US Patent & Trademark Office
Patent Public Search | Text View

United States Patent Application Publication	20250257661
Kind Code	A1
Publication Date	August 14, 2025
Inventor(s)	Neville; Jason et al.

METHODS OF FORMING OR REPAIRING PART WITH OVERHUNG SECTION, AND RELATED TURBOMACHINE PART

Abstract

Method of forming or repairing a part with an overhung section. The method may include removing a portion, and adding a section to the part. The section includes the overhung section. The adding includes sequentially layering at least one plurality of material layers on the part, the at least one plurality of material layers approximating dimensions of the section including the overhung section. The sequential layering may include, for example, laser welding, and may be carried out in a number of ways that create varied layers within the overhung section. The method may include machining the at least one plurality of material layers to form the section including the overhung section.

Inventors: **Neville; Jason (Greenville, SC), Woolridge; Jillian Jamison (Greenville, SC), Salm; Jacob Andrew (Greenville, SC), Hart; Kassy Moy (Greenville, SC)**

Applicant: **GE Infrastructure Technology LLC** (Greenville, SC)

Family ID: **1000008560287**

Appl. No.: **19/097234**

Filed: **April 01, 2025**

Related U.S. Application Data

parent US continuation 18255984 20230605 parent-grant-document US 12331656 US continuation PCT/US2020/063759 20201208 child US 19097234

Publication Classification

Int. Cl.: **F01D5/20** (20060101); **F01D5/22** (20060101)

U.S. Cl.:

CPC **F01D5/20** (20130101); **F01D5/22** (20130101); F05D2220/30 (20130101); F05D2230/80 (20130101); F05D2240/307 (20130101)

Background/Summary

[0001] This application is a continuation of application Ser. No. 18/255,984 (Docket No. 603288-US-11), filed 5 Jun. 2023, which was the National Stage of International Application No. PCT/US2020/063759, filed 8 Dec. 2020.

TECHNICAL FIELD

[0002] The disclosure relates generally to part manufacturing and repair, and more particularly, to methods of forming or repairing a turbomachine part, such as a turbomachine blade, with an overhung section.

BACKGROUND

[0003] Industrial parts may include portions that overhang other sections of the part. The overhung sections may need to be added during formation, or repaired after a period of use. One illustrative application includes flared tips of turbomachine blades, such as those available from GE Vernova, Cambridge, MA. Flared tip turbomachine blades include an airfoil having a pressure side and a suction side coupled along leading and trailing edges. The flared tip is coupled to a radially outer end of the airfoil, and may extend circumferentially beyond the pressure side and/or suction side of the airfoil, i.e., using an axis of the turbomachine as a reference. Traditional non-flared turbomachine blades require a two-dimensional build-up of material in the vertical or radial direction, e.g., using casting or additive manufacture. For manufacture of flared tip turbomachine blades, material is added in both the circumferential and radial direction. Repair of the flared tip turbomachine blades is currently not possible, so they are replaced. Similar situations exist with other turbomachine hot gas path components, and other industrial parts, having overhung sections.

BRIEF DESCRIPTION

[0004] An aspect of the disclosure provides a turbomachine part, comprising: a body having a first side, a second side and a longitudinal axis; and an overhung section extending in an overhung manner from at least one of the first side and the second side of the body, wherein at least a portion of the overhung section includes a plurality of material layers, wherein each material layer extends at an acute angle relative to the longitudinal axis of the body.

[0005] Another aspect of the disclosure relates to a method, comprising: adding a section to a part, the section including an overhung section, the adding including sequentially layering a plurality of material layers on a surface of the part, the plurality of material layers approximating dimensions of the section including the overhung section; and machining the plurality of material layers to form the section including the overhung section.

[0006] An aspect of the disclosure relates to a method of forming an overhung section on a part, the method comprising: forming a surface on the part, the surface being at an angle that is neither perpendicular nor parallel to a target outer planar surface of the overhung section; sequentially layering a plurality of material layers on the part, the plurality of material layers approximating dimensions of the overhung section; and machining the plurality of material layers to form the overhung section and the target outer planar surface, the target outer planar surface being at the angle relative to the plurality of material layers.

[0007] An aspect of the disclosure provides a turbomachine part, comprising: a body having a first side, a second side and a longitudinal axis; and an overhung section extending in an overhung manner from at least one of the first side and the second side of the body, wherein at least a portion of the overhung section includes a plurality of material layers, wherein each material layer extends at a perpendicular angle relative to a longitudinal axis of the body.

[0008] Another aspect of the disclosure includes a turbomachine part, comprising: a body having a first side and a second side; and an overhung section extending in an overhung manner from at least one of the first side and the second side of the body, wherein at least a portion of the overhung section includes a first plurality of material layers extending in a first direction, and a second plurality of material layers extending in a second direction at a non-coplanar direction relative to the first direction of the first plurality of material layers.
[0009] An aspect of the disclosure relates to a method, comprising: adding a section to a part, the section including an overhung section, the adding including: sequentially layering a first plurality of material layers on the part extending in a first direction; and sequentially layering a second plurality of material layers on the part extending in a second direction, different from the first direction, the second plurality of material layers meeting with the first plurality of material layers, wherein the first plurality of material layers and the second plurality of material layers collectively approximate dimensions of the section including the overhung section and are non-coplanar relative to one another; and machining the first plurality of material layers and the second plurality of material layers to form the section including the overhung section.
[0010] The illustrative aspects of the present disclosure are designed to solve the problems herein described and/or other problems not discussed.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0011] These and other features of this disclosure will be more readily understood from the following detailed description of the various aspects of the disclosure taken in conjunction with the accompanying drawings that depict various embodiments of the disclosure, in which:
[0012] FIG. **1** is a schematic representation of an illustrative industrial application in the form of a gas turbine including a turbomachine part with an overhung section such as a flared tip rail, according to embodiments of the disclosure;
[0013] FIG. **2** is a sectional view of the compressor section of the gas turbine of FIG. **1**;
[0014] FIG. **3** is a sectional view of the turbine section of the gas turbine of FIG. **1**;
[0015] FIG. **4** is a perspective view of an illustrative turbomachine part in the form of a turbine rotor blade having a flared tip rail;
[0016] FIG. **5** shows a cross-sectional view of an illustrative overhung section in the form of flared tip rail including a portion to be removed and an intended removal line;
[0017] FIG. **6** shows a cross-sectional view of the part after removing the portion of FIG. **5**, creating a surface upon which to build a new overhung section;
[0018] FIG. **7** shows a cross-sectional view of sequentially layering a plurality of material layers on the surface of the part;
[0019] FIG. **8** shows an enlarged cross-sectional view of a plurality of material layers each made of a series of weld beads;
[0020] FIG. **9** shows a schematic plan view of series of weld beads of two layers of material extending in different directions;
[0021] FIG. **10** shows a cross-sectional view of machining the part of FIG. **7** to form a new overhung section;
[0022] FIG. **11** shows a cross-sectional view of an overhung section in the form of flared tip rail including a portion to be removed and an intended removal line;
[0023] FIG. **12** shows a cross-sectional view of the part after removing the portion of FIG. **11** and rotating the part, creating a surface upon which to build a new overhung section;
[0024] FIG. **13**A shows a cross-sectional view of sequentially layering a plurality of material layers on the surface of the part of FIG. **12** in a substantially horizontal position;

[0025] FIG. **13**B shows a cross-sectional view of sequentially layering a plurality of material layers on the surface at a different rotated angle than FIG. **13**A;
[0026] FIG. **14** shows as cross-sectional view of machining the part of FIGS. **13**A-B to form a new overhung section;
[0027] FIG. **15** shows a cross-sectional view of sequentially layering a first plurality of material layers on a first surface of the part in FIG. **6** in a first direction;
[0028] FIG. **16** shows a cross-sectional view of the part after removing the portion of FIG. **6**, and optionally creating two surfaces upon which to build the new overhung section;
[0029] FIG. **17** shows a cross-sectional view of the part after rotating the part and layering a first plurality of material layers;
[0030] FIG. **18**A shows a cross-sectional view of sequentially layering a second plurality of material layers on a second surface of the part in a second direction;
[0031] FIG. **18**B shows a cross-sectional view of sequentially layering a second plurality of material layers on a second surface of the part in a second direction;
[0032] FIG. **18**C shows a cross-sectional view of the part after repeating sequential layering first and second pluralities of material layers on the part between rotations of the part;
[0033] FIG. **18**D shows a cross-sectional view of sequentially layering pluralities of material layers at a non-perpendicular angle on the part;
[0034] FIG. **18**E shows a cross-sectional view of sequentially layering pluralities of material layers at a non-perpendicular angle on the part;
[0035] FIG. **19** shows a cross-sectional view of sequentially layering a first plurality of material layers on a first surface of the part in a first direction, creating a stepped extension;
[0036] FIG. **20** shows a cross-sectional view of the part of FIG. **19** after rotating the part;
[0037] FIG. **21** shows a cross-sectional view of sequentially layering a second plurality of material layers on a second surface of the part of FIG. **20** in a second direction;
[0038] FIG. **22** shows as cross-sectional view of machining the part of FIG. **21** to form a new overhung section;
[0039] FIG. **23** shows a cross-sectional view of a pair of overhung sections in an illustrative part in the form of a double flared tip rail including portions to be removed and intended removal lines;
[0040] FIG. **24** shows a cross-sectional view an illustrative overhung section in the form of double flared tip rail that extends inwardly; and
[0041] FIG. **25** shows a cross-sectional view of an illustrative overhung section in the form of flared tip rail having a portion removed and the part rotated by a predetermined angle to form an inclined build surface; and
[0042] FIG. **26** shows a cross-sectional view of sequentially layering a plurality of material layers on the inclined surface of the part.
[0043] It is noted that the drawings of the disclosure are not necessarily to scale. The drawings are intended to depict only typical aspects of the disclosure and therefore should not be considered as limiting the scope of the disclosure. In the drawings, like numbering represents like elements between the drawings.

DETAILED DESCRIPTION

[0044] Aspects and advantages of the present application are set forth below in the following description, or may be obvious from the description, or may be learned through practice of the disclosure. Reference will now be made in detail to present embodiments of the disclosure, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical designations to refer to features in the drawings. As will be appreciated, each example is provided by way of explanation of the disclosure, not limitation of the disclosure. In fact, it will be apparent to those skilled in the art that modifications and variations can be made in the present disclosure without departing from the scope or spirit thereof. For instance, features illustrated or described as part of one embodiment may be used on another embodiment to yield a still further embodiment. It is intended that the present disclosure covers such modifications and variations as come within the scope of the appended claims and their equivalents. Certain terms have been selected to describe the present disclosure and its component subsystems and parts. To the extent possible, these terms have been chosen based on the terminology common to the technology field. Still it will be appreciated that such terms often are subject to differing interpretations. For example, what may be referred to herein as a single component, may be referenced elsewhere as consisting of multiple components, or, what may be referenced herein as including multiple components, may be referred to elsewhere as being a single component. Thus, in understanding the scope of the present disclosure, attention should not only be paid to the particular terminology used, but also to the accompanying description and context, as well as the structure, configuration, function, and/or usage of the component being referenced and described, including the manner in which the term relates to the several figures, as well as, the precise usage of the terminology in the appended claims. Further, while the following examples are presented in relation to an illustrative application of a turbomachine blade usable in a compressor or turbine of a gas turbine system, the technology of the present application also may be applicable to other categories of turbomachines, without limitation, and a large variety of other industrial parts, as would be understood by a person of ordinary skill in the relevant technological arts.

[0045] Given the nature of how gas turbines operate, several terms prove particularly useful in describing certain aspects of their function, and may be advantageous in describing the methods disclosed. As will be understood, these terms may be used both in describing the gas turbine or one of the subsystems thereof, e.g., the compressor, combustor, or turbine, as well as to describe or claim components or subcomponents for usage therewithin. In the latter case, the terminology should be understood as describing those components as they would be upon proper installation and/or function within the gas turbine engine or primary subsystem. These terms and their definitions, unless specifically stated otherwise, are as follows.

[0046] The terms “forward” and “aft” refer to directions relative to the orientation of the gas turbine and, more specifically, the relative positioning of the compressor and turbine sections of the engine. Thus, as used therein, the term “forward” refers to the compressor end while “aft” refers to the turbine end. It will be appreciated that each of these terms may be used to indicate direction of movement or relative position along the central axis of the engine. As stated above, these terms may be used to describe attributes of the gas turbine or one of its primary subsystems, as well as for components or subcomponents positioned therewithin. Thus, for example, when a component, such as a turbomachine blade, is described or claimed as having a “forward face”, it may be understood as referring to a face that faces toward the forward direction as defined by the orientation of the gas turbine (i.e., the compressor being designated as the forward end and turbine being designated as the aft end). To take a major subsystem like the turbine as another example (and assuming a typical gas turbine arrangement such as the one shown in FIG. **1**), the forward and aft directions may be defined relative to a forward end of the turbine, where a working fluid enters the turbine, and an aft end of the turbine, where the working fluid exits the turbine.

[0047] The terms “downstream” and “upstream” are used herein to indicate position within a specified conduit or flowpath relative to the direction of flow (hereinafter “flow direction”) moving through it. Thus, the term “downstream” refers to the direction in which a fluid is flowing through the specified conduit, while “upstream” refers to the direction opposite to that. These terms may be construed as referring to the flow direction through the conduit given normal or anticipated operation. Given the configuration of gas turbines, particularly the arrangement of the compressor and turbine sections about a common shaft or rotor, as well as the cylindrical configuration common to many combustor types, terms describing position relative to an axis may be regularly used herein. In this regard, it will be appreciated that the term “radial” refers to movement or position perpendicular to an axis. Related to this, it may be required to describe relative distance from the central axis. In such cases, for example, if a first component resides closer to the central axis than a second component, the first component will be described as being either "radially inward" or "inboard" of the second component. If, on the other hand, the first component resides further from the central axis, the first component will be described as being either "radially outward" or "outboard" of the second component. As used herein, the term "axial" refers to movement or position parallel to an axis, while the term "circumferential" refers to movement or position around an axis. Unless otherwise stated or plainly contextually apparent, these terms should be construed as relating to the central axis of the compressor and/or turbine sections of the gas turbine as defined by the rotor extending through each, even if the terms are describing or claiming attributes of non-integral components—such as rotor or stator blades—that function therein.

[0048] The term "turbomachine blade" or "blade", without further specificity, is a reference to the rotating blades of either the compressor or the turbine, and so may include both compressor rotor blades and turbine rotor blades, and may also be a reference to stationary blades of either the compressor or the turbine and so may include both compressor stator blades and turbine stator blades. The term "blades" may be used to generally refer to either type of blade. Thus, without further specificity, the term "turbomachine blade" or "blade" is inclusive to all type of turbine engine blades, including compressor rotor blades, compressor stator blades, turbine rotor blades, turbine stator blades, and the like.

[0049] In addition, several descriptive terms may be used regularly herein, as described below. The terms "first", "second", and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components.

[0050] As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. "Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur or that the subsequently describe component or element may or may not be present, and that the description includes instances where the event occurs or the component is present and instances where it does not occur or is not present.

[0051] Where an element or layer is referred to as being "on," "engaged to," "connected to" or "coupled to" another element or layer, it may be directly on, engaged to, connected to, or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly engaged to," "directly connected to" or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0052] By way of background, referring now with specificity to the figures, FIGS. **1-3** illustrate an illustrative gas turbine in accordance with the present disclosure or within which turbomachine parts of the present disclosure may be used. FIG. **1** is a schematic representation of a gas turbine **10**. In general, gas turbines operate by extracting energy from a pressurized flow of hot gas produced by the combustion of a fuel in a stream of compressed air. As illustrated in FIG. **1**, gas turbine **10** may be configured with an axial compressor **12** that is mechanically coupled by a common shaft or rotor to a downstream turbine section or turbine **14**, and a combustor **16** positioned between compressor **12** and turbine **14**. As illustrated in FIG. **1**, gas turbine **10** may be formed about a common central axis **18**.

[0053] FIG. **2** illustrates a view of an illustrative multi-staged axial compressor **12** that may be used in gas turbine **10** of FIG. **1**. As shown, compressor **12** may have a plurality of stages, each of which include a row of compressor rotor blades **20** and a row of compressor stator blades **22**. Thus, a first stage may include a row of compressor rotor blades **20**, which rotate about a central shaft, followed by a row of compressor stator blades **22**, which remain stationary during operation. FIG. **3** illustrates a partial view of an illustrative turbine section or turbine **14** that may be used in gas turbine **10** of FIG. **1**. Turbine **14** also may include a plurality of stages. Three illustrative stages are shown, but more or less may be present. Each stage may include a plurality of turbine nozzles or stator blades **24**, which remain stationary during operation, followed by a plurality of turbine buckets or rotor blades **26**, which rotate about the shaft during operation. Turbine stator blades **24** generally are circumferentially spaced one from the other and fixed about the axis of rotation to an outer casing. Turbine rotor blades **26** may be mounted on a turbine wheel or rotor disc (not shown) for rotation about a central axis. It will be appreciated that turbine stator blades **24** and turbine rotor blades **26** lie in the hot gas path or working fluid flowpath through turbine **14**. The direction of flow of the combustion gases or working fluid within the working fluid flowpath is indicated by the arrow.

[0054] In one example of operation for gas turbine **10**, the rotation of compressor rotor blades **20** within axial compressor **12** may compress a flow of air. In combustor **16**, energy may be released when the compressed air is mixed with a fuel and ignited. The resulting flow of hot gases or working fluid from combustor **16** is then directed over turbine rotor blades **26**, which induces the rotation of turbine rotor blades **26** about the shaft. In this way, the energy of the flow of working fluid is transformed into the mechanical energy of the rotating blades and, given the connection between the rotor blades and the shaft, the rotating shaft. The mechanical energy of the shaft may then be used to drive the rotation of compressor rotor blades **20**, such that the necessary supply of compressed air is produced, and/or, for example, a generator to produce electricity.

[0055] For background purposes, FIG. **4** provides a perspective view of an illustrative part **28** having an overhung section **30**. For purposes of description, part **28** is illustrated as a flared tip turbomachine blade **25**, and more particularly, a turbine rotor blade **26**. It is noted that the teachings of the disclosure are also applicable to any part **28** with overhung section **30** other than a turbomachine blade **25**, as described herein, such as any other hot gas path (HGP) part of gas turbine **10**. The teachings of the disclosure are also applicable to other industrial parts having an overhung section.

[0056] Turbomachine blade **25** may include a root **31** that is configured for attaching to a rotor disc. Root **31**, for example, may include a dovetail **32** configured for mounting in a corresponding dovetail slot in the perimeter of a rotor disc. Root **31** may further include a shank **34** that extends between dovetail **32** and a platform **36**. Platform **36**, as shown, generally forms the junction between root **31** and an airfoil **40**, with the airfoil being the active component of turbine rotor blade **26** that intercepts the flow of working fluid through turbine **14** and induces the desired rotation. Platform **36** may define the inboard end of airfoil **40**. Platform **36** also may define a section of the inboard boundary of the working fluid flowpath through turbine **14**.

[0057] Airfoil **40** of the turbomachine blade typically includes a concave pressure face **42** and a circumferentially or laterally opposite convex suction face **44**. Pressure face **42** and suction face **44** may extend axially between opposite leading and trailing edges **46**, **48**, respectively, and, in the radial direction, between an inboard end, which may be defined at the junction with platform **36**, and an outboard tip, which may include a flared tip rail. Airfoil **40** may include a curved or contoured shape that is designed for promoting desired aerodynamic performance.

[0058] As used herein, turbomachine blade **25** and components thereof may be described according to orientation characteristics of turbine **14**. It should be appreciated that, in such cases, turbomachine blade **25** is assumed to be properly installed within turbine **14**. Such orientation characteristics may include radial, axial, and circumferential directions defined relative to central axis **18** (FIG. **1**) of turbine **14**. Forward and aft directions may be defined relative to a forward end of turbine **14**, at where the working fluid enters turbine **14** from combustor **16**, and an aft end of turbine **14**, at where the working fluid exits turbine **14**. A rotation direction may be defined relative to an expected direction of rotation of turbomachine blade **25** about central axis **18** (FIG. **1**) of turbine **14** during operation.

[0059] As indicated above, the disclosure provides methods of forming or repairing part **28** with an overhung section **30**, e.g., a flared tip of turbomachine blade **25**. For repair purposes, the method may include removing a portion, and adding a section to the part. For purposes of initially forming part **28**, the method may add a section to a portion of part **28** already formed. In any event, the section being added or formed includes the overhung section. The adding includes sequentially layering one or more pluralities of material layers on the part. When complete, the plurality of material layers approximates dimensions of the section including the overhung section. The sequential layering may include, for example, laser welding, cold metal transfer (CMT), tungsten inert gas (TIG) welding, laser sintering, direct metal laser melting (DMLM), net shape methods, near net shape methods, etc., and may be carried out in a number of ways that create varied layers within the section. The method and resulting part formed thereby may be formed by net shape methods that minimize or eliminate post build processing or finishing. The method may include machining the at least one plurality of material layers to form the section including the overhung section.

[0060] FIG. **5** shows an enlarged, cross-sectional view of a used part **28** having a body **60** having a first side **62** and an opposing, second side **64**, according to embodiments of the disclosure. Body **60** may also have a longitudinal axis **75**. Longitudinal axis may be any axis of reference of body **60**, e.g., through a length thereof. In terms of an airfoil **40**, the longitudinal axis may be a radial axis as the airfoil is positioned in gas turbine **10** (FIG. **1**). Overhung section **30** extends in an overhung manner from, for example, first side **62** of body **60**. Overhung section **30** lacks vertical structural support in a portion thereof. In one embodiment, overhung section **30** is opposite an opposing member **66** on second side **64** of body **60**, and has more mass than opposing member **66**. In the example shown, part **28** includes turbomachine blade **25** including a flared tip rail **70** that overhangs, for example, suction face **44** of the blade on first side **62**. Hence, flared tip rail **70** is an example of an overhung section **30** (FIG. **4**) of a part **28**. Body **60** includes airfoil **40**, and flared tip rail **70** is opposite an opposing member **66** in the form of a radially extending tip rail **134** extending from an end of airfoil **40**. Flared tip rail **70** extends circumferentially relative to an axis **18** (FIG. **1**) of gas turbine **10**. In other embodiments, overhung section **30** may be opposite another overhung section, e.g., flared tip rail **70**, that may or may not have different mass, and may extend around the periphery of airfoil **40**—see e.g., FIGS. **23** and **24**.

[0061] A damaged overhung portion may include overhung flared tip rail **70**, i.e., an overhung flared tip rail lacking structural support. Portion **72** may include any structure that is desired to be removed, and may include a portion with no damage or a portion with a variety of damage such as but not limited to worn surfaces, cracks, openings, roughness, etc. In this situation, as shown in FIG. **6**, portion **72** may be removed from part **28** to create a surface **74** on the part, e.g., on turbomachine blade **25**. Portion **72** may also be defined by surface/line **74***a*, where the portion removed is deeper and extends to a non-flared section of suction face **44**. Portion **72** may be removed using any now known or later developed technique including but not limited to: electric discharge machining (EDM), mechanical cutting/grinding, laser cutting, etc. As shown in FIG. **6**, while some remnants of flared tip rail **70** may or may not remain, portion **72** is removed so as to form a surface **74** upon which the removed section can be reformed. Surface **74** may be flat, curved or have a three-dimensional shape or profile. As also shown in FIG. **6**, in one embodiment, the angle of surface **74** can be a substantially horizontal plane, i.e., with body in a vertical position—longitudinal axis **75** vertical. As will be described herein, surface **74** may also be formed at a non-horizontal angle, and the part rotated as required to allow formation of new layers. In one non-limiting example, at most half of flared tip rail **70** is removed, e.g., based on at most half of portion **72** being removed. In another non-limiting example, more than half of flared tip rail **70** is removed, e.g., based on more than half of portion **72** being removed.

[0062] Embodiments of the disclosure may also include initial manufacture of flared tip rail **70**. In this case, the starting structure, as shown in FIG. **6**, may be manufactured using any appropriate technique for the material and structure being built. Non-limiting examples may include casting and additive manufacture. In any event, surface **74** upon which an overhung section is to be built, is generated.

[0063] FIG. **7** shows a cross-sectional view of adding a section **76** to part **28**, where section **76** includes a new overhung section **78**. The adding includes sequentially layering a plurality **80** of material layers **82** on part **28**, i.e., on surface **74**. Collectively, when complete, the plurality of material layers **82** approximates dimensions of the section including new overhung section **78**. That is, the added section approximates dimensions of the desired new overhung section **78** being added, or portion **72** being replaced. As used herein, “approximate dimensions” generally indicates the new overhung section **78** can be formed by material removal with machining, and little or no additional material add. The adding of material layers **82** can be provided in a number of ways. For example, material layers **82** may be formed using laser welding, laser cladding, cold metal transfer (CMT), tungsten inert gas (TIG) welding, additive manufacturing, metal sintering, direct metal laser melting (DMLM), etc. In this case, as shown in the enlarged cross-sectional view of material layers **82** in FIG. **8**, sequential layering of plurality **80** of material layers **82** on part **28** includes forming a series of weld beads **84** to form each layer **82**. Any number of weld beads **84** may be used to form a single layer. The layers may be formed using the welding in any pattern, e.g., starting at a center or periphery and forming them in a continuous spiral weld bead, or forming individual linear weld beads side-by-side that extend from side to side of surface **74**, or a combination thereof. Surface **74** may be positioned in a substantially horizontal position (e.g., no more than +/−3° from horizontal) during the sequential layering to foster even layering of material, and then portion **72** can be replaced by sequentially layering at least one plurality **80** of material layers **82** on surface **74**.

[0064] In FIG. **7**, only a single plurality **80** of material layers **82** is used. Here, a second end **90** of the plurality of material layers **82** is stair-stepped to approximate dimensions of the overhung section (to be formed). In one example, a first end **86** of a single plurality **80** of material layers **82** are illustrated as generally aligned with a surface **88** of part **28**, and a second end **90** of single material layers **82** are stair-stepped to approximate dimensions of the overhung section (to be formed). Here, second ends **90** progressively extend to larger extents over suction face **44** of turbomachine blade **25** in an overhung fashion, moving upwardly as illustrated. Here, each layer **82** may have first ends **86** thereof radially or vertically aligned. It is noted that first ends **86** of the single plurality of material layers **82** may not be precisely aligned as illustrated, and may have uneven edges relative to surface **88** of part **28**. These uneven edges may be later machined to be aligned with surface **88** of part **28**.

[0065] FIG. **9** shows a schematic plan view of weld beads **84** of layers **82**. As illustrated, weld beads **84** of different layers **82**A may be angled relative to weld beads **84** of other layers **82**B. For example, series of weld beads **84** for at least one first material layer **82**A of plurality **80** of material layers **82** may be formed at a non-parallel angle to the series of weld beads **84** for at least one second material layer **82**B of the same plurality **80** of layers. Any angle may be employed to foster strength in the new section **76** (FIG. **10**). In addition to the direction of weld beads, the sequential layering may be carried out in a manner to control a local temperature of the structure to prevent thermal cracking. For example, a user could jump from place-to-place on a build surface **74** to allow cooling in one area while working in another area, and ensuring a new weld bead is applied in a location that has cooled prior to application of the new weld bead.

[0066] FIG. **10** shows part **28** after machining plurality **80** of material layers **82** to form new section **76** including new overhung section **78**. Where the process is replacing portion **72** (FIG. **5**), overhung section **78** may match a shape and dimensions of portion **72** (FIG. **5**). Alternatively, it may have a different shape and dimensions to provide improved performance and/or longevity. Machining may include any manner of material removal allowing blending of surfaces, resulting in the desired shape and dimension for new section **76**. Non-limiting and non-comprehensive examples of machining may include: milling, grinding, cutting, polishing, etc. As noted, body **60** may include an airfoil **40** of turbomachine blade **25**. In this case, overhung section **78** includes flared tip rail **70** extending from one of first side **62** (shown) and second side **64** of the airfoil **40**. In FIG. **10**, turbomachine blade **25** includes flared tip rail **70** extending from airfoil **40**, with radially-facing outer surface **138** of overhung section **78** being parallel to axis **18** of the turbomachine.

[0067] In FIG. **7**, surface **74** is formed so as to be parallel to a radially-facing outer surface **92** of new section **76**, e.g., perhaps extending parallel relative to axis **18** (FIG. **1**) of gas turbine **10** (FIG. **1**). In other words, surface **74** extends perpendicular to a longitudinal axis **75** of the part, or in terms of a turbomachine blade, a radial axis **75** of body **60** of airfoil **40**. Consequently, part **28** includes at least a portion of overhung section **78** that includes a plurality **80** of material layers **82**, where each material layer **82** extends at a perpendicular angle relative to a longitudinal axis **75** of body **60**. The portion of overhung section **78** may include at most half of overhung section **78** extending from a floor surface **136** to a radially-facing outer surface (when blade mounted) of overhung section **78**, or more than half of overhung section **78**. In an alternative embodiment, as shown in FIG. **25**, part **28** may be rotated so that surface **74** is inclined from horizontal. For example, the angle of rotation θ**1** may be about 15° to about 60°, so that longitudinal axis **75** of part **28** is at angle of rotation θ**1** from vertical. FIG. **26** shows a cross-sectional view of adding new section **76** to part **28**, where new section **76** includes a new overhung section **78**. The adding includes sequentially layering a plurality **80** of inclined material layers **82** on part **28**, i.e., on inclined surface **74**. Collectively, when complete, plurality **80** of material layers **82** approximates dimensions of new section **76** including overhung section **78** with a greater overhang angle than would be obtainable with a horizontal surface build as shown in FIG. **7**. That is, the added section **76** approximates dimensions of the desired new overhung section **78** being added, or damaged section **72** (FIG. **5**) being replaced, or if desired, with a greater overhang angle. For example, an overhang angle θ**2** may be about 50° to about 65°, or about 55° to about 60°. The overhang angle θ**2** is measured between the longitudinal axis **75** of the part and a line intersecting the bottom corners (or edge) of the overhanging material layers **82**, as shown in FIG. **26**. The inclined build reduces the perceived overhang of each layer, so that greater amounts of overhang may be successfully obtained.

[0068] As shown in FIG. **11**, in alternative embodiments, removing portion **72** of part **28** may include creating a surface **94** that is not perpendicular to longitudinal axis **75** of body **60**, i.e., a radial axis **75** of body **60** of airfoil **40**. Rather, surface **94** may be at an acute angle δ relative to longitudinal axis **75** of body **60**, i.e., a radial axis **75** of airfoil **40**. To be clear, an acute angle is between 0° and 90°. Surface **94** may also be at an acute angle α relative to an axis **18** (added in phantom in FIG. **11**) of gas turbine **10**. Additionally, surface **94** will be at an angle that is neither perpendicular nor parallel to a target radially-facing outer planar surface **96** (FIG. **14**) of new overhung section **78** of the final product, i.e., a new flared tip rail.

[0069] As shown in FIG. **13**A, surface **94** may be rotated so as to be substantially horizontal (+/−3°) prior to sequentially layering plurality **80** of material layers **82** thereon. Alternatively, as shown in FIG. **13**B, part **28** may be rotated to position surface **94** at angle β other than horizontal and vertical prior to sequentially layering plurality **80** of material layers **82**. Part **28** may alternatively be rotated to the FIG. **13**B position after a certain number of material layers **82** are sequentially layered. Angle β may be any angle that allows for the desired stepping of plurality **80** of material layers **82**, i.e., that is not substantially horizontal as defined herein. For example, angle β may be such that ends **98** of layers **82** step outwardly in a manner that allows later machining of the ends to be aligned with surface **88**, and such that ends **100** of layers **82** step outwardly in a manner that forms new overhung section **78** of part **28**. Angle β may allow formation of overhung section **78** with an extent that could not be created if surface **94** was horizontal. For example, an outward length L**2** (FIG. **14**) of new overhung section **78** could be greater than an initial outward length L**1** (FIG. **11**) of original overhung section **30**, or an angle ε**2** of new overhang section **78** relative to radial axis **75** of body **60** may be greater than an initial angle ε**1** (FIG. **11**) of original overhang section **30** relative to radial axis **75** of body **60**. Angle β may be any angle that allows for the sequential layering without allowing undesired forming of the layers, e.g., in the form of dripping, slumping or breaking.

[0070] FIGS. **13**A-B also show sequentially layering plurality **80** of layers **82** on surface **94**. In this case, each end **98**, **100** of layers **82** may be stair-stepped. That is, as shown in FIGS. **13**A-B, the sequential layering of plurality **80** of material layers **82** may include forming a first end **98** of the plurality of material layers in a stair-stepped manner from a first side of the surface **94**, and a second end **100** of plurality **80** of material layers **82** in a stair-stepped manner from a second side of the surface **94**. One of the first end and the second ends (**100** as shown) approximates dimensions of section **76** including overhung section **78**, as described herein. Ends **98** may be stair-stepped so as to be aligned with surface **88** of part **28**, when finished, and as noted, ends **100** may be stair-stepped so as to form new overhung section **78** of part **28**, e.g., a new flared tip rail for turbomachine blade **25**. Here, as shown in phantom in FIG. **14**, after machining, layers **82** in new overhung section **78** of the finished product extend at acute angle α relative to axis **18** (shown schematically in phantom) of gas turbine **10** (FIG. **1**), at acute angle α relative to target outer surface **96** (FIG. **14**), and at an acute angle δ relative to longitudinal axis **75** of body **60** or part **28** (i.e., radial axis **75** of airfoil **40**). In addition, target outer surface **96**, when complete, is at angle α relative to plurality **80** of material layers **82** and surface **94** upon which the layers are built. It is to be understood that while target surface **96** is shown as planar, it may also not be a planar surface; for example, surface **96** could be curved or have a three-dimensional profile.

[0071] FIG. **14** shows machining plurality **80** of material layers **82** to form overhung section **78** and target outer planar surface **138**. Target outer (planar) surface **96** is at angle α relative to plurality **80** of material layers **82**. Turbomachine part **28**, shown in FIG. **14**, includes body **60** having a first side **62**, a second side **64** which may be opposed first side **62**, and a longitudinal axis **75**. Overhung section **76** extends in an overhung manner from at least one of first side **62** (shown) and second side **64** of body **60**. FIG. **23** shows overhung sections extending from both sides. As noted in FIG. **14**, at least a portion of overhung section **78** includes a plurality **80** of material layers **82**, where each material layer **82** extends at an acute angle δ relative to longitudinal axis **75** of body **60**. In one embodiment, a radially extending tip rail **134** may extend from the airfoil **40** (from the other side of body **60**), and radially-facing outer surface **138** of the overhung section **78** may be parallel to axis **18** of the turbomachine, when in an operative position.

[0072] Referring to FIGS. **15-22**, in another embodiment of the disclosure, more than one plurality of material layers **82** may be used to form new section **76** including new overhung section **78**. Here, a section **76** may be added to part **28**, including overhung section **78** by sequential layering more than one plurality of material layers. The method may include sequentially layering a first plurality of material layers on the part extending in a first direction, and sequentially layering a second plurality of material layers on the part extending in a second direction different than the first direction, e.g., two pluralities of layers built on perpendicular surfaces formed on the part. The second plurality of material layers generally meets with the first plurality of material layers, i.e., to form new section **76**. The different layers of each plurality of layers can vary in material, e.g., material layers may alternate material within a given plurality of layers. In addition or alternatively, the material within each plurality of layers may be the same, but the two pluralities of layers may use different material. Either or both pluralities of material layers **82** may use the same or different material than body **60**.

[0073] As shown in FIGS. **6** and **15**, if applied to a used part, any portion **72** of part **28** may be removed, creating surface **74**. Otherwise, formation of new section **76** may be from a part initially formed, as shown in FIG. **6**. In one embodiment, as shown in FIG. **15**, adding section **76** to part **28** including overhung section **78** may include sequential layering a first plurality **110** of material layers **82** on part **28** extending in a first direction, e.g., generally horizontal as shown but perhaps with some angle departing from horizontal. In this example, first plurality **110** of layers **82** may be sequentially formed horizontally on part **28** in a manner that consumes a portion **112** (FIG. **6**) of flared tip rail **70**. Alternatively, as shown in FIG. **16**, prior to the first sequential layering, any material desired, such as portion **112** (shown in phantom) of flared tip rail **70** (FIG. **6**), may be removed to form another surface **114**. That is, another portion **112** of part **28** is removed to create another surface **114**. In this case, after any necessary rotation, layers **82** may be sequentially formed horizontally on part **28** on surface **114**, i.e., not consuming any other material. In this setting, sequential layering of first plurality **110** of material layers **82** is on surface **114** and forms an extension **116** of surface **114**. Ends **118** of layers **82** are ideally aligned with surface **74** when formed, but where they are not aligned, they may be machined to be aligned with surface **74**. In FIG. **15**, sequential layering of first plurality **110** of material layers **82** creates extension **116** of surface **74**. As will be described herein, alternative embodiments may form the extension with a stair-stepped end—see e.g., FIGS. **18**C and **19**.

[0074] FIG. **17** shows rotating part **28** such that surface **74** is at a different angle, e.g., substantially horizontal, and FIG. **18**A shows sequentially layering a second plurality **120** of material layers **82** on part **28** extending in a second, different direction, e.g., perpendicular to first plurality **110** of material layers **82**. In this embodiment, as noted, sequential layering of first plurality **110** of material layers **82** creates extension **116** of surface **74**, and as shown in FIG. **18**A, sequential layering of a second plurality **120** of material layers **82** is on first surface **74** and extension **116** of first surface **74**. Second plurality **120** of material layers **82** meet with first plurality **110** of material layers **82**, i.e., generally they come together and mate or generally mate together.

[0075] FIGS. **18**A-**18**E show various embodiments that result in first plurality **110** of material layers **82** and second plurality **120** of material layers **82** collectively approximating the dimensions of new section **76** including new overhung section **78**, and being non-coplanar relative to one another. As will be described, the second plurality **120** of material layers **82** can extend in a variety of non-coplanar directions (i.e., not in the same plane) relative to the first direction of first plurality **110** of material layers **82**. FIGS. **17** and **18**A show an embodiment in which the eventual horizontal second plurality **120** of material layers **82** extends over vertical first plurality **110** of material layers **82**, i.e., with angle γ between surfaces **74**, **114** substantially perpendicular (90°+/−2°). FIG. **18**B shows an alternative embodiment in which plurality **110**, **120** of material layers are reversed in position. That is, second plurality **120** of material layers **82** is formed first on surface **74** and provides extension **116**. Then, part **28** is rotated to have surface **114** and extension **116** available to be built on, and first plurality **110** of material layers **82** is formed. First plurality **110** of material layers **182** ends up extending adjacent ends of second plurality **120** of material layers **82** that form extension **116**.

[0076] FIG. **18**C shows another alternative embodiment of the part after repeating the sequentially layering of each plurality. In other words, less than all material layers **82** of first and second pluralities **110**, **120** of material layers **82** are formed on the part between rotations of the part. Here, some number of layers, e.g., 1-4, less than all layers of first or second plurality **110**, **120** of material layers **82** are built on one surface **74**, **114**; the part is then rotated, and another number of layers, e.g., 1-4, less than all of the other plurality **110**, **120** of material layers **82**, is built on the opposing surface **74**, **114**. This approach creates a stair-stepped mating or generally stair-stepped mating of groups of layers **82** within each plurality **110**, **120**. This process may be advantageous for reducing thermal stress, and to address other mechanical issues.

[0077] FIGS. **18**D-E show other alternative embodiments of the part in which surfaces **74** and **114** are formed in non-coplanar directions and have a non-perpendicular (90°) angle γ. Here, the positioning of surfaces **74** or **114** during layering of respective pluralities **110**, **120** of material layers **82** can be at any position necessary to ensure the desired joining of layers and accommodate hardware welding constraints. FIG. **18**D shows surfaces **74**, **114** at an obtuse angle γ ($90^\circ<\gamma<180^\circ$), and FIG. **18**E shows surfaces **74**, **114** at an angle γ that is greater than 180°.

[0078] FIGS. **19-21** show an alternative embodiment that is substantially similar to that described relative to FIGS. **15-18**E, except sequential layering of the first and second plurality **110**, **120** of material layers **82** each create stair-stepped ends that generally meet with one another. As with FIGS. **15** and **16**, the first sequential layering may consume portion **112** of the part, or another surface **114** can be created by removing portion **112** of the part and the layering completed on the surface. In any event, prior to the layering, for used part applications, any portion **72** of part **28** may be removed to create surface **74**, **114**.

[0079] FIG. **19** shows sequential layering of first plurality **110** of material layers **82** to create a stair-stepped extension **122** of surface **114**. FIG. **20** shows any necessary rotating of the part, and FIG. **21** shows sequential layering of second plurality **120** of material layers **82** on surface **74** and stair-stepped extension **122** (FIG. **20**) of surface **74**. More particularly, sequential layering of second plurality **120** of material layers **82** on surface **74** is carried out to generally mate material layers **82** thereof with stair-stepped extension **122** of surface **74** formed by first plurality **110** of material layers **82**, creating an interlocked bond. Here, as shown in FIG. **21**, the two pluralities **110**, **120** of material layers **82** may have mating stair-stepped ends, or have generally mating stair-stepped ends with perhaps some voids **83** therebetween at some locations. That is, ends of first plurality **110** of material layers **82** meet ends of second plurality **120** of material layers **82** in a stair-stepped fashion, perhaps with some voids **83** therein. While surfaces **74**, **114** are shown as perpendicular to one another in FIGS. **19-22**, any of the angles γ described relative to FIGS. **18**A-E may be employed with the stair-stepped layers.

[0080] FIG. **22** shows part **28** after machining pluralities **110**, **120** of material layers **82** to form section **76** including new overhung section **78**. This process can follow any of the described processes of sequentially layering more than one plurality of material layers. This machining process may be as described relative to FIG. **10**. While the machining is shown carried out from the FIG. **21** embodiment, it will be recognized that similar machining may be performed on the FIGS. **18**A-E embodiments.

[0081] FIG. **22** illustrates a turbomachine part **28** including body **60** having first side **62** and second side **64**. Overhung section **78** extends in an overhung manner from at least one of first side **62** and second side **64** (shown) of body **60**. At least a portion of overhung section **78** includes a first plurality **110** of material layers **82** extending in a first direction, and a second plurality **120** of material layers **82** extending in a second direction at a non-coplanar direction (see angle γ) relative to the first direction of first plurality **110** of material layers **82**—see FIGS. **18**A-E.

[0082] FIG. **23** shows an enlarged, cross-sectional view of a part **28** having a body **60** having a first side **62** and an opposing, second side **64**, according to other embodiments of the disclosure. Here, overhung sections **30**, **230** extend in an overhung manner from first side **62** of body **60** and from second side **64** of body, respectively. Overhung sections **30**, **230** both lack vertical structural support in a portion thereof. In this embodiment, overhung sections **30**, **230** may have the same mass and extend to the same extent, or one or the other may have more mass and extend to a different extent. In the example shown, part **28** includes turbomachine blade **25** including a flared tip rail **70**, **270** that overhangs, for example, suction face **44** and pressure face **42** of the blade. It is noted, however, that flared tip rail **70** may extend around an entire periphery of a tip of airfoil **40**. Hence, flared tip rail **70** is an example of an overhung section **30**, **230** of a part **28**. Body **60** includes airfoil **40**, and flared tip rail **70**. Flared tip rail **70** extends circumferentially relative to an axis **18** (FIG. **1**) of gas turbine **10**. While FIGS. **5-22** show a process for repairing flared tip rail **70** on one side of airfoil **40**, it will be readily recognized that the teachings of the disclosure can be repeated as many times and with as many build surfaces **74**, **94**, **114**, **116**, as necessary. Any number of portions **72** (damaged overhung portions) may be repaired or added.

[0083] FIG. **24** shows an enlarged, cross-sectional view of a part **28** having a body **60** having a first side **62** and an opposing, second side **64**, according to other embodiments of the disclosure. In FIGS. **5-23**, overhung section(s) **30**, **230** extended outwardly relative to body **60** of airfoil **40**. In FIG. **24**, overhung sections **330**, **430** extend in an overhung manner inwardly from first side **62** of body **60** and from second side **64** of body, respectively. Overhung sections **330**, **430** both lack vertical structural support in a portion thereof. In this embodiment, overhung sections **330**, **430** may have the same mass and extend to the same extent inwardly, or one or the other section may have more mass and extend to a different extent. While not shown, it will be recognized that one of inwardly extending overhung sections **330**, **430** may be replaced with a radially extending tip rail **134**, such as in FIG. **5**. Overhung sections **330**, **430** may be repaired or added according to any of the embodiments described herein. It is to be understood that the overhung sections may extend over pressure face **42**, suction face **44** and floor surface **136**, or all of these surfaces/faces or combinations thereof.

[0084] Part **28** may include a metal. In one embodiment, part **28** is made of metal such as a metal or metal alloy, such as a superalloy with a columnar grain structure (e.g., directionally solidified (DS) blades). In one embodiment, part **28** may be made of a first metal, which may include a pure metal or an alloy. As used herein, “superalloy” refers to an alloy having numerous excellent physical characteristics compared to conventional alloys, such as but not limited to: high mechanical strength, high thermal creep deformation resistance, like Rene N5, Rene N500, Rene 108, CM247, Haynes alloys, Inconel, MP98T, TMS alloys, CMSX single crystal alloys. In one embodiment, superalloys for which teachings of the disclosure may be especially advantageous are those superalloys having a high gamma prime (γ′) value. “Gamma prime” (γ′) is the primary strengthening phase in nickel-based alloys. Example high gamma prime superalloys include but are not limited to: Rene 108, N4, N5, N500, GTD 444, MarM 247 and IN 738. New section **76** and plurality **80**, **110**, **120** of material layers **82** may include the first metal, creating turbomachine blade **25** with all of the same material. In an alternative embodiment, section **76** may include a second, different metal than the first metal. In one embodiment, all of layers **82** of a particular plurality **80**, **110**, **120** of layers **82** may be the same material, but a different material than the rest of part **28**. That is, part **28** includes a first metal, and plurality(ies) **80**, **110**, **120** of material layers **82** includes a second, different metal than the first metal. Hence, new section **76** may be of a uniform material. Alternatively, different layers **82** of a plurality **80**, **110**, **120** of material layers **82** may be different, resulting in new section **76** having different materials therein. That is, plurality **80**, **110**, **120** of material layers **82** may include at least one first material layer including a first metal, and at least one second material layer including a second, different metal than the first metal. For example, material layers **82** of new section **76** near, for example, surface **74** or surface **114**, may match the material of part **28**, and layers away from surface **74** or surface **94** may be of a different material, e.g., harder to withstand more wear. Alternatively, different pluralities of layers may have different materials therewithin. That is, wherein at least one plurality **80**, **110**, **120** of material layers **82** may include at least one first material layer including a first metal, and at least one second material layer may include a second, different metal than the first metal. FIGS. **10**, **14** and **22** show material layers in phantom.

[0085] With reference to FIGS. **4**, **10**, **14**, and **22**, embodiments of the disclosure also include a turbomachine part **130** for gas turbine **10** (FIG. **1**). Turbomachine part **130** may include a turbomachine blade **25** including, as shown in FIGS. **4** and **5**, body **60** in the form of airfoil **40** having a first side **62** in the form of suction face **44**, and a second side **64** in the form of pressure face **42**. Turbomachine part **130** in the form of turbomachine blade **25** may also include root **31** (FIG. **4**). As shown in FIGS. **10**, **14** and **22**, turbomachine part **130** may also include new overhung section **78** in the form of a flared tip rail **132** extending in an overhung manner from at least one of first side **62** and second side **64** of body **60**, i.e., from at least one of pressure face **42** and suction face **44** (latter shown) of airfoil **40**. As shown in FIG. **14**, overhung section **78** in the form of new flared tip rail **132** may be opposite an opposing member **66** on second side **64** of body **60** in the form of radially extending tip rail **134**. Overhung section **78** and opposing member **66** extend from floor surface **136** of the body, e.g., an outer radial surface of airfoil **40**. Overhung section **30** may have more mass than opposing member **66**. As shown in FIG. **23**, overhung sections **30**, **230** in the form of new flared tip rail **232** may be formed on body **60**. It is emphasized that each overhung section **30**, **230** in FIG. **23** may take the form of any of the embodiments described herein. As shown in FIG. **24**, overhung sections **330**, **430** in the form of new inwardly extending flared tip rail(s) may also be formed on body **60**. In any event, the overhung sections extend from floor surface **136**, i.e., outer radial surface of airfoil **40**. Overhung section **30**, **230**, **330**, **430** may have the same or different masses and may extend to the same or different extents. In any event, overhung sections **30**, **230**, **330**, **430** extend circumferentially relative to axis **18** (FIG. **1**) of the turbomachine. It is also noted that overhung sections **30**, **230**, **330**, **430** may take the form of a single unitary overhung section that extends about an entire periphery of airfoil **40**.

[0086] As described herein, overhung section **30**, **230**, **330**, **430** in the form of flared tip rail **132** includes at least one plurality **80** of material layers **82** therein. In one embodiment, the plurality of layers **82** are positioned in at most half of the overhung section extending from floor surface **136** to radially-facing outer surface **201**, i.e., based on at most half of portion **72** being removed. As shown in FIG. **14**, in one embodiment, each material layer **82** may extend at an acute angle δ relative to a radial axis **75** of body **60**, and at an acute angle α relative to radially-facing outer surface **138** of overhung section **30**, i.e., a radially-facing outer surface of flared tip rail **132**. In this setting, surface **94** upon which plurality **80** of material layers **82** of new flared tip rail **132** were formed may also extend at an acute angle α relative to axis **18** (FIG. **1**) of gas turbine **10** with the turbomachine blade **26** and radial axis **75** of body **60**, in an operative position in the turbomachine. In another embodiment, shown in FIG. **22**, flared tip rail **132** may include a first plurality **110** of material layers **82** therein extending in a first direction and a second plurality **120** of material layers **82** extending in a second direction at a non-coplanar direction (not 180°) to the first direction of first plurality **110** of material layers **82**. The two plurality of layers may abut (FIGS. **18**A-B), have mating stair-stepped ends (FIG. **22**), or have generally mating stair-stepped ends (FIG. **21**) with perhaps some voids **83** therebetween at some locations. In one embodiment, one of two pluralities **120** of material layers **82** may be substantially parallel to axis **18** (FIG. **1**) of gas turbine **10** (FIG. **1**) with turbomachine part **130** in an operative position in the turbomachine (perpendicular to radial axis **75**). Further, the other of the two pluralities **110** of material layers **82** may extend in a non-coplanar direction relative to the plurality **120** of material layers **82**. As illustrated in FIGS. **18**A-C, the non-coplanar direction may be substantially perpendicular, i.e., 90°+/−2°. FIGS. **18**D-E show other non-coplanar directions that are not substantially perpendicular, i.e., not at 90°+/−2°.

[0087] Body **60** in the form of airfoil **40** may include a first metal, and at least one of the plurality of material layers **82** may include a second, different metal than the first metal. In other embodiments, plurality **80**, **110**, **120** of material layers **82** may include at least one first material layer therein including a first metal, and at least one second material layer therein including a second, different metal than the first metal. That is, each different material may be used within a given plurality of material layers. For example, layers **82** of new section **76** near surface **74** may match the material of part **28**, and layers away from surface **74** may be of a different material, e.g., harder to withstand more wear.

[0088] As shown in FIG. **8**, each material layer **82** may include a series of weld beads **84**. As shown in FIG. **9**, the series of weld beads **84** for at least one first material layer **82**A of the plurality of material layers may be at non-parallel angles to the series of weld beads **84** for at least one second material layer **82**B of the plurality of material layers.

[0089] Embodiments of the disclosure provide several methods for creating material layers for material addition and/or repair of overhung sections such as flared tip rails on turbine rotor blades. Flared tip rails can be machined to have the desired dimensions, shape, etc., post-operation to

maintain engine performance.
[0090] The foregoing drawings show some of the processing associated according to several embodiments of this disclosure. In this regard, each drawing represents a process associated with embodiments of the method described. It should also be noted that in some alternative implementations, the acts noted in the drawings may occur out of the order noted in the figure or, for example, may in fact be executed substantially concurrently or in the reverse order, depending upon the act involved. Also, one of ordinary skill in the art will recognize that additional processes that describe the processing may be added.
[0091] Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about,” “approximately” and “substantially,” are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Here and throughout the specification and claims, range limitations may be combined and/or interchanged; such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. “Approximately,” as applied to a particular value of a range, applies to both end values and, unless otherwise dependent on the precision of the instrument measuring the value, may indicate +/−10% of the stated value(s).
[0092] The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present disclosure has been presented for purposes of illustration and description but is not intended to be exhaustive or limited to the disclosure in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The embodiment was chosen and described in order to best explain the principles of the disclosure and the practical application and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

Claims

1. A turbomachine part, comprising: a body having a first side, a second side, and a longitudinal axis; and an overhung section extending in an overhung manner from at least one of the first side and the second side of the body, such that a portion of the overhung section lacks structural support in a direction parallel to the longitudinal axis of the body, wherein at least a portion of the overhung section includes a plurality of material layers, and each material layer extends at a perpendicular angle relative to a longitudinal axis of the body.
2. The turbomachine part of claim 1, wherein the body includes a first metal, and the plurality of material layers includes a second, different metal than the first metal.
3. The turbomachine part of claim 1, wherein the plurality of material layers includes at least one first material layer including a first metal, and at least one second material layer including a second, different metal than the first metal.
4. The turbomachine part of claim 1, wherein each layer of the plurality of material layers includes a series of weld beads.
5. The turbomachine part of claim 4, wherein the series of weld beads for at least one first material layer of the plurality of material layers is at a non-parallel angle to the series of weld beads for at least one second material layer of the plurality of material layers.
6. The turbomachine part of claim 1, wherein the overhung section extends from a first surface of the body, wherein the plurality of material layers is positioned in at most half of the overhung

section extending from the first surface to a radially-facing outer surface of the overhung section.

7. The turbomachine part of claim 1, wherein the body includes an airfoil of a turbomachine blade, and wherein the overhung section includes a flared tip rail extending from one of a first side and a second side of the airfoil, and further comprising a radially extending tip rail extending from the airfoil, and wherein a radially-facing outer surface of the overhung section is parallel to an axis of the turbomachine.

8. A gas turbine including the turbomachine part of claim 1.

9. A turbomachine part, comprising: a body having a first side, a second side, and a longitudinal axis; and an overhung section extending in an overhung manner from at least one of the first side and the second side of the body, such that a portion of the overhung section lacks structural support in a direction parallel to a longitudinal axis of the body, wherein at least a portion of the overhung section includes a first plurality of material layers extending in a first direction, and a second plurality of material layers extending in a second direction at a non-coplanar direction relative to the first direction of the first plurality of material layers.

10. The turbomachine part of claim 9, wherein the body includes a first metal, and at least one of the first and second plurality of material layers includes a second, different metal than the first metal.

11. The turbomachine part of claim 9, wherein within each of the first and second plurality of material layers, at least one first material layer includes a first metal, and at least one second material layer includes a second, different metal than the first metal.

12. The turbomachine part of claim 9, wherein each layer of the first and second plurality of material layers includes a series of weld beads.

13. The turbomachine part of claim 12, wherein the series of weld beads for at least one first material layer of one of the first and second plurality of material layers is at a non-parallel angle to the series of weld beads for at least one second material layer of the one of the first and second plurality of material layers.

14. The turbomachine part of claim 9, wherein the body includes an airfoil of a turbomachine blade, and wherein the overhung section includes a flared tip rail extending from an end of the airfoil, and further comprising a radially extending tip rail extending from the end of the airfoil.

15. The turbomachine part of claim 9, wherein ends of the first plurality of material layers meet ends of the second plurality of material layers in a stair-stepped fashion.

16. The turbomachine part of claim 15, wherein a material layer of the first and second plurality of material layers progressively extends to larger extents relative to a previous material layer such that the first and second plurality of material layers form mating stair-stepped ends.

17. A gas turbine including the turbomachine part of claim 9.