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(54) **TURBINE ENGINE AND TURBINE ENGINE COMPONENT WITH COOLING PEDESTALS**

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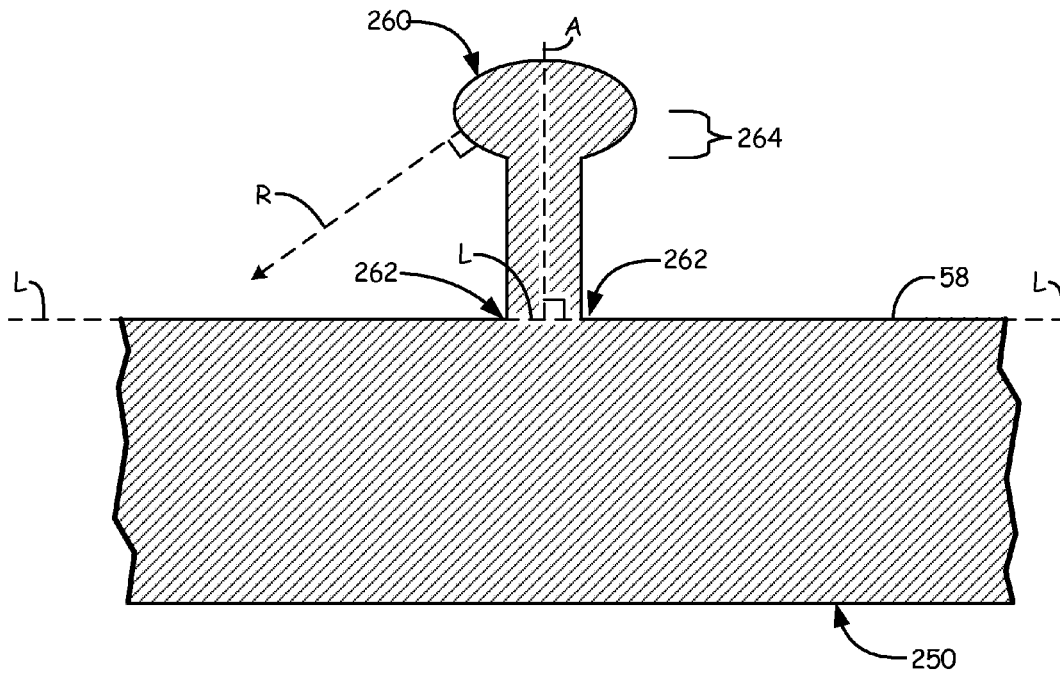
(57) **ABSTRACT**

§ 371 (c)(1),  
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A turbine engine component includes a surface to be cooled by a flow of cooling air and a plurality of pedestals projecting from the surface to be cooled. At least one of the pedestals includes a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**Related U.S. Application Data**

(60) Provisional application No. 61/805,171, filed on Mar. 26, 2013.



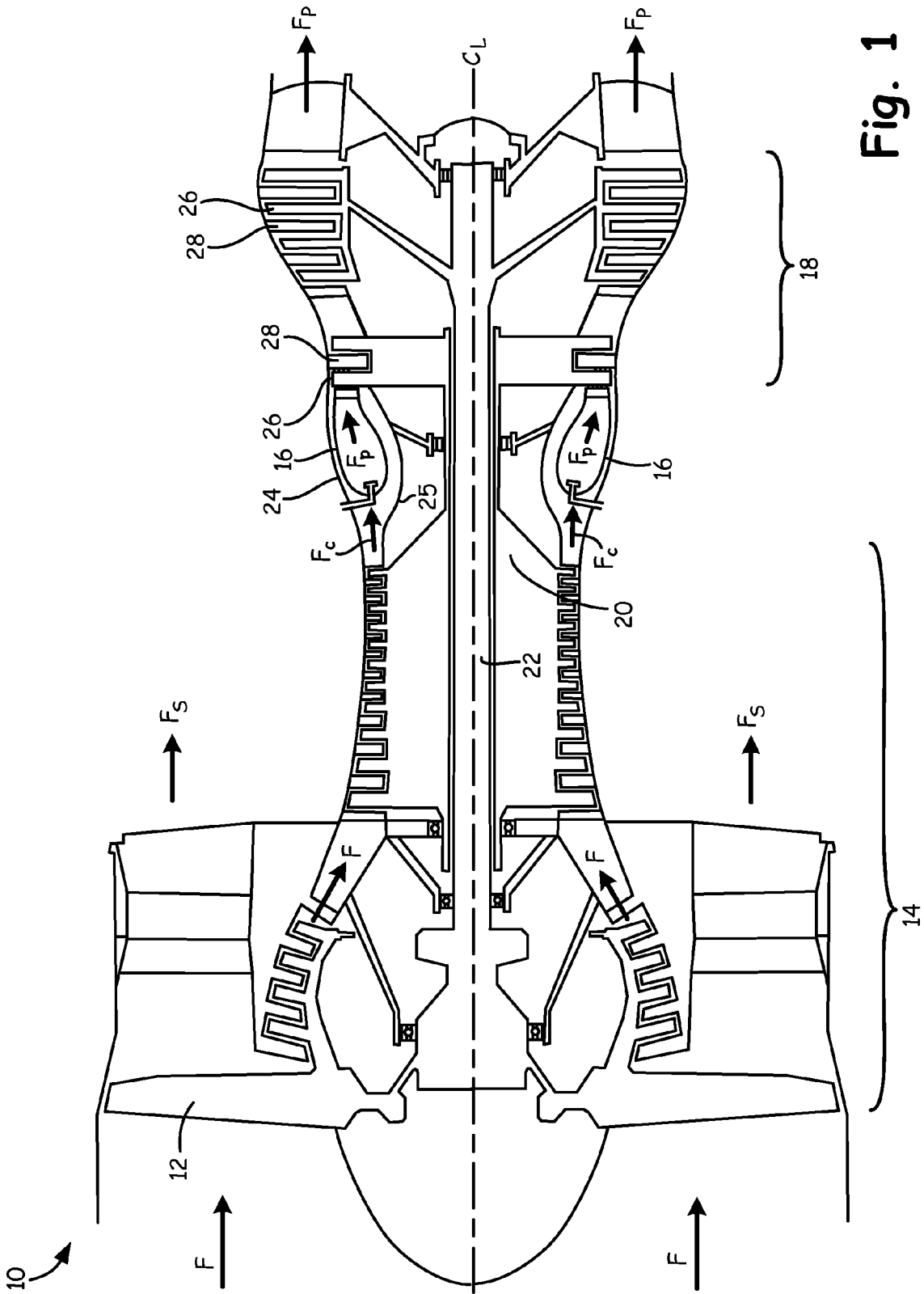


Fig. 1

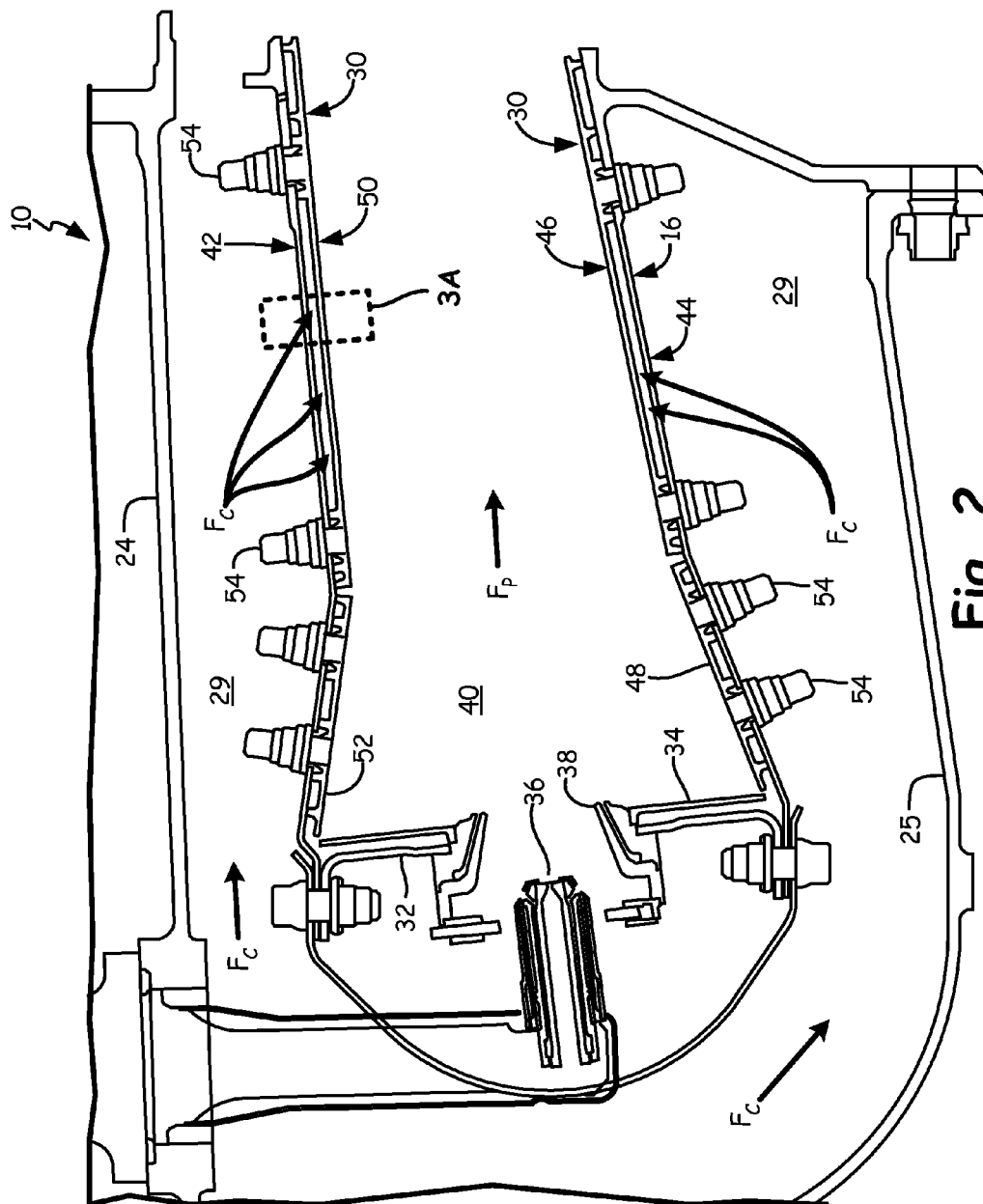


Fig. 2

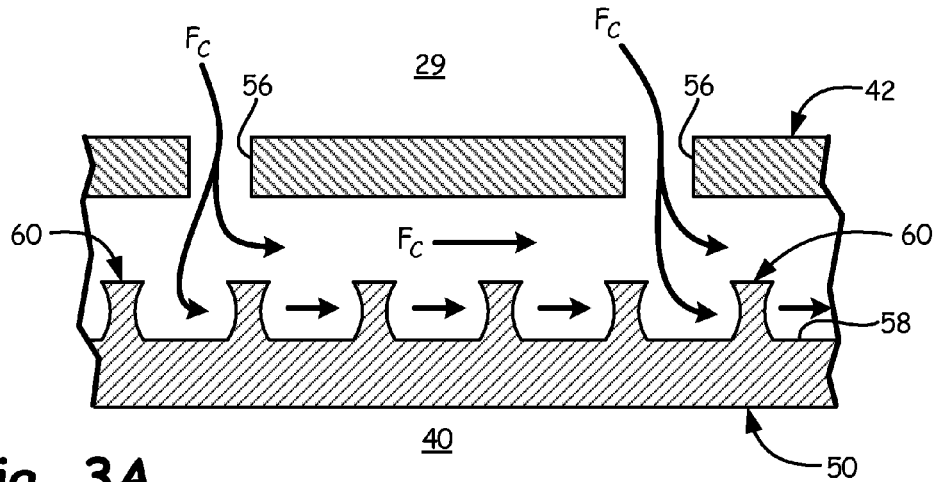


Fig. 3A

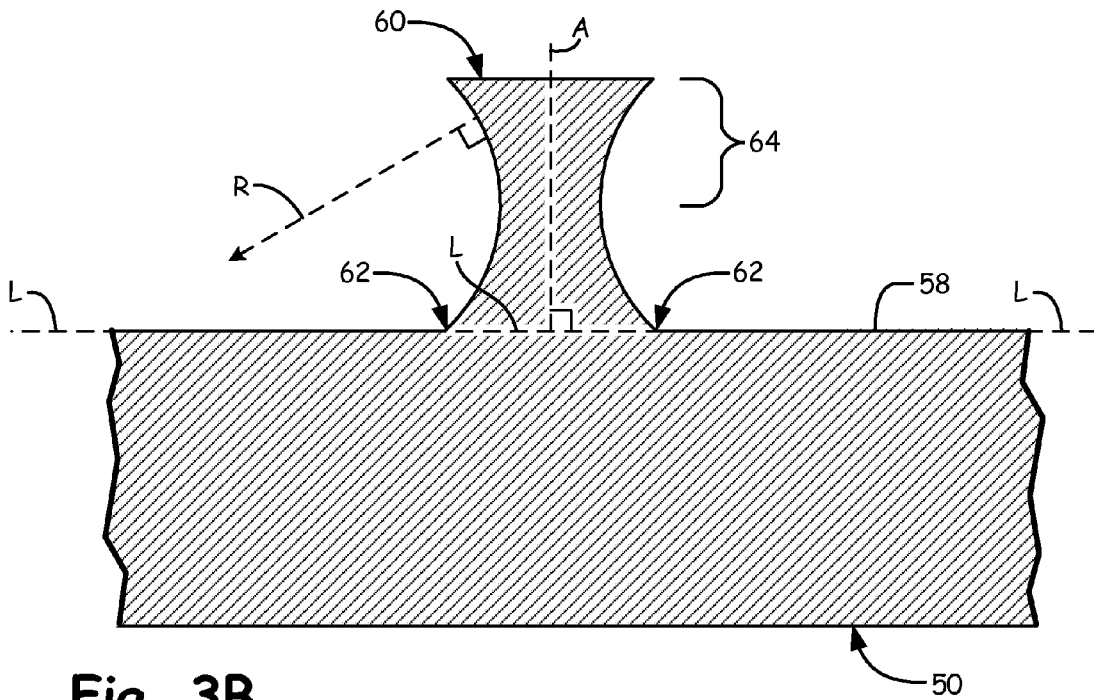


Fig. 3B

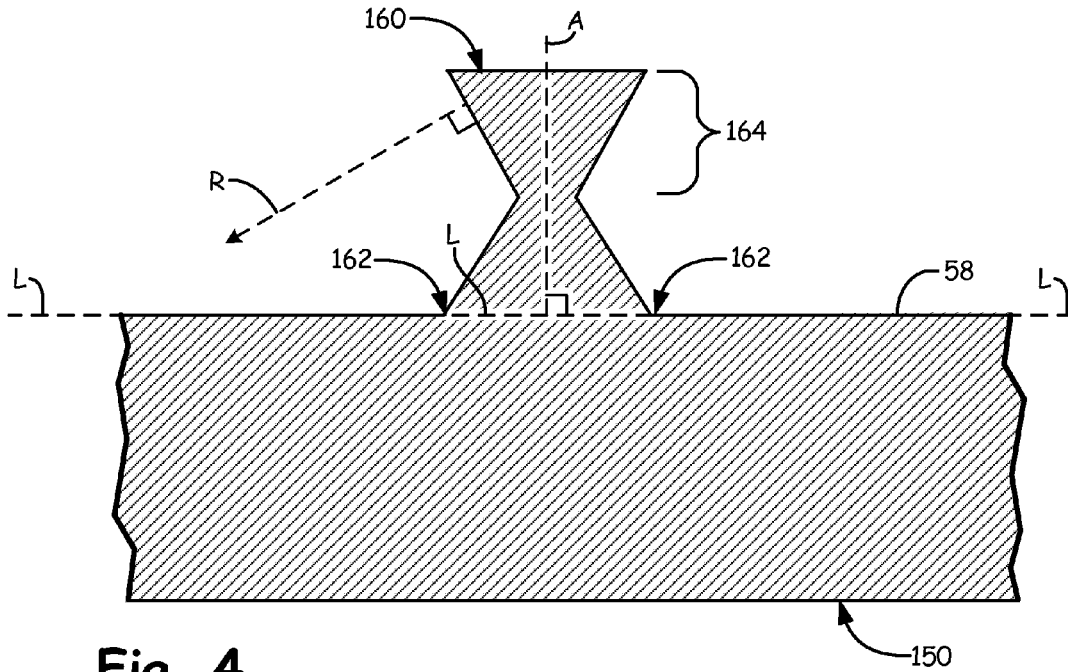


Fig. 4

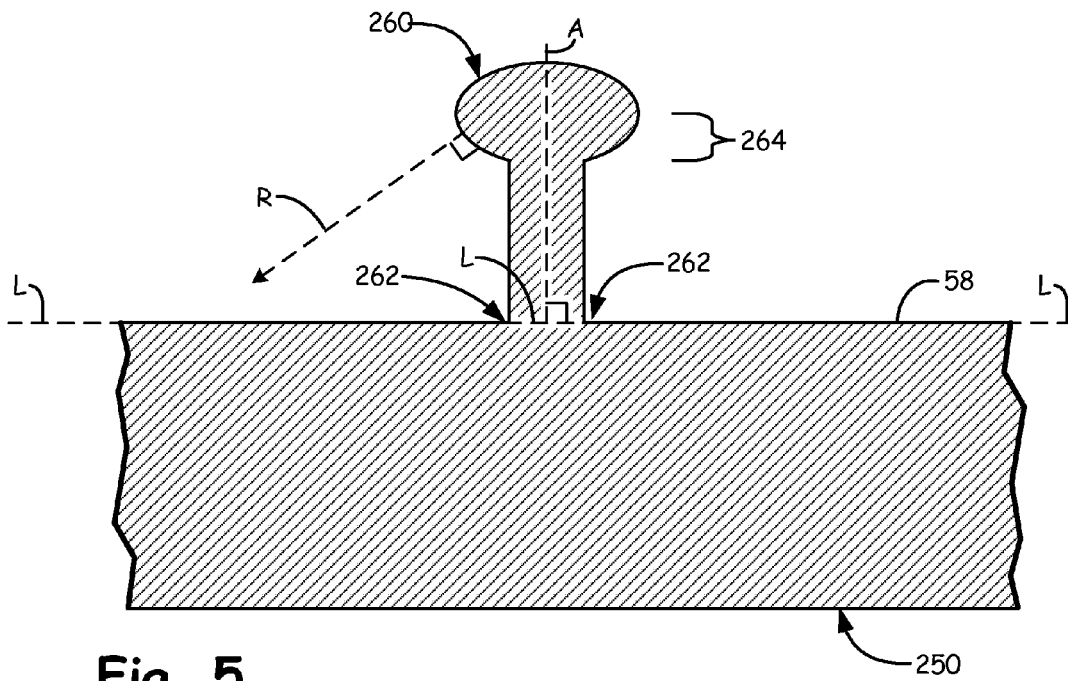


Fig. 5

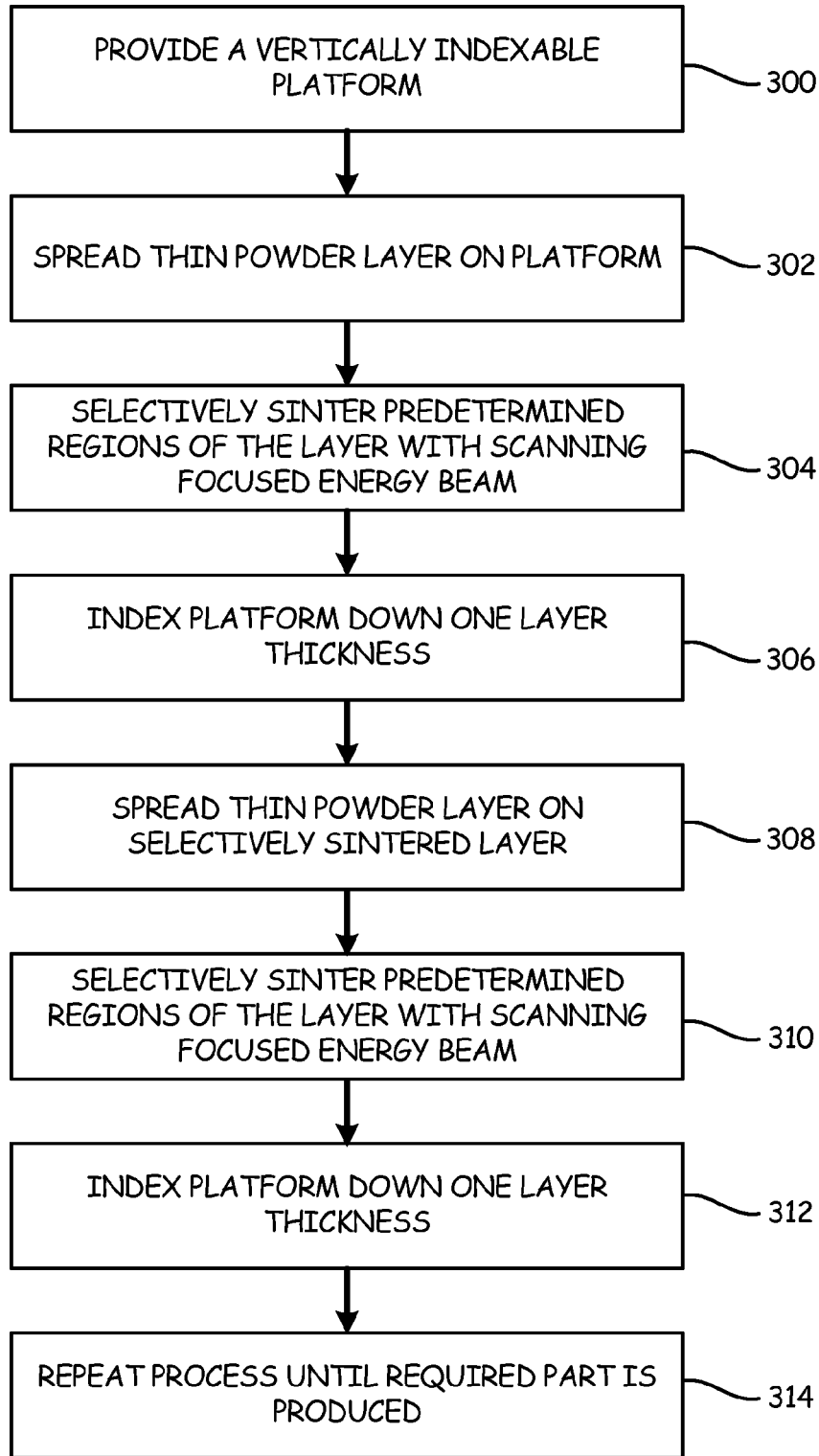


Fig. 6

## TURBINE ENGINE AND TURBINE ENGINE COMPONENT WITH COOLING PEDESTALS

### CROSS-REFERENCE TO RELATED APPLICATION(S)

**[0001]** This application claims the benefit of PCT application PCT/US2014/031168 filed Mar. 19, 2014, for “TURBINE ENGINE AND TURBINE ENGINE COMPONENT WITH IMPROVED COOLING PEDESTALS” by Ronald R. Soucy and Robert P. Delisle, and U.S. Provisional Application No. 61/805,171 filed Mar. 26, 2013, for “TURBINE ENGINE AND TURBINE ENGINE COMPONENT WITH IMPROVED COOLING PEDESTALS” by Ronald R. Soucy and Robert P. Delisle.

### BACKGROUND

**[0002]** The present invention relates to turbine engines. In particular, the invention relates to cooling pedestals for a turbine engine.

**[0003]** A turbine engine ignites compressed air and fuel in a combustion chamber, or combustor, to create a flow of hot combustion gases to drive multiple stages of turbine blades. The turbine blades extract energy from the flow of hot combustion gases to drive a rotor to perform useful work, for example, driving a fan to provide thrust or a generator rotor to provide electrical power. The turbine blades also drive a compressor to provide the compressed air.

**[0004]** A flow of cooling air is typically provided by the compressed air produced upstream of the combustor. Some of the energy extracted from the flow of combustion gases must be used to provide the compressed air, thus reducing the energy available to do useful work and reducing an overall efficiency of the turbine engine. Improvements in the efficient use of compressed air for cooling engine components can improve the overall efficiency of the turbine engine.

**[0005]** Some turbine engine components are directly exposed to the flow of combustion gases and must survive in a high-temperature environment. Often, surfaces of the engine components exposed to high temperatures are cooled by the flow of cooling air to remove heat and prolong the useful life of the component. The efficiency by which heat is exchanged between a component surface to be cooled and the flow of cooling air is often enhanced by the use of cooling pedestals (also known as pin fins). The cooling pedestals project away from the surface to be cooled and into the flow of cooling air. The pedestals increase the heat transfer area as well as the speed of the flow of cooling air, thereby increasing heat transfer efficiency. As heat transfer efficiency improves, less cooling air is necessary to adequately cool the component improving the overall efficiency of the turbine engine.

**[0006]** While the use of cooling pedestals improves heat transfer efficiency between turbine engine components exposed to the flow of combustion gases and the flow of cooling air, further improvement in the heat transfer efficiency of cooling pedestals can improve overall turbine engine efficiency.

### SUMMARY

**[0007]** A turbine engine component includes a surface to be cooled by a flow of cooling air and a plurality of pedestals projecting from the surface to be cooled. At least one of the pedestals includes a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the

pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**[0008]** Another embodiment is a gas turbine engine including a compressor section, a turbine section, and a combustor section arranged between the compressor section and the turbine section. The compressor provides a flow of cooling air. The combustor section includes a plenum in fluid communication with the compressor section to receive the flow of cooling air, a combustion chamber in fluid communication with the turbine section, and at least one combustor heat shield between the combustion chamber and the plenum. The combustor heat shield includes a surface to be cooled by a flow of cooling air and a plurality of pedestals projecting from the surface to be cooled. At least one of the pedestals includes a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0009]** FIG. 1 is a sectional view of gas turbine engine including a turbine engine component with cooling pedestals embodying the present invention.

**[0010]** FIG. 2 is an enlarged sectional view of the combustor of the gas turbine engine shown in FIG. 1 including cooling pedestals embodying the present invention.

**[0011]** FIGS. 3A-3B are enlarged and further enlarged sectional views of a combustor heat shield embodying the present invention.

**[0012]** FIG. 4 is an enlarged sectional view of another combustor heat shield embodying the present invention.

**[0013]** FIG. 5 is an enlarged sectional view of yet another combustor heat shield embodying the present invention.

**[0014]** FIG. 6 is a diagram of a direct digital manufacturing process.

### DETAILED DESCRIPTION

**[0015]** A turbine engine component includes pedestals projecting from a surface to be cooled by a flow of cooling air. At least some of the pedestals include a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a plane defined by an intersection between the surface to be cooled and the pedestal. The component may be formed by a direct digital manufacturing process.

**[0016]** FIG. 1 is a representative illustration of a gas turbine engine including a turbine engine component embodying the present invention. The view in FIG. 1 is a longitudinal sectional view along an engine center line. FIG. 1 shows gas turbine engine 10 including fan 12, compressor 14, combustor 16, turbine 18, high-pressure rotor 20, low-pressure rotor 22, outer casing 24, and inner casing 25. Turbine 18 includes rotor stages 26 and stator stages 28.

**[0017]** As illustrated in FIG. 1, fan 12 is positioned along engine center line  $C_L$  at one end of gas turbine engine 10. Compressor 14 is adjacent fan 12 along engine center line  $C_L$ , followed by combustor 16. Combustor 16 is an annular structure that extends circumferentially around engine center line  $C_L$ . Turbine 18 is located adjacent combustor 16, opposite compressor 14. High-pressure rotor 20 and low-pressure rotor 22 are mounted for rotation about engine center line  $C_L$ . High-pressure rotor 20 connects a high-pressure section of turbine 18 to compressor 14. Low-pressure rotor 22 connects

a low-pressure section of turbine 18 to fan 12. Rotor blades 26 and stator vanes 28 are arranged throughout turbine 18 in alternating rows. Rotor blades 26 connect to high-pressure rotor 20 and low-pressure rotor 22. Outer casing 24 surrounds turbine engine 10 providing structural support for compressor 14, and turbine 18, as well as containment for a flow of cooling air Fc. Inner casing 25 is generally radially inward from combustor 16 providing structural support for combustor 16 as well as containment for the flow of cooling air Fc.

[0018] In operation, air flow F enters compressor 14 through fan 12. Air flow F is compressed by the rotation of compressor 14 driven by high-pressure rotor 20 producing a flow of cooling air Fc. Cooling air Fc flows between combustor 16 and each of outer case 24 and inner case 25. A portion of cooling air Fc enters combustor 16, with the remaining portion of cooling air Fc employed farther downstream for cooling other components exposed to high-temperature combustion gases, such as rotor blades 26 and stator vanes 28. Compressed air and fuel are mixed and ignited in combustor 16 to produce high-temperature, high-pressure combustion gases Fp. Combustion gases Fp exit combustor 16 into turbine section 18. Stator vanes 28 properly align the flow of combustion gases Fp for an efficient attack angle on subsequent rotor blades 26. The flow of combustion gases Fp past rotor blades 26 drives rotation of both high-pressure rotor 20 and low-pressure rotor 22. High-pressure rotor 20 drives a high-pressure portion of compressor 14, as noted above, and low-pressure rotor 22 drives fan 12 to produce thrust Fs from gas turbine engine 10. Although embodiments of the present invention are illustrated for a turbofan gas turbine engine for aviation use, it is understood that the present invention applies to other aviation gas turbine engines and to industrial gas turbine engines as well.

[0019] FIG. 2 is an enlarged view illustrating details of combustor 16 of gas turbine engine 10 shown in FIG. 1. FIG. 2 illustrates combustor 16, outer case 24, and inner case 25. Outer case 24 and inner case 25 are radially outward and inward, respectively, from combustor 16, thus creating annular plenum 29 around combustor 16. Combustor 16 is an annular structure that extends circumferentially around engine center line  $C_L$ . Combustor 16 includes combustor liner 30, bulkhead 32, bulkhead heat shield 34, fuel nozzle 36, swirler 38, and combustion chamber 40. Combustor liner 30 includes outer shell 42, inner shell, 44, aft inside diameter (ID) heat shield 46, forward ID heat shield 48, aft outside diameter (OD) heat shield 50, forward OD heat shield 52, and studs 54. Combustor 16 is an annular structure that extends circumferentially around engine center line  $C_L$ , thus combustor liner 30 is arcuate in shape, with an axis coincident with engine center line  $C_L$ .

[0020] Combustion chamber 40 within combustor 16 is bordered radially by combustor liner 30, and by bulkhead 32 on the upstream axial end, with a combustion gas opening on the downstream axial end. Swirler 38 connects fuel nozzle 36 to bulkhead 32 through an opening in bulkhead 32. Bulkhead 32 is protected from the hot flow of combustion gases Fp generated within combustion chamber 40 by bulkhead heat shield 34. Aft ID heat shield 46 and forward ID heat shield 48 are attached to inner shell 44 to make up the inside diameter portion of combustor liner 30. Similarly, aft OD heat shield 50 and forward OD heat shield 52 are attached to outer shell 42 to make up the outside diameter portion of combustor liner 30. Heat shields 46, 48, 50, 52 are attached to their respective

shell 42, 44 by studs 52 projecting from heat shields 46, 48, 50, 52. Heat shields 46, 48, 50, 52 are made of a high-temperature metal alloy.

[0021] In operation, fuel from fuel nozzle 36 mixes with air in swirler 38 and is ignited in combustion chamber 40 to produce the flow of combustion gases Fp for use by turbine 18 as described above in reference to FIG. 1. As the flow of combustion gases Fp passes through combustion chamber 40, combustor liner 30 is cooled by a flow of cooling air Fc flowing from plenum 29 through combustor liner 30. The flow of cooling air Fc flows through outer shell 42 and across heat shields 50, 52 to cool heat shields 50, 52, as shown in greater detail below in reference to FIGS. 3A, 4A, and 5A. Similarly, the flow of cooling air Fc flows through inner shell 44 and across heat shields 46, 48 to cool heat shields 46, 48.

[0022] FIG. 3A is an enlarged cross-sectional view of a combustor heat shield embodying the present invention. FIG. 3A shows a portion of combustor liner 30 of FIG. 2 including a portion of outer shell 42 and heat shield 50. As shown in FIG. 3A, outer shell 42 includes cooling holes 56. Heat shield 50 includes surface to be cooled 58 and a plurality of cooling pedestals 60. Cooling holes 56 are openings in outer shell 42 to permit the flow of cooling air Fc to flow from plenum 29, through outer shell 42, and across surface to be cooled 58. Cooling pedestals 60 are typically arranged in a two-dimensional array, with a single dimension shown in the cross-sectional view of FIG. 3A. As shown in FIG. 3A and detailed further in FIG. 3B, cooling pedestals 60 project from surface to be cooled 58 and are shaped such that a portion of the surface of each cooling pedestal 60 faces surface to be cooled 58.

[0023] FIG. 3B is a further enlarged cross-sectional view of heat shield 50 of FIG. 3A. FIG. 3B shows a single cooling pedestal 60 projecting from surface to be cooled 58. Cooling pedestal 60 includes intersections 62 and pedestal surface 64. In cross-section, intersections 62 are two points where cooling pedestal 60 intersects surface to be cooled 58. Pedestal surface 64 is a portion of a surface of pedestal 60 oriented such that ray R normal to pedestal surface 64 and directed away from pedestal surface 64 intersects line L defined by intersections 62. Ray R is understood throughout to be used in a geometric sense, as a portion of line that starts at an endpoint and extends to infinity. In the embodiment of FIG. 3B, cooling pedestal 60 has a curved hourglass shape such that throughout pedestal surface 64, any ray R normal to pedestal surface 64 will intersect line L. Rays normal to and directed out from any other portion of the surface of pedestal 60 will not intersect line L. A feature of cooling pedestal 60 created by pedestal surface 64 may be referred to as a reentrant profile. Because of the reentrant profile, cooling pedestals 60 have a larger heat transfer area when compared with cooling pedestals that do not include the reentrant profile. In addition, a flow profile of cooling air Fc across surface to be cooled 58 may be managed more efficiently for improved overall heat transfer because cooling pedestals 60 are able to produce increasing flow velocities away from surface to be cooled 58. As heat transfer efficiency improves, less cooling air is necessary to adequately cool heat shield 50, thus improving the overall efficiency of turbine engine 10.

[0024] The curved hourglass shape of cooling pedestals 60 illustrated in FIGS. 3A and 3B is merely exemplary. FIG. 4 is an enlarged sectional view of another combustor heat shield embodying the present invention. FIG. 4 illustrates heat shield 150 including cooling pedestals 160 having an angular



hourglass shape. Heat shield **150** is identical to heat shield **50** in form and function as described above in reference to FIGS. **3A** and **3B**, except that cooling pedestals **60** are replaced by cooling pedestals **160**. As shown FIG. **4**, cooling pedestal **160** projects from surface to be cooled **58**. Cooling pedestal **160** includes intersections **162** and pedestal surface **164**. In cross-section, intersections **162** are two points where cooling pedestal **160** intersects surface to be cooled **58**. Pedestal surface **164** is a portion of a surface of pedestal **160** oriented such that ray R normal to pedestal surface **164** and directed away from pedestal surface **164** intersects line L defined by intersections **162**. In the embodiment of FIG. **4**, cooling pedestal **160** has an angular hourglass shape such that throughout pedestal surface **164**, any ray R normal to pedestal surface **164** will intersect line L. Rays normal to and directed out from any other portion of the surface of pedestal **160** will not intersect line L. As with the embodiment described above in reference to FIG. **3**, pedestal surface **164** creates a reentrant profile for cooling pedestal **160**, resulting in the previously noted heat transfer efficiency improvements.

**[0025]** Another exemplary pedestal shape is illustrated in FIG. **5**. FIG. **5** is an enlarged sectional view of yet another combustor heat shield embodying the present invention. FIG. **5** illustrates heat shield **250** including cooling pedestals **260** having a mushroom shape. Heat shield **250** is identical to heat shield **50** in form and function as described above in reference to FIGS. **3A** and **3B**, except that cooling pedestals **60** are replaced by cooling pedestals **260**. As shown FIG. **5**, cooling pedestal **260** projects from surface to be cooled **58**. Cooling pedestal **260** includes intersections **262** and pedestal surface **264**. In cross-section, intersections **262** are two points where cooling pedestal **260** intersects surface to be cooled **58**. Pedestal surface **264** is a portion of a surface of pedestal **260** oriented such that ray R normal to pedestal surface **264** and directed away from pedestal surface **264** intersects line L defined by intersections **262**. In the embodiment of FIG. **5**, cooling pedestal **260** has a mushroom shape such that throughout pedestal surface **264**, any ray R normal to pedestal surface **264** will intersect line L. Rays normal to and directed out from any other portion of the surface of pedestal **260** will not intersect line L. As with the embodiment described above in reference to FIG. **3**, pedestal surface **264** creates a reentrant profile for cooling pedestal **260**, resulting in the previously noted heat transfer efficiency improvements.

**[0026]** In some embodiments, cooling pedestal **60**, cooling pedestal **160**, or cooling pedestals **260** may be symmetrical about pedestal axis A. Pedestal axis A is perpendicular to surface to be cooled **58**. Cross-sections of cooling pedestals **60**, **160**, **260** perpendicular to pedestal axis A may be one of an ellipsis, for example, a circle; and a parallelogram, for example, a diamond.

**[0027]** In the embodiments illustrated above, all cooling pedestals are of the same shape. However, it is understood that the present invention encompasses embodiments where cooling pedestal arrays include cooling pedestals of mixed shapes. For example, a heat shield embodying the present invention may include a pedestal array including a mix of cooling pedestals **60**, cooling pedestals **160**, and cooling pedestals **260**, as described above, in addition to cooling pedestals not including a reentrant profile.

**[0028]** Turbine engine components embodying the present invention may be formed by a rapid, economical, and reproducible direct digital manufacturing process. This replaces investment casting processes typically employed to form tur-

bine engine components such as combustor heat shields. The unique reentrant pedestal shapes of the present invention may be either commercially impractical or impracticable to form by investment casting. The reentrant slope and blind hole necessary to form such pedestals combine to make moving material into and out of the molds very difficult. In contrast, direct digital manufacturing processes do not require a mold. One embodiment of the process is outlined in FIG. **6**. Using direct digital manufacturing, a part is manufactured layer by layer on a platform (Step **300**) in a chamber with a controlled environment, preferably an inert atmosphere or vacuum. First, a thin layer of a powder of the material that will form the desired part (e.g. combustor heat shield) is spread on the platform (Step **302**). One or more focused energy beams are then scanned across the platform to manufacture pre-selected areas of the powder (Step **304**). The manufactured areas on the platform represent a single cross sectional slice of the desired part. The energy beams are directed according to a CAD model of the part inserted in the memory of computerized scanning hardware. Following the first scan, the platform is indexed downwardly by one layer thickness (Step **306**) and another powder layer is spread on the manufactured layer (Step **308**). This layer is then scanned by the energy beam(s) to selectively manufacture pre selected areas of the second layer of the part (Step **310**) after which the platform is indexed downwardly again (Step **312**). The process is repeated layer-by-layer until the clamping insert is produced (Step **314**). The dimensional accuracy of clamping inserts produced by this type of direct digital manufacturing scales as the beam diameter, servo-control accuracy of the scan and the powder size. Surface roughness is a function of particle size. Smaller particles produce smoother surfaces. Overall, dimensional tolerances of better than  $\pm 0.5$  mils are known in the art.

**[0029]** Direct digital manufacturing of the present invention may be by, but not restricted to, selective laser sintering, electron beam sintering, and direct metal laser sintering. Selected laser sintering is taught in U.S. Pat. No. 4,863,538 to Deckard and is incorporated herein in its entirety by reference. Electron beam sintering is taught in U.S. Pat. No. 7,454,262 to Larsson and is incorporated herein in its entirety by reference. Direct metal laser sintering is taught in U.S. Pat. No. 6,042,774 to Wilkening et al. and is incorporated herein in its entirety by reference. The Deckard and Wilkening et al. processes use scanning lasers as energy sources. One form of direct digital manufacturing for the present invention is direct metal laser sintering.

#### Discussion of Possible Embodiments

**[0030]** The following are non-exclusive descriptions of possible embodiments of the present invention.

**[0031]** A turbine engine component according to an exemplary embodiment of this disclosure, among other possible things includes a surface to be cooled by a flow of cooling air; and a plurality of pedestals projecting from the surface to be cooled, at least one of the pedestals including a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**[0032]** A further embodiment of the foregoing turbine engine component, wherein the plurality of pedestals and the surface to be cooled can be formed as a single piece.

**[0033]** A further embodiment of any of the foregoing turbine engine components, wherein the plurality of pedestals and the surface to be cooled can be formed of a high-temperature metal.

**[0034]** A further embodiment of any of the foregoing turbine engine components, wherein the plurality of pedestals and the surface to be cooled can be formed by direct digital manufacturing technology from metal alloy powder.

**[0035]** A further embodiment of any of the foregoing turbine engine components, wherein the direct digital manufacturing technology can include at least one of direct metal laser sintering, electron beam sintering, and selected laser sintering.

**[0036]** A further embodiment of any of the foregoing turbine engine components, wherein the direct digital manufacturing technology can include direct metal laser sintering.

**[0037]** A further embodiment of any of the foregoing turbine engine components, wherein the pedestal can be symmetrical about a pedestal axis perpendicular the surface to be cooled.

**[0038]** A further embodiment of any of the foregoing turbine engine components, wherein sections of the pedestal perpendicular to the pedestal axis can be one of ellipses and parallelograms.

**[0039]** A further embodiment of any of the foregoing turbine engine components, wherein each pedestal of the plurality of pedestals projecting from the surface to be cooled can include a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**[0040]** A further embodiment of any of the foregoing turbine engine components, wherein the turbine engine component can be a combustor heat shield.

**[0041]** A gas turbine engine according to an exemplary embodiment of this disclosure, among other possible things includes a compressor section, a turbine section, and a combustor section arranged between the compressor section and the turbine section. The compressor provides a flow of cooling air. The combustor section includes a plenum in fluid communication with the compressor section to receive the flow of cooling air, a combustion chamber in fluid communication with the turbine section, and at least one combustor heat shield between the combustion chamber and the plenum. The combustor heat shield includes a surface to be cooled by a flow of cooling air and a plurality of pedestals projecting from the surface to be cooled. At least one of the pedestals includes a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**[0042]** A further embodiment of the foregoing gas turbine engine, wherein combustor heat shield can be formed as a single piece.

**[0043]** A further embodiment of any of the foregoing gas turbine engines, wherein the combustor heat shield can be formed of a high-temperature metal.

**[0044]** A further embodiment of any of the foregoing gas turbine engines, wherein the combustor heat shield can be formed by direct digital manufacturing technology from metal alloy powder.

**[0045]** A further embodiment of any of the foregoing gas turbine engines, wherein the direct digital manufacturing

technology can include at least one of direct metal laser sintering, electron beam sintering, and selected laser sintering.

**[0046]** A further embodiment of any of the foregoing gas turbine engines, wherein the direct digital manufacturing technology can include direct metal laser sintering.

**[0047]** A further embodiment of any of the foregoing gas turbine engines, wherein the combustor section can further include a plurality of combustor heat shields, each of the plurality of combustor heat shields having an inner surface facing the combustion chamber and an outer surface facing away from the combustion chamber, and the a surface to be cooled by the flow of cooling air is the outer surface.

**[0048]** A further embodiment of any of the foregoing gas turbine engines, wherein the pedestal can be symmetrical about a pedestal axis perpendicular the surface to be cooled.

**[0049]** A further embodiment of any of the foregoing gas turbine engines, wherein sections of the pedestal perpendicular to the pedestal axis can be one of ellipses and parallelograms.

**[0050]** A further embodiment of any of the foregoing gas turbine engines, wherein each pedestal of the plurality of pedestals projecting from the surface to be cooled can include a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**[0051]** Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

1. A turbine engine component comprising:

a surface to be cooled by a flow of cooling air; and  
a plurality of pedestals projecting from the surface to be cooled, at least one of the pedestals including a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

2. The component of claim 1, wherein the plurality of pedestals and the surface to be cooled are formed as a single piece.

3. The component of claim 2, wherein the plurality of pedestals and the surface to be cooled are formed of a high-temperature metal.

4. The component of claim 1, wherein the plurality of pedestals and the surface to be cooled are formed by direct digital manufacturing technology from metal alloy powder.

5. The component of claim 4, wherein the direct digital manufacturing technology includes at least one of direct metal laser sintering, electron beam sintering, and selected laser sintering.

6. The component of claim 5, wherein the direct digital manufacturing technology includes direct metal laser sintering.

7. The component of claim 1, wherein the pedestal is symmetrical about a pedestal axis perpendicular the surface to be cooled.

8. The component of claim 7, wherein sections of the pedestal perpendicular to the pedestal axis are one of ellipses and parallelograms.

9. The component of claim 1, wherein each pedestal of the plurality of pedestals projecting from the surface to be cooled

includes a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**10.** The component of claim **1**, wherein the turbine engine component is a combustor heat shield.

**11.** A gas turbine engine comprising:

a compressor section providing a flow of cooling air;

a turbine section; and

a combustor section arranged between the compressor section and the turbine section, the combustor section including:

a plenum in fluid communication with the compressor section to receive the flow of cooling air;

a combustion chamber in fluid communication with the turbine section; and

at least one combustor heat shield between the combustion chamber and the plenum, the combustor heat shield including:

a surface to be cooled by the flow of cooling air, the surface facing away from the combustion chamber;

a plurality of pedestals projecting from the surface to be cooled, at least one of the pedestals including a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

**12.** The engine of claim **11**, wherein the combustor heat shield is formed as a single piece.

**13.** The engine of claim **12**, wherein the combustor heat shield is formed of a high-temperature metal.

**14.** The engine of claim **11**, wherein the combustor heat shield is formed by direct digital manufacturing technology from metal alloy powder.

**15.** The engine of claim **14**, wherein the direct digital manufacturing technology includes at least one of direct metal laser sintering, electron beam sintering, and selected laser sintering.

**16.** The engine of claim **15**, wherein the direct digital manufacturing technology includes direct metal laser sintering.

**17.** The engine of claim **11**, wherein the combustor section further includes a plurality of combustor heat shields, each of the plurality of combustor heat shields having an inner surface facing the combustion chamber and an outer surface facing away from the combustion chamber, and the a surface to be cooled by the flow of cooling air is the outer surface.

**18.** The engine of claim **11**, wherein the pedestal is symmetrical about a pedestal axis perpendicular the surface to be cooled.

**19.** The engine of claim **18**, wherein sections of the pedestal perpendicular to the pedestal axis are one of ellipses and parallelograms.

**20.** The engine of claim **11**, wherein each pedestal of the plurality of pedestals projecting from the surface to be cooled includes a pedestal surface oriented such that a ray normal to the pedestal surface and directed away from the pedestal surface intersects a line defined by an intersection between the surface to be cooled and the pedestal.

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