereinafter developed. A difference between the cover **100** and the cover **200** may be that the cover **200** may include ribbing or texture **201** (hereinafter "ribbing **201**"). The ribbing **201** may provide structural integrity to the cover **200**, and consequently, may allow the cover **200** to be thinner relative to cover **100** while affording the same or similar level of protection. In addition, the ribbing **201** may provide a textured surface that may facilitate the gripping and handling of the cover **200** by an operator without slippage. The ribbing **201** may be a generally hexagonal pattern as shown or may take on other regular or irregular shapes. For example, in some embodiments, the ribbing **201** may be polygonal, triangular, circular, squared, or may include a pattern that includes two or more symmetric or asymmetric shapes. The ribbing **201** may be unitary with the cover **200** and may be additively manufactured together with the cover **200**. While not shown in FIG. **9**, the cover **200**, like the cover **100**, may have a pair of upper stops and lower stops **134**A, **134**B, **136**A, and/or **136**B on the interior surfaces of the cover **200**. That is, the cover **200** may in examples be identical to the cover **100** except for the inclusion of the ribbing **201** in the cover **200**.

(45) As noted, in some examples, the surfaces of the cover **100** and the cover **200** may not precisely mate with the surfaces of the airfoil **12** that are being protected. For example, while the airfoil **12** is within the cover **100** or the cover **200**, there may be one or more spaces between the surfaces of the airfoil **12** and the surfaces of the cover **100** or cover **200**. Loose correspondence between the airfoil **12** and the cover **100** or **200**, as opposed to tight skin-on-skin correspondence between the airfoil **12** and the cover **100** and **200**, may allow for more permissive tolerances for the cover **100** or **200**. The cover **100** and **200** may therefore be fabricated using additive manufacturing processing with consumer level printers, as opposed to high-end commercial additive printers that may be required to manufacture blade covers with tight tolerances.

(46) FIG. **10** shows a flowchart illustrating a method **300** of making and using a cover, such as the cover **100** or the cover **200**. At step **302**, the cover (e.g., cover **100** or cover **200**) may be additively manufactured. At step **304**, a component may be associated with the cover such that at least a portion of the component is protected by the cover. For example, the airfoil **12** of the blade **10** may be placed inside the cover **100** or cover **200** for protection. At step **306**, one or more finishing processes may be carried out to the exposed portions of the component while the remainder component is protected by cover **100** or cover **200**. For example, the exposed dovetail **18** of the blade **10** may be coated, machined, deburred, or otherwise finished while the airfoil **12** is shielded by the cover **100** or cover **200**. Once the finishing is complete, the component (e.g., blade **10**) may be disassociated from the cover **100** or cover **200** at step **308**. If required, the portion of the component that was shielded by the cover **100** or **200** may now be finished to prepare the component for operation.

(47) Thus, as has been described, cover **100** and cover **200** may protect one or more portions of a component while one or more exposed portions of the component undergo one or more finishing processes.

(48) Many different arrangements of the various components depicted, as well as components not shown, are possible without departing from the spirit and scope of the present disclosure. Embodiments of the present disclosure have been described with the intent to be illustrative rather than restrictive. Alternative embodiments will become apparent to those skilled in the art that do not depart from its scope. A skilled artisan may develop alternative means of implementing the aforementioned improvements without departing from the scope of the present disclosure.

(49) It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations and are contemplated within the scope of the claims. Not all steps listed in the various figures need be carried out in the specific order described.

Claims

1. A unitary cover for a gas turbine component, the unitary cover comprising: a unitarily constructed cover for the gas turbine component, the unitarily constructed cover including: a top portion; a bottom portion; at least one wall extending from the top portion to the bottom portion; a chamber accessible via the bottom portion, the chamber configured to retain the component such that at least a part of the component is protected by the unitary cover; and a first stop and a second stop each extending into the chamber, the first stop and the second stop disposed in different vertical planes; wherein: the unitary cover includes an elastomeric material; each of the first stop and the second stop are disposed on the bottom portion; the first stop includes a first lower stop and a second lower stop, the first lower stop facing the second lower stop; the second stop includes a first upper stop and a second upper stop, the first upper stop facing the second upper stop; and the at least one wall includes a plurality of walls, each of the first lower stop, the second lower stop, the first upper stop, and the second upper stop being disposed on a different one of the plurality of walls.
2. The unitary cover of claim 1, wherein the unitary cover is additively manufactured.
3. The unitary cover of claim 2, wherein the gas turbine component is at least one of a blade and a vane.
4. The unitary cover of claim 1, wherein the top portion includes a first section, a second section, and a recessed portion between the first section and the second section.
5. The unitary cover of claim 4, wherein: at least one of the first section and the second section is frusto-ovalur; and the recessed section includes a cutout.
6. The unitary cover of claim 1, wherein the bottom portion includes a parallelogram configuration.
7. The unitary cover of claim 1, wherein the at least one wall includes ribbing.
8. An additively manufactured unitary cover for a blade of a gas turbine, the unitary cover comprising: a unitarily constructed cover including: a top portion corresponding to a tip of the blade; a bottom portion; at least one wall extending from the top portion to the bottom portion; a chamber accessible via the bottom portion, the chamber configured to retain the blade such that at least a part of the blade is protected by the unitary cover; and a first stop and a second stop each extending into the chamber, the first stop and the second stop disposed in different vertical planes.
9. The additively manufactured unitary cover of claim 8, wherein the at least a part of the blade protected by the unitary cover includes an airfoil and a gas path surface of a platform of the blade.
10. The additively manufactured unitary cover of claim 9, wherein the first stop includes a first lower stop and a second lower stop, the first lower stop facing the second lower stop.
11. The additively manufactured unitary cover of claim 8, wherein the second stop is configured to maintain a distance between the tip of the blade and the top portion.
12. The additively manufactured unitary cover of claim 8, wherein when the blade is retained in the chamber, a dovetail of the blade is exposed.
13. A unitary cover for a gas turbine component, the unitary cover comprising: a unitarily constructed cover for the gas turbine component, the unitarily constructed cover including: a top portion; a bottom portion; at least one wall extending from the top portion to the bottom portion; a chamber accessible via the bottom portion, the chamber configured to retain the component such that at least a part of the component is protected by the unitary cover; and a first stop and a second stop each extending into the chamber, the first stop and the second stop disposed in different vertical planes; wherein: the unitary cover includes an elastomeric material; the first stop is configured to contact the component to preclude the component from falling out of the unitary cover; the second stop is configured to contact the component to maintain a distance between the component and the top portion.
14. A unitary cover for a gas turbine component, the unitary cover comprising: a unitarily

constructed cover for the gas turbine component, the unitarily constructed cover including: a top portion; a bottom portion; at least one wall extending from the top portion to the bottom portion; a chamber accessible via the bottom portion, the chamber configured to retain the component such that at least a part of the component is protected by the unitary cover; and a first stop and a second stop each extending into the chamber, the first stop and the second stop disposed in different vertical planes; wherein: the unitary cover includes an elastomeric material; and the at least one wall includes four walls.

15. The unitary cover for a gas turbine component of claim 14, wherein the at least one wall includes ribbing.

16. A unitary cover for a gas turbine component, the unitary cover comprising: a unitarily constructed cover for the gas turbine component, the unitarily constructed cover including: a top portion; a bottom portion; at least one wall extending from the top portion to the bottom portion; a chamber accessible via the bottom portion, the chamber configured to retain the component such that at least a part of the component is protected by the unitary cover; and a first stop and a second stop each extending into the chamber, the first stop and the second stop disposed in different vertical planes; wherein: the unitary cover includes an elastomeric material; and the top portion includes a first section, a second section, and a recessed section between the first section and the second section.

17. A unitary cover for a gas turbine component, the unitary cover comprising: a unitarily constructed cover for the gas turbine component, the unitarily constructed cover including: a top portion; a bottom portion; at least one wall extending from the top portion to the bottom portion; a chamber accessible via the bottom portion, the chamber configured to retain the component such that at least a part of the component is protected by the unitary cover; and a first stop and a second stop each extending into the chamber, the first stop and the second stop disposed in different vertical planes; wherein: the unitary cover includes an elastomeric material; and the bottom portion includes a parallelogram configuration.