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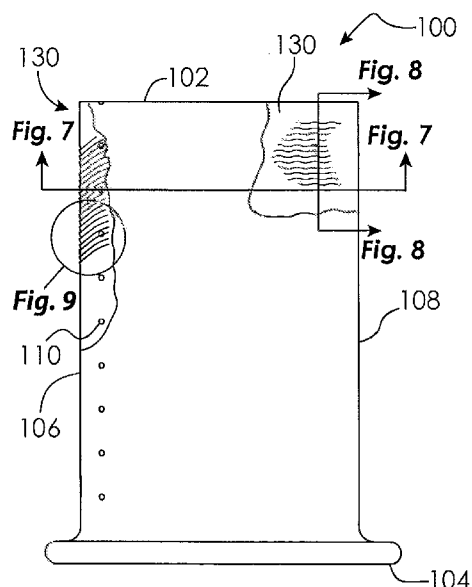
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[Continued on next page]

(54) Title: METHOD FOR DETECTING A COMPROMISED COMPONENT

**Fig. 6**

(57) Abstract: A method for providing visually detectable changes to a surface that has been subjected to a temperature in excess of a predetermined temperature. A coating is applied to the surface, wherein the coating will melt when the predetermined temperature has been reached. Centrifugal forces acting on the melted coating will cause it to be displaced such that the disturbed surface is visibly detectable upon inspection after solidifying.

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

— *of inventorship (Rule 4.17(iv))*

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- *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

METHOD FOR DETECTING A COMPROMISED COMPONENT

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of and incorporates by reference herein the disclosure of U.S. Serial No. 61/809,611, filed April 8, 2013.

TECHNICAL FIELD OF THE DISCLOSURE

[0002] The present disclosure is generally related in some embodiments to turbine engines and, more specifically, to detecting a compromised component.

BACKGROUND OF THE DISCLOSURE

[0003] Turbine engines generally include fan, compressor, combustor and turbine sections positioned along an axial centerline sometimes referred to as the engine's "axis of rotation". The fan, compressor, and combustor sections add work to air (also referred to as "core gas") flowing through the engine. The turbine extracts work from the combusted core gas to drive the fan and compressor sections. The fan, compressor, and turbine sections each include a series of stator and rotor assemblies. The stator assemblies, which do not rotate (but may have variable pitch vanes), increase the efficiency of the engine by guiding core gas flow into or out of the rotor assemblies.

[0004] Each rotor assembly typically includes a plurality of blades extending out from the circumference of a disk, or may comprise a unitary structure of disks and blades. One or more turbine stages downstream of the combustor and are therefore subjected to highly elevated temperatures during normal operation of the turbine engine. For example, it is not uncommon for the combustion gasses coming out of the combustor to significantly exceed 2000 degrees Fahrenheit. To withstand such temperatures, many turbine engines employ cooling passages within the airfoils and other components located in the turbine, wherein cooler gases are routed to the internal cooling passages (which typically exit through an opening in the surface of the component) in order to reduce the metal temperature of the components. Subsequent loss of cooling due to contamination (obstructing the cooling passage), cooling air system delivery malfunction, or other failure modes can result in overheating of the blades and other components subjected to elevated temperatures, causing reduced life.

[0005] A significant amount of labor is required to disassemble the engine to inspect these cooling passages for contamination. Intermittent loss of cooling may be more difficult to detect, such as that resulting from an intermittent valve failure. Improvements are therefore needed in the ability to diagnose when turbine components such as airfoils are subjected to excess temperatures during operation in order to ensure reliable operation.

SUMMARY OF THE DISCLOSURE

[0006] In one embodiment, a method for determining if a component having a coating thereon has been compromised is disclosed, the method comprising the steps of: a) visually inspecting the coating; and b) determining that the component has been compromised if the coating is displaced.

[0007] In another embodiment, a method for determining if a component has been operated above a predetermined temperature is disclosed, the method comprising the steps of: a) applying a coating to the component; b) visually inspecting the coating; and c) determining that the component has been operated above the predetermined temperature if the coating is displaced.

[0008] Other embodiments are also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a schematic cross-sectional view of a gas turbine engine.

[0010] FIG. 2 is an elevational view of a high pressure turbine blade in a gas turbine engine in an embodiment.

[0011] FIG. 3 is a cross-sectional view of the blade of FIG. 2.

[0012] FIG. 4 is an elevational view of a high pressure turbine blade in a gas turbine engine in an embodiment.

[0013] FIG. 5 is a cross-sectional view of the blade of FIG. 4.

[0014] FIG. 6 is an elevational view of a high pressure turbine blade in a gas turbine engine in an embodiment.

[0015] FIG. 7 is a first cross-sectional view of the blade of FIG. 6.

[0016] FIG. 8 is a second cross-sectional view of the blade of FIG. 6.

[0017] FIG. 9 is a close-up view of a portion of the blade of FIG. 6.

[0018] FIG. 10 is a partial perspective view of a first stage high pressure turbine blade with a coating applied thereto in a pattern according to an embodiment, wherein visibility of the pattern as viewed through a borescope indicates exceeding a predetermined temperature.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

[0019] Reference will now be made to certain embodiments and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the below claims is thereby intended, and alterations and modifications in the illustrated device, and further applications of the principles of the invention as illustrated therein are herein contemplated as would normally occur to one skilled in the art.

[0020] FIG. 1 illustrates a gas turbine engine 10 of a type normally provided for use in a subsonic flight, generally comprising in serial flow communication a fan 12 through which ambient air is propelled, a compressor section 14 for pressurizing a portion of the air (the gas path air), a combustor 16 in which the compressed air is mixed with fuel and ignited for generating a stream of hot combustion gases, and a turbine section 18 for extracting energy from the combustion gases.

[0021] It has been determined by the present inventors that a coating may be employed to provide external borescope-inspectable indication of excessive metal temperatures (caused by plugged cooling passages or other causes). While described in the context of a blade airfoils, it is also applicable to a vane, a seal or other components subjected to high temperatures. Referring to FIG. 2, there is shown a view of a high pressure turbine blade 100. As is known in the art, gases flowing through the turbine engine impact the blade 100, thereby causing rotation of the high pressure turbine rotor stage(s). The blade 100 includes a tip 102 designed to rub against a segmented blade outer air seal (BOAS 105, see FIG. 10), thereby providing a seal to prevent

gases from flowing between the blade 100 and the blade outer air seal. The blade 100 is coupled to a rotor assembly of the turbine (not shown) at root 104, and receives the cooling gases into its cooling passages from the turbine rotor assembly. Both the leading edge 106 and trailing edge 108 and other surfaces of the blade may include a plurality of cooling holes 110 formed therein.

[0022] As mentioned hereinabove, the standard method for inspecting the blade 100 and its cooling passages involves opening the engine case and may include partially disassembling the engine. Some of the blades 100 must be destructively tested to determine the state of the cooling passages. It is common for this process to take several days for the inspection of each engine. Turbine engines are equipped with ports that allow a borescope to be used to make a visible inspection of various internal portions of the engine, including the turbine, as shown in FIG. 2. With normal inspection schedules within the engine, this allows for periodic inspection of the cooling passages. However, some OEM coating systems that are applied to the blades 100 provide no advanced warning of compromised cooling/metal temperatures of the blade 100.

[0023] The present inventors have determined that a coating can be used to detect when a component, such as the blade 100, has been subjected to elevated temperatures that may have compromised the component. Those skilled in the art will recognize in view of the present disclosure that the embodiments disclosed herein are not limited in use to turbine blades, or even surfaces and components within a gas turbine engine. Rather, the presently disclosed embodiments will find application in any area where it is desired to produce a visible indication that a surface or component has been subjected to a temperature that exceeds a given threshold.

[0024] A cross-sectional view of the blade 100 is shown in FIG. 3. As is visible in the cross-section, the blade 100 comprises a base alloy portion 112 that includes cooling channels 114. The base alloy portion 112 is coated with a metallic coating 116. In one embodiment, the metallic coating 116 may comprise NiCoCrAlY. In other embodiments, other coatings such as aluminides may be used. Those skilled in the art will recognize from the present disclosure that any coating that exhibits a displaced appearance (as described herein) when exposed to temperatures above a predetermined temperature may be used. A metallic coating 116 comprising NiCoCrAlY can be applied in any desired manner, including low pressure plasma spray, an air plasma spray or using high velocity oxy-fuel (HVOF) spraying, to name just three non-limiting examples. A thermal barrier coating 118 may be applied to the blade 100 on top of the metallic coating 116. In some embodiments, the thermal barrier coating 118 comprises A stabilized zirconia, such as YSZ, GdZr or combinations of these coatings applied in layers. In other embodiments, other coatings may be used. Those skilled in the art will recognize from the present disclosure that the particular thermal barrier coating used, if any, is not critical to the presently disclosed embodiments. The thermal barrier coating 118 may be applied in any desired manner, and is applied in some embodiments using air plasma spray or electron beam physical vapor deposition (EB-PVD), to name just two non-limiting examples.

[0025] Thermal barrier coating 118 can spall during normal operation, or be eroded due to small particles in the gas path. Once the thermal barrier coating 118 is spalled or eroded, the metallic coating 116 will visibly rumple once it has been heated above a predetermined temperature, indicating metal substrate temperatures that have exceeded a predetermined limit. The rumpling process occurs when the metallic coating 116 is heated to a temperature near its

melting temperature and starts to flow. Centrifugal forces acting on the rotating blade 100 will cause the metallic coating 116 to run toward the tip 102 of the blade 100. The thermal barrier coating 118 is applied as a thin coating and has a very high melting temperature. The thermal barrier coating 118 tends to spall off in chunks when its interface temperature has exceeded a design value. Once the thermal barrier coating 118 has spalled, the metallic coating 116 exhibits visibly detectable changes when it overheats, and these changes can be detected with a borescope inspection in order to determine that the part requires service.

[0026] FIGs. 4 and 5 show, respectively, elevational and cross-sectional views of the blade 100 after it has been operated for a period of time. When exposed to high temperatures, but not temperatures that are above the predetermined temperature above which the blade 100 should be serviced, the thermal barrier coating 118 may exhibit a spalled appearance, as indicated at the areas 120. The spalled areas 120 may appear as discolored or have a different reflectivity (dull or shiny) when compared to other areas of the blade 100, but these areas are not "rumpled". A spalled thermal barrier coating 118 can result from operating for an extended time under normal operating conditions through particle erosion, or it is an indication that the thermal barrier coating 118 has been exposed to a temperature at or above its spallation point (causing failure of the mechanical or chemical bond between the thermal barrier coating 118 and the underlying metallic coating 116) and has spalled, resulting in pitting of the surface or larger areas where the thermal barrier coating 118 is partially or completely missing. The spalled areas 120 are typically not an indication that the blade 100 has seen excessive temperatures and this therefore is not an indication that the blade 100 should be serviced.

[0027] FIGs. 6 and 7 show, respectively, elevational and cross-sectional views of the blade 100 after it has been operated for a period of time. When exposed to high temperatures above the predetermined temperature above which the blade 100 should be serviced, the metallic coating 116 will exhibit a displaced appearance (a rumpled appearance or other evidence of having flowed), as indicated at the areas 130. A displaced metallic coating 116 is an indication that the metallic coating 116 has been exposed to a temperature near, at or above its melting point and has flowed. As used herein, the term "displaced" is intended to encompass a metallic coating 116 that is rumpled or otherwise exhibits evidence of having flowed.

[0028] FIG. 8 is a cross-sectional view of a rumpled portion of area 130. As can be seen, the metallic coating 116 has rumpled and solidified, leaving the surface formed into a series of peaks 132 and valleys 134. FIG. 9 is a close-up view of a portion of the area 130 at leading edge 106, more clearly showing the rumpled portion exhibiting a series of peaks 132 and valleys 134. The coating has also flowed into the cooling hole 110 and partially obstructed the cooling hole 110. As used herein, the term "displaced" is also intended to encompass a metallic coating 116 that has flowed into a cooling hole 110.

[0029] The use of the thermal barrier coating 118 and metallic coating 116 in combination with a schedule of borescope visual inspection can dramatically improve the ability to detect failed cooling passages in the turbine blades 100. As described hereinabove, the standard inspection method of opening the engine case and partially disassembling the engine is typically performed once for every three years of operation of the engine. When the thermal barrier coating 118, metallic coating 116, and the presently disclosed displaced coating detection

methods are used, relatively non-invasive borescope inspections can provide yearly (or other desired schedule) detection of compromised cooling passages.

[0030] The metallic coating 116 may be the primary coating applied to the surface or component, or may be applied as a base coating under other coating, such as thermal barrier coatings. The metallic coating 116 does not have to be applied to the entire surface, but can in some embodiments be applied to only a portion of the surface to be inspected. In some embodiments, a second layer of the metallic coating 116 is applied to a surface (such as by stenciling, to give just one non-limiting example), or a thin amount is removed from the primary layer of metallic coating 116 in some areas to leave a positive, to form a pattern or even a message. For example, if the metallic coating 116 is applied to a surface in a pattern that spells out "WARRANTY VOIDED", a visual indication may be provided that the surface was operated at an elevated temperature that is sufficient to void the warranty of the engine, as illustrated in FIG. 10.

[0031] The metallic coating 116 may also be used to diagnose a profile problem in the output of a turbine engine combustor. The output of the combustor is nominally pointed toward the center of the exhaust flow passage. If the combustor output is skewed toward the inside diameter of the flow passage, increased heat will be generated at the junction of the blade 100 and the rotor. The weight of the blade 100 and the centrifugal forces applied to it during operation of the engine can potentially cause the blade 100 to detach from the rotor due to the compromised metal at the blade/rotor junction. Similarly, if the combustor output is skewed toward the outside diameter of the flow passage, increased heat will be generated at the tip 102

of the blade 100 and the weakened structure at the tip 102 may not be able to support itself and may break off. Inspection of metallic coating 116 applied to the static vanes and/or the flow passage near the combustor output can provide a visual indication of where there may be a problem with the alignment of the combustor output.

[0032] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only certain embodiments have been shown and described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

What is claimed:

1. A method for determining if a component having a coating thereon has been compromised, the method comprising the steps of:
 - a) visually inspecting the coating; and
 - b) determining that the component has been compromised if the coating is displaced.
2. The method of claim 1, wherein the coating comprises a metallic coating.
3. The method of claim 2, wherein the metallic coating comprises NiCoCrAlY.
4. The method of claim 2, wherein the metallic coating comprises more than one layer.
5. The method of claim 1, wherein the component comprises an turbine blade in a turbine engine.
6. The method of claim 5, wherein the component comprises a high pressure turbine blade in a turbine engine.
7. The method of claim 1, further comprising the step of:
 - c) determining that the component should be serviced if it is determined at step (b) that the component has been compromised.

8. The method of claim 1, wherein the displaced coating is rumpled.
9. The method of claim 1, wherein the displaced coating exhibits evidence of having flowed.
10. The method of claim 2, wherein the metallic coating is at least partially covered by a thermal barrier coating.
11. The method of claim 1, wherein the component includes at least one cooling hole formed therein and the displaced coating has flowed into at least one of the at least one cooling holes.
12. A method for determining if a component has been operated above a predetermined temperature, the method comprising the steps of:
 - a) applying a coating to the component;
 - b) visually inspecting the coating; and
 - c) determining that the component has been operated above the predetermined temperature if the coating is displaced.
13. The method of claim 12, wherein step (a) further comprises:
 - a) applying the coating in a pattern to the component.

14. The method of claim 12, wherein step (a) further comprises:
 - a) applying the coating in multiple layers.
15. The method of claim 13, wherein the pattern comprises letters forming a message.
16. The method of claim 15, wherein the message comprises "WARRANTY VOIDED".
17. The method of claim 12, wherein the component comprises a turbine blade in a turbine engine.
18. The method of claim 17, wherein the component comprises a high pressure turbine blade in a turbine engine.
19. The method of claim 12, wherein the displaced coating is rumped.
20. The method of claim 12, wherein the displaced coating exhibits evidence of having flowed.
21. The method of claim 12, wherein the coating comprises a metallic coating.
22. The method of claim 21, wherein the metallic coating comprises NiCoCrAlY.

23. The method of claim 21, where in the metallic coating is applied using one of a low pressure plasma spray, an air plasma spray or high velocity oxy-fuel spraying.
24. The method of claim 12, wherein the component includes at least one cooling hole formed therein and the displaced coating has flowed into at least one of the at least one cooling holes.
25. The method of claim 21, wherein the coating is at least partially covered by a thermal barrier coating.

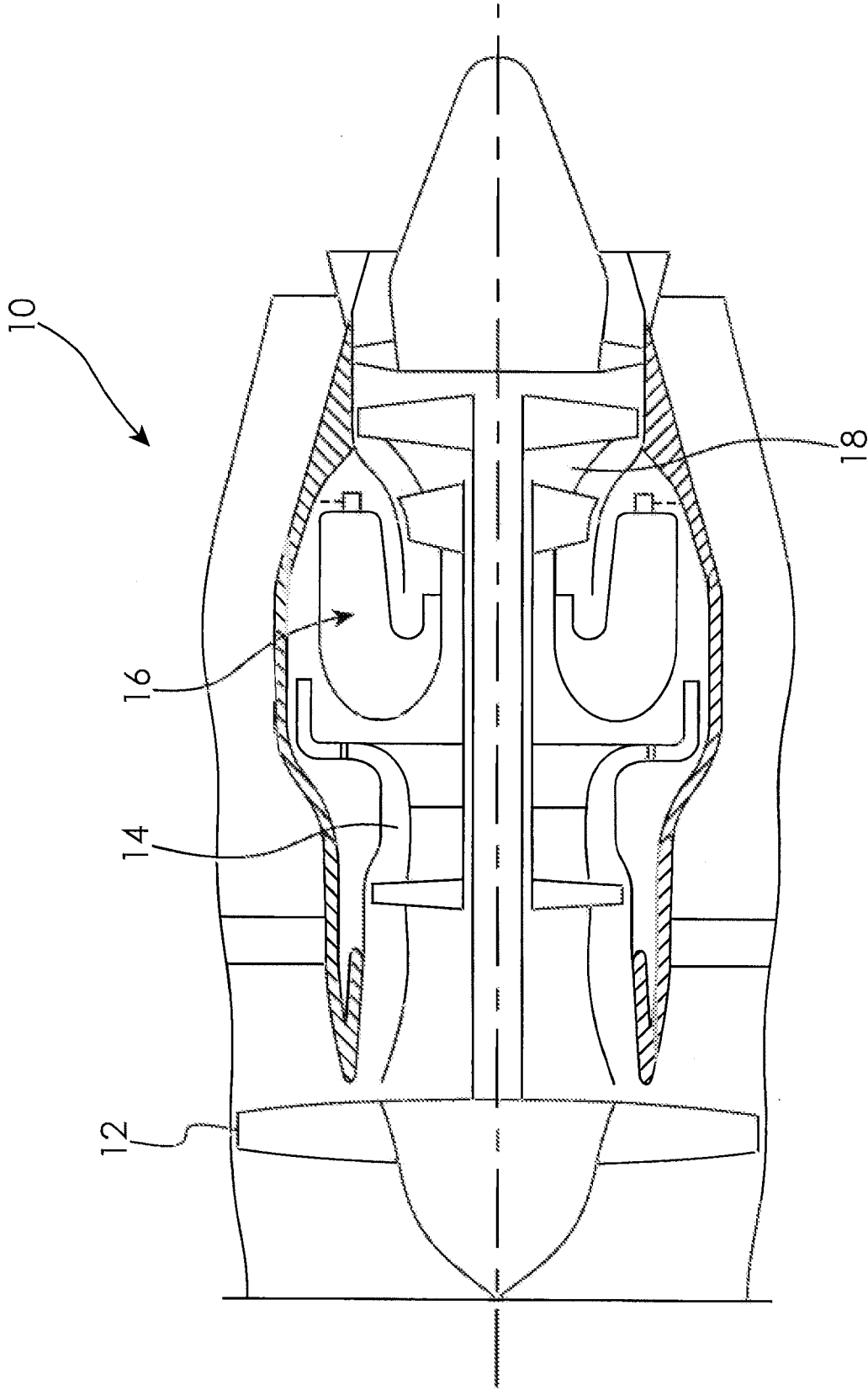


Fig. 1

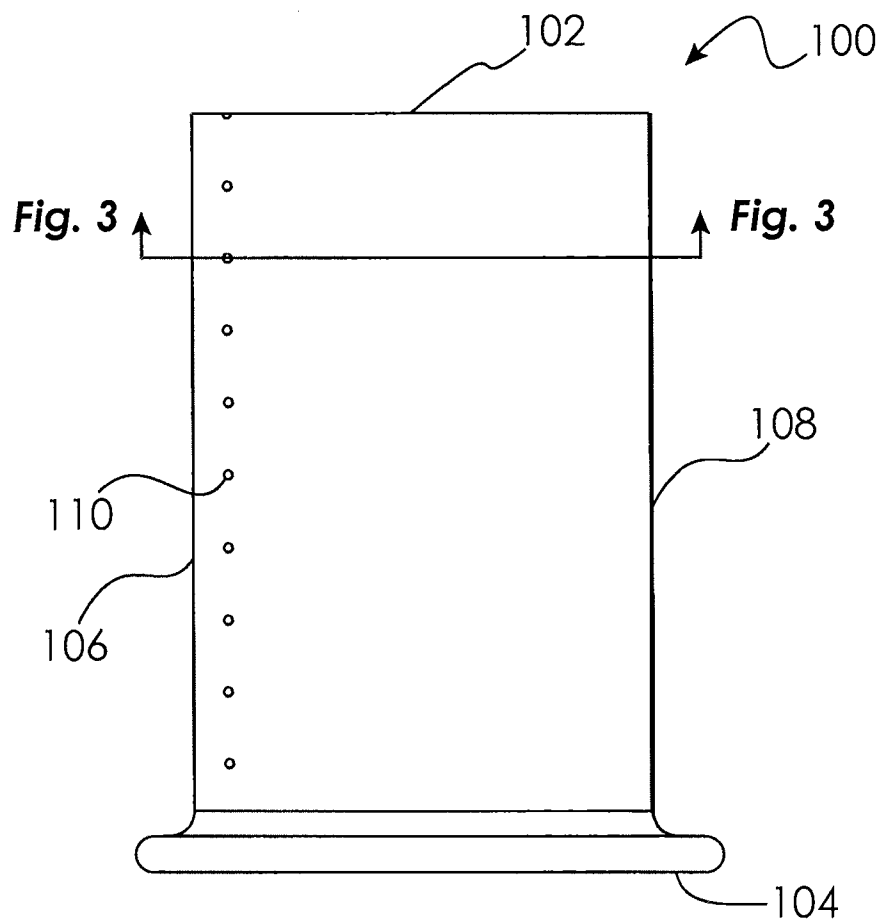


Fig. 2

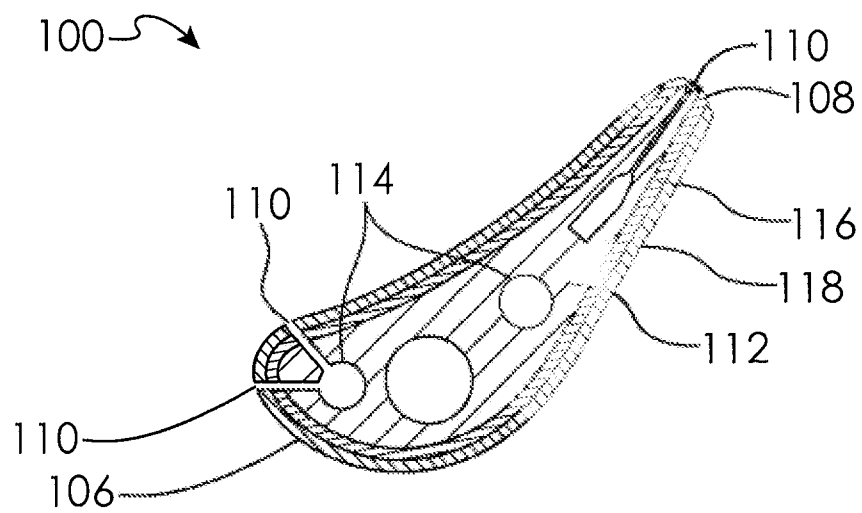


Fig. 3

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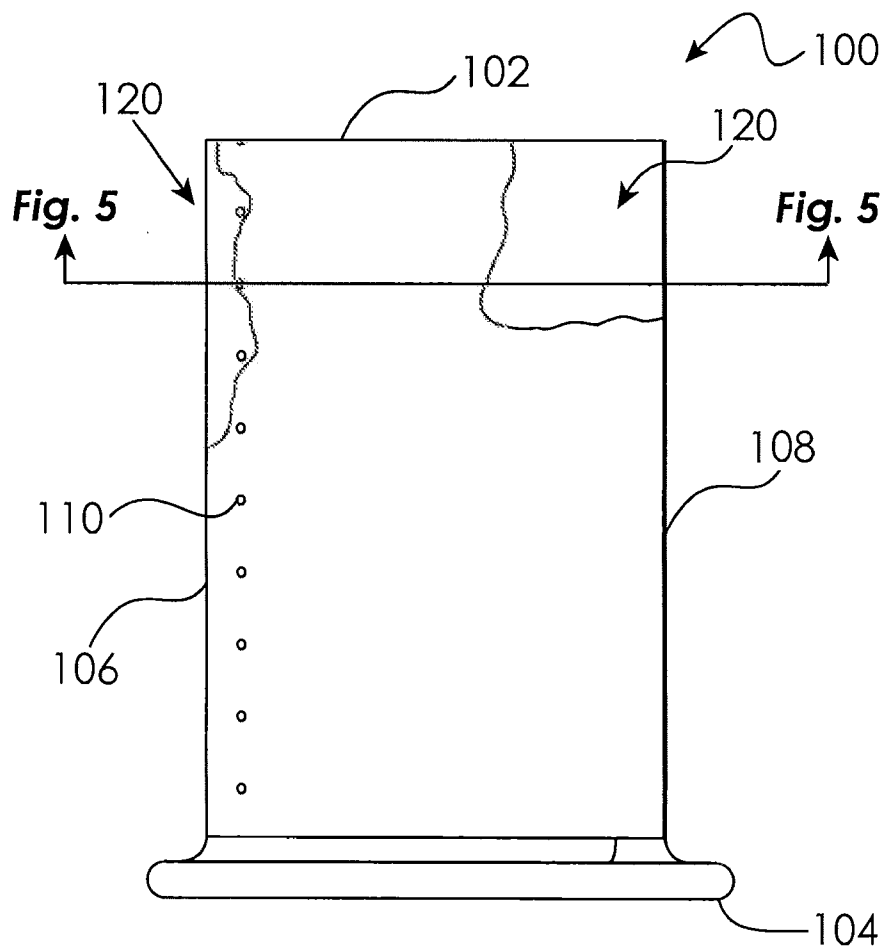


Fig. 4

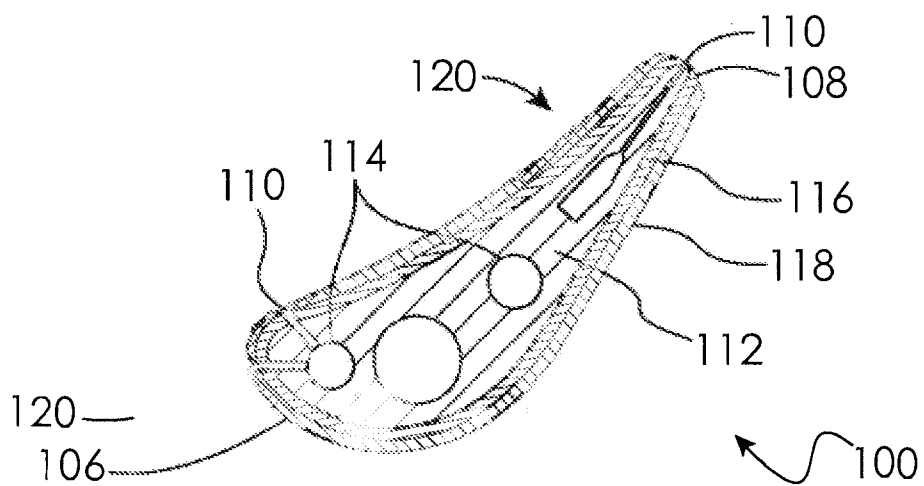


Fig. 5

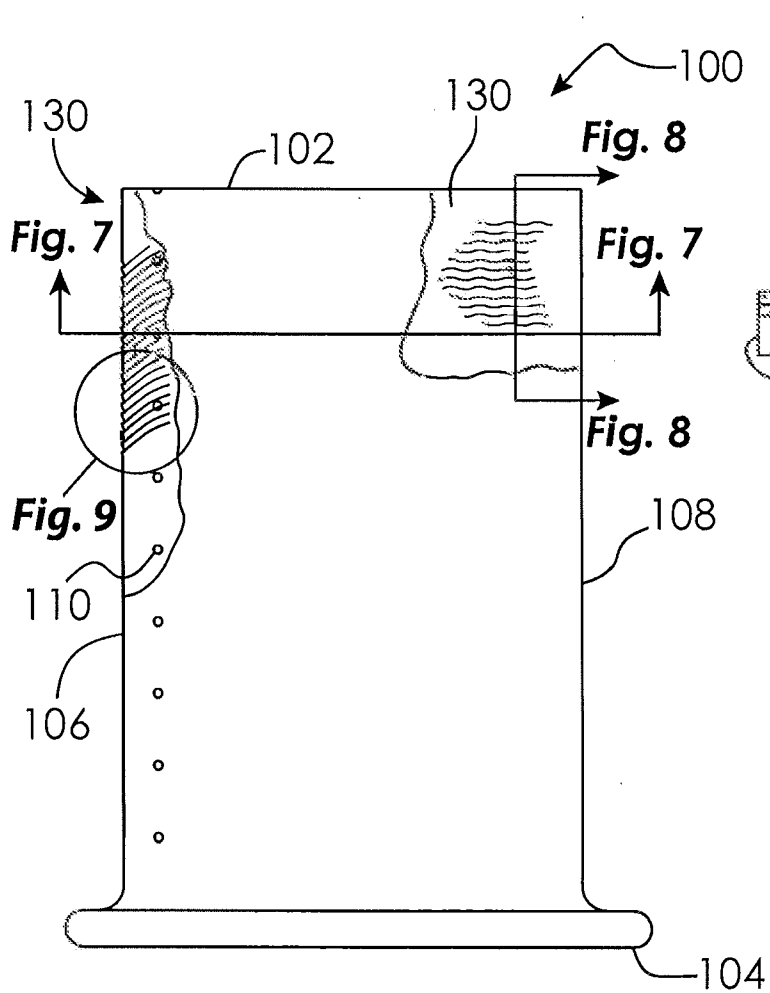


Fig. 6

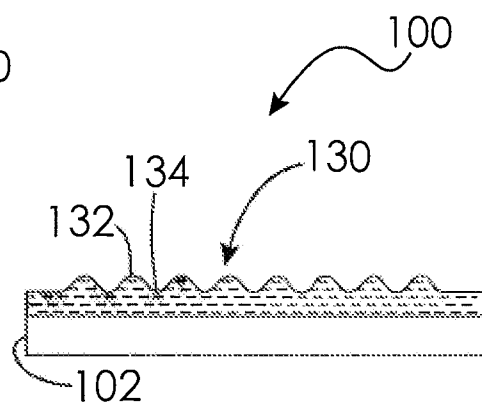


Fig. 8

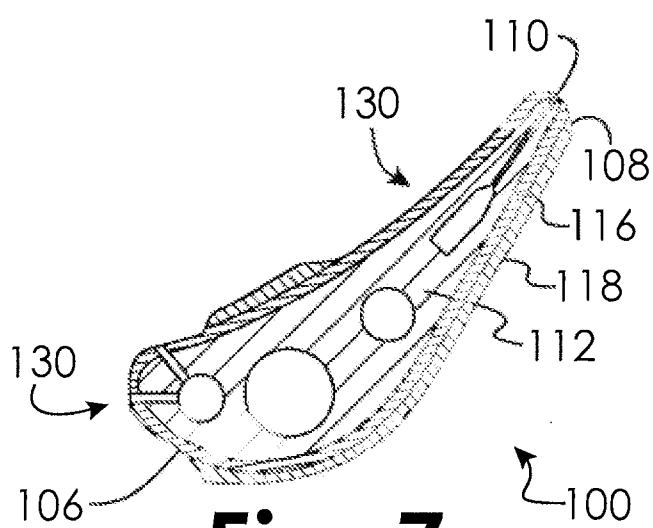


Fig. 7

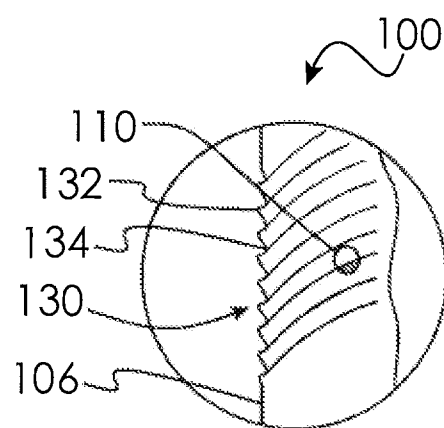


Fig. 9

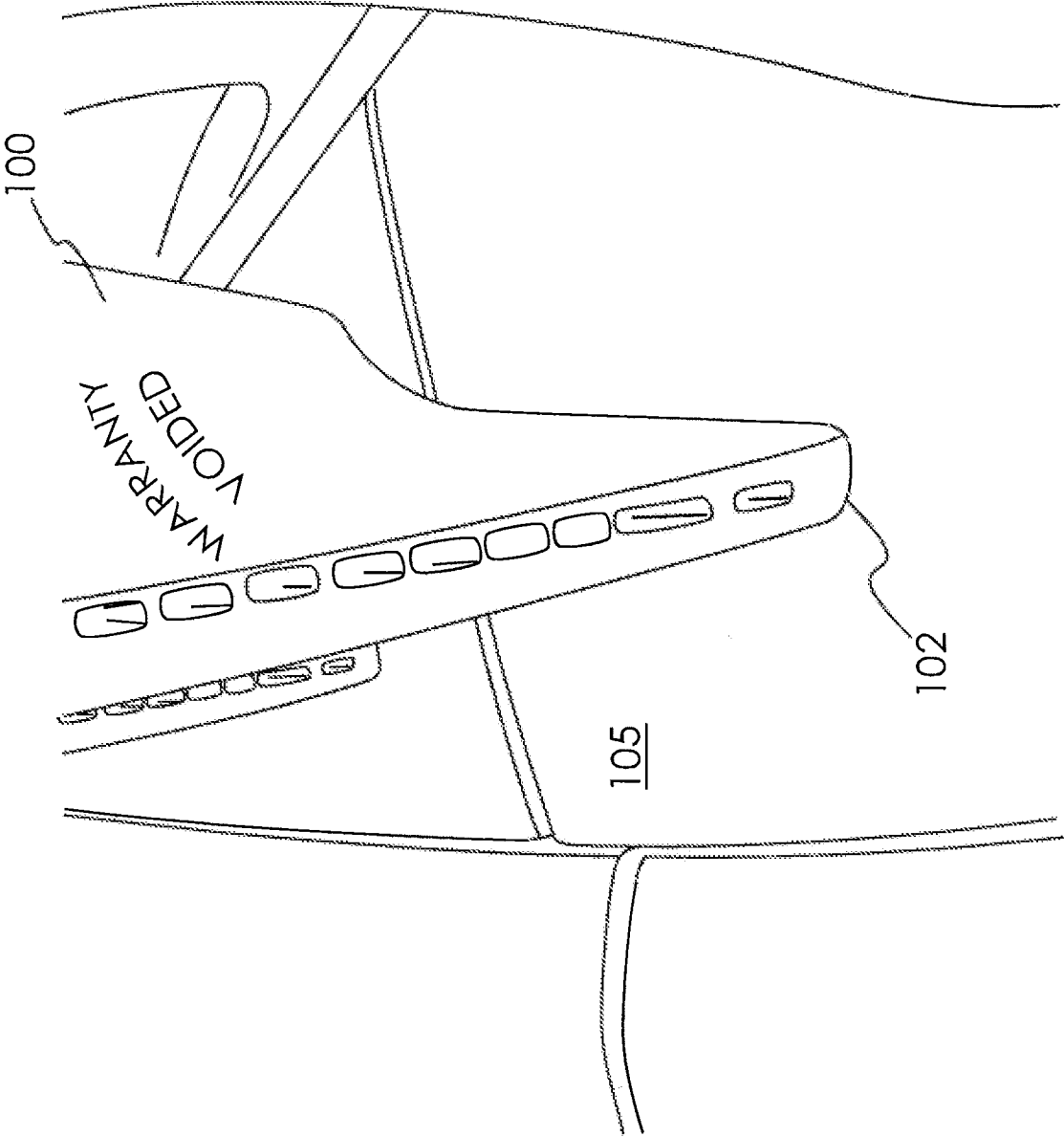


Fig. 10