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(54) **Methods and apparatus for fabricating gas turbine engines**

(57) Methods and apparatus of fabricating gas turbine engine components (118) are provided. The method (200) includes positioning a non-consumable shield (206) adjacent to an edge (136) of the component such that a gap (210) is defined between the shield and the component, wherein the shield and gap form a fluid flow restriction adjacent to the edge, and inducing an electrical current from an anode (202) to the component through an electrolyte bath such that a coating is applied to the component.

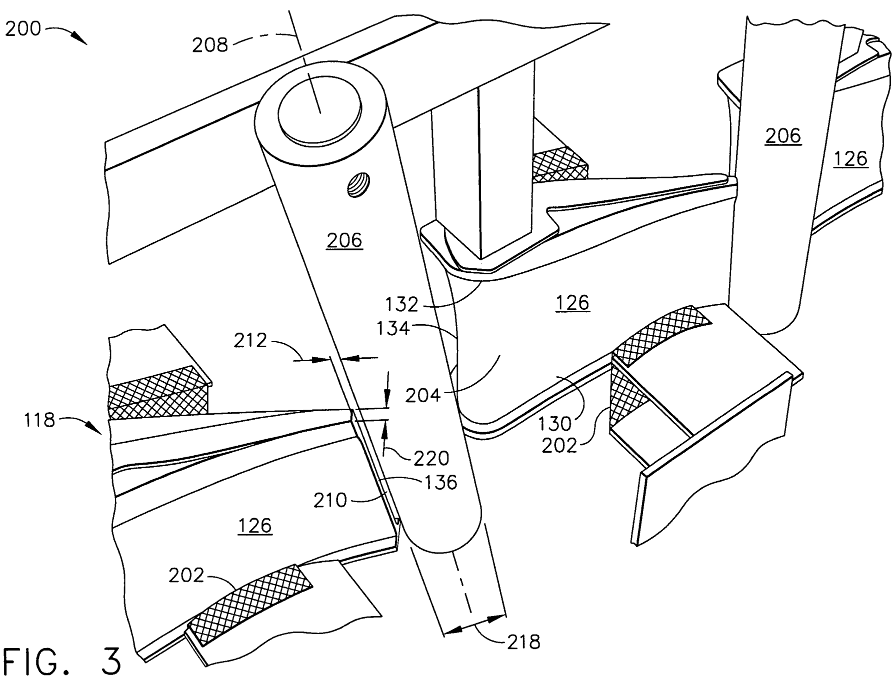

FIG. 3

EP 1 627 992 A2

Description

[0001] This invention relates generally to turbine engines, and more specifically to environmental coatings used with turbine engine components.

[0002] At least some known gas turbine engines include a forward fan, a core engine, and a power turbine. The core engine includes at least one compressor that provides pressurized air to a combustor wherein the air is mixed with fuel and ignited for generating hot combustion gases. The combustion gases flow downstream to one or more turbines that extract energy therefrom to power the compressor and provide useful work, such as powering an aircraft. A turbine section may include a stationary turbine nozzle positioned at the outlet of the combustor for channeling combustion gases into a turbine rotor disposed downstream thereof.

[0003] The turbine nozzle may include a plurality of circumferentially spaced apart vanes. The vanes are impinged by the hot combustion gases exiting the combustor and are at least partially coated to facilitate protecting the vanes from the environment and to facilitate reducing wear. Specifically, in at least same engines, a platinum aluminide coating is be applied to turbine components, including the vanes to facilitate environmentally protecting the components. The application of platinum aluminide coatings is generally a three-step process that may include an electroplating process, a diffusion heat treatment, and an aluminiding process. During electroplating, platinum is plated over the surface of the component to be coated. Such that an electroplate coat of substantially uniform thickness is applied across the entire surface of the component. However, a magnetic field generated by current flow between the component to be coated and an anode used in coating may be non-uniformly distributed across the component, and more specifically such flux lines may be more dense adjacent sharp edges on the part, such as adjacent the trailing edge of the nozzle vane. As a result, a thicker coating of plating may be applied to such edges relative to the convex and concave surfaces of the airfoil portion of the vane. Over time, the uneven distribution of coatings may cause cracking: At least one known method of controlling the electroplate thickness adjacent the trailing edge requires that a disposable, metallic "robber" be positioned adjacent to the trailing edge to thieve current from the edge during the coating application. However, within such methods the effectiveness of the robber degrades over time and it may require frequent replacement.

[0004] In one embodiment of the invention, a method of fabricating a gas turbine engine component are provided. The method includes positioning a non-consumable shield adjacent to an edge of the component such that a gap is defined between the shield and the component, wherein the shield and gap form a fluid flow restriction adjacent to the edge, and inducing an electrical current from an anode to the component through an electrolyte bath such that a coating is applied to the component.

[0005] In another embodiment of the invention, an electroplating apparatus is provided. The electroplating apparatus includes an electroplating bath that includes an electrolytic solution, a power source, an anode coupled to the power source, a component coupled to the power source and immersed within the electrolytic solution wherein the component includes a plating surface bordered by an edge, and a non-consumable shield positioned adjacent to the component edge such that a gap is defined between the edge and the shield and wherein the shield and the gap form a fluid flow restriction adjacent to the edge.

[0006] In yet another embodiment of the invention, an electroplating apparatus is provided. The electroplating apparatus includes an electroplating bath including an electrolytic solution comprising platinum, a power source, an anode coupled to the power source, a component to be electroplated coupled to the power source and immersed within the electrolytic solution wherein the component includes a plating surface and an edge, and a non-consumable shield positioned adjacent to the edge such that a gap is defined between the edge and the shield and wherein the shield and the gap form a fluid flow restriction adjacent to the edge. The shield is configured to displace an electric field away from the edge to facilitate reducing an amount of electroplating deposited on the edge.

[0007] The invention will now be described in greater detail, by way of example, with reference to the drawings, in which:-

Figure 1 is a longitudinal cross-sectional view of an exemplary high bypass ratio turbofan engine;

Figure 2 is a perspective view of an exemplary first stage, high pressure turbine nozzle segment that may be used with the gas turbine engine (shown in Figure 1);

Figure 3 is a perspective view of an exemplary electroplating process for applying an electroplate coating to the vanes shown in Figure 2.

Figure 4 is a cross-sectional view of high pressure turbine nozzle vane 118 that may be used in the electroplating process shown in Figure 3; and

Figure 5 is a graph of electroplate coating thickness readings taken at each of the plurality of test locations shown in Figure 4.

[0008] As used herein, the term "component" may include any component configured to be coupled with a gas turbine engine that may be coated with a metallic film coating, for example a high pressure turbine nozzle vane. A high pressure turbine nozzle vane is intended as exemplary only, and thus is not intended to limit in any way the definition and/or meaning of the term "component". Furthermore, although the invention is described herein in association with a gas turbine engine, and more specifically for use with a high pressure turbine nozzle vane for a gas turbine engine, it should be understood that the present invention is applicable to other gas turbine engine stationary components and rotatable components. Accordingly, practice of the present invention is not limited to high pressure turbine nozzle vanes for a gas turbine engine. In addition, although the invention is described herein in association with a electrolytic bath process, it should be understood that the present invention may be applicable to any electroplating process, for example, brush electroplating. Accordingly, practice of the present invention is not limited to an electroplating process using an electrolytic bath.

[0009] Figure 1 is a longitudinal cross-sectional view of an exemplary high bypass ratio turbofan engine 10. Engine 10 includes, in serial axial flow communication about a longitudinal centerline axis 12, a fan 14, a booster 16, a high pressure compressor 18, a combustor 20, a high pressure turbine 22, and a low pressure turbine 24. High pressure turbine 22 is drivingly connected to high pressure compressor 18 with a first rotor shaft 26, and low pressure turbine 24 is drivingly connected to booster 16 and fan 14 with a second rotor shaft 28.

[0010] During operation of engine 10, ambient air passes through fan 14, booster 16, and compressor 18, the pressurized air stream enters combustor 20 where it is mixed with fuel and burned to provide a high energy stream of hot combustion gases. The high-energy gas stream passes through high-pressure turbine 22 to drive first rotor shaft 26. The gas stream passes through low-pressure turbine 24 to drive second rotor shaft 28, fan 14, and booster 16. Spent combustion gases exit out of engine 10 through an exhaust duct (not shown).

[0011] It should be noted that although the present description is given in terms of a turbofan aircraft engine, embodiments of the present invention may be applicable to any gas turbine engine power plant such as that used for marine and industrial applications. The description of the engine shown in Figure 1 is only illustrative of the type of engine to which some embodiments of the present invention is applicable.

[0012] Figure 2 is a perspective view of an exemplary first stage, high pressure turbine nozzle segment 114 that may be used with the gas turbine engine 10 (shown in Figure 1). High pressure turbine nozzle segment 114 may be positioned axially between combustor 20 and high pressure turbine 22 such that a row of first stage turbine rotor blades (not shown) is positioned downstream from high pressure turbine nozzle segment 114. A plurality of high pressure turbine nozzles 114 may be circumferentially spaced about axis 12 to form a high pressure turbine nozzle (not shown). High pressure turbine nozzle segment 114 includes at least one nozzle vane 118 coupled at opposite radial ends to a respective radially inner band 120 and a respective radially outer band 122. High pressure turbine nozzle segment 114 are typically formed in arcuate segments having two or more vanes 118 per segment 114. Vanes 118 may be cooled during operation against a flow of hot combustion gases 116 using a flow of cooling air 124 that may be channeled from, for example, a discharge of compressor 18 to individual vanes 118 through outer band 122.

[0013] Each vane 118 includes a generally concave pressure sidewall 126, and a circumferentially opposite generally convex, suction sidewall 128. Sidewalls 126 and 128 may extend longitudinally in span along a radial axis of the nozzle between bands 120 and 122 wherein a root 130 couples to inner band 120 and a tip 132 couples to outer band 122. Sidewalks 126 and 128 extend chorale or axially between a leading edge 134 and an opposite trailing edge 136.

[0014] Figure 3 is a perspective view of an exemplary electroplating process 200 for applying an electroplate coating to vanes 118 (shown in Figure 2). In the exemplary embodiment, vane 118 may energized to a predetermined negative voltage with respect to a grid 202 such that when an electrolyte solution containing metal ions, for example, platinum covers a surface of vane 118, for example, sidewall 126, the metal ions in the electrolyte solution may be preferentially attracted to and bonded to sidewall 126 to form an electroplate coating 204. In the exemplary embodiment, a non-conducting, non-consumable shield 206 is positioned adjacent trailing edge 136 such that a longitudinal axis 208 of shield 206 is substantially parallel to trailing edge 136 and separated by a gap 210 having a predetermined distance 212. In the exemplary embodiment, distance 212 is approximately thirty mils. In an alternative embodiment, distance 212 is a distance greater than or less then thirty mils. In the exemplary embodiment, shield 206 is fabricated from a non-conducting material, for example, plastic and has an outside diameter 218, for example, three-quarters inches, that is substantially greater than the thickness 220 of vane 118 at trailing edge 136. The relatively larger diameter of shield 206 with respect to the thickness of trailing edge 136 substantially blunts the geometry of trailing edge 136 and facilitates blocking at least a portion of the electrical current through trailing edge 136. Additionally, the close clearance of distance 212 to trailing edge 136 facilitates reducing a flow of electrolyte solution proximate trailing edge 136. Shield 206 may be formed to follow the contour of an irregularly shaped or curved edge while maintaining gap distance 212. Additionally, shield 206 may include an irregular cross-section, for example, shield 206 may be a hollow or solid and may include a groove or slot configured to be aligned with edge 136 for optimizing the flow restrictive gap distance 212 and/or the electrical characteristics of the electric field proximate gap distance 212.

[0015] Figure 4 is a cross-sectional view of high pressure turbine nozzle vane 118 that may be used in electroplating process 200 (shown in Figure 3). Vane 118 includes concave pressure sidewall 126 and convex suction sidewall 128 that each extend axially between leading edge 134 and trailing edge 136. A plurality of thickness test locations are located at predetermined locations about a perimeter of vane 118 and are labeled 401-410.

[0016] Figure 5 is a graph 500 of electroplate coating thickness readings taken at each of the plurality of test locations 401-410 (shown in Figure 4). Graph 500 includes an x-axis 502 whose units correlate with each respective test location, 401-410 (shown in Figure 4). For example, electroplate coating thickness reading 401 is taken proximate leading edge 134, electroplate coating thickness reading 406 is taken proximate trailing edge 136, and electroplate coating thickness readings 404 and 409 are taken proximate convex side 128 and proximate concave side 126 respectively. A y-axis 504 may be graduated in units of mils indicative of a thickness of a plating coating corresponding to the respective location, 401-410.

[0017] In the exemplary embodiment, a trace 506 joins points on graph 500 corresponding to an exemplary electroplate process for coating nozzle vane 118 with a metallic film coating. Trace 506 illustrates readings taken using the electroplate process wherein shield 206 is not utilized to form a flow restrictive gap distance 212 adjacent edge 136. Trace 506 illustrates a metallic film coating thickness at location 406 that is approximately 100% greater than the metallic film coating thickness at locations 401-405 and 407-410.

[0018] A trace 508 illustrates readings taken at locations 401-410 after using the electroplate process wherein shield 206 is utilized to form a flow restrictive gap distance 212 adjacent edge 136 and to displace an electric field adjacent edge 136. Shield 206 facilitates plating a uniform metallic film coating thickness at locations 401-410. Trace 506 illustrates a metallic film coating thickness at location 406 that is approximately only 25% greater than the metallic film coating thickness at locations 401-405 and 407-410. Using shield 206 results in a more uniform metallic film coating thickness around the perimeter of vane 118.

[0019] A thickness ration may be defined as a ratio of a maximum thickness from locations around the perimeter of the airfoil (t_{max}) to a minimum thickness (t_{min}),

$$\text{Thickness Ratio} = \frac{t_{MAX}}{t_{MIN}}.$$

[0020] Trace 508 exhibits a thickness ratio of approximately 1.94, using the above formula, while trace 506 exhibits a thickness ratio of approximately 3.03, which represents a 40% improvement in uniformity of the metallic film coating thickness about the perimeter of vane 118.

[0021] The above-described methods and apparatus are cost-effective and highly reliable for providing a substantially uniform metallic film coating thickness on gas turbine engine components, such as a high pressure turbine first stage nozzle. Specifically, the shield positioned adjacent the edge of the nozzle vane to be coated, defines an electrolyte flow restrictive gap and displaces a portion of the electric field adjacent the edge. Restricting the electrolyte flow adjacent the edge permits the electrolyte to be depleted in the gap and reduces the metallic ion concentration available for plating the edge. Displacing a portion of the electric field adjacent the edge facilitates reducing the electroplating motive force and thus, the rate of plating on the edge. The methods and apparatus facilitate fabrication of machines, and in particular gas turbine engines, in a cost-effective and reliable manner.

[0022] Exemplary embodiments of electroplating methods and apparatus components are described above in detail. The components are not limited to the specific embodiments described herein, but rather, components of each apparatus may be utilized independently and separately from other components described herein. Each electroplating method and apparatus component can also be used in combination with other electroplating methods and apparatus components.

Claims

1. A method (200) of fabricating a gas turbine engine component (118), said method comprising:

> positioning a non-consumable shield (206) adjacent to an edge of the component such that a gap (210) is defined between the shield and the component, wherein the shield and gap form a fluid flow restriction adjacent to the edge; and
> inducing an electrical current from an anode (202) to the component through an electrolyte bath such that a coating (204) is applied to the component.

2. A method in accordance with Claim 1 further comprising electroplating the component such that a thickness (220) of the plating coating on the edge (136) of the component is substantially equal to a thickness of the plating coating across the surface (126, 128) of the component.

3. A method in accordance with Claim 1 or 2 wherein inducing an electrical current from an anode to the component comprises coupling the component as a cathode in the electrical circuit.

4. A method in accordance with Claim 1, 2 or 3 wherein positioning a non-consumable shield adjacent to an edge of the component comprises positioning a non-conductive shield adjacent to the edge such that at least a portion of an electric field generated is displaced away from the edge.

5. A method in accordance with Claim 1, 2 or 3 wherein positioning a non-consumable shield adjacent to an edge of the component comprises selecting a size of the shield to facilitate displacing an electric field away from the edge, such that the coating deposited on the edge is substantially uniform with respect to the coating deposited on the component.

6. A method in accordance with Claim 1, 2 or 3 wherein positioning a non-consumable shield adjacent to an edge of the component comprises positioning a non-conductive shield adjacent to the edge of the component.

7. A method in accordance with Claim 1, 2 or 3 wherein positioning a non-consumable shield adjacent to an edge of the component comprises positioning a shield adjacent to the edge of the component such that a width of the gap is equal to between approximately 0.254 mm and approximately 1.27 mm.

8. A method in accordance with Claim 1, 2 or 3 wherein positioning a non-consumable shield adjacent to the edge of the component comprises positioning the shield adjacent to the edge of the component such that a width of the gap is equal to approximately 0.762 mm.

9. A method in accordance with Claim 1, 2 or 3 wherein positioning a non-consumable shield adjacent to the edge of the component comprises positioning the shield adjacent to the edge, such that the shield has a contour that substantially matches a contour of the edge.

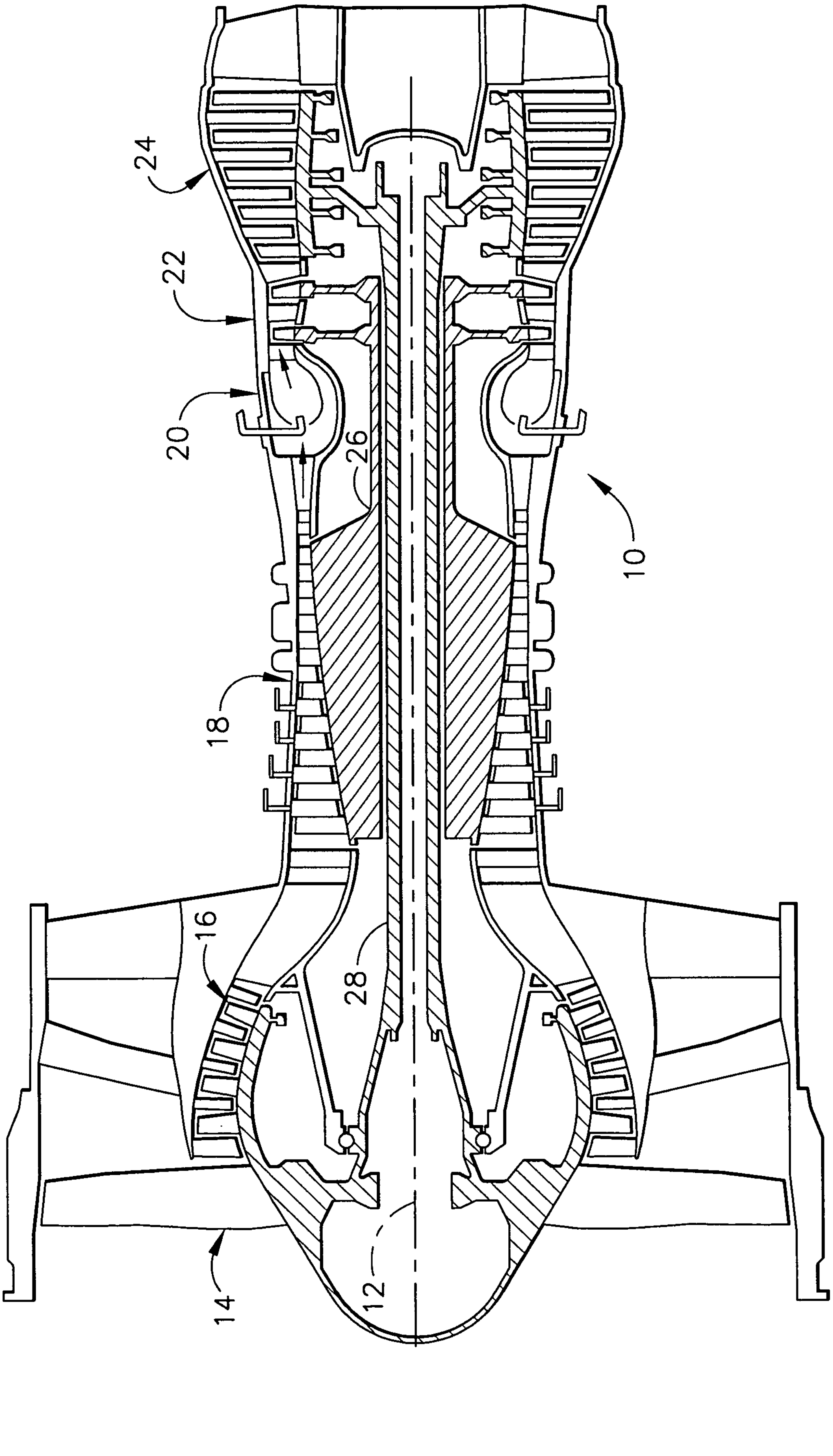

FIG. 1

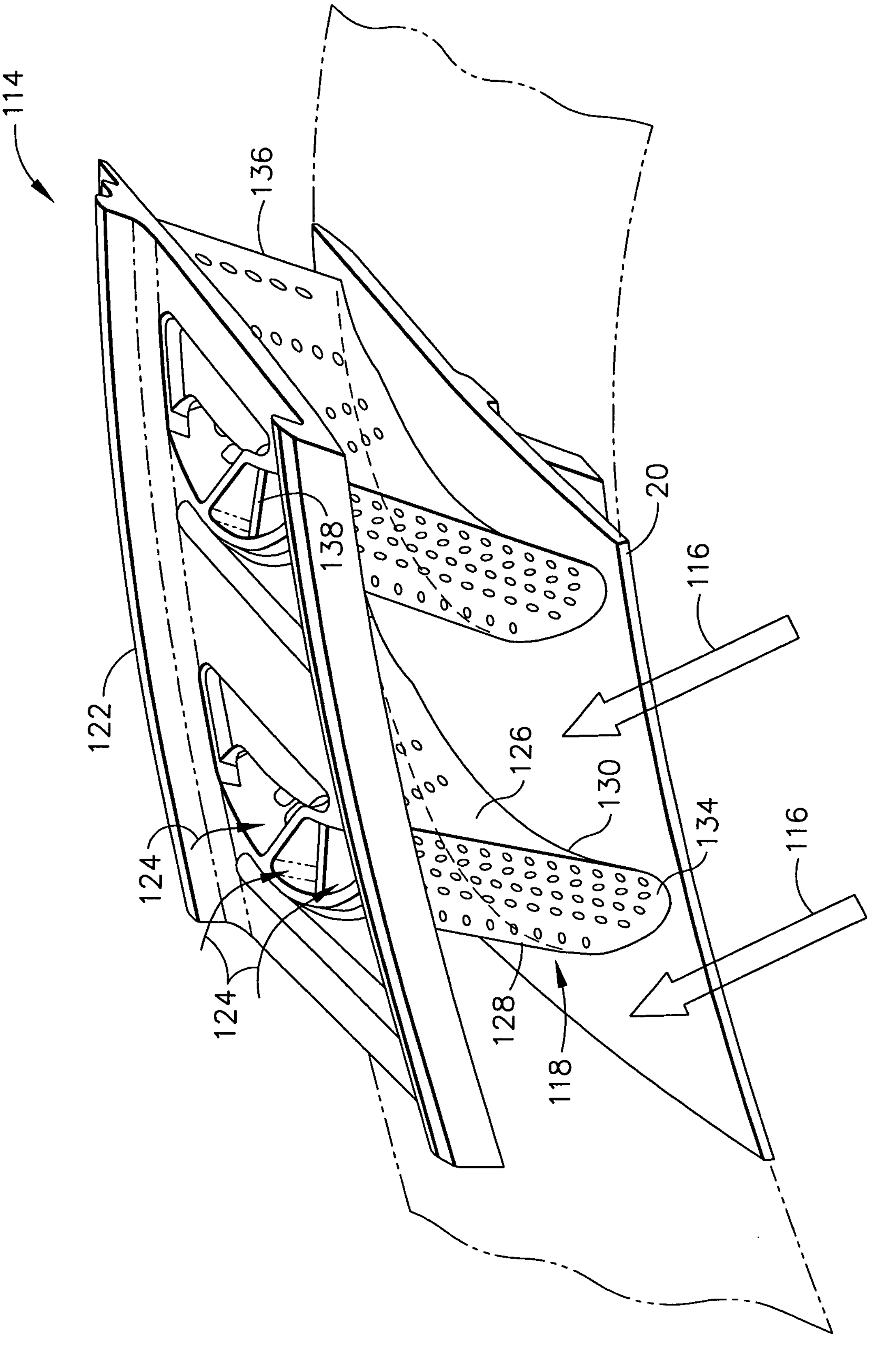

FIG. 2

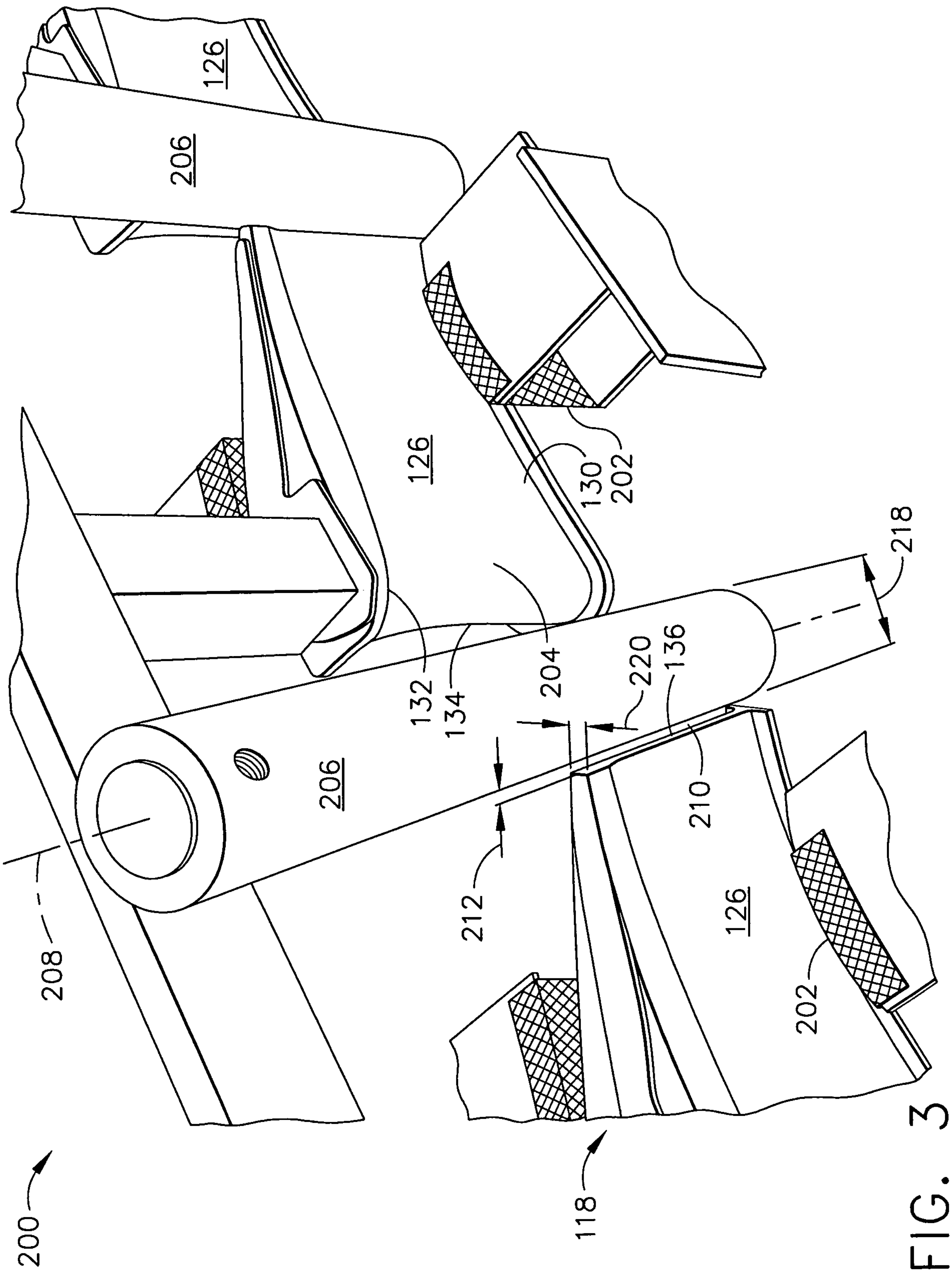
126
206
126
130
202
218
132
134
204
220
136
206
210
212
126
202
208
200
118

FIG. 3

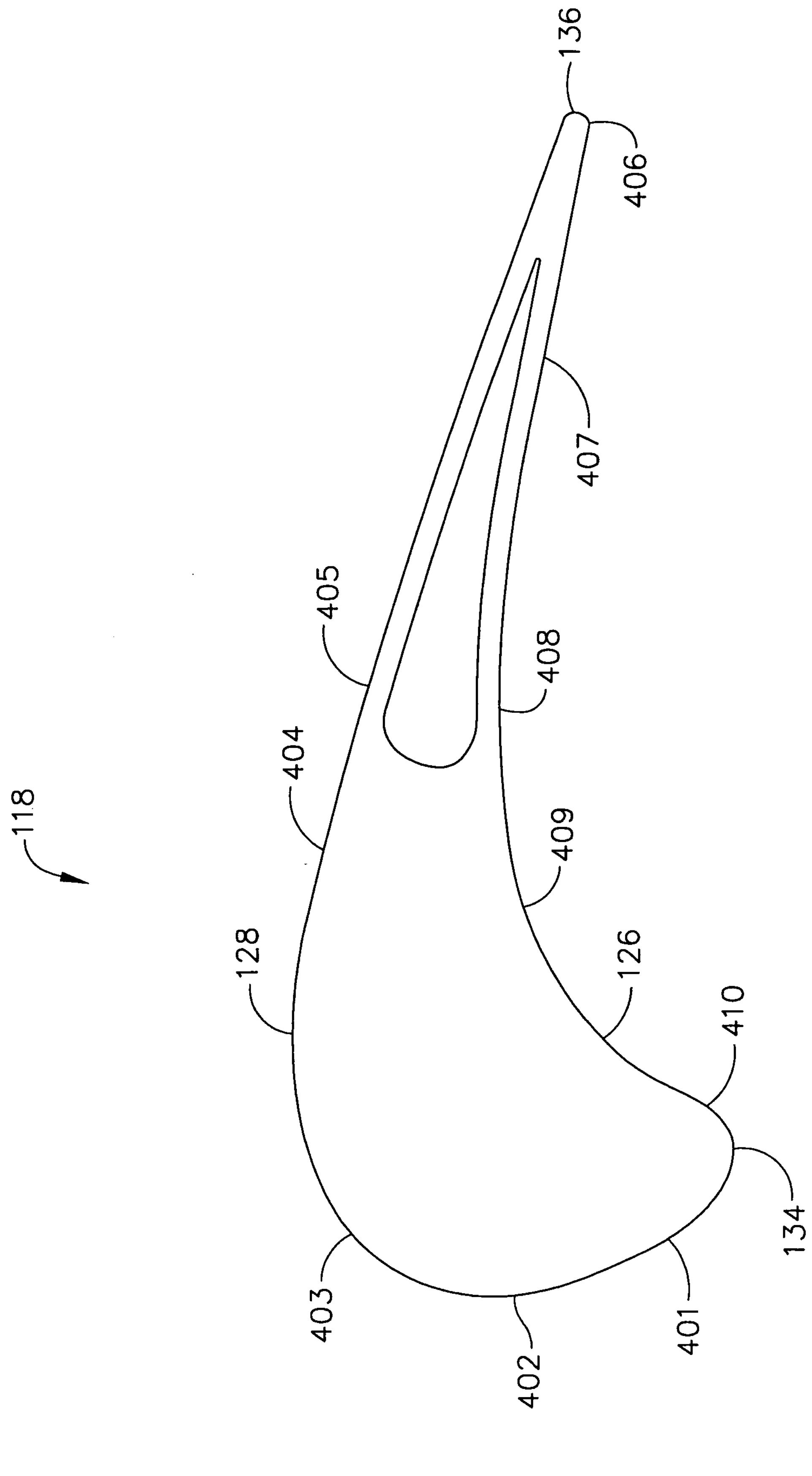

FIG. 4

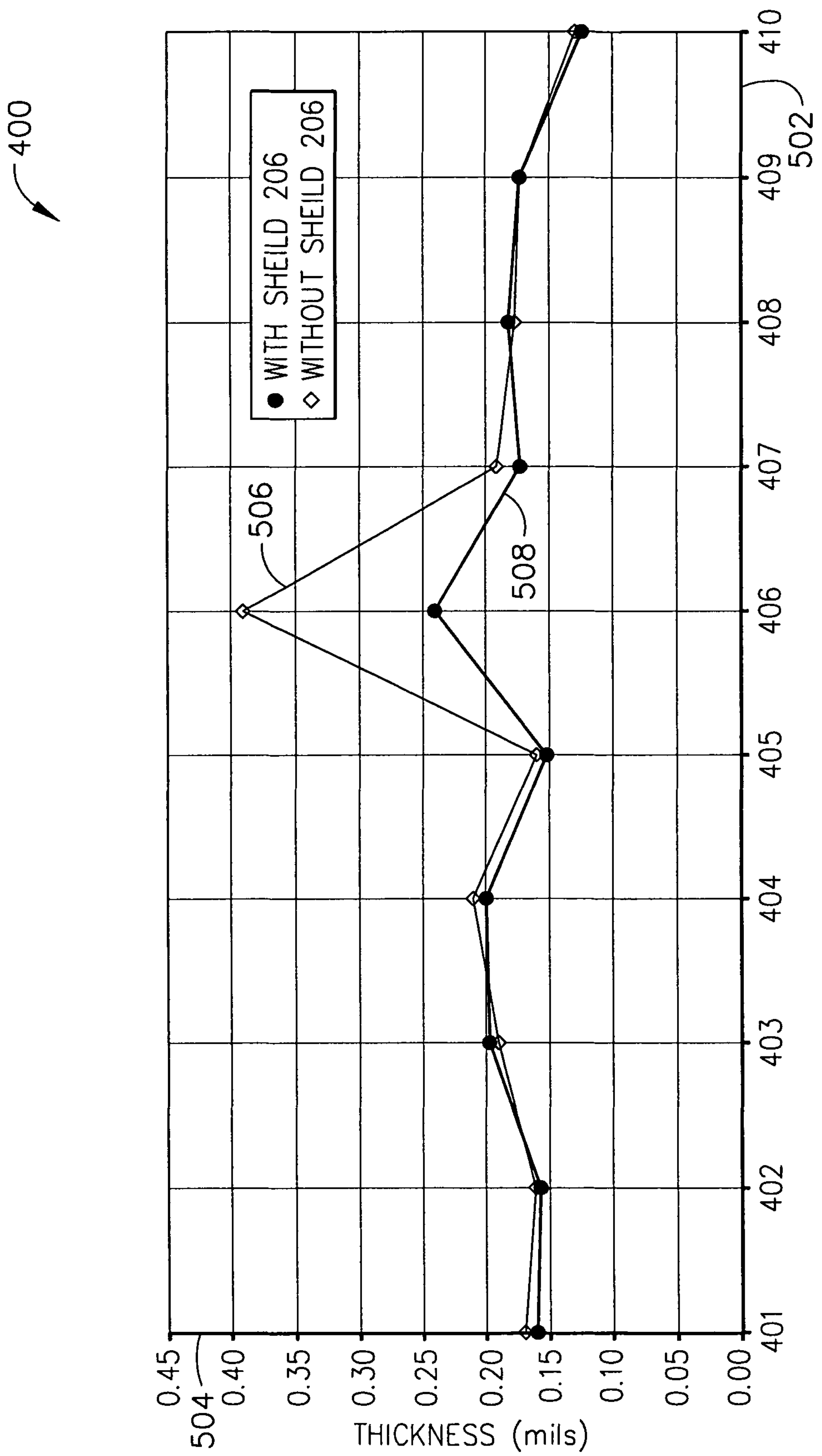
400
WITH SHEILD 206
WITHOUT SHEILD 206
506
508
502
504
THICKNESS (mils)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
401
402
403
404
405
406
407
408
409
410

FIG. 5