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(54) **DIE CAST SYSTEM FOR FORMING A COMPONENT USABLE IN A GAS TURBINE ENGINE**

DRUCKGUSSSYSTEM ZUM FORMEN EINES BAUTEILS FÜR EINEN GASTURBINENMOTOR

SYSTÈME DE COULAGE SOUS PRESSION DESTINÉ À FORMER UN COMPOSANT UTILISABLE
DANS UNE À TURBINE A GAZ

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Description

FIELD OF THE INVENTION

[0001] This invention is directed generally to die cast systems, and more particularly to manufacturing methods for turbine airfoils usable in turbine engines.

BACKGROUND

[0002] Turbine blade airfoils typically have internal cooling systems formed from a plurality of cooling channels, as shown in Figure 2 and 3. To form these cooling channels inside of a blade, a casting mold is often used and includes an internal ceramic core and external ceramic shell. The ceramic core, as shown in Figure 1, is manufactured to include detail features on the core die surface in order to form efficient cooling devices inside the blade casting. The core dies typically used to form cores are most often formed from hard steel, which are expensive to manufacture. The core die surfaces are typically in direct contact with the ceramic core material during the high pressure injection process. The core die will wear out after sufficient injections and lead to non-conforming casting. To maintain accurate casting dimensions, the core die needs to be reworked or replaced when a core die becomes worn, which is an expensive endeavor. Even a small improvement on an internal surface requires that a completely new die be made. Thus, a need exists for a more robust, less expensive system.

SUMMARY OF THE INVENTION

[0003] A die cast system having an inner liner insert that enables the configuration of a component produced by the system to be easily changed by changing the inner liner insert without having to rework the die housing is disclosed. Because the inner liner insert only need be removed and replaced to change the configuration of an outer surface of a component produced by the system, the cost savings is significant in contrast with conventional systems in which the die would have to be reworked. The die cast system may also include an inner liner formed from first and second end sub-inner liners, whereby the first end sub-inner liner may be from a first material that is less compliant than a material forming the second end sub-inner liner enabling more intricate cooling systems to be created by the second end sub-inner liner that is formed from a more compliant material.

[0004] In at least one embodiment, the die cast system may include a die housing having one or more inner chambers forming an insert receiving chamber and one or more inner liners positioned within the insert receiving chamber of the inner chamber of the die housing. The inner liner may have an inner surface defining boundaries useful to form an inner surface of a turbine component, whereby the inner liner may be formed via a selective laser melting process. The inner liner may be formed

from a first side sub-inner liner forming a first side of the turbine component and a second side sub-inner liner forming a second side of the turbine component. The first side sub-inner liner may form an outer wall of a suction side of an airfoil usable in a gas turbine engine and may include at least one cavity on an inner side of the outer wall that is configured to form at least a portion of an internal airfoil cooling system. The second side sub-inner liner may form an outer wall of a pressure side of an airfoil usable in a gas turbine engine and may include one or more cavities on an inner side of the outer wall that is configured to form at least a portion of an internal airfoil cooling system.

[0005] In at least one embodiment, the inner liner may be formed from a non-ceramic, flexible material. The inner liner may be formed from a different material than the die housing. The die housing may be formed from a first sub-die housing and a second sub-die housing having a mateable interface positioned therebetween such that the first and second sub-die housings are mateable at the mateable interface.

[0006] In another embodiment, the inner liner may be formed from a first end sub-inner liner forming a first end of the turbine component and a second end sub-inner liner forming a second end of the turbine component. The first end sub-inner liner may be formed from a first material that is less compliant than a material forming the second end sub-inner liner. The second end sub-inner liner being more compliant may be used to form intricate aspects to the internal cooling system. The first end sub-inner liner may be configured to form a leading edge of an airfoil usable in a turbine engine and second end sub-inner liner is configured to form a trailing edge of the airfoil usable in the turbine engine.

[0007] In at least one embodiment, the first end sub-inner liner may be formed from a first end, first side sub-inner liner and a first end, second side sub-inner liner. The first end, first side sub-inner liner may form a suction side outer wall of an upstream portion of a suction side of an airfoil usable in a gas turbine engine and may include one or more cavities on an inner side of the suction side outer wall that is configured to form at least a portion of an internal airfoil cooling system. The first end, second side sub-inner liner may form a pressure side outer wall of a pressure side of the upstream portion of an airfoil usable in a gas turbine engine and may include one or more cavities on an inner side of the pressure side outer wall that is configured to form at least a portion of an internal airfoil cooling system.

[0008] The second end sub-inner liner may be formed from a second end, first side sub-inner liner and a second end, second side sub-inner liner. The second end, first side sub-inner liner may form a suction side outer wall of a downstream portion of a suction side of an airfoil usable in a gas turbine engine and may include one or more cavities on an inner side of the suction side outer wall that is configured to form at least a portion of an internal airfoil cooling system. The second end, second side sub-

inner liner may form a pressure side outer wall of a pressure side of the downstream portion of an airfoil usable in a gas turbine engine and may include one or more cavities on an inner side of the pressure side outer wall that is configured to form at least a portion of an internal airfoil cooling system.

[0009] A method of forming a turbine component is disclosed. The method may include injecting a ceramic material into at least one inner cavity formed within a composite die cast system, wherein the die cast system may be formed from a die housing having one or more inner chambers forming an insert receiving chamber and one or more inner liners positioned within the insert receiving chamber of the inner chamber of the die housing. The inner liner may have an inner surface defining boundaries useful to form an inner surface of a turbine component. The inner liner may be formed via a selective laser melting process. The method may also include removing the die cast system thereby revealing a ceramic core.

[0010] The method may include firing the ceramic core, placing the ceramic core within an inner cavity formed by an inner surface of a wax die, and injecting wax into one or more openings formed between the ceramic core and the inner surface of the wax die. The method may also include removing the wax die to reveal a wax component, coating the wax component with a ceramic coating to form a ceramic shell with a ceramic core positioned therein and removing the wax component within the ceramic coating leaving one or more cavities within the ceramic coating. The method may also include filling the cavity within the ceramic coating with a molten metal and removing the ceramic shell and the ceramic core to form a cast component.

[0011] An advantage of the composite die cast system is that because the inner liner insert only need be removed and replaced to change the configuration of an inner surface of a component produced by the system, a significant cost savings is captured in contrast with conventional systems in which the die would have to be reworked.

[0012] Another advantage of the hybrid die cast system is that use of the hybrid die cast system will reduce time and effort required to create a core die in a conventional casting process.

[0013] Yet another advantage of the hybrid die cast system is that the inner liner may be formed from different portions formed from different materials, thereby enabling portions of the inner liner proximate to aspects of the core where intricate aspects of an internal cooling system are located, to be formed from more compliant material enabling those intricate aspects of the internal cooling system to be formed.

[0014] These and other embodiments are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The accompanying drawings, which are incor-

porated in and form a part of the specification, illustrate embodiments of the presently disclosed invention and, together with the description, disclose the principles of the invention.

Figure 1 is a perspective view of a conventionally formed core.

Figure 2 is a cross-sectional view of two adjacent conventional turbine airfoils.

Figure 3 is a cross-sectional view of a conventional turbine airfoil with an internal cooling system.

Figure 4 is a cross-sectional view of an inner liner of the die cast system.

Figure 5 is a cross-sectional view of an inner liner positioned within a die housing of the die cast system.

Figure 6 is a cross-sectional view of a ceramic material injected within the inner liner positioned within a die housing of the die cast system.

Figure 7 is a cross-sectional view of a ceramic core.

Figure 8 is a cross-sectional view of a ceramic core after firing.

Figure 9 is a cross-sectional view of a ceramic core after firing placed in a wax die and wax injected into the openings between the ceramic core and the wax die.

Figure 10 is a cross-sectional view of a wax pattern with the ceramic core and with the wax die removed.

Figure 11 is a cross-sectional view of the wax pattern with a ceramic shell formed around the wax pattern.

Figure 12 is a cross-sectional view of the ceramic shell and ceramic core with the wax pattern removed.

Figure 13 is a cross-sectional view of the ceramic shell and ceramic core with molten metal in the ceramic casting mold.

Figure 14 is a casting of a component with the ceramic shell and ceramic core removed.

Figure 15 is a flow chart of a method of forming a casting component, such as, but not limited to, an airfoil from cast metal.

Figure 16 is a cross-sectional view of an alternative inner liner of the die cast system.

Figure 17 is a cross-sectional view of the alternative inner liner of Figure 16 positioned within a die housing of the die cast system.

Figure 18 is a cross-sectional view of a ceramic material injected within the alternative inner liner of Figure 16 positioned within a die housing of the die cast system.

Figure 19 is a cross-sectional view of a ceramic core.

Figure 20 is a cross-sectional view of a ceramic core after firing.

Figure 21 is a cross-sectional view of a ceramic core after firing placed in a wax die and wax injected into the openings between the ceramic core and the wax die.

Figure 22 is a cross-sectional view of a wax pattern with the ceramic core and with the wax die removed.

Figure 23 is a cross-sectional view of the wax pattern with a ceramic shell formed around the wax pattern. Figure 24 is a cross-sectional view of the ceramic shell and ceramic core with the wax pattern removed. Figure 25 is a cross-sectional view of the ceramic shell and ceramic core with molten metal in the ceramic casting mold.

Figure 26 is a casting of a component with the ceramic shell and ceramic core removed.

Figure 27 is a perspective view of a turbine airfoil formed with the die cast system of Figures 4-14 and 16-26 and via the method of using the system shown in Figure 15.

Figure 28 is a cross-sectional view of the turbine airfoil taken along section line 28-28 in Figure 27.

DETAILED DESCRIPTION OF THE INVENTION

[0016] As shown in Figures 4-28, a die cast system 10 having an inner liner insert 12 that enables the configuration of a component 14 produced by the system 10 to be easily changed by changing the inner liner insert 12 without having to rework the die housing 16 is disclosed. Because the inner liner insert 12 only need be removed and replaced to change the configuration of an inner surface 18 of a component 14 produced by the system 10, the cost savings is significant in contrast with conventional systems in which the die would have to be reworked. The die cast system 10 may also include an inner liner 12 formed from first and second end sub-inner liners 20, 22, whereby the first end sub-inner liner 20 may be from a first material that is less compliant than a material forming the second end sub-inner liner 22 enabling more intricate cooling systems to be created by the second end sub-inner liner 22, which is more compliant than the first end inner liner 20.

[0017] In at least one embodiment, the die cast system 10 may include a die housing 16 may have one or more inner chambers 23 forming an insert receiving chamber 24. The die cast system 10 may also include one or more inner liners 12 positioned within the insert receiving chamber 24 of the inner chamber 24 of the die housing 16. The inner liner 12 may have an inner surface 26 defining boundaries useful to form an inner surface 18 of a turbine component 14. In at least one embodiment, the inner surface 26 of the inner liner 12 may be configured to form an airfoil 138 usable in a gas turbine engine. The airfoil 138 may be formed from a generally elongated, hollow airfoil 140 having a leading edge 142 on an opposite side from a trailing edge 144 and separated by a concave pressure side 146 and a convex suction side 148. The generally elongated, hollow airfoil 60 may have one or more film cooling holes 150 at one or more of the leading edge 142 forming a showerhead, concave pressure side 146, the convex suction side 148 or the trailing edge 144, or any combination thereof.

[0018] In at least one embodiment, the inner liner 12 may be formed via a selective laser melting process, with

a material such as, but not limited to, iron. The inner liner 12 may be formed from a first side sub-inner liner 30 forming a first side 32 of the turbine component 14 and a second side sub-inner liner 34 forming a second side 36 of the turbine component 14. In at least one embodiment, as shown in Figure 4-6, the first side sub-inner liner 30 may be formed from an outer wall 38 of a suction side 40 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 46 of the outer wall 38 that is configured to form at least a portion of an internal airfoil cooling system 48. The second side sub-inner liner 34 may form an outer wall 50 of a pressure side 52 of the airfoil shaped core 42 and may include one or more cavities 44 on an inner side 56 of the outer wall 50 that is configured to form at least a portion of an internal airfoil cooling system 48. In at least one embodiment, as shown in Figures 4-6, the first side sub-inner liner 30 and the second side sub-inner liner 34 may together form a plurality of inner cavities 44 forming the internal airfoil cooling system 48.

[0019] In at least one embodiment, the inner liner 12 may be formed from a non-ceramic material, such as, but not limited to, iron, or another appropriate material. The inner liner 12 may be formed from a different material than the die housing 16. The die housing 16 may be formed from a first sub-die housing 58 and a second sub-die housing 60 having a mateable interface 62 positioned therebetween such that the first and second sub-die housings 58, 60 are mateable at the mateable interface 62.

[0020] In at least one embodiment, as shown in Figures 16-18, the inner liner 12 may be formed from a first end sub-inner liner 20 forming a first end 64 of the turbine component 14 and a second end sub-inner liner 22 forming a second end 66 of the turbine component 14. The first end sub-inner liner 20 may be formed from a first material that is less compliant than a material forming the second end sub-inner liner 22. As such, that less compliant material may be used to form intricate aspects of the internal cooling system 48. In at least one embodiment, the second end sub-inner liner 22 form from the less compliant material may be formed by processes employed by Mikro Systems of Charlottesville, VA. The first end sub-inner liner 20 may be configured to form a leading edge 70 of an airfoil shaped core 42 usable in a turbine engine, and second end sub-inner liner 22 may be configured to form a trailing edge 72 of the airfoil shaped core 42 usable in the turbine engine.

[0021] In at least one embodiment, as shown in Figures 16-18, the first end sub-inner liner 20 may be formed from a first end, first side sub-inner liner 74 and a first end, second side sub-inner liner 76. The first end, first side sub-inner liner 74 may form a suction side outer wall 38 of an upstream portion 78 of a suction side 40 of an airfoil shaped core 42. The first end, first side sub-inner liner 74 may include one or more cavities 44 on an inner side 46 of the suction side outer wall 38 that is configured to form at least a portion of an internal airfoil cooling system

48. The first end, second side sub-inner liner 76 may form a pressure side outer wall 50 of a pressure side 52 of the upstream portion 78 of an airfoil shaped core 42. The first end, second side sub-inner liner 76 may include one or more cavities 44 on an inner side 56 of the pressure side outer wall 50 that is configured to form at least a portion of the internal airfoil cooling system 48.

[0022] Similarly, the second end sub-inner liner 22 may be formed from a second end, first side sub-inner liner 80 and a second end, second side sub-inner liner 82. The second end, first side sub-inner liner 80 may form a suction side outer wall 38 of a downstream portion 84 of a suction side 40 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 46 of the suction side outer wall 38 that is configured to form at least a portion of an internal airfoil cooling system 48. The second end, second side sub-inner liner 82 may form a pressure side outer wall 50 of a pressure side 52 of the downstream portion 84 of the airfoil shaped core 42 and may include one or more cavities 44 on an inner side 56 of the pressure side outer wall 50 that is configured to form at least a portion of the internal airfoil cooling system 48.

[0023] As shown in Figure 15, a method 100 of forming a turbine component 14 may include forming a ceramic core die 90 at 101 and Figures 4 and 16 via a selective laser melting process. The die 90 may be positioned within a die housing 16 at 102 and Figures 5 and 17. The method 100 may also include injecting a ceramic material 98 at 103 and Figures 6 and 18 into one or more inner cavities 44 formed within a die cast system 10 in which the die cast system 10 may be formed from a die housing 16 having one or more inner chambers 23 forming an insert receiving chamber 24. The die cast system 10 may also include one or more inner liners 12 positioned within the insert receiving chamber 24 of the inner chamber 23 of the die housing 16. The inner liner 12 may have an inner surface 26 defining boundaries useful to form an inner surface 18 of a turbine component 14. The inner liner 12 may be formed via a selective laser melting process. The method may include removing the die cast system 10 at 104 and Figures 7 and 19 thereby revealing a ceramic core 90.

[0024] The method may also include firing the ceramic core 90 at 106 and Figures 8 and 20 and placing the ceramic core 90 at 108 within an inner cavity 92 formed by an inner surface 94 of a wax die 96. The method may also include injecting wax 88 at 110 and Figures 9 and 21 into at least opening 92 formed between the ceramic core 90 and the inner surface 94 of the wax die 96. The method may include removing the wax die 96 at 112 and Figures 10 and 22 to reveal a wax component 86 and coating the wax component 86 at 114 and Figures 11 and 23 with a ceramic coating 116 to form a ceramic shell 118 with a ceramic core 90 positioned therein. The method may include removing the wax component 86 at 120 and Figures 12 and 24 within the ceramic coating 116 leaving one or more cavities 122 within the ceramic coat-

ing 116. The method may include filling the cavity 122 at 124 and Figures 13 and 25 within the ceramic coating 116 with a molten metal and removing the ceramic shell 118 and the ceramic core 90 at 126 and Figures 14 and 26 to form a cast component 14.

[0025] The step of injection a ceramic material at 102 may include injecting a ceramic material into at least one inner cavity 122 formed within the composite die cast system 10, wherein the inner liner 12 is formed from a first side sub-inner liner 30 forming a first side 32 of the turbine component 14 and a second side sub-inner liner 34 forming a second side 36 of the turbine component 14. The step of injection a ceramic material at 102 may include injecting a ceramic material into at least one inner cavity 122 formed within the composite die cast system 10, wherein the first side sub-inner liner 30 may form an outer wall 38 of a suction side 40 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 46 of the outer wall 38 that is configured to form at least a portion of an internal airfoil cooling system 48. The second side sub-inner liner 34 may form an outer wall 50 of a pressure side 52 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 56 of the outer wall 50 that is configured to form at least a portion of an internal airfoil cooling system 48.

[0026] The step of injection a ceramic material at 102 may include injecting a ceramic material into at least one inner cavity 122 formed within the composite die cast system 10, wherein the inner liner 12 may be formed from a first end sub-inner liner 20 forming a first end 64 of the turbine component 14 and a second end sub-inner liner 22 forming a second end 66 of the turbine component 14, wherein the first end sub-inner liner 20 may be formed from a first material having a less compliant than a material forming the second end sub-inner liner 22.

[0027] The step of injection a ceramic material at 102 may include injecting a ceramic material into at least one inner cavity 122 formed within the composite die cast system 10, wherein the first end sub-inner liner 20 may be formed from a first end, first side sub-inner liner 74 and a first end, second side sub-inner liner 76, and wherein the first end, first side sub-inner liner 74 may form a suction side outer wall 38 of an upstream portion 78 of a suction side 40 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 46 of the suction side outer wall 38 that is configured to form at least a portion of an internal airfoil cooling system 48. The first end, second side sub-inner liner 76 may form a pressure side outer wall 50 of a pressure side 52 of the upstream portion 78 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 56 of the pressure side outer wall 50 that is configured to form at least a portion of an internal airfoil cooling system 48.

[0028] The step of injection a ceramic material at 102 may include injecting a ceramic material into at least one inner cavity 122 formed within the composite die cast system 10, wherein the second end sub-inner liner 22 may be formed from a second end, first side sub-inner

liner 80 and a second end, second side sub-inner liner 82, and wherein the second end, first side sub-inner liner 80 may form a suction side outer wall 38 of a downstream portion 84 of a suction side 40 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 46 of the suction side outer wall 38 that is configured to form at least a portion of an internal airfoil cooling system 48. The second end, second side sub-inner liner 82 may form a pressure side outer wall 50 of a pressure side 52 of the downstream portion 84 of an airfoil shaped core 42 and may include one or more cavities 44 on an inner side 56 of the pressure side outer wall 50 that is configured to form at least a portion of an internal airfoil cooling system 48.

[0029] The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of this invention. Modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope as defined in the appended claims.

Claims

1. A core die cast system (10) comprising:

a die housing (16) having at least one inner chamber (23) forming an insert receiving chamber (24);
at least one inner liner (12) positioned within the insert receiving chamber (24) of the at least one inner chamber (23) of the die housing (16), wherein the at least one inner liner (12) has an inner surface (26) defining boundaries useful to form a ceramic core (90) for shaping an inner surface (18) of a turbine component (14) in a later casting process; and
wherein the inner liner (12) is formed via a selective laser melting process.

2. The core die cast system (10) of claim 1, **characterized in that** the at least one inner liner (12) is formed from a first side sub-inner liner (30) defining boundaries useful to form the ceramic core (90) for shaping a first side (32) of the turbine component (14) in a later casting process and a second side sub-inner liner (34) defining boundaries useful to form the ceramic core (90) for shaping a second side (36) of the turbine component (14) in a later casting process.

3. The core die cast system (10) of claim 2, **characterized in that** the first side sub-inner liner (30) defines boundaries useful to form the ceramic core (90) for shaping an outer wall (38) of a suction side (40) of an airfoil usable in a gas turbine engine and includes at least one cavity (44) on an inner side (46) of the outer wall (38) that is configured to form at least a portion of an internal airfoil cooling system (48), and

wherein the second side sub-inner liner (34) defines boundaries useful to form the ceramic core (90) for shaping an outer wall (50) of a pressure side (52) of an airfoil usable in a gas turbine engine and includes at least one cavity (44) on an inner side (56) of the outer wall (50) that is configured to form at least a portion of an internal airfoil cooling system (48).

4. The core die cast system (10) of claim 1, **characterized in that** the at least one inner liner (12) is formed from a non-ceramic material.

5. The core die cast system (10) of claim 1, **characterized in that** the at least one inner liner (12) is formed from a different material than the die housing (16).

6. The core die cast system (10) of claim 1, **characterized in that** the die housing (16) is formed from a first sub-die housing (58) and a second sub-die housing (60) having a mateable interface (62) positioned therebetween such that the first and second sub-die housings (58, 60) are mateable at the mateable interface (62).

7. The core die cast system (10) of claim 1, **characterized in that** the inner liner (12) is formed from a first end sub-inner liner (20) defining boundaries useful to form the ceramic core (90) for shaping a first end (64) of the turbine component (14) in a later casting process and a second end sub-inner liner (22) defining boundaries useful to form the ceramic core (90) for shaping a second end (66) of the turbine component (14) in a later casting process.

8. The core die cast system (10) of claim 7, **characterized in that** the first end sub-inner liner (20) is formed from a first material that is less compliant than a material forming the second end sub-inner liner (22), which is formed from a more compliant material enabling more intricate cooling systems to be created by the second end sub-inner liner (22).

9. The core die cast system (10) of claim 7, **characterized in that** the first end sub-inner liner (20) defines boundaries useful to form the ceramic core (90) for shaping a leading edge (70) of an airfoil usable in a turbine engine in a later casting process and second end sub-inner liner (22) defines boundaries useful to form the ceramic core (90) for shaping a trailing edge (72) of the airfoil usable in the turbine engine in a later casting process.

10. The core die cast system (10) of claim 7, **characterized in that** the first end sub-inner liner (20) is formed from a first end, first side sub-inner liner (74) and a first end, second side sub-inner liner (76).

11. The core die cast system (10) of claim 10, **charac-**

terized in that the first end, first side sub-inner liner (74) defines boundaries useful to form the ceramic core (90) for shaping a suction side outer wall (38) of an upstream portion (78) of a suction side (40) of an airfoil usable in a gas turbine engine and includes at least one cavity (44) on an inner side (46) of the suction side outer wall (38) that is configured to form at least a portion of an internal airfoil cooling system (48), and wherein the first end, second side sub-inner liner (76) defines boundaries useful to form the ceramic core (90) for shaping a pressure side outer wall (50) of a pressure side (52) of the upstream portion (78) of an airfoil usable in a gas turbine engine and includes at least one cavity (44) on an inner side (56) of the pressure side outer wall (50) that is configured to form at least a portion of an internal airfoil cooling system (48).

12. The core die cast system (10) of claim 7, **characterized in that** the second end sub-inner liner (22) is formed from a second end, first side sub-inner liner (80) and a second end, second side sub-inner liner (82).

13. The core die cast system (10) of claim 12, **characterized in that** the second end, first side sub-inner liner (80) defines boundaries useful to form the ceramic core (90) for shaping a suction side outer wall (38) of a downstream portion (84) of a suction side (40) of an airfoil usable in a gas turbine engine and includes at least one cavity (44) on an inner side (46) of the suction side outer wall (38) that is configured to form at least a portion of an internal airfoil cooling system (48), and wherein the second end, second side sub-inner liner (82) defines boundaries useful to form the ceramic core (90) for shaping a pressure side outer wall (50) of a pressure side (52) of the downstream portion (84) of an airfoil usable in a gas turbine engine and includes at least one cavity (44) on an inner side (56) of the pressure side outer wall (50) that is configured to form at least a portion of an internal airfoil cooling system (48).

14. A method (100) of forming a turbine component (14) comprising:

injecting a ceramic material (98) into at least one inner cavity (44) formed within a core die cast system (10), wherein the core die cast system (10) comprises:

a die housing (16) having at least one inner chamber (23) defining an insert receiving chamber (24);

at least one inner liner (12) formed via selective laser melting and positioned within the insert receiving chamber (24) of the at least one inner chamber (23) of the die

housing (16), wherein the at least one inner liner (12) has an inner surface (26) corresponding to an inner surface (18) of the turbine component (14);

removing the die cast system (10) to reveal one or more ceramic cores (90);
firing the one or more ceramic cores (90);
placing the one or more ceramic cores (90) within an inner cavity (92) formed by an inner surface (94) of a wax die (96); and
injecting wax (88) into one or more openings (92) formed between the one or more ceramic cores (90) and the inner surface (94) of the wax die (96);
removing the wax die (96) to reveal a wax component (86);
coating the wax component (86) with a ceramic coating (116) to form a ceramic shell (118) with a ceramic core (90) positioned therein;
removing the wax component (86) within the ceramic coating (116) leaving one or more cavities (122) within the ceramic coating (116);
filling the one or more cavities (122) within the ceramic coating (116) with a molten metal; and
removing the ceramic shell (118) and the one or more ceramic cores (90) to form the turbine component (14) with the inner surface (18).

Patentansprüche

1. Kerndruckgussystem (10), umfassend:

ein Gussformgehäuse (16) mit mindestens einer inneren Kammer (23), die eine Einsatzaufnahmekammer (24) formt;
mindestens eine Innenverkleidung (12), die in der Einsatzaufnahmekammer (24) der mindestens einen inneren Kammer (23) des Gussformgehäuses (16) positioniert ist, wobei die mindestens eine Innenverkleidung (12) eine Innenfläche (26) aufweist, die Grenzen definiert, die nützlich sind, um einen Keramik Kern (90) zum Formen einer Innenfläche (18) eines Turbinenbauteils (14) in einem späteren Gussprozess zu formen; und
wobei die Innenverkleidung (12) über einen selektiven Laserschmelzprozess geformt wird.

2. Kerndruckgussystem (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die mindestens eine Innenverkleidung (12) aus einer Unterinnenverkleidung (30) auf einer ersten Seite, die Grenzen definiert, die nützlich sind, um den Keramik Kern (90) zum Formen einer ersten Seite (32) des Turbinenbauteils (14) in einem späteren Gussprozess zu formen und einer Unterinnenverkleidung (34) auf einer zweiten

Seite geformt wird, die Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen einer zweiten Seite (36) des Turbinenbauteils (14) in einem späteren Gussprozess zu formen.

3. Kerndruckgussystem (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die Unterinnenverkleidung (30) auf der ersten Seite Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen einer Außenwand (38) einer Saugseite (40) eines Schaufelprofils zu formen, das in einem Gasturbinenmotor verwendet werden kann und mindestens einen Hohlraum (44) auf einer Innenseite (46) der Außenwand (38) einschließt, der konfiguriert ist, um zumindest einen Teil eines inneren Schaufelprofilkühlsystems (48) zu formen, und wobei die Unterinnenverkleidung (34) auf der zweiten Seite Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen einer Außenwand (50) einer Druckseite (52) eines Schaufelprofils zu formen, das in einem Gasturbinenmotor verwendet werden kann und mindestens einen Hohlraum (44) auf einer Innenseite (56) der Außenwand (50) einschließt, der konfiguriert ist, um zumindest einen Teil eines inneren Schaufelprofilkühlsystems (48) zu formen.
4. Kerndruckgussystem (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die mindestens eine Innenverkleidung (12) aus einem Nicht-Keramikmaterial geformt wird.
5. Kerndruckgussystem (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die mindestens eine Innenverkleidung (12) aus einem anderen Material geformt wird als das Gussformgehäuse (16).
6. Kerndruckgussystem (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** das Gussformgehäuse (16) aus einem ersten Untergussformgehäuse (58) und einem zweiten Untergussformgehäuse (60) geformt wird, die eine dazwischen positionierte zusammenpassende Schnittfläche (62) aufweisen, so dass das erste und zweite Untergussformgehäuse (58, 60) an der zusammenpassenden Schnittfläche (62) zusammenpassen.
7. Kerndruckgussystem (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Innenverkleidung (12) aus einer Unterinnenverkleidung (20) an einem ersten Ende, die Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen eines ersten Endes (64) des Turbinenbauteils (14) in einem späteren Gussprozess zu formen und einer Unterinnenverkleidung (22) an einem zweiten Ende geformt wird, die Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen eines zweiten Endes (66) des Turbinenbauteils (14) in einem späteren Gussprozess zu formen.

8. Kerndruckgussystem (10) nach Anspruch 7, **dadurch gekennzeichnet, dass** die Unterinnenverkleidung (20) an dem ersten Ende aus einem ersten Material geformt wird, das weniger nachgiebig ist als ein Material, das die Unterinnenverkleidung (22) an dem zweiten Ende formt, welche aus einem nachgiebigeren Material geformt wird, das ermöglicht, dass kompliziertere Kühlsysteme von der Unterinnenverkleidung (22) an dem zweiten Ende hervorgerufen werden können.
9. Kerndruckgussystem (10) nach Anspruch 7, **dadurch gekennzeichnet, dass** die Unterinnenverkleidung (20) an dem ersten Ende Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen einer Vorderkante (70) eines Schaufelprofils zu formen, das in einem Turbinenmotor in einem späteren Gussprozess verwendet werden kann und die Unterinnenverkleidung (22) an dem zweiten Ende Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen einer Hinterkante (72) des Schaufelprofils zu formen, das in dem Turbinenmotor in einem späteren Gussprozess verwendet werden kann.
10. Kerndruckgussystem (10) nach Anspruch 7, **dadurch gekennzeichnet, dass** die Unterinnenverkleidung (20) an dem ersten Ende aus einer Unterinnenverkleidung (74) an einem ersten Ende, auf einer ersten Seite und einer Unterinnenverkleidung (76) an einem ersten Ende, auf einer zweiten Seite geformt wird.
11. Kerndruckgussystem (10) nach Anspruch 10, **dadurch gekennzeichnet, dass** die Unterinnenverkleidung (74) an dem ersten Ende, auf der ersten Seite Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen einer Saugseitenaußenwand (38) eines vorgelagerten Teils (78) einer Saugseite (40) eines Schaufelprofils zu formen, das in einem Gasturbinenmotor verwendet werden kann und mindestens einen Hohlraum (44) auf einer Innenseite (46) der Saugseitenaußenwand (38) einschließt, der konfiguriert ist, um zumindest einen Teil eines inneren Schaufelprofilkühlsystems (48) zu formen, und wobei die Unterinnenverkleidung (76) an dem ersten Ende, auf der zweiten Seite Grenzen definiert, die nützlich sind, um den Keramikern (90) zum Formen einer Druckseitenaußenwand (50) einer Druckseite (52) des vorgelagerten Teils (78) eines Schaufelprofils zu formen, das in einem Gasturbinenmotor verwendet werden kann und mindestens einen Hohlraum (44) auf einer Innenseite (56) der Druckseitenaußenwand (50) einschließt, der konfiguriert ist, um zumindest einen Teil eines inneren Schaufelprofilkühlsystems (48) zu formen.
12. Kerndruckgussystem (10) nach Anspruch 7, **da-**

durch gekennzeichnet, dass die Unterinnenverkleidung (22) an dem zweiten Ende aus einer Unterinnenverkleidung (80) an einem zweiten Ende, auf einer ersten Seite und einer Unterinnenverkleidung (82) an einem zweiten Ende, auf einer zweiten Seite geformt wird.

13. Kerndruckgusssystem (10) nach Anspruch 12, **dadurch gekennzeichnet, dass** die Unterinnenverkleidung (80) an dem zweiten Ende, auf der ersten Seite Grenzen definiert, die nützlich sind, um den Keramikkerne (90) zum Formen einer Saugseitenaußenwand (38) eines nachgelagerten Teils (84) einer Saugseite (40) eines Schaufelprofils zu formen, das in einem Gasturbinenmotor verwendet werden kann und mindestens einen Hohlraum (44) auf einer Innenseite (46) der Saugseitenaußenwand (38) einschließt, der konfiguriert ist, um zumindest einen Teil eines inneren Schaufelprofilkühlsystems (48) zu formen, und wobei die Unterinnenverkleidung (82) an dem zweiten Ende, auf der zweiten Seite Grenzen definiert, die nützlich sind, um den Keramikkerne (90) zum Formen einer Druckseitenaußenwand (50) einer Druckseite (52) des nachgelagerten Teils (84) eines Schaufelprofils zu formen, das in einem Gasturbinenmotor verwendet werden kann und mindestens einen Hohlraum (44) auf einer Innenseite (56) der Druckseitenaußenwand (50) einschließt, der konfiguriert ist, um zumindest einen Teil eines inneren Schaufelprofilkühlsystems (48) zu formen.

14. Verfahren (100) zum Formen eines Turbinenbauteils (14), umfassend:
Einspritzen eines Keramikmaterials (98) in mindestens einen inneren Hohlraum (44), der in einem Kerndruckgusssystem (10) geformt wird, wobei das Kerndruckgusssystem (10) Folgendes umfasst:

ein Gussformgehäuse (16) mit mindestens einer inneren Kammer (23), die eine Einsatzaufnahmekammer (24) definiert;
mindestens eine Innenverkleidung (12), die über selektives Laserschmelzen geformt wird und in der Einsatzaufnahmekammer (24) der mindestens einen inneren Kammer (23) des Gussformgehäuses (16) positioniert ist, wobei die mindestens eine Innenverkleidung (12) eine Innenfläche (26) aufweist, die einer Innenfläche (18) des Turbinenbauteils (14) entspricht;
Entfernen des Druckgusssystems (10), um einen oder mehrere Keramikkerne (90) freizulegen;
Brennen des einen oder der mehreren Keramikkerne (90);
Platzieren des einen oder der mehreren Keramikkerne (90) in einem inneren Hohlraum (92), der durch eine Innenfläche (94) einer Wachsform (96) geformt wird; und

Einspritzen von Wachs (88) in eine oder mehrere Öffnungen (92), die zwischen dem einen oder den mehreren Keramikkerne (90) und der Innenfläche (94) der Wachsform (96) geformt werden;

Entfernen der Wachsform (96), um ein Wachsbauteil (86) freizulegen;

Beschichten des Wachsbauteils (86) mit einer Keramikbeschichtung (116), um eine Keramikhülle (118) mit einem darin positionierten Keramikkerne (90) zu formen;

Entfernen des Wachsbauteils (86) in der Keramikbeschichtung (116), wobei ein oder mehrere Hohlräume (122) in der Keramikbeschichtung (116) zurückbleiben;

Füllen des einen oder der mehreren Hohlräume (122) in der Keramikbeschichtung (116) mit einem geschmolzenen Metall; und

Entfernen der Keramikhülle (118) und des einen oder der mehreren Keramikkerne (90), um das Turbinenbauteil (14) mit der Innenfläche (18) zu formen.

Revendications

1. Système de coulage sous pression de noyau (10) comprenant :

un boîtier de matrice (16) ayant au moins une chambre intérieure (23) formant une chambre de réception d'insert (24) ;

au moins une garniture intérieure (12) positionnée à l'intérieur de la chambre de réception d'insert (24) de l'au moins une chambre intérieure (23) du boîtier de matrice (16), dans lequel l'au moins une garniture intérieure (12) présente une surface intérieure (26) définissant des limites utiles pour former un noyau en céramique (90) pour le façonnage d'une surface intérieure (18) d'un composant de turbine (14) dans un processus de coulée ultérieure ; et

dans lequel la garniture intérieure (12) est formée via un processus de fusion sélective au laser.

2. Système de coulage sous pression de noyau (10) selon la revendication 1, **caractérisé en ce que** l'au moins une garniture intérieure (12) est formée à partir d'une première garniture sous-intérieure latérale (30) définissant des limites utiles pour former le noyau en céramique (90) pour le façonnage d'un premier côté (32) du composant de turbine (14) dans un processus de coulée ultérieure et une seconde garniture sous-intérieure latérale (34) définissant des limites utiles pour former le noyau en céramique (90) pour le façonnage d'un second côté (36) du composant de turbine (14) dans un processus de coulée

ultérieur.

3. Système de coulage sous pression de noyau (10) selon la revendication 2, **caractérisé en ce que** la première garniture sous-intérieure latérale (30) définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une paroi extérieure (38) d'un côté extrados (40) d'un profil aérodynamique utilisable dans une turbine à gaz et comprend au moins une cavité (44) sur un côté intérieur (46) de la paroi extérieure (38) qui est conçue pour former au moins une partie d'un système de refroidissement de profil aérodynamique interne (48), et dans lequel la seconde garniture sous-intérieure latérale (34) définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une paroi extérieure (50) d'un côté intrados (52) d'un profil aérodynamique utilisable dans une turbine à gaz et comprend au moins une cavité (44) sur un côté intérieur (56) de la paroi extérieure (50) qui est conçue pour le façonnage d'au moins une partie d'un système de refroidissement de profil aérodynamique interne (48). 5 10 15 20
4. Système de coulage sous pression de noyau (10) selon la revendication 1, **caractérisé en ce que** l'au moins une garniture intérieure (12) est formée d'un matériau non céramique. 25
5. Système de coulage sous pression de noyau (10) selon la revendication 1, **caractérisé en ce que** l'au moins une garniture intérieure (12) est formée d'un matériau différent de celui du boîtier de matrice (16). 30
6. Système de coulage sous pression de noyau (10) selon la revendication 1, **caractérisé en ce que** le boîtier de matrice (16) est formé d'un premier boîtier de sous-matrice (58) et d'un second boîtier de sous-matrice (60) présentant une interface adaptable (62) positionnée entre eux de sorte que les premier et second boîtiers de sous-matrice (58, 60) peuvent s'adapter à l'interface adaptable (62). 35 40
7. Système de coulage sous pression de noyau (10) selon la revendication 1, **caractérisé en ce que** la garniture intérieure (12) est formée à partir d'une garniture sous-intérieure (20) d'une première extrémité définissant des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une première extrémité (64) du composant de turbine (14) dans un processus de coulée ultérieur et une garniture sous-intérieure (22) d'une seconde extrémité définissant des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une seconde extrémité (66) du composant de turbine (14) dans un processus de coulée ultérieur. 45 50 55
8. Système de coulage sous pression de noyau (10) selon la revendication 7, **caractérisé en ce que** la garniture sous-intérieure (20) d'une première extrémité est formée d'un premier matériau qui est moins souple qu'un matériau formant la garniture sous-intérieure (22) d'une seconde extrémité, qui est formée d'un matériau plus souple permettant la création de systèmes de refroidissement plus complexes par la garniture sous-intérieure (22) d'une seconde extrémité.
9. Système moulé sous pression de noyau (10) selon la revendication 7, **caractérisé en ce que** la garniture sous-intérieure (20) d'une première extrémité définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'un bord d'attaque (70) d'un profil aérodynamique utilisable dans un moteur à turbine dans un processus de coulée ultérieur et une garniture sous-intérieure (22) d'une seconde extrémité définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'un bord de fuite (72) du profil aérodynamique utilisable dans le moteur à turbine dans un processus de coulée ultérieur.
10. Système de coulage sous pression de noyau (10) selon la revendication 7, **caractérisé en ce que** la garniture sous-intérieure (20) d'une première extrémité est formée d'une première garniture sous-intérieure latérale (74) d'une première extrémité et d'une seconde garniture sous-intérieure latérale (76) d'une première extrémité.
11. Système de coulage sous pression de noyau (10) selon la revendication 10, **caractérisé en ce que** la première garniture sous-intérieure latérale (74) d'une première extrémité définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une paroi extérieure (38) du côté extrados d'une partie amont (78) d'un côté extrados (40) d'un profil aérodynamique utilisable dans une turbine à gaz et comprend au moins une cavité (44) sur un côté intérieur (46) de la paroi extérieure du côté extrados (38) qui est conçue pour former au moins une partie d'un système de refroidissement de profil aérodynamique interne (48), et dans lequel la seconde garniture sous-intérieure latérale (76) d'une première extrémité définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une paroi extérieure du côté intrados (50) d'un côté intrados (52) de la partie amont (78) d'un profil aérodynamique utilisable dans une turbine à gaz et comprend au moins une cavité (44) sur un côté intérieur (56) de la paroi extérieure du côté intrados (50) qui est conçue pour former au moins une partie d'un système de refroidissement de profil aérodynamique interne (48).
12. Système de coulage sous pression de noyau (10)

selon la revendication 7, **caractérisé en ce que** la garniture sous-intérieure (22) d'une seconde extrémité est formée d'une première garniture sous-intérieure latérale (80) d'une seconde extrémité et d'une seconde garniture sous-intérieure latérale (82) d'une seconde extrémité.

13. Système de coulage sous pression de noyau (10) selon la revendication 12, **caractérisé en ce que** la première garniture sous-intérieure latérale (80) d'une seconde extrémité définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une paroi extérieure du côté extradados (38) d'une partie aval (84) d'un côté extradados (40) d'un profil aérodynamique utilisable dans une turbine à gaz et comprend au moins une cavité (44) sur un côté intérieur (46) de la paroi extérieure du côté extradados (38) qui est conçue pour former au moins une partie d'un système de refroidissement de profil aérodynamique interne (48), et dans lequel la seconde garniture sous-intérieure latérale (82) d'une seconde extrémité définit des limites utiles pour former le noyau en céramique (90) pour le façonnage d'une paroi extérieure du côté intrados (50) d'un côté intrados (52) de la partie aval (84) d'un profil aérodynamique utilisable dans une turbine à gaz et comprend au moins une cavité (44) sur un côté intérieur (56) de la paroi extérieure du côté intrados (50) qui est conçue pour former au moins une partie d'un système de refroidissement de profil aérodynamique interne (48).

14. Procédé (100) de formation d'un composant de turbine (14) comprenant :

l'injection d'un matériau céramique (98) dans au moins une cavité intérieure (44) formée dans un système de coulage sous pression de noyau (10), dans lequel le système de coulage sous pression de noyau (10) comprend :

un boîtier de matrice (16) présentant au moins une chambre intérieure (23) définissant une chambre de réception d'insert (24) ;
au moins une garniture intérieure (12) formée par fusion laser sélective et positionnée à l'intérieur de la chambre de réception d'insert (24) de l'au moins une chambre intérieure (23) du boîtier de matrice (16), dans lequel l'au moins une garniture intérieure (12) présente une surface intérieure (26) correspondant à une surface intérieure (18) du composant de turbine (14) ;

le retrait du système de coulage sous pression (10) pour révéler un ou plusieurs noyaux en céramique (90) ; la cuisson des un ou plusieurs

noyaux en céramique (90) ;
la mise en place des un ou plusieurs noyaux en céramique (90) à l'intérieur d'une cavité intérieure (92) formée par une surface intérieure (94) d'une matrice à cire (96) ; et
l'injection de la cire (88) dans une ou plusieurs ouvertures (92) formées entre les un ou plusieurs noyaux en céramique (90) et la surface intérieure (94) de la matrice à cire (96) ;
le retrait de la matrice à cire (96) pour révéler un composant de cire (86) ;
l'application sur le composant de cire (86) d'un revêtement céramique (116) pour former une coque en céramique (118) avec un noyau en céramique (90) positionné à l'intérieur ;
le retrait du composant de cire (86) à l'intérieur du revêtement céramique (116) en laissant une ou plusieurs cavités (122) à l'intérieur du revêtement céramique (116) ;
le remplissage des une ou plusieurs cavités (122) à l'intérieur du revêtement céramique (116) avec un métal fondu ; et
le retrait de la coque en céramique (118) et des un ou plusieurs noyaux en céramique (90) pour former le composant de turbine (14) avec la surface intérieure (18).

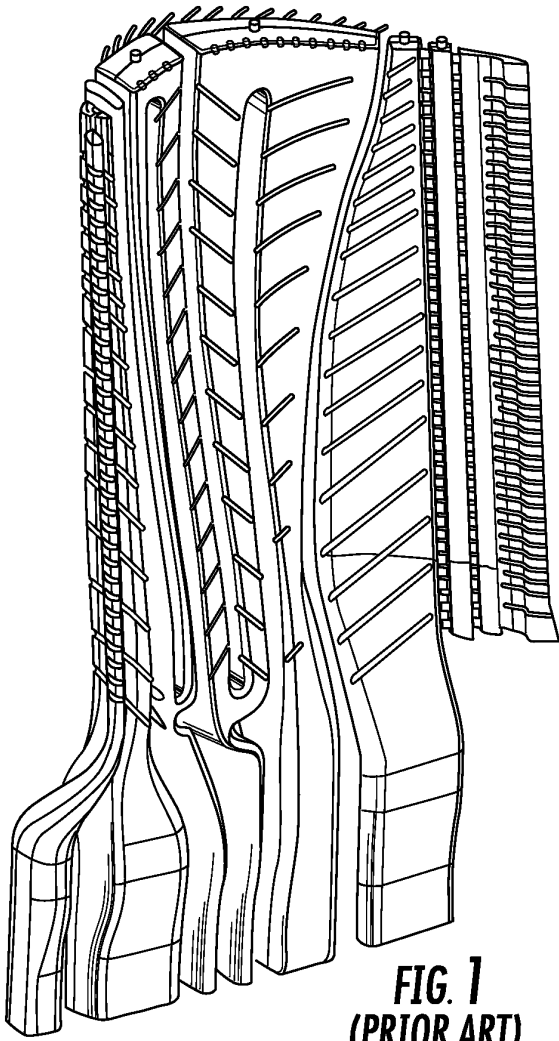


FIG. 1
(PRIOR ART)

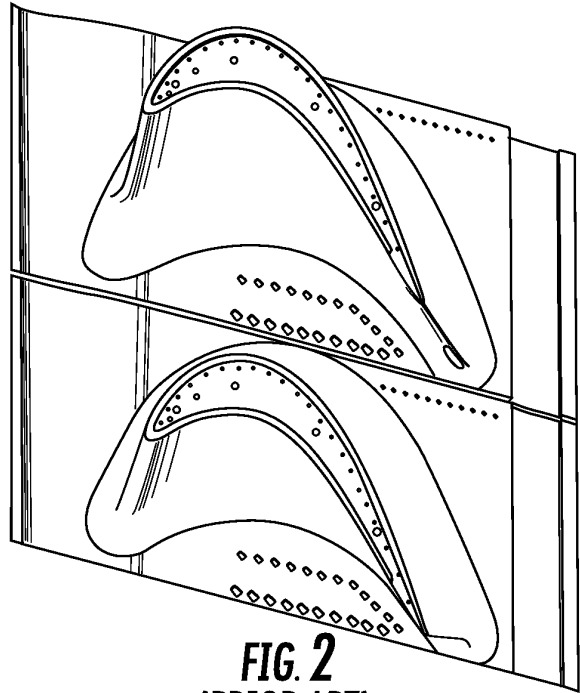


FIG. 2
(PRIOR ART)

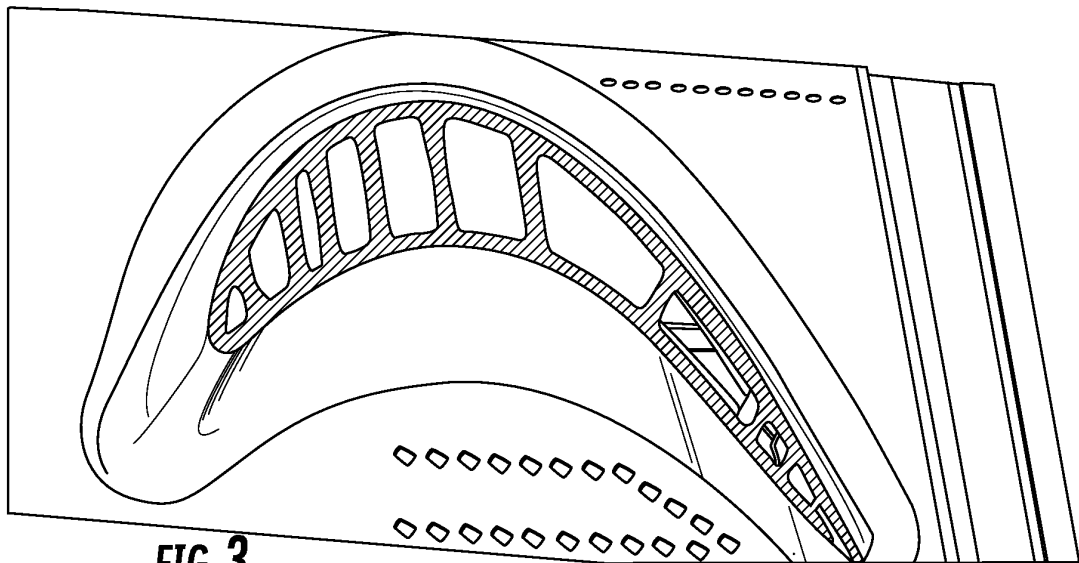
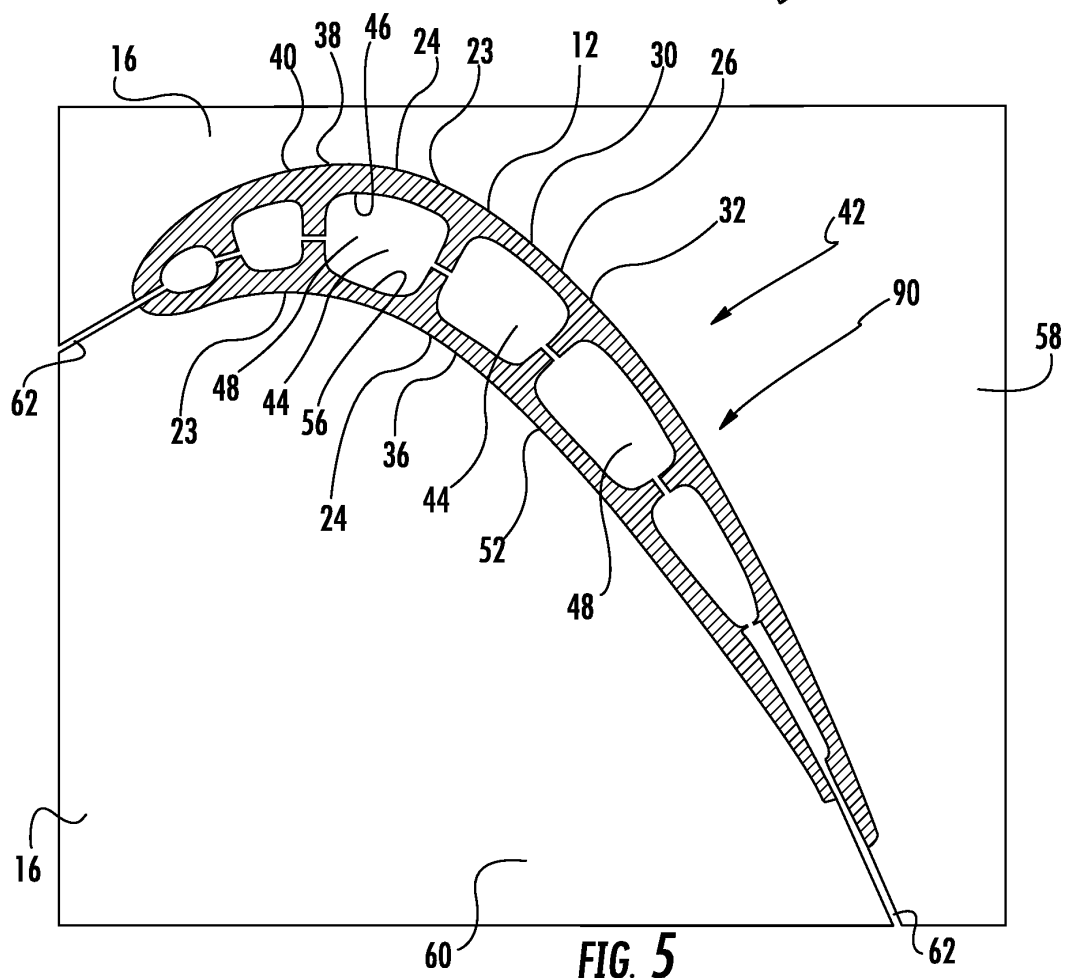
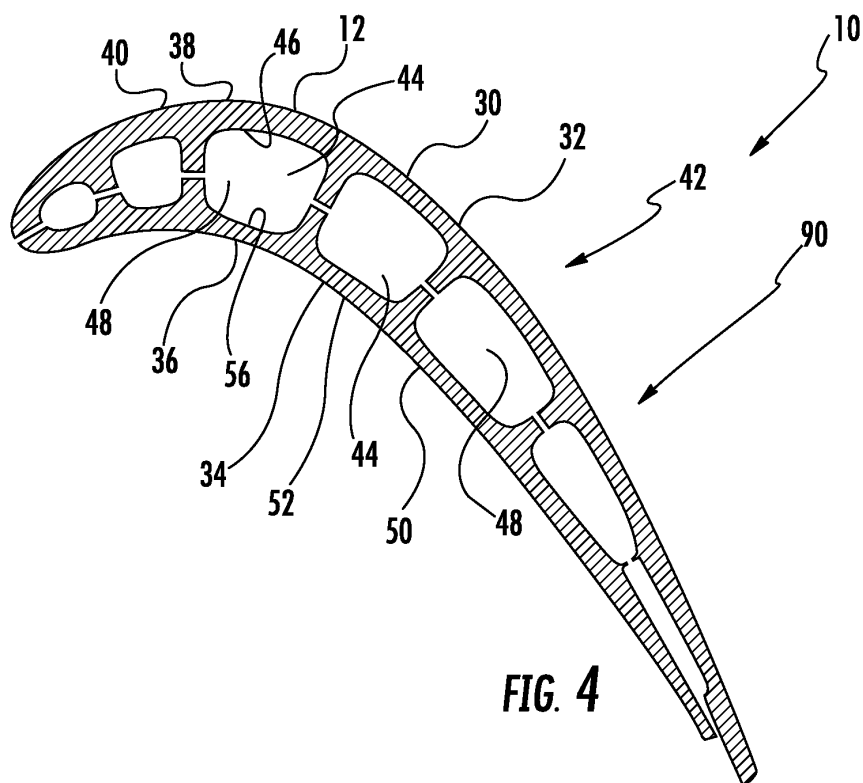
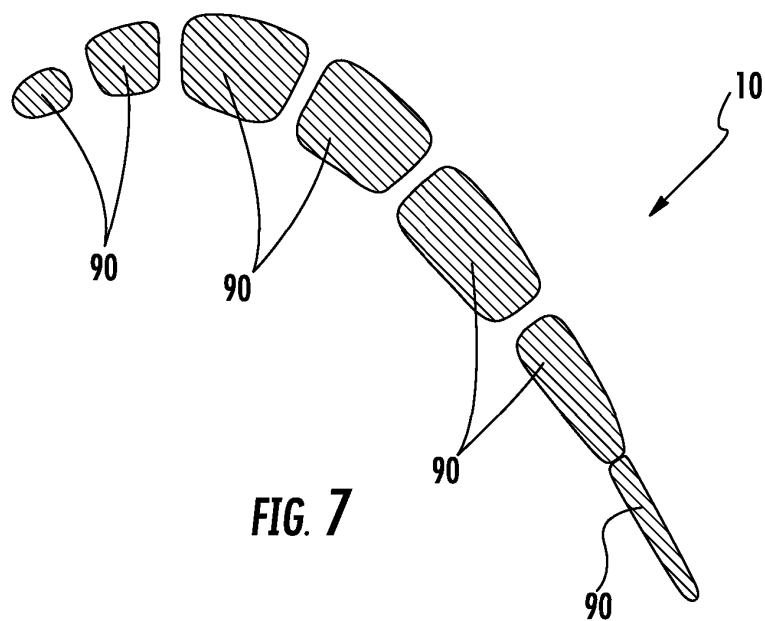
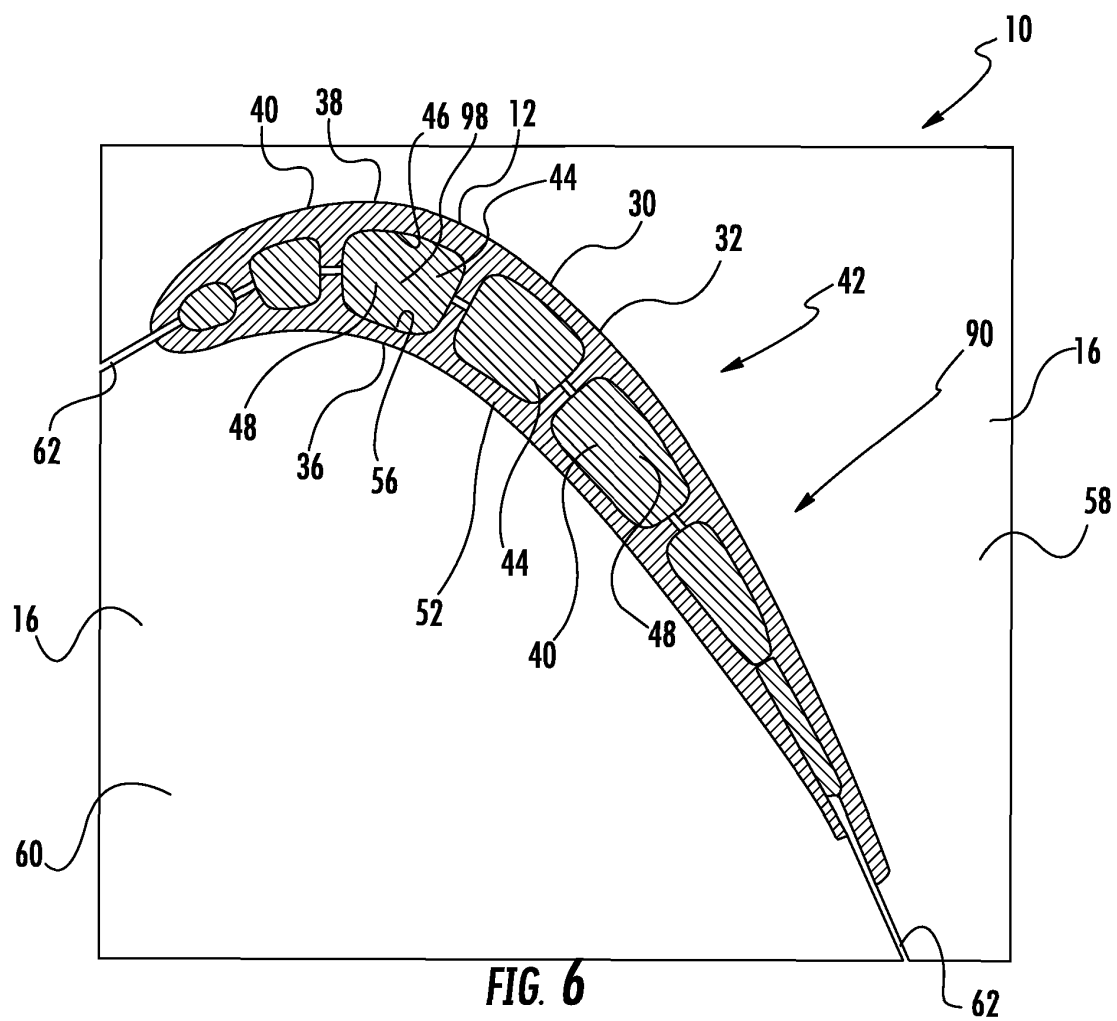
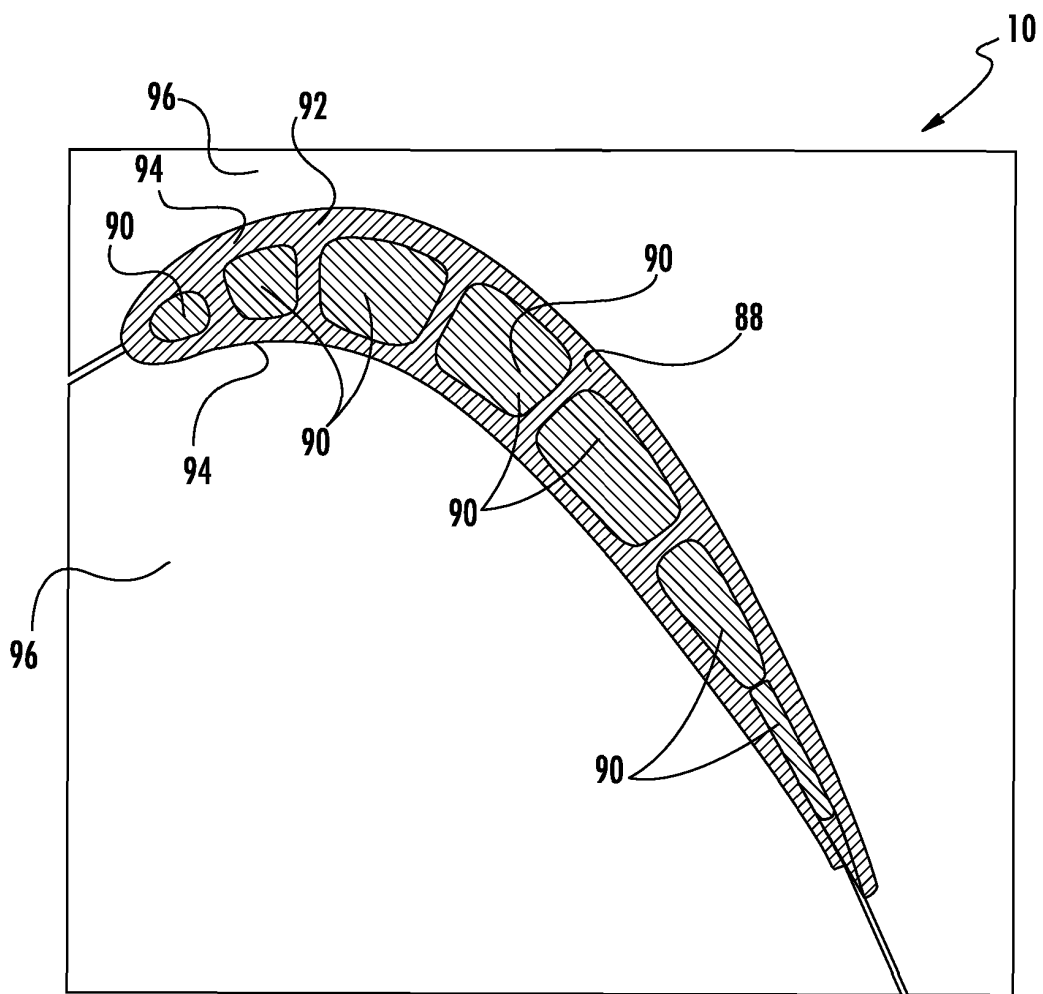
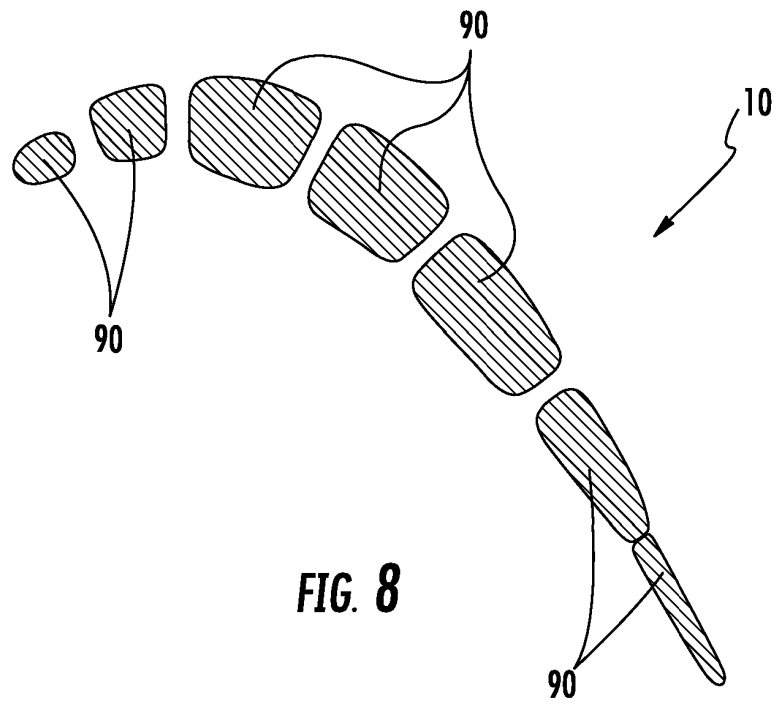


FIG. 3
(PRIOR ART)







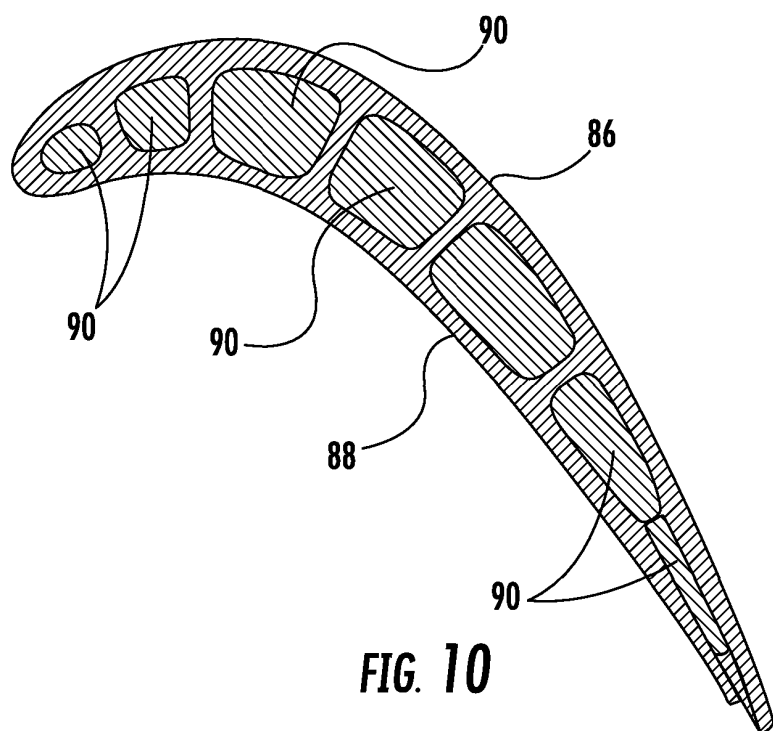


FIG. 10

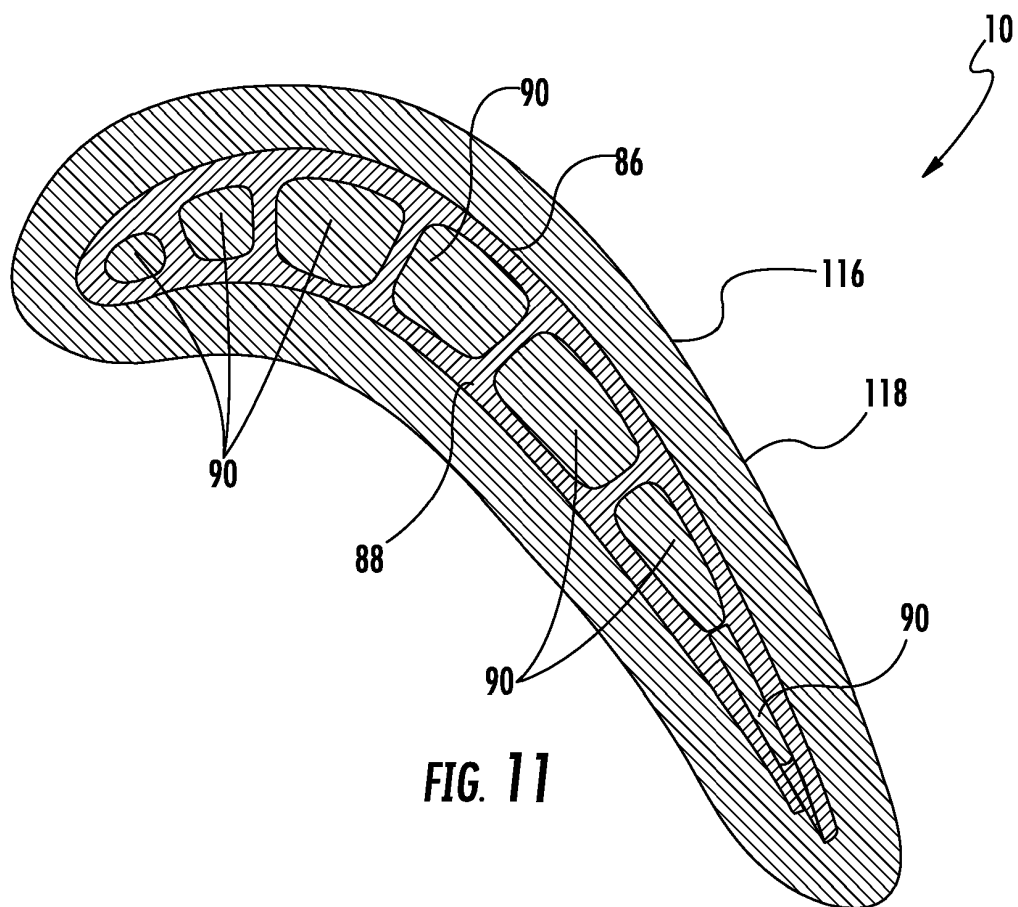


FIG. 11

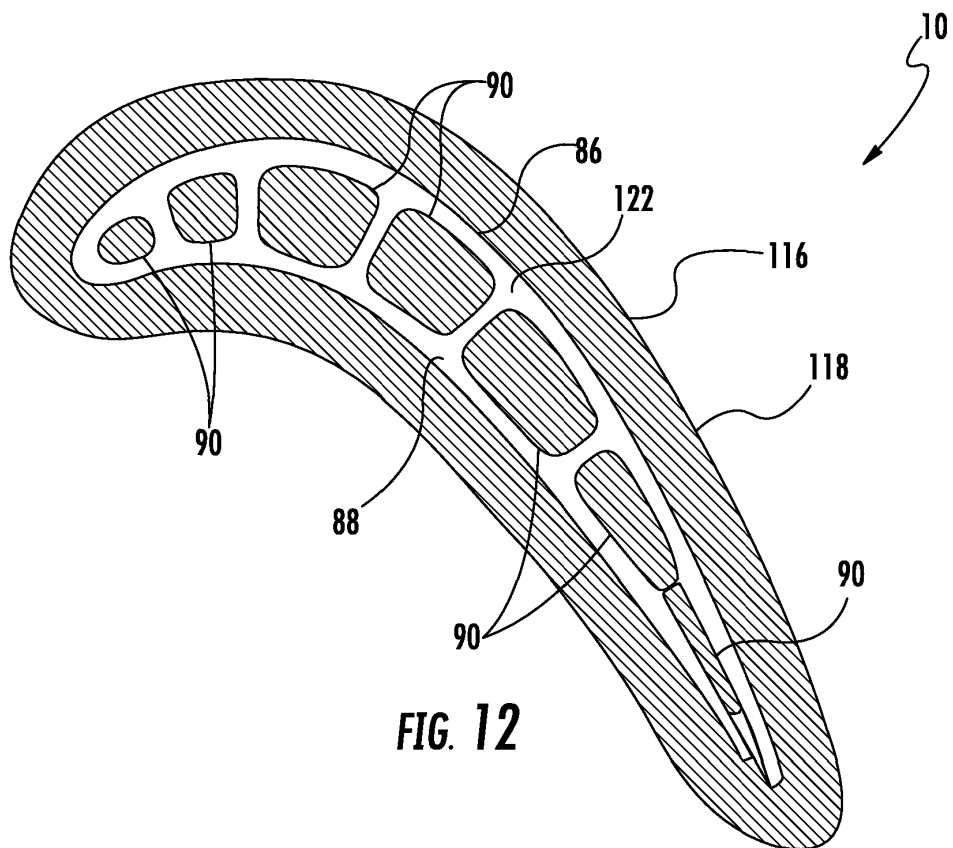


FIG. 12

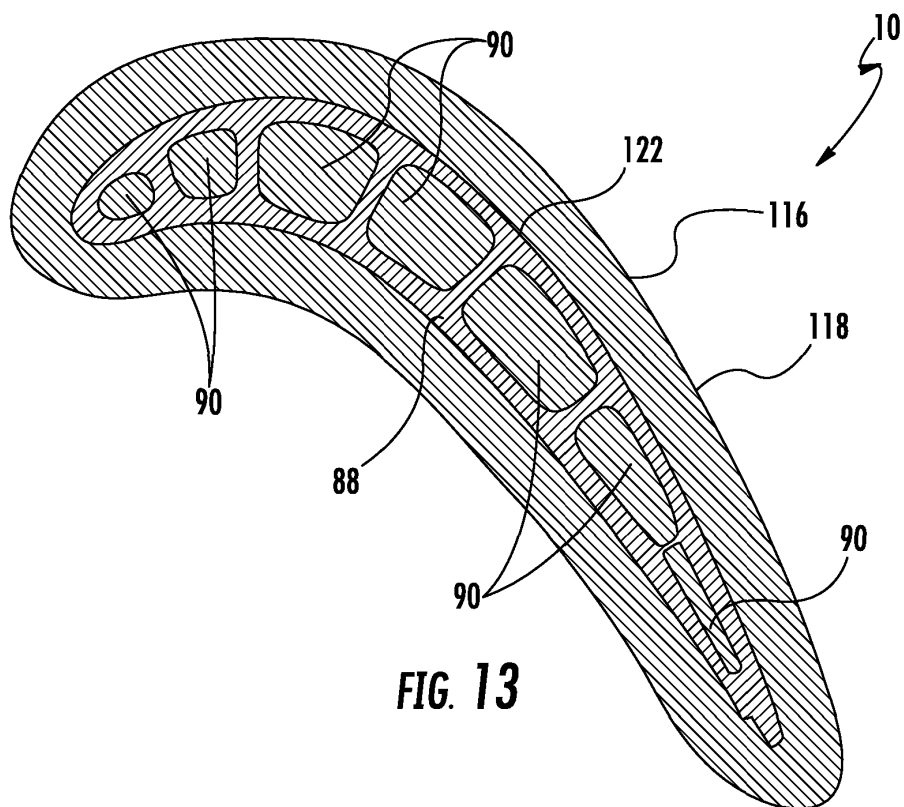
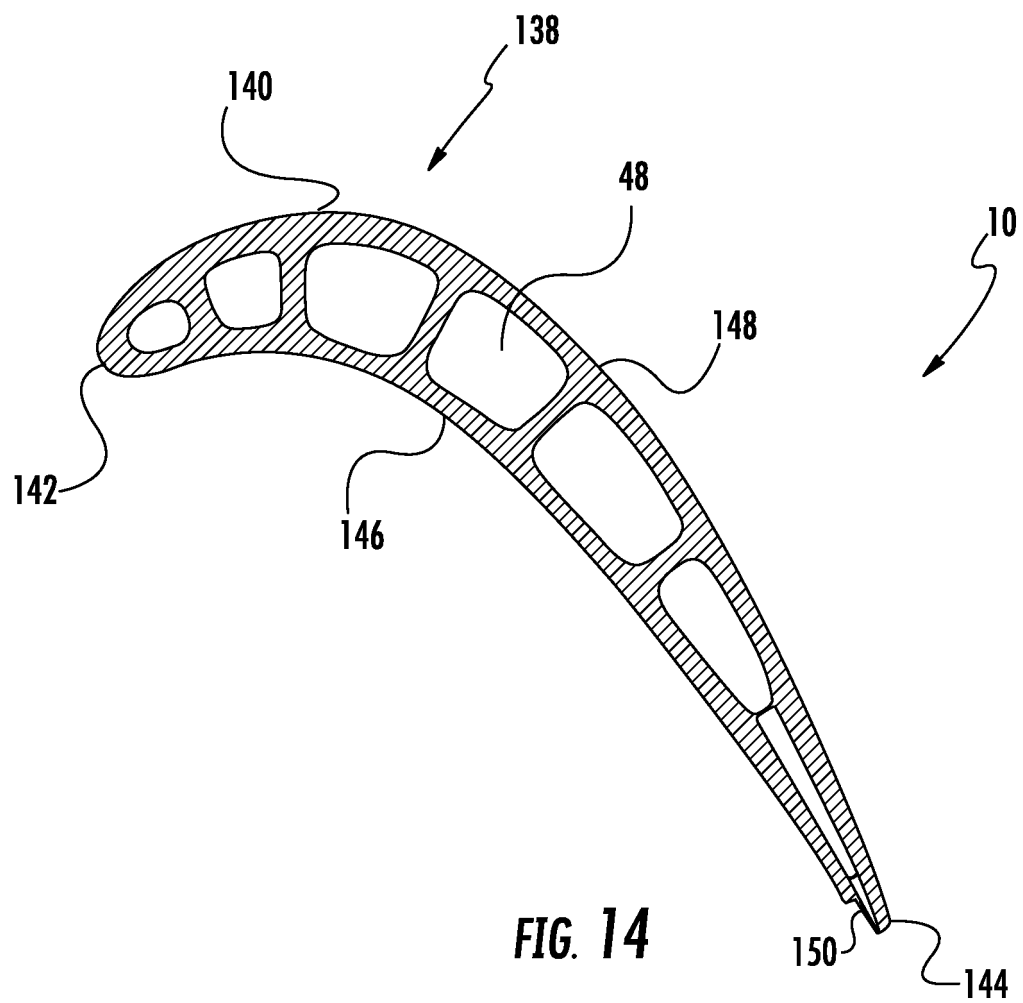
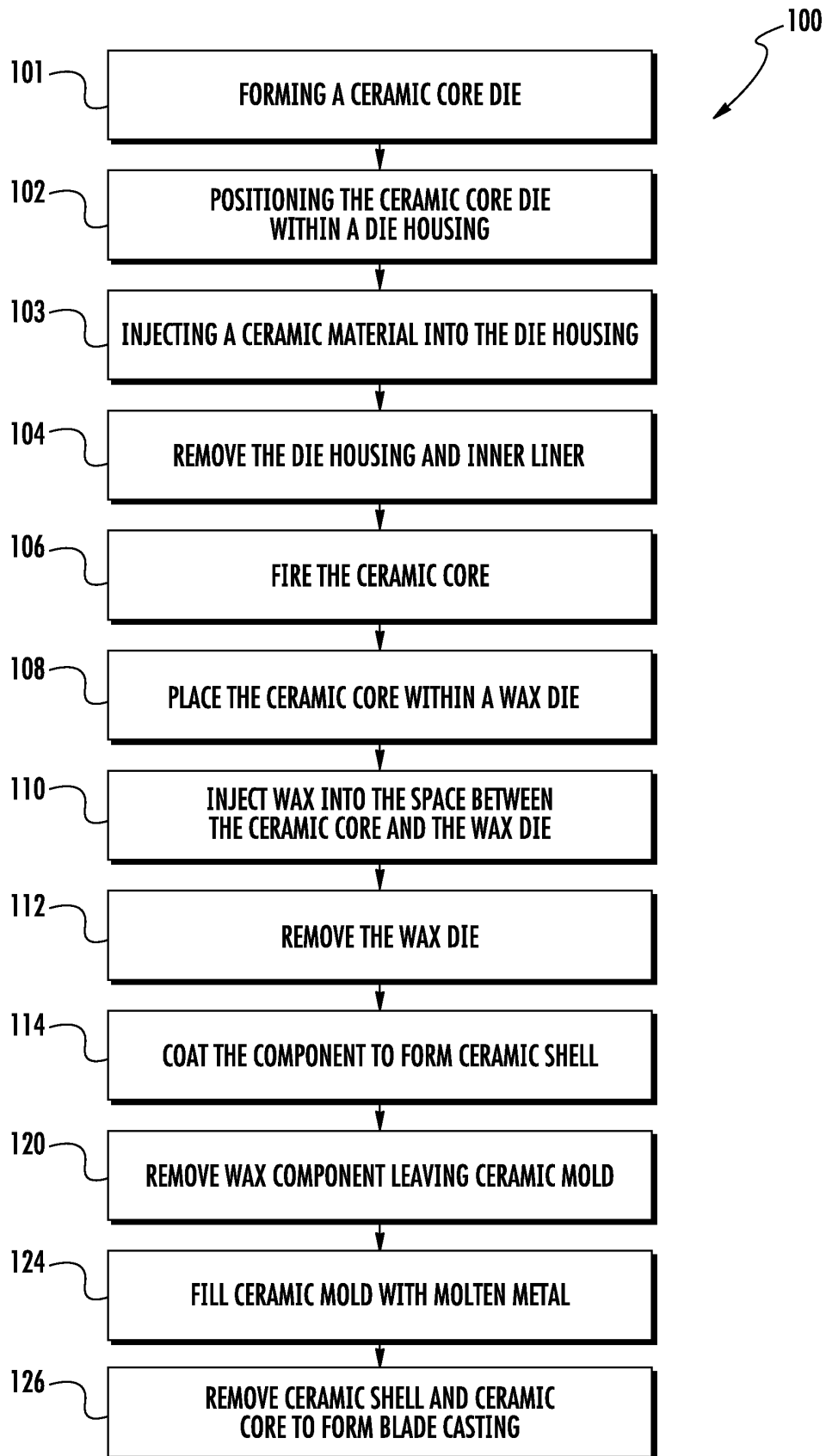
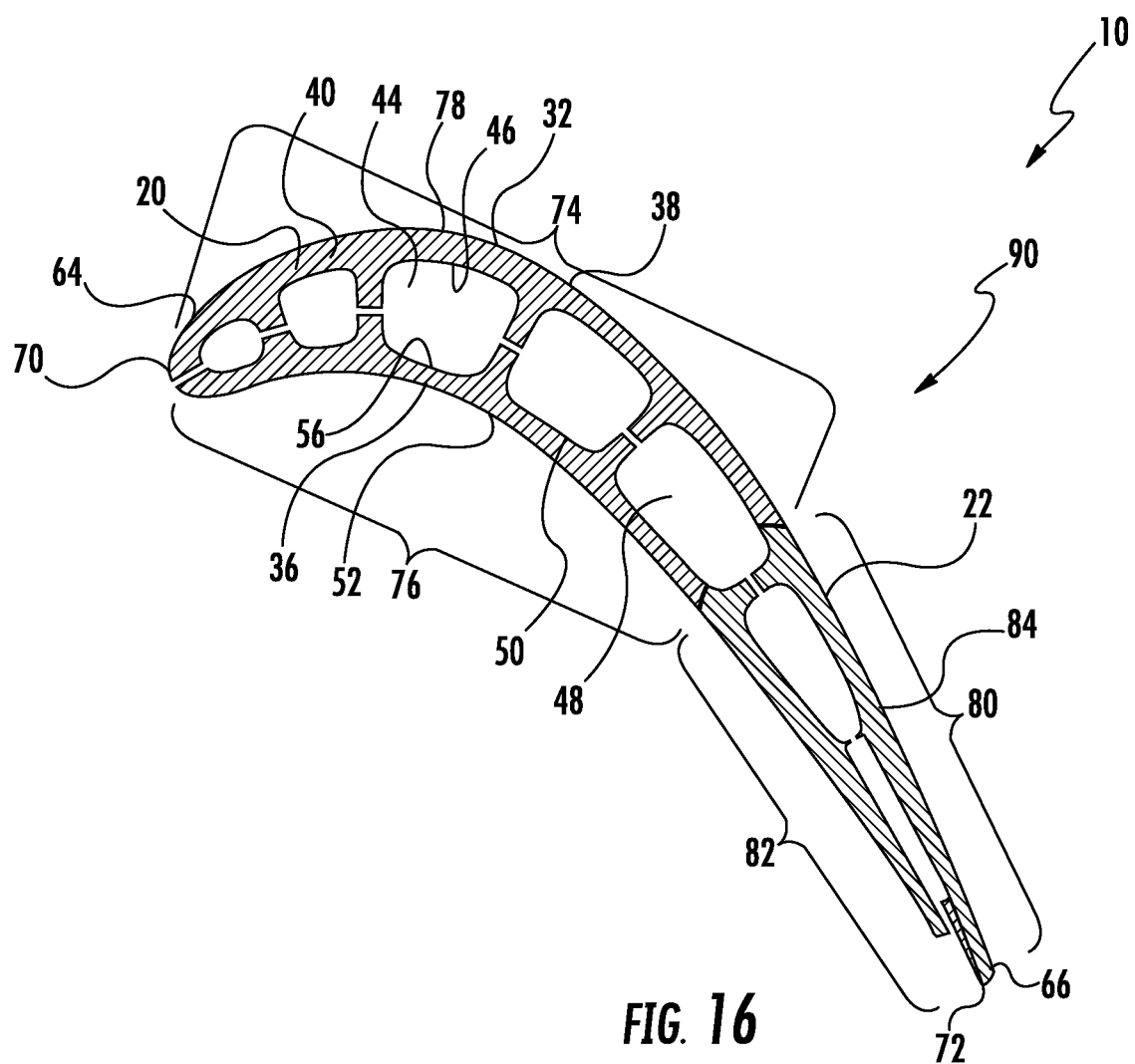


FIG. 13



**FIG. 15**



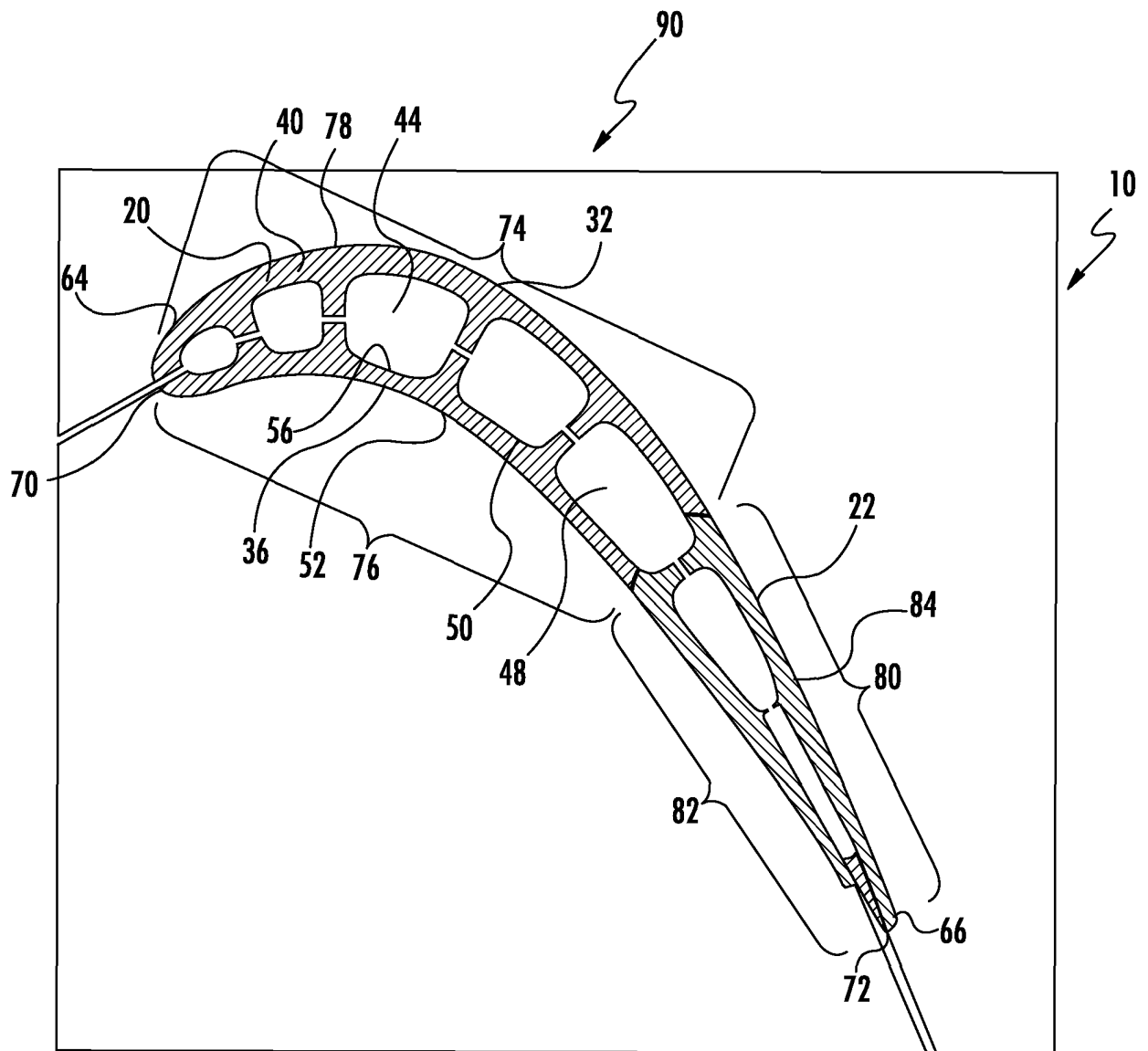


FIG. 17

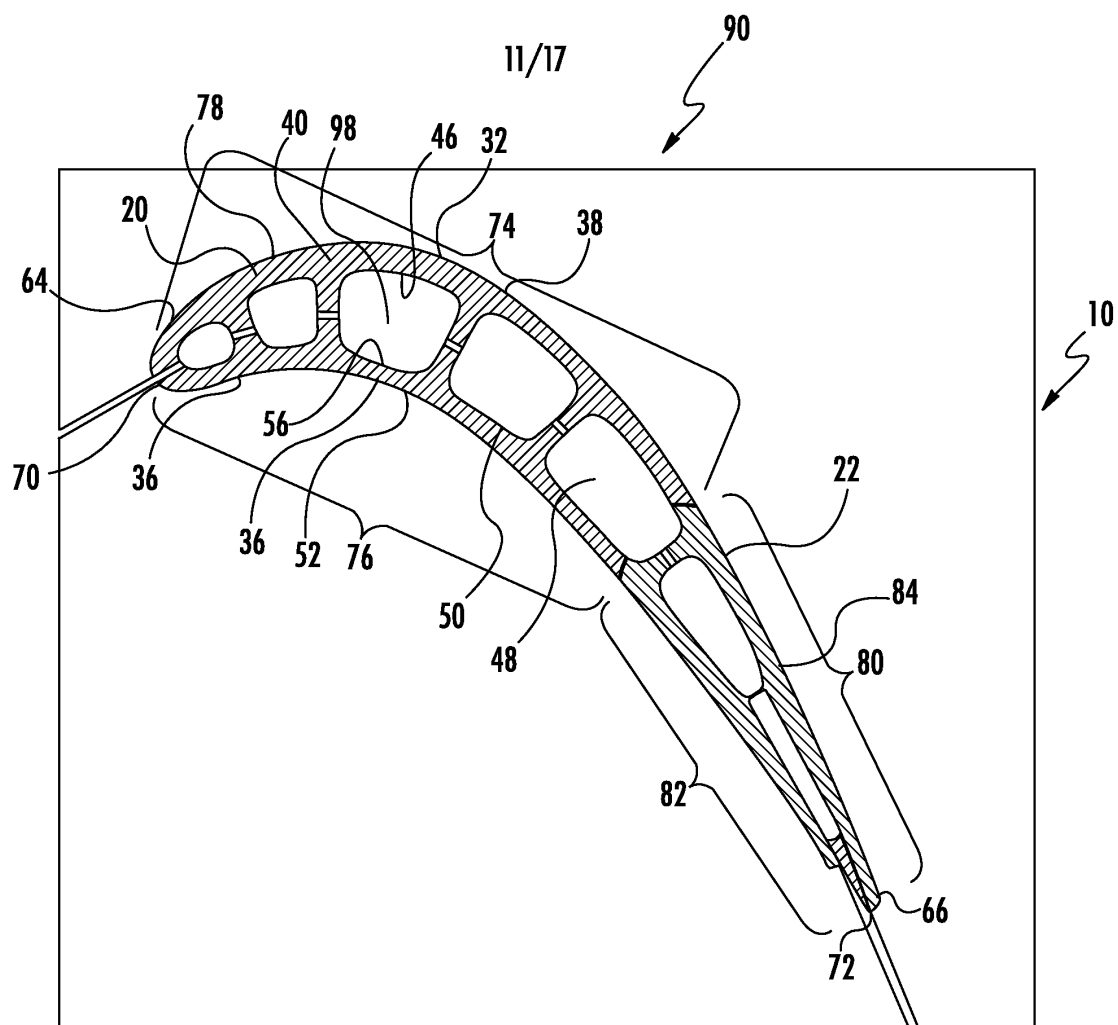


FIG. 18

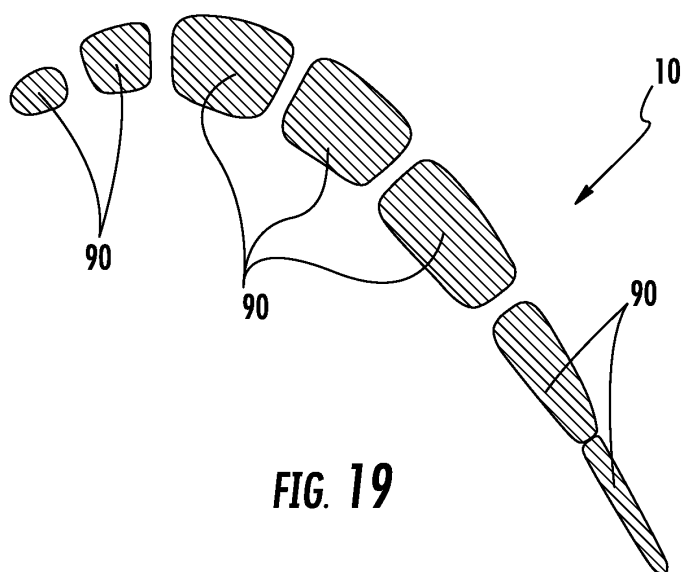
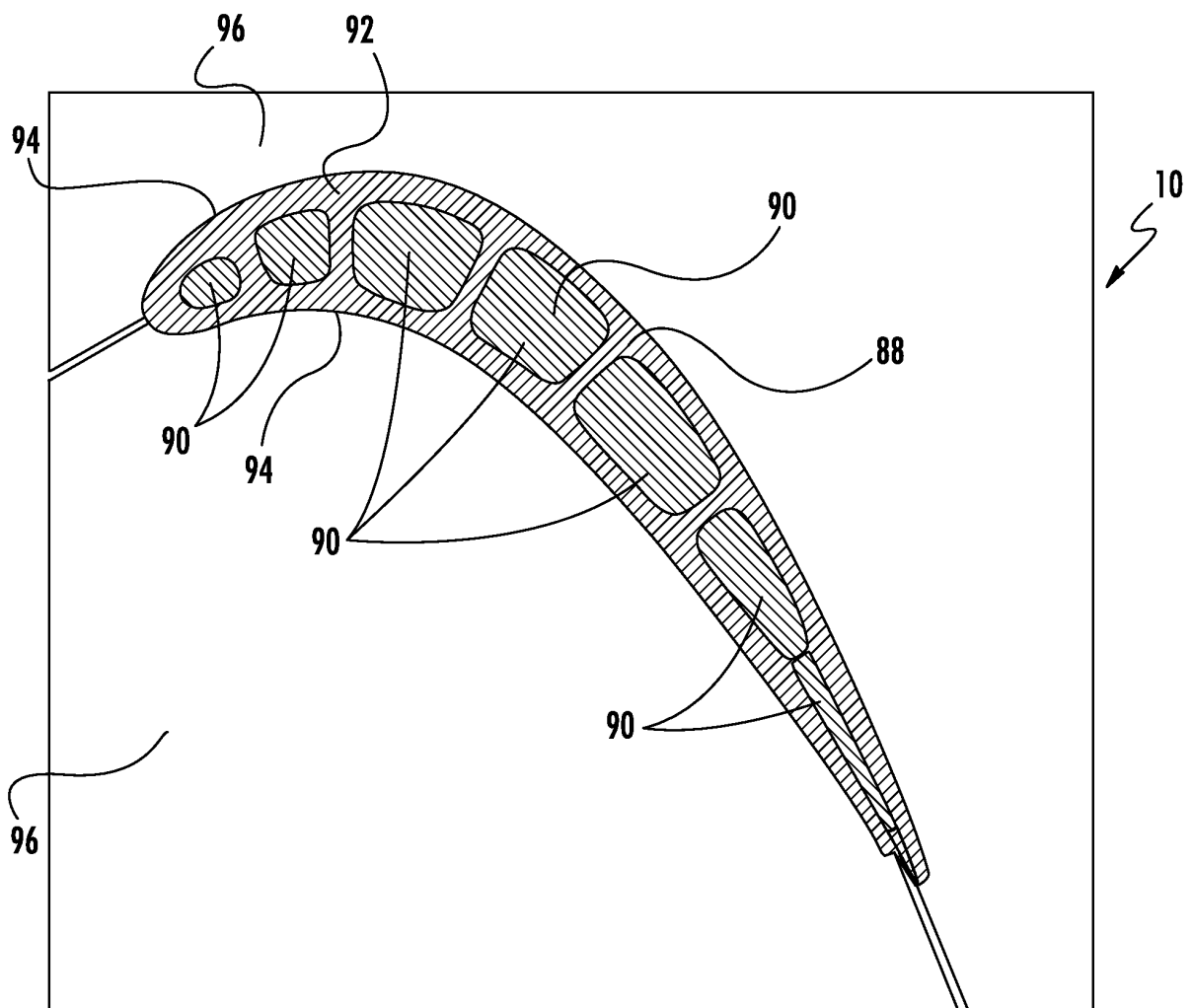
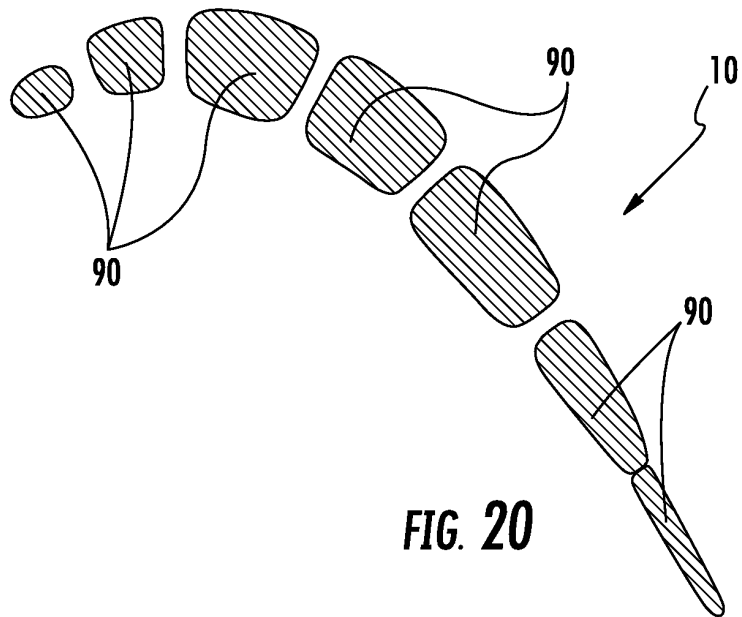
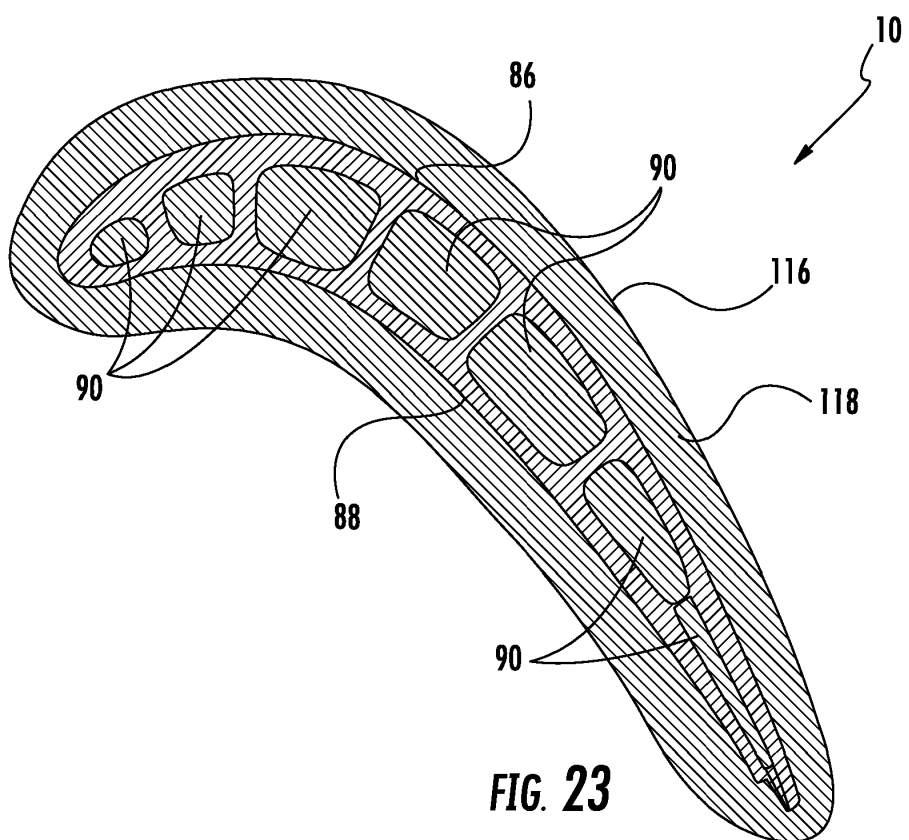
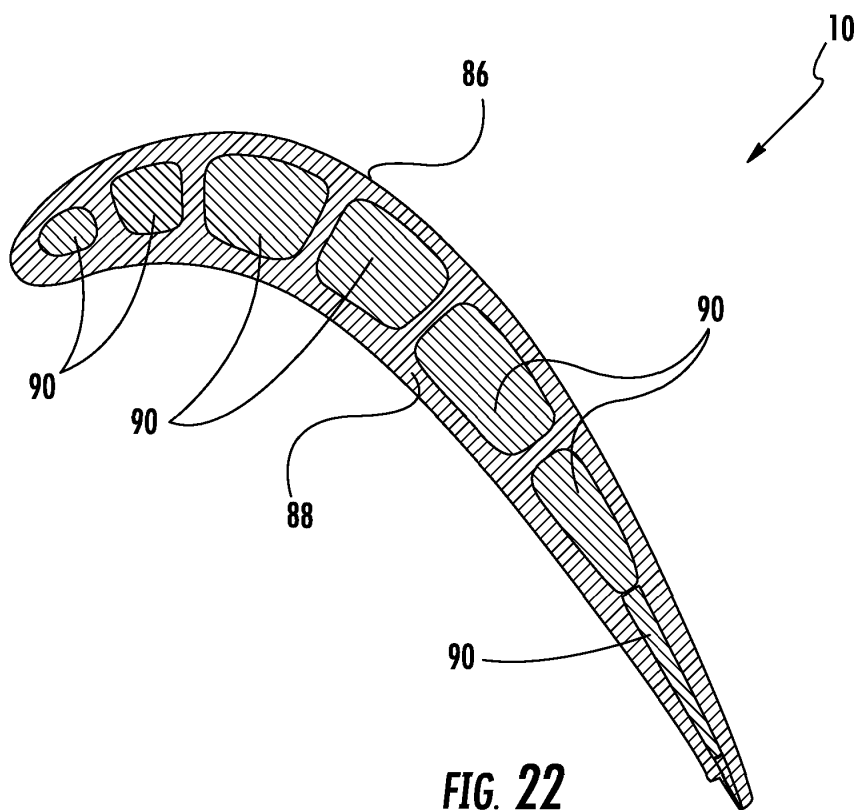
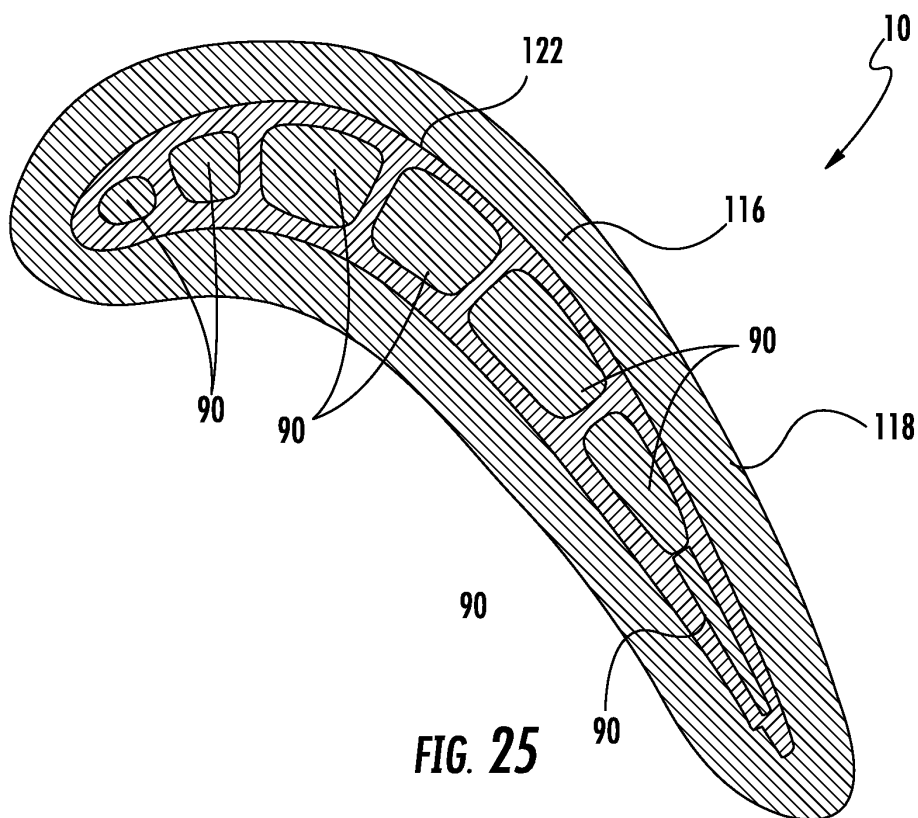
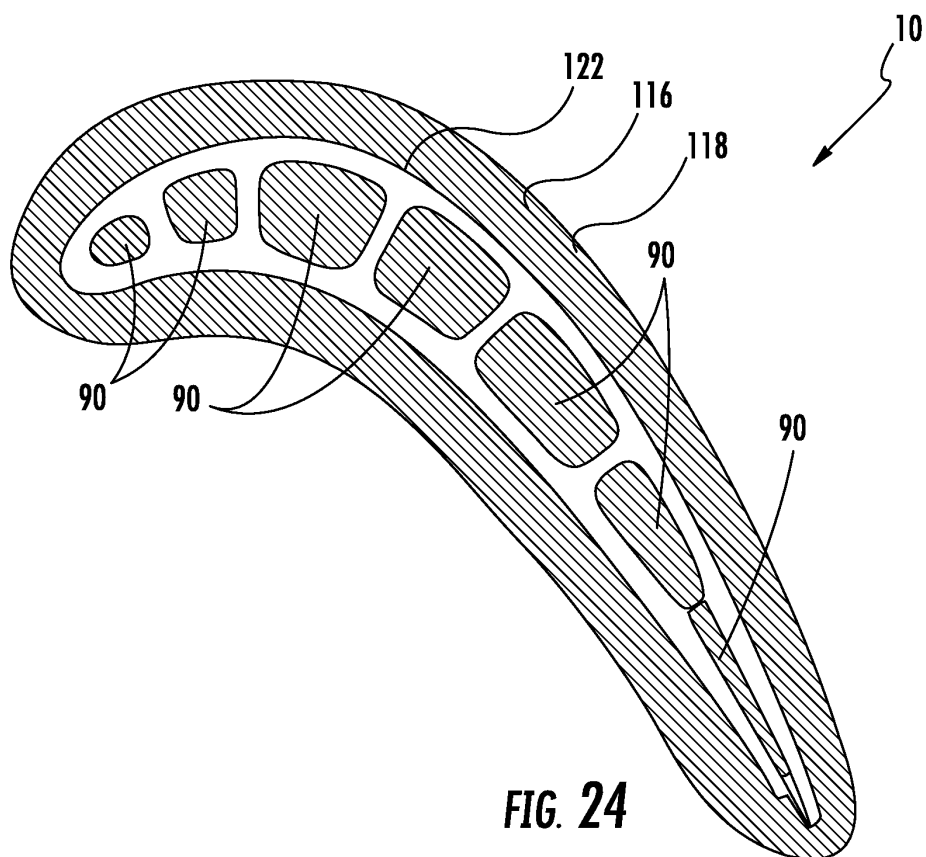


FIG. 19







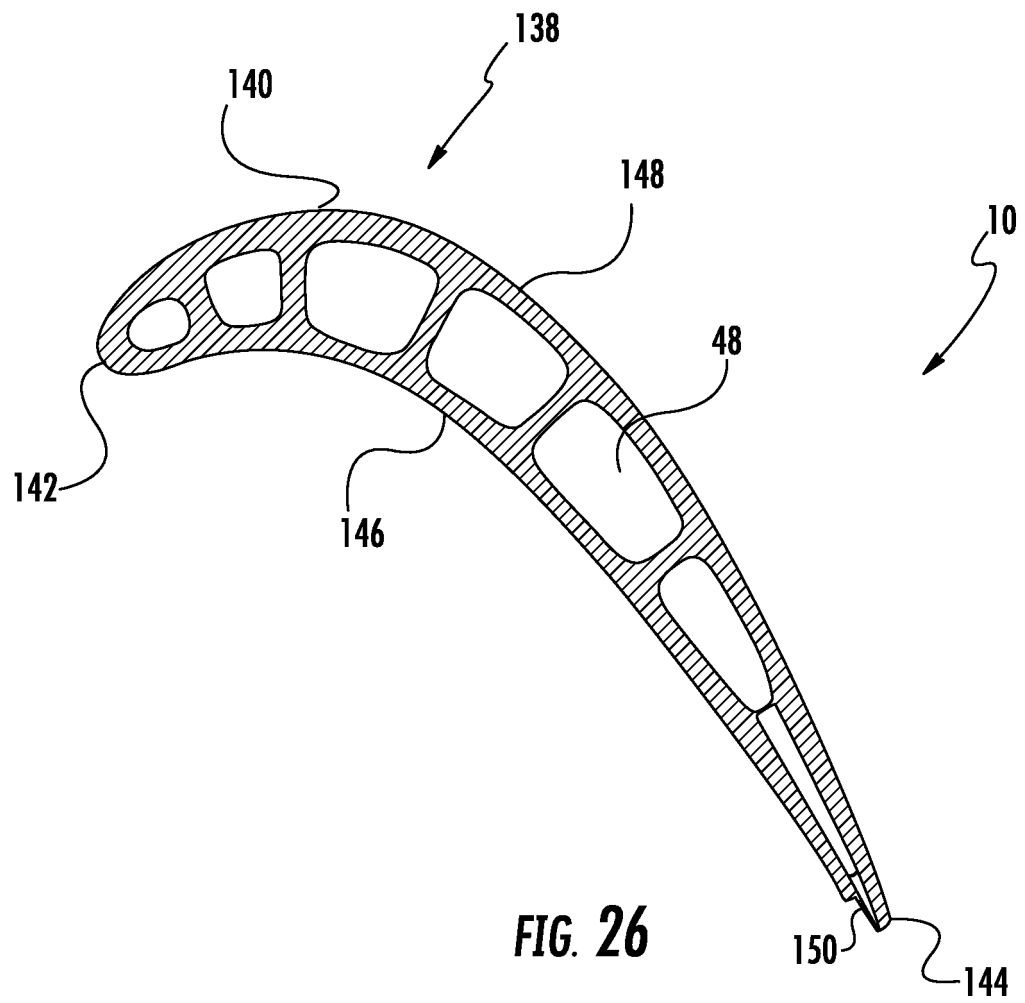


FIG. 26

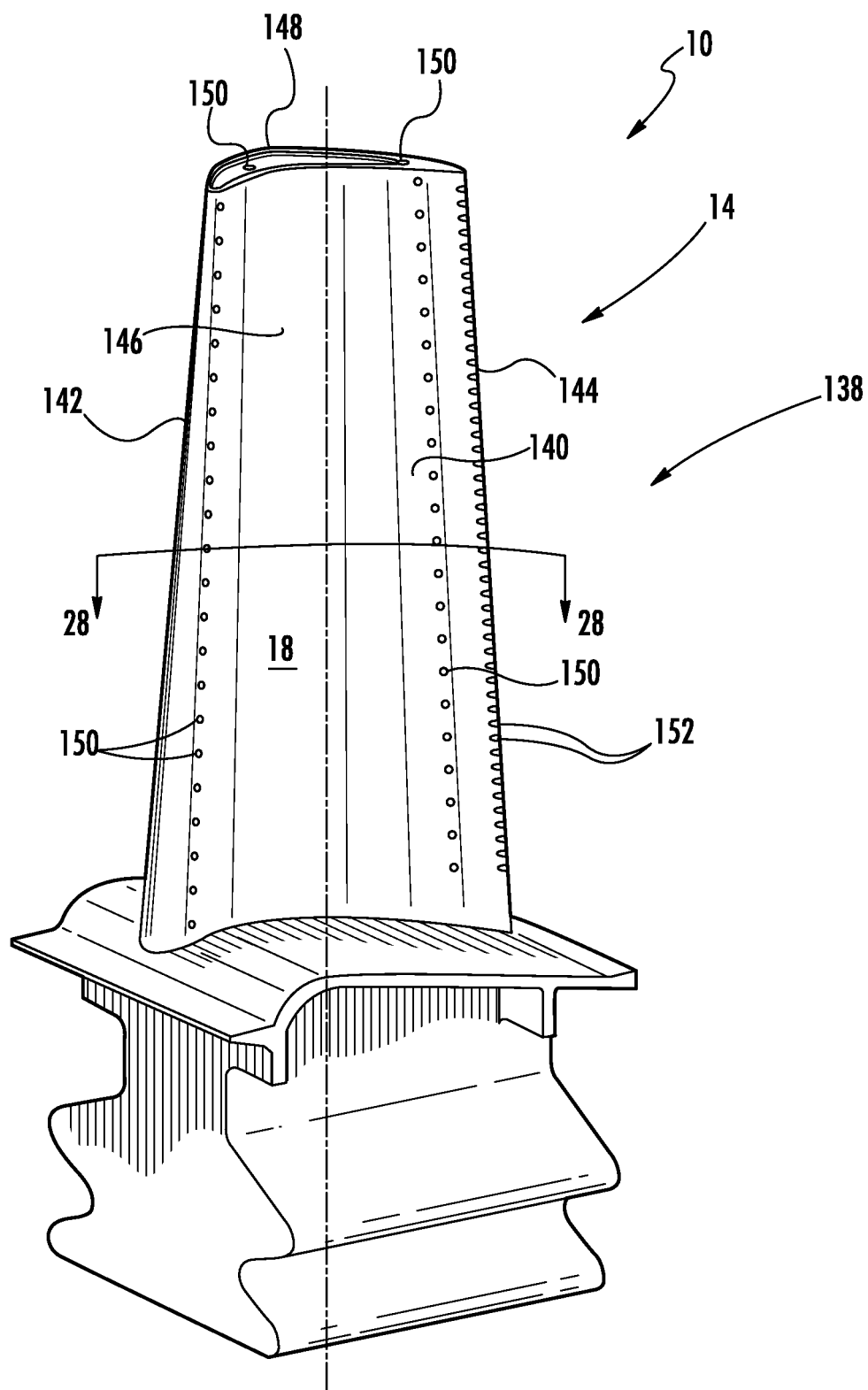


FIG. 27

