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(54) **METHOD OF MANUFACTURING A COMPONENT AND THERMAL MANAGEMENT PROCESS**

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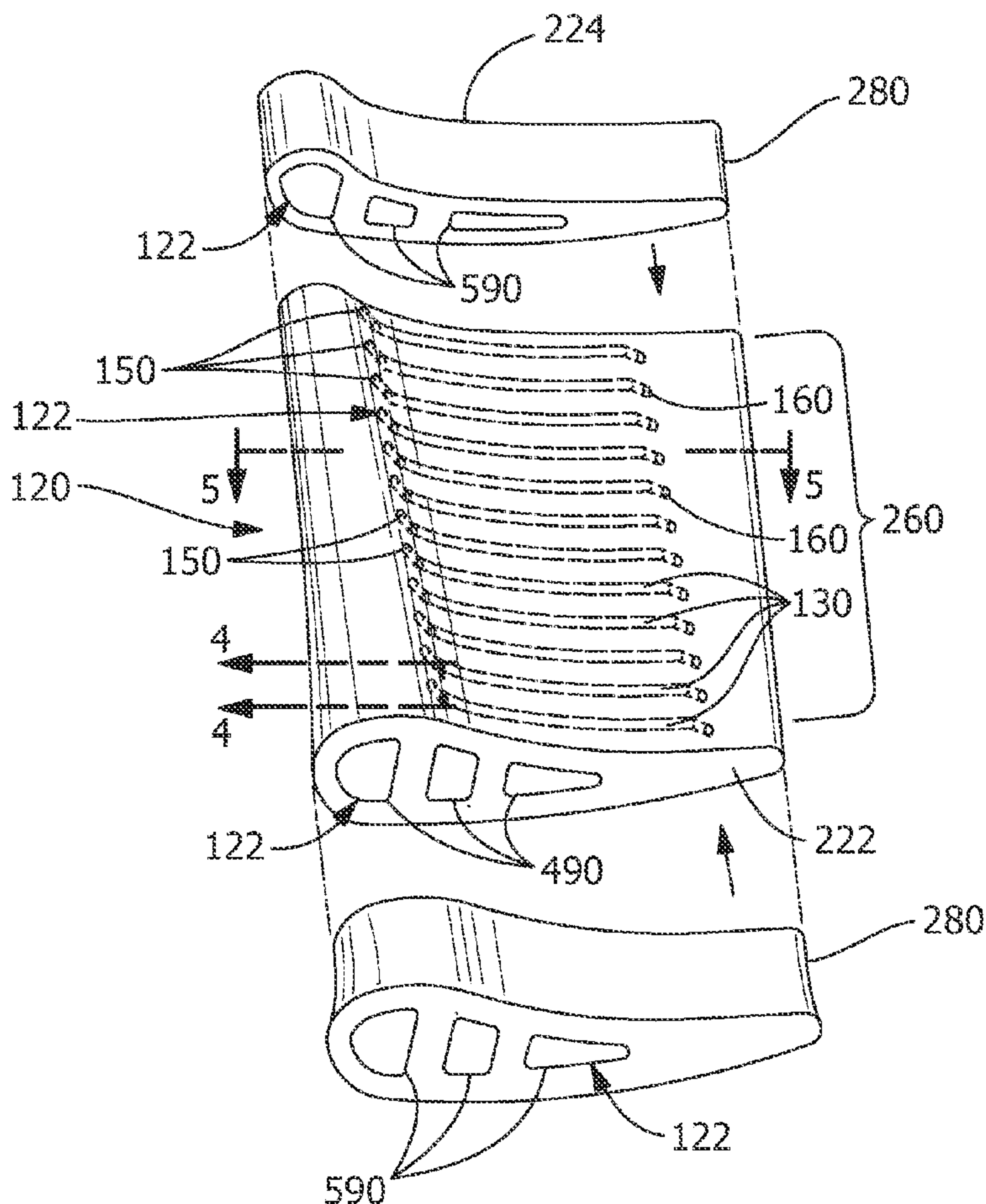
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(57) **ABSTRACT**

A method of manufacturing a component and a method of thermal management are provided. The methods include forming at least one portion of the component, printing a cooling member of the component and attaching the at least one portion to the cooling member of the component. The cooling member includes at least one cooling feature. The at least one cooling feature includes at least one cooling channel adjacent to a surface of the component, wherein printing allows for near-net shape geometry of the cooling member with the at least one cooling channel being located within a range of about 127 (0.005 inches) to about 762 micrometers (0.030 inches) from the surface of the component. The method of thermal management also includes transporting a fluid through at least one fluid pathway defined by the at least one cooling channel within the component to cool the component.



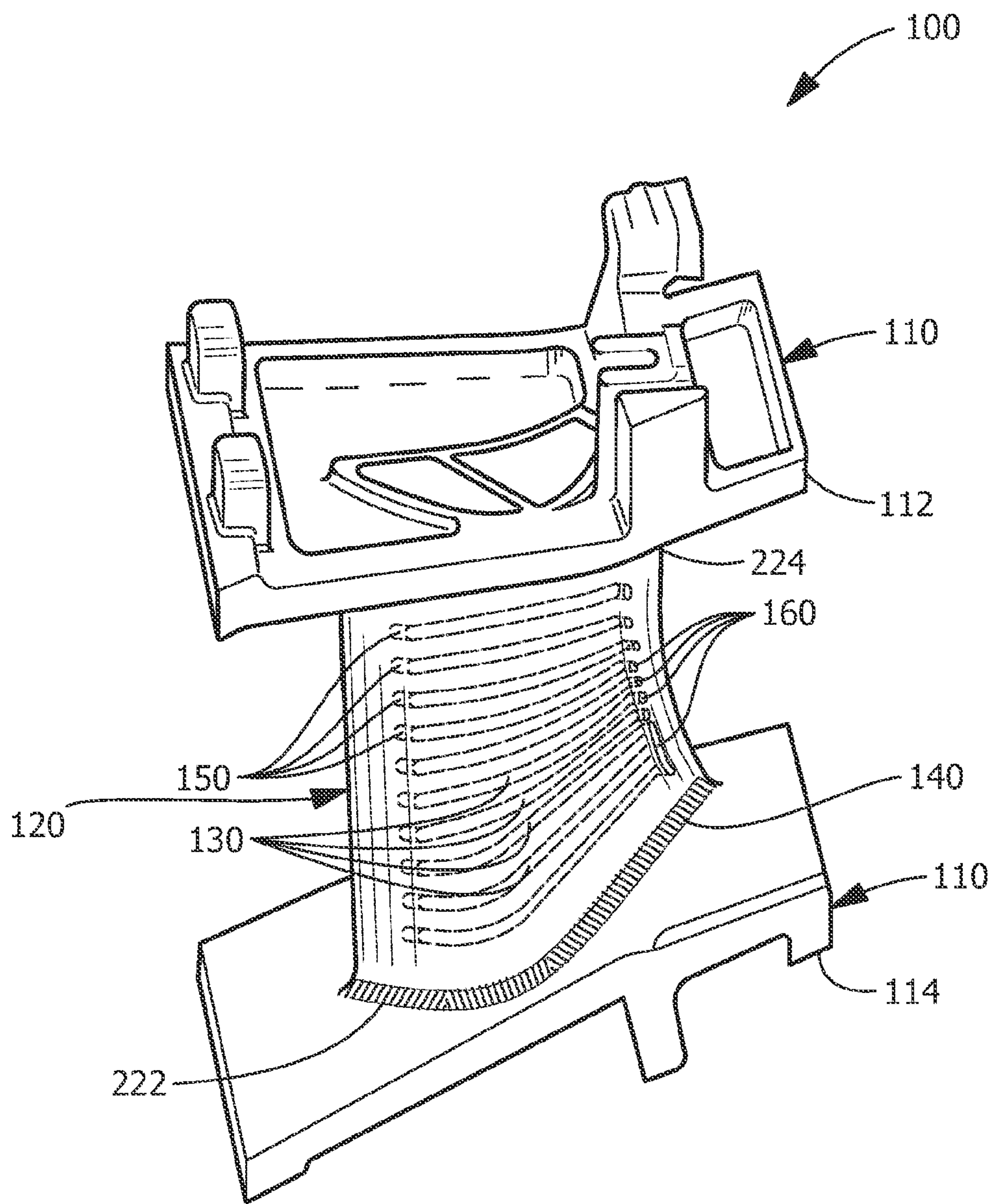


FIG. 1

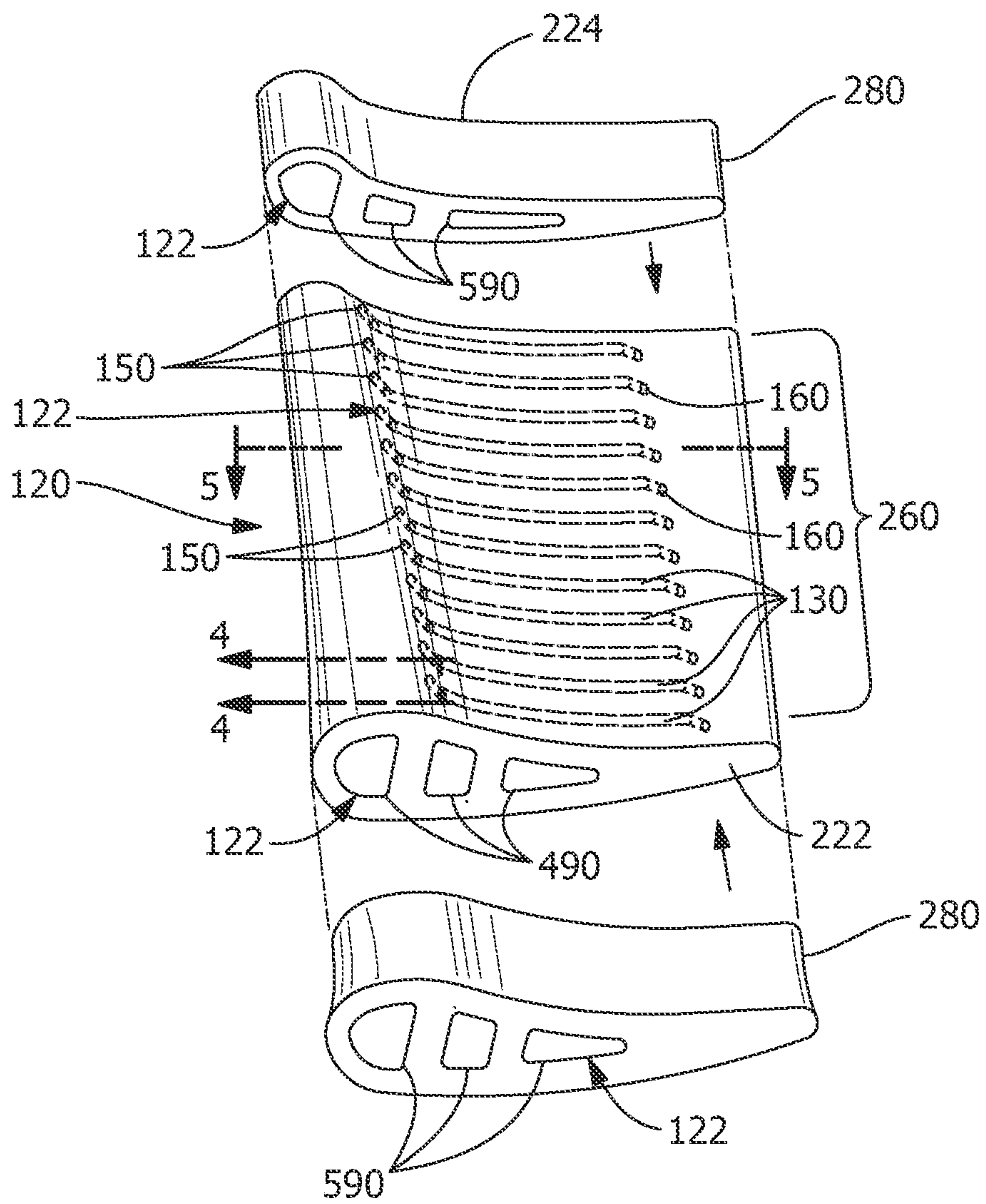


FIG. 2

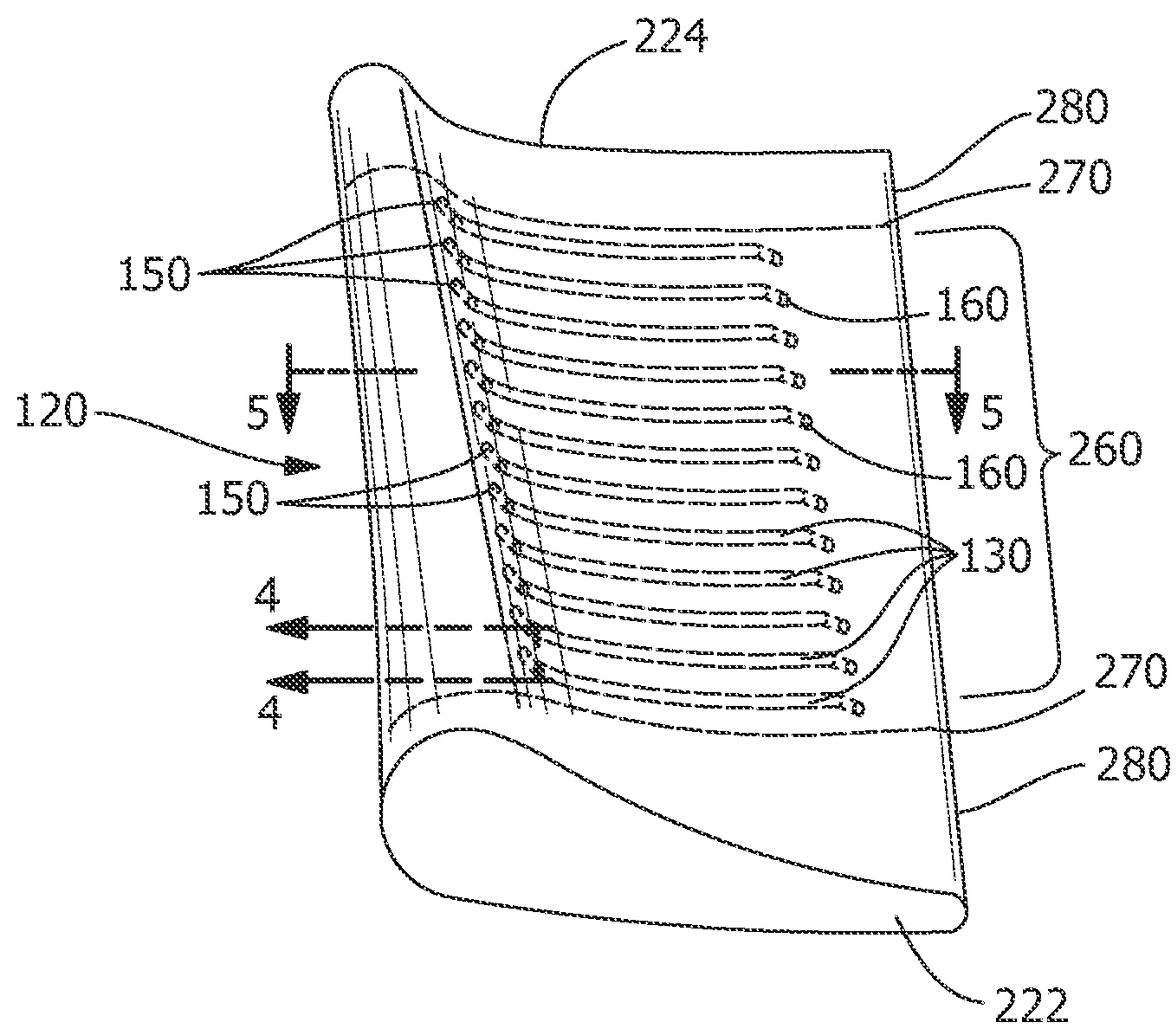


FIG. 3

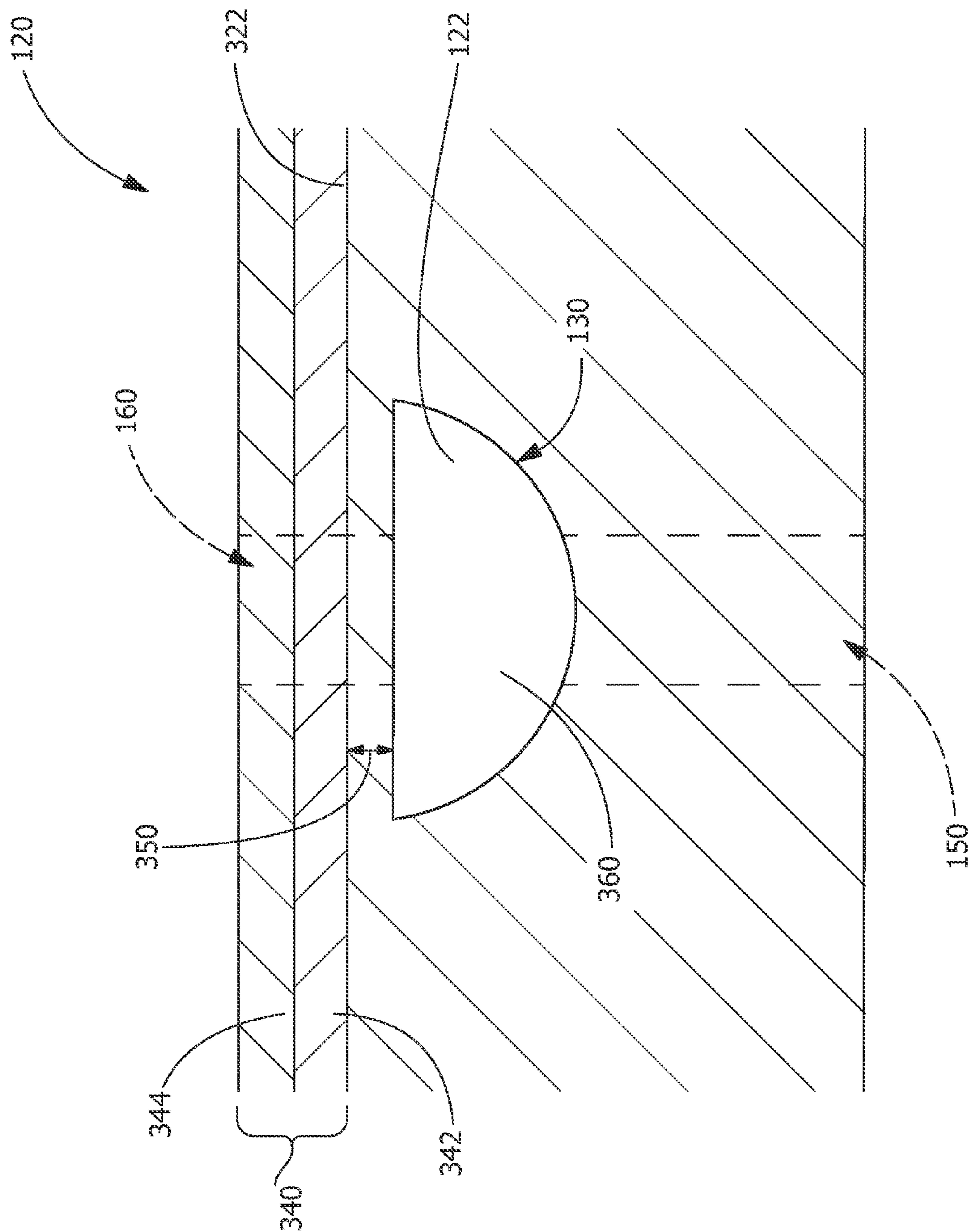


FIG. 4

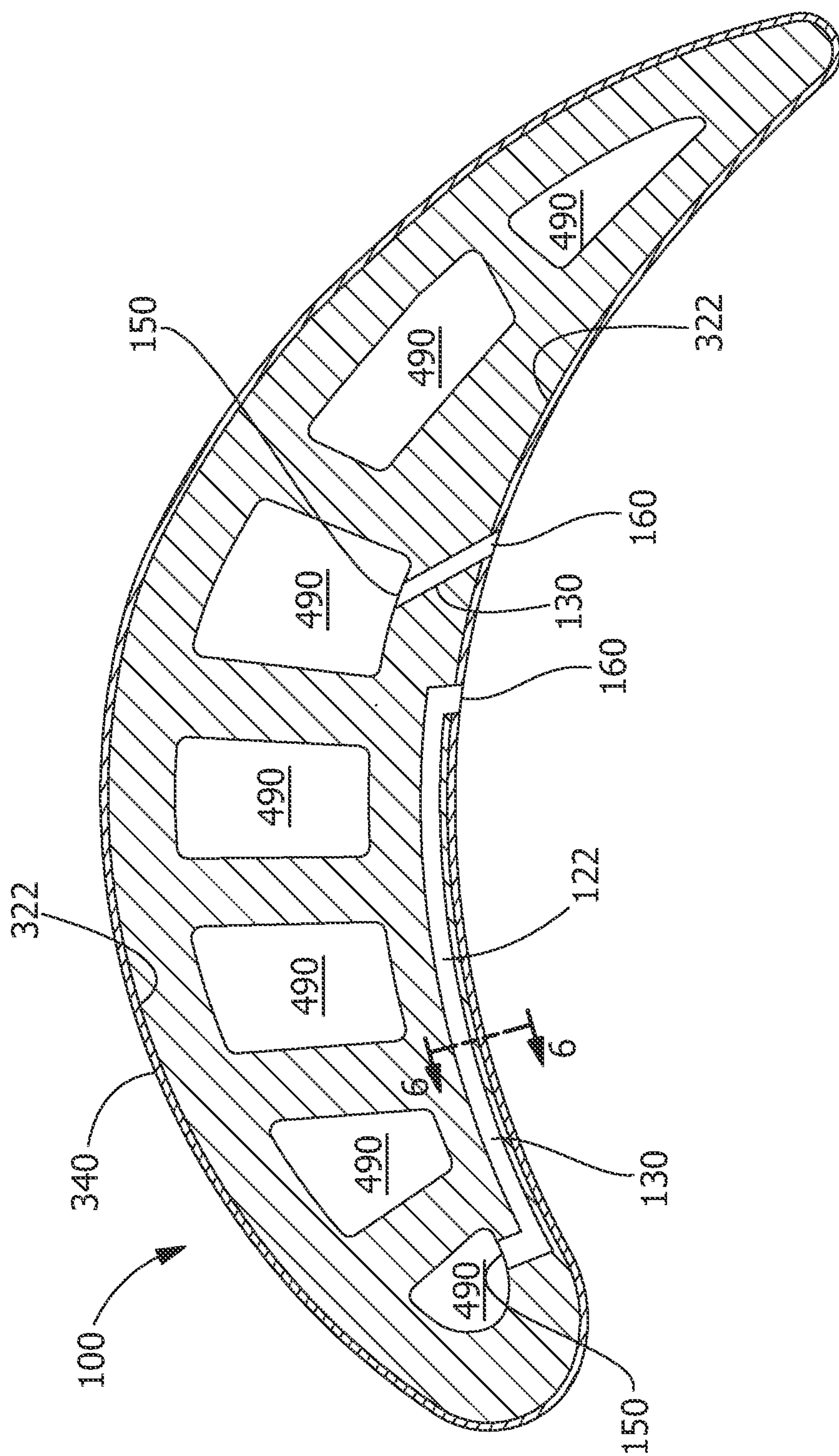


FIG. 5

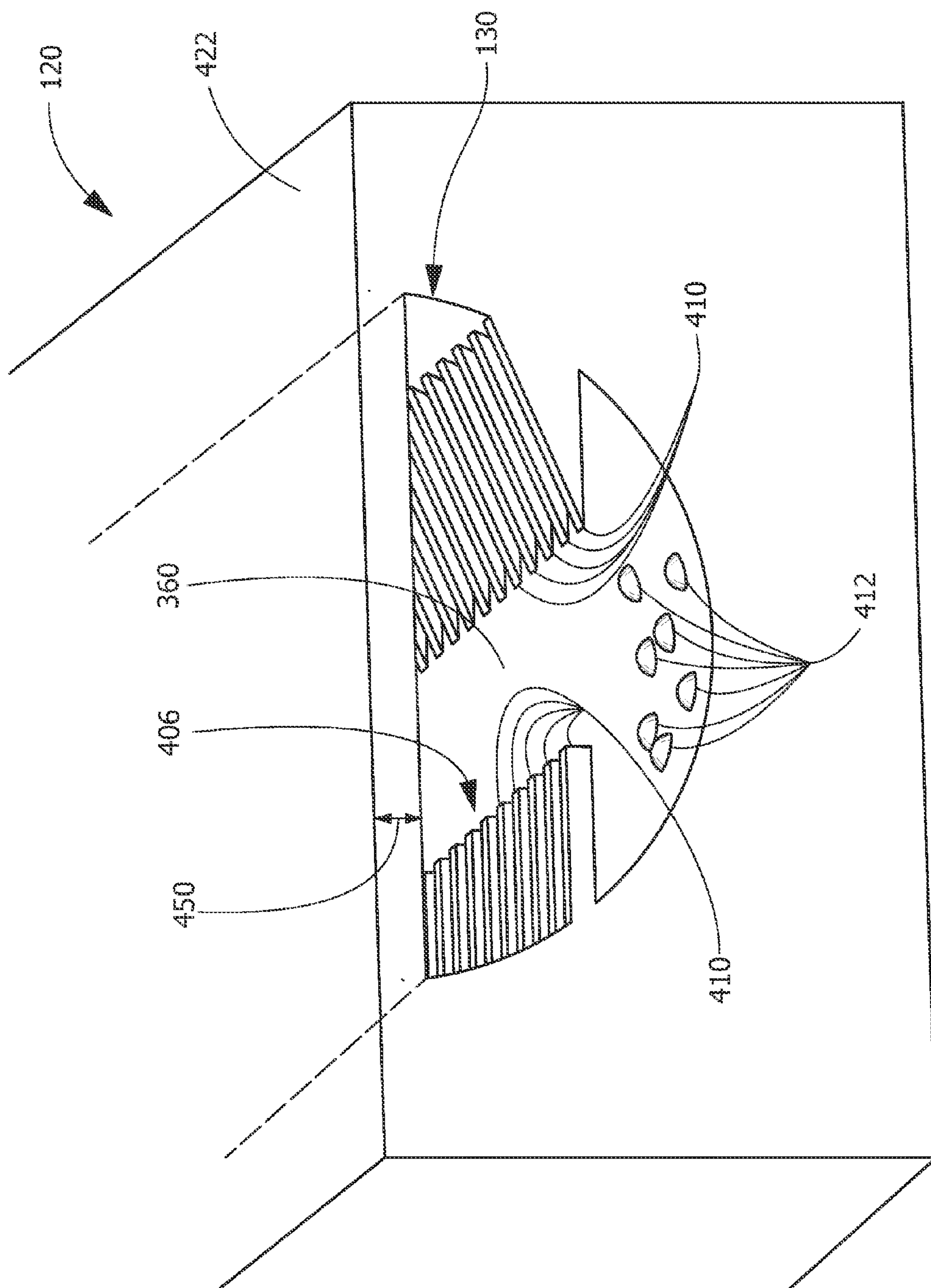


FIG. 6

**METHOD OF MANUFACTURING A
COMPONENT AND THERMAL
MANAGEMENT PROCESS**

FIELD OF THE INVENTION

[0001] The present invention is directed to processes of manufacturing and thermal management processes using the manufactured component. More specifically, the present invention is directed to manufacturing processes for forming components that include cooling features formed therein.

BACKGROUND OF THE INVENTION

[0002] Turbine systems are continuously being modified to increase efficiency and decrease cost. One method for increasing the efficiency of a turbine system includes increasing the operating temperature of the turbine system. To increase the temperature, the turbine system must be constructed of materials able to withstand elevated temperatures during continued use.

[0003] In addition to modifying component materials and coatings, one common method of increasing temperature capability of a turbine component includes the use of cooling channels. The cooling channels are often incorporated into metals and alloys used in high temperature regions of gas turbines. Manufacturing cooling channels in components can be difficult and time-consuming. One technique includes casting the channels in the components using complex molds. The complex molds are often difficult to position relative to the component surface near the hot gas path where cooling is required. Another technique includes machining the channels into components after casting, which then requires closing the open channels off at the surface of the component by welding or brazing insert and impingement plates to the surface. The final component is then coated using thermal spraying. Closing the cooling channels can often inadvertently fill the cooling channels blocking the flow of cooling fluids, such as air from a compressor section of a gas turbine.

[0004] Selective laser melting (or three-dimensional printing) is a relatively inexpensive process capable of manufacturing difficult to fabricate components. However, components printed by selective laser melting do not have the same temperature capability as cast high temperature superalloy materials. Thus, use in high temperature environments has been perceived as ill-advised.

[0005] A method of forming a component and a thermal management process that do not suffer from one or more of the above drawbacks would be desirable in the art.

BRIEF DESCRIPTION OF THE INVENTION

[0006] According to an exemplary embodiment of the present disclosure, a method of forming a component is provided. The method includes forming at least one portion of the component, printing a cooling member of the component, and attaching the at least one portion to the cooling member of the component. The cooling member includes at least one cooling feature. The at least one cooling feature includes a cooling channel adjacent to a surface of the component, wherein printing allows for near-net shape geometry of the cooling member with the at least one cooling channel being located within a range of about 127 micrometers (0.005 inches) to about 762 micrometers (0.030 inches) from the surface of the component.

[0007] According to another exemplary embodiment of the present disclosure, a method of thermal management of a component is provided. The method includes forming at least one portion of the component, printing a cooling member of the component, attaching the at least one portion to the cooling member of the component, and transporting a fluid through at least one fluid pathway defined by the at least one cooling channel within the component to cool the component. The cooling member includes at least one cooling feature. The at least one cooling feature includes at least one cooling channel adjacent to a surface of the component. Printing allows for near-net shape geometry of the cooling member with the at least one cooling channel being located within a range of about 127 micrometers (0.005 inches) to about 762 micrometers (0.030 inches) from the surface of the component. The cooling channel defines a fluid pathway through which the fluid is transported.

[0008] Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a perspective view of a component including a plurality of cooling channels formed therein, according to an embodiment of the disclosure.

[0010] FIG. 2 is a exploded perspective view of a cooling member of a component including cooling features.

[0011] FIG. 3 is a perspective view of a cooling member of a component including cooling features formed therein, according to an embodiment of the disclosure.

[0012] FIG. 4 is a cross-sectional view along line 4-4 of FIG. 3 of the component, illustrating a cooling channel formed in the component, according to an embodiment of the disclosure.

[0013] FIG. 4 is a cross-sectional view along line 4-4 of FIG. 2 of the component, illustrating at least one cooling channel including supply and exit passages, according to an embodiment of the disclosure.

[0014] FIG. 5 is a cross-sectional view along line 5-5 of FIG. 3 of the component, illustrating cooling features formed in the component, according to an embodiment of the disclosure.

[0015] FIG. 6 is a cross-sectional view along line 6-6 of FIG. 5 of a cooling channel formed in the component illustrating features that disrupt laminar flow of a fluid, according to an embodiment of the disclosure.

[0016] Wherever possible, the same reference numbers will be used throughout the drawings to represent the same parts.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Provided is a manufacturing process and a thermal management process using the manufactured component. Embodiments of the present disclosure, in comparison to processes and articles that do not include one or more of the features disclosed herein, provide additional cooling and heating, permit cooling in new regions, permit cooling with new materials, permit cooler and/or hotter streams to be directed from flow within turbine components, permit the useful life of turbine components to be extended, permit turbine systems using embodiments of the turbine components to be more efficient, permit turbine components to be

manufactured more easily, permit manufacturing of cooling features that previously could not be made, permit manufacturing of components that otherwise cannot be made using traditional manufacturing processes, permit hybrid material construction of turbine components or a combination thereof.

[0018] One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0019] When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0020] The term "printing" refers to a three-dimensional printing process. Examples of three-dimensional printing processes include, but are not limited to, the processes known to those of ordinary skill in the art, such as Direct Metal Laser Melting ("DMLM"), Direct Metal Laser Sintering ("DMLS"), Selective Laser Sintering ("SLS"), Selective Laser Melting ("SLM"), and Electron Beam Melting ("EBM"). As used herein, the term "three-dimensional printing process" refers to the processes described above as well as other suitable current or future processes that include the build-up of materials layer by layer.

[0021] Referring to FIG. 1, in one embodiment, the component **100** may be a static component, rotating component or combustion hardware in a turbine system. Examples of static components include, but are not limited to, nozzles, vanes, shrouds, near flow path seals, transition pieces, and combinations thereof. Component **100** includes at least one portion **110** and a cooling member **120**. Cooling member **120** is attached to at least one portion **110** by any suitable joining technique, such as, but not limited to, brazing, welding or mechanical means. For example, in FIG. 1, component **100**, a nozzle, includes cooling member **120**, an airfoil, attached to a first end portion **114** and a second end portion **112**.

[0022] To manufacture component **100**, at least one portion **110** is formed. Suitable methods for forming at least one portion **110** include casting or printing. In one embodiment, at least one portion **110** is formed using traditional manufacturing methods, such as, but not limited to casting. At least one portion **110** may be cast using molds to form the desired shape using desired materials to provide desired strength and thermal characteristics.

[0023] Printing cooling member **120** or at least one portion **110** may include using three-dimensional printing to form at least one cooling feature **122** (see FIGS. 2 and 5). The at least one cooling feature **122** includes cooling channels **130** and cooling cavities **490** and **590**. The at least one cooling channel **130** is adjacent to the surface **322** of component **100**. In an alternative embodiment, as shown in FIG. 2, a segment of

cooling member **120** or portion **110** may be printed with at least one cooling channel **130**, then the printed segment of cooling member **120** or portion **110** including at least one cooling channel **130** is attached to other segments of cooling member **120** or portion **110**, without cooling channels. The other segment of cooling member **120** or portion **110** may be formed using methods such as, but not limited to, casting, forging, or printing. The three-dimensional printing includes distributing an atomized powder onto a substrate plate (not shown) using a coating mechanism (not shown). The substrate plate is positioned within a chamber (not shown) having a controlled atmosphere, for example, an inert gas, such as argon, nitrogen, other suitable inert gases, or a combination thereof. The atomized powder is melted, for example, by electron beam melting, laser melting, or other melting from other energy sources, to form a portion or layer of a three-dimensional product, such as, a segment of cooling member **120** or at least one portion **110** of a component **100**. The process is repeated to form the three-dimensional product, such as cooling member **120** or portion **110**.

[0024] Three-dimensional printing may use atomized powders that are thermoplastic, metal, metallic, ceramic, other suitable materials, or a combination thereof. Suitable materials for the atomized powder include, but are not limited to, stainless steel, tool steel, cobalt chrome, titanium, aluminum, alloys thereof, nickel based superalloys, or combinations thereof. In one embodiment, the material for the atomized powder corresponds with material for an alloy suitable for the hot-gas path of a turbine system. The material for cooling member **120** may be the same or different than material chosen for portion **110**. At least one portion **110** may be selected from a first material and cooling member **120** may be selected from a second material. In one embodiment, the first material may be different than the second material. Alternatively, the first material may be the same as the second material. Suitable examples of first material for at least one portion **110**, include, but are not limited to, nickel, iron, cobalt, chromium, molybdenum, aluminum, titanium, gold, silver, stainless steel, alloys thereof, nickel based superalloys, cobalt superalloys, or combinations thereof. Suitable examples of second material for cooling member **120**, include, but are not limited to, nickel, iron, cobalt, chromium, molybdenum, aluminum, titanium, gold, silver, stainless steel, alloys thereof, nickel based superalloys, cobalt superalloys, or combinations thereof. Suitable examples of commercially available materials, include, but are not limited to, Co—Cr (70Co, 27Cr, 3Mo), Stainless Steel 316, INCONEL® alloy 625 and INCONEL® alloy 718, INCONEL® alloy 738 (INCONEL® being available from Special Metals Corporation, Princeton, Ky.), GTD-222® (a trademark of General Electric Company), Haynes® 282® alloy (available from Haynes International, Kokomo, Ind.), UDIMET® alloy 500 (being available from Special Metals Corporation, Princeton, Ky.). In one embodiment, material for cooling member **120** may be chosen so as to have a higher thermal conductivity than the material from which at least one portion **110** is formed thereby enabling increased efficiency and requiring less fluid to be used to alter the temperature of surface **322** of component **100**.

[0025] One example of a three-dimensional printing process is selective laser melting which uses a predetermined design file or two-dimensional slices of a three-dimensional file, for example, from a computer-aided design program. The thickness of the two-dimensional slices determines the reso-

lution of the selective laser melting. For example, when the two-dimensional slices are 20 micrometers thick, the resolution will be greater than when the two-dimensional slices are 100 micrometers thick for the printing of a predetermined component, such as, the cooling member 120. In one embodiment, cooling member 120 or at least one portion 110 formed from the printing is near-net-shape and includes a plurality of cooling features 122 such as at least one cooling cavity 490, 590 and a plurality of cooling channels 130 formed therein. As shown in FIG. 2, cooling member 120 may be an airfoil, having near-net-shape and a plurality of cooling features 122 such as cooling cavities 490, 590 and cooling channels 130 formed therein. In one embodiment, cooling member 120 may be printed as a single piece (see FIG. 1). In an alternative embodiment, as shown in FIGS. 2 and 3, cooling member 120 may be formed as a first segment 260 including a plurality of cooling channels 130 and at least one cooling cavity 490 and at least one second segment 280 optionally including a plurality of cooling cavities 590. As shown in FIGS. 2 and 3, the at least one cooling cavity 490 of the first segment 260 may be aligned with the at least one cooling cavity 590 of the second cavity. The first segment 260 may be joined to the at least one second segment 280 using any suitable joining technique, shown by dashed lines 270 (see FIG. 3). Printed cooling member 120 includes a first end 222 and a second end 224. First end 222 or second end 224 may be attached to portion 110 using any suitable joining process, such as, but not limited to, brazing, welding or mechanical attachment means. As shown in FIG. 1, first end 222 of cooling member 120 is attached to first end portion 114 and second end 224 of cooling member 120 is attached to second end portion 112 by welding or brazing, illustrated by a joint 140. Suitable examples of attaching include, but are not limited to, arc welding, beam welding, brazing, transient liquid phase (TLP) bonding, and diffusion bonding.

[0026] In one embodiment, as shown in FIG. 1, cooling member 120 is a single printed piece including cooling channels 130, cooling cavities 490 and first openings 150 or supply passages and second openings 160 or exit passages formed therein. In an alternative embodiment, as shown in FIGS. 2 and 3, cooling member 120 is formed in steps. In one step, a first segment 260 including a plurality of cooling features 122 including cooling channels 130 and/or cooling cavities 490 and/or first and second openings 150 and 160 are printed. In another step, at least one second segment 280 is formed using three-dimensional printing or traditional casting techniques. As discussed above, first segment 260 may be formed using a first material and at least one second segment 280 may be formed using a second material. In one embodiment, first and second materials are the same. In an alternative embodiment, first and second materials are different. After first segment 260 and at least one second segment 280 are formed, cooling member 120 is built by joining first segment 260 and at least one second segment 280 along joint lines 270 (see FIG. 3). Any suitable joining method may be used to join first segment 260 and at least one second segment 280, such as, but not limited to, arc welding, beam welding, brazing, transient liquid phase (TLP) bonding, and diffusion bonding.

[0027] As shown in FIG. 4, first openings 150 of supply passages from cooling cavity 490 to cooling channel 130 and second openings 160 or exit passages for coolant to leave channel 130 may also be printed into cooling member 120 or first segment 260 of cooling member 120. First openings 150 or inlets may be attached to cooling channel cavities 490

running throughout the length of component 100. First openings 150 and second openings 160 are interconnected by cooling channels 130. In one embodiment, second openings 160 may be cylindrical holes but could also be shaped holes to enable coolant exiting the cooling channel 130 to provide film coverage to the downstream portion of the component. Second openings 160 or exit passages may also be trenches where coolant from one or more cooling channels 130 enters to spread along the trench and then exit the trench as film (see FIG. 1).

[0028] Referring to FIG. 5, using three-dimensional printing allows the at least one cooling channel 130 to be located at a distance 350 within a range of about 127 micrometers (0.005 inches) to about 762 micrometers (0.030 inches) from surface 322 of cooling member 120 of component 100. Alternatively, three-dimensional printing allows the at least one cooling channel 130 to be located at a distance 350 of at least less than about 508 micrometers (0.020 inches) from the surface 322 of cooling member 120 of component 100 (see FIG. 5). Distance 350 between cooling channel 130 and surface 322 of component 100 may be up to at least less than or as little as about 127 micrometers (0.005 inches). Distance 350 between cooling channel 130 and surface 322 of component 100 may be constant throughout cooling channel 130 length in component 100. In an alternative embodiment, distance 350 may be varied throughout length of cooling channel 130 in component 100 (see FIG. 4). Distance 350 may be from about 127 micrometers (0.005 inches) to about 1524 micrometers (0.060 inches), or alternatively about 254 micrometers (0.010 inches) to about 1270 micrometers, or alternatively about 254 micrometers (0.010 inches) to about 1016 micrometers, or alternatively about 254 micrometers (0.010 inches) to about 508 micrometers (0.020 inches), or alternatively less than about 508 micrometers (0.020 inches), or alternatively about 254 micrometers (0.010 inches) or alternatively about 127 micrometers (0.005 inches). In comparison, typical casting methods used to form a component with cooling channels will have cooling channels located at about 2540 micrometers (0.100 inches) from surface.

[0029] Using three-dimensional printing to form at least one cooling channel 130 in cooling member 120 or at least one portion 110 reduces manufacturing steps and saves time and resources because cooling channels do not need to be drilled into the surface of component. Printing cooling member 120 or at least one portion 110 with cooling channels 130 formed therein also reduces manufacturing steps and time and resources because open cooling channels do not need to be closed using insert plates. The three-dimensional printing processes also allows the geometry (length, width, height, and depth) of the cooling channels 130 and at least one fluid pathway 360 therein to be varied along the length of cooling channel 130 within cooling member 120. For example, cooling channel 130 may constrict or narrow in some areas or widen in other areas to match the cooling or heating local demands of component 100. Cooling channel 130 dimensions may be changed as necessary and the dimensions do not need to be constant from one end to another. In one embodiment, cooling channel 130 may be a semi-circle having a width and depth of about 254 micrometers (0.010 inches) to about 2540 micrometers (0.100 inches) or alternatively about 762 micrometers (0.030 inches) to about 1524 micrometers (0.060 inches).

[0030] In one embodiment, prior to joining cooling member 120 to at least one portion 110, an optional step of hot

isostatic pressing (HIP) and/or solution heat-treating is performed to strengthen the printed cooling member **120** or at least one portion **110**. During HIP operation, internal defects such as porosity and microfissures are closed or healed due to the temperature and applied pressure. During solution heat treatment, all deleterious precipitates are put into solution in the material matrix thereby providing the best properties. These heat treatments change the grain structure through formation of new grains ultimately strengthening the printed cooling member **120**.

[0031] As shown in FIG. 4, surface **322** may be coated with a protective coating **340**. Protective coating **340** may include any number of layers, such as, but not limited to a bond coating **342** and thermal barrier coating **344** applied to bond coating **342**. Protective coating **340** may be applied prior to joining cooling member **120** to at least one portion **110**. Protective coating **340** may be applied after cooling member **120** is jointed to at least one portion **110** by welding, brazing or other suitable mechanical joining means.

[0032] Transporting a fluid through at least one fluid pathway **360** defined by at least one cooling channel **130** within the component alters, cools, or heats surface **322** of component **100**. The changes in geometry may be designed so as to maximize or minimize the alteration of temperature at any particular location along the length of at least one cooling channel **130** in component **100**. The changes in geometry may enable highly specific manipulation of the thermal characteristics of surface **322** by at least one cooling channel **130**. The geometry changes may enable the modification of thermal management properties of a component design with minimized cost and time compared to methods and articles that do not include one or more of the features disclosed herein.

[0033] Referring to FIG. 6, in one embodiment, at least one cooling channel **130** may include at least one feature to disrupt laminar flow of a fluid through the at least one fluid pathway **360**. The at least one feature to disrupt laminar flow may include turbulators **406**, which mix the fluid in the at least one fluid pathway **360** from the middle to the sides and from the sides to the middle, making the at least one fluid pathway **360** effectively longer. Turbulators **406** may also increase the surface area of at least one cooling channel **130**, which increases heat transfer from or to the fluid flowing through the at least one fluid pathway **360** to or from the substrate **322**. Suitable examples of turbulators **406** include, but are not limited to, fin **410** and bumps **412**. Turbulators **406** may be of any suitable shape or size, and may be included on the at least one inner surface of cooling channel **130** in any suitable arrangement or spacing to achieve the desired effect. Turbulators **406** may be formed within at least one cooling channel **130** using a three-dimensional printing process, resulting in a single homogeneous piece.

[0034] Also provided is a method of thermal management. The method includes forming at least one portion **110** of component **100** (see FIG. 1). The method includes printing a cooling member **120** (see FIG. 1) or first segment **260** and at least one second segment **280** and building cooling member **120** of component **100** (see FIGS. 2 and 3). The method includes attaching the at least one portion **110** to cooling member **120** of component **100** (see FIG. 1). The method includes transporting a fluid through the at least one fluid pathway **360** defined by the at least one cooling channel **130** within component **100** to cool component **100** (see FIGS. 4 and 6).

[0035] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method of manufacturing a component comprising:
 - forming at least one portion of the component;
 - printing a cooling member of the component, the cooling member including at least one cooling feature, the at least one cooling feature including at least one cooling channel adjacent to a surface of the component, wherein printing allows for near-net shape geometry of the cooling member with the at least one cooling channel being located within a range of about 127 (0.005 inches) to about 762 micrometers (0.030 inches) from the surface of the component; and
 - attaching the at least one portion to the cooling member of the component.
2. The method of claim 1, wherein the at least one cooling feature further includes at least one cooling cavity adjacent to the at least one cooling channel.
3. The method of claim 2, wherein the step of printing further includes creating a first opening in the at least one cooling channel, the first opening joining the at least one cooling cavity to the at least one cooling channel.
4. The method of claim 3, wherein the step of printing further includes creating a second opening in the at least one cooling channel, the second opening being in the surface of the component.
5. The method of claim 2, wherein the at least one portion of the component further includes at least one cooling cavity.
6. The method of claim 5, wherein the at least one cooling cavity of the at least one portion aligns with the at least one cooling cavity of the cooling member.
7. The method of claim 1, wherein the step of forming includes casting or three-dimensional printing of the at least one portion.
8. The method of claim 1, wherein the step of printing uses a three-dimensional printing process.
9. The method of claim 1, wherein the step of attaching includes welding, brazing transient liquid phase (TLP) bonding, diffusion bonding, mechanical attachment, or combinations thereof.
10. The method of claim 1, wherein the at least one portion is selected from a first material and the cooling member is selected from a second material.
11. The method of claim 10, wherein the first material is the same as the second material.
12. The method of claim 10, wherein the first material is different than the second material.
13. The method of claim 10, wherein the first material is selected from nickel, iron, cobalt, chromium, molybdenum, aluminum, titanium, stainless steel, nickel based superalloys, cobalt super alloys or combinations thereof.
14. The method of claim 10, wherein the second material is selected from nickel, iron, cobalt, chromium, molybdenum,

aluminum, titanium, stainless steel, nickel based superalloys, cobalt super alloys or combinations thereof.

15. The method of claim **1**, wherein the at least one cooling channel is located at least less than about 508 micrometers (0.020 inches) away from the surface of the component.

16. The method of claim **1**, wherein the at least one cooling channel is located at least less than about 254 micrometers (0.010 inches) away from the surface of the component.

17. The method of claim **1**, wherein the at least one cooling channel has a varying geometry throughout the cooling member.

18. The method of claim **1**, further comprising applying at least one protective coating after the step of attaching.

19. A method of thermal management of a component comprising:

- forming at least one portion of the component;
- printing a cooling member of the component, the cooling member including at least one cooling feature, the at

least one cooling feature including at least one cooling channel adjacent to a surface of the component, wherein printing allows for near-net shape geometry of the cooling member with the at least one cooling channel being located within a range of about 127 (0.005 inches) to about 762 micrometers (0.030 inches) from the surface of the component;

attaching the at least one portion to the cooling member of the component; and

transporting a fluid through at least one fluid pathway defined by the at least one cooling channel within the component to cool the component.

20. The method of claim **20**, wherein the at least one cooling channel is located at least less than about 508 micrometers (0.020 inches) away from the surface of the component.

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