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(54) METHOD OF FORMING A CERAMIC MATRIX COMPOSITE COMPONENT, A CERAMIC MATRIX COMPOSITE COMPONENT AND A TIP MEMBER

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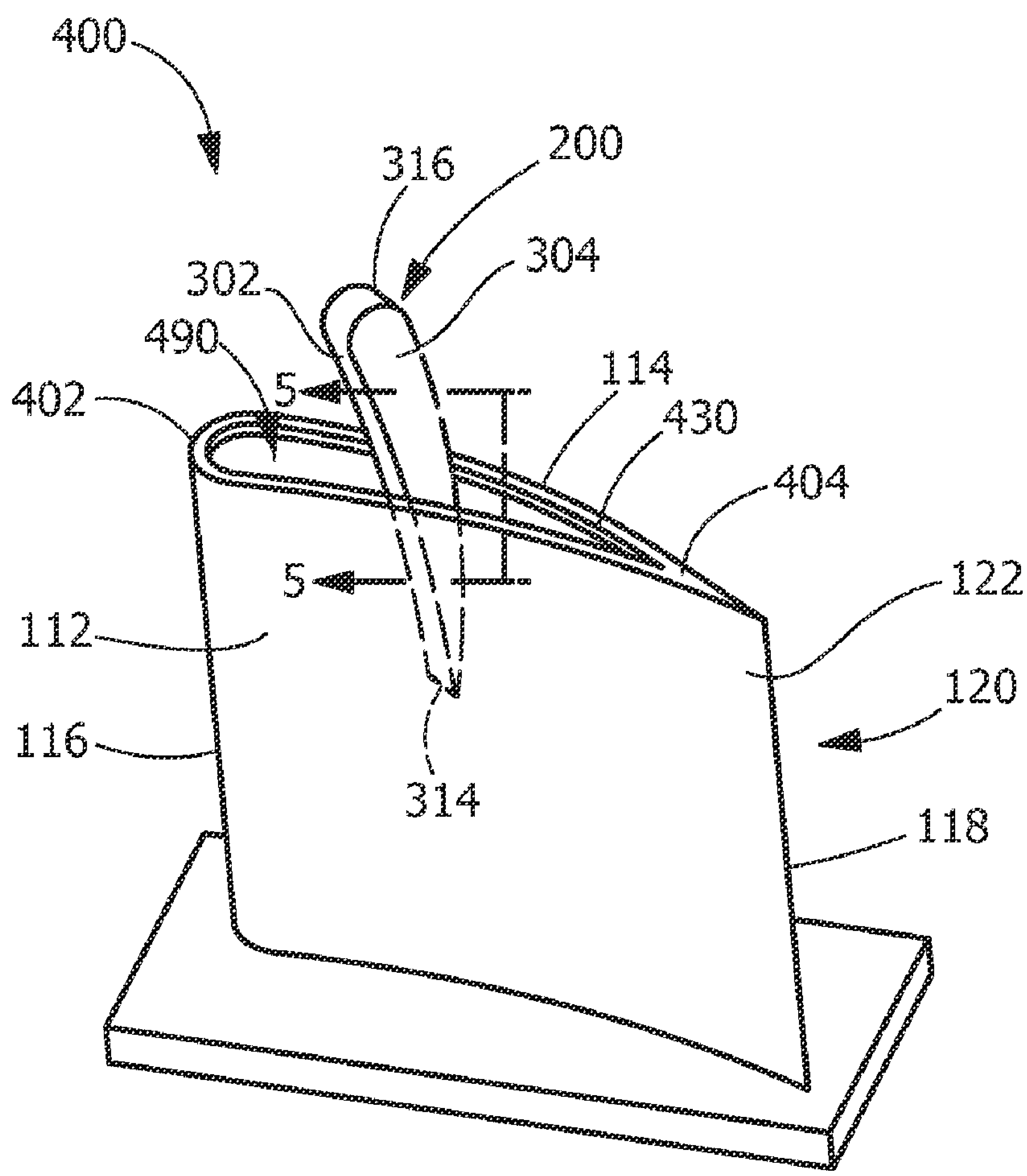
USPC **416/232**; 264/269; 428/34.4; 428/80

(57) ABSTRACT

A method of forming a ceramic matrix composite (CMC) component, a CMC component and a tip member are provided. The method of form the CMC component includes providing a component preform having a first end, a second end, and a cavity, the cavity having a pre-determined shape and a first engagement surface. The method includes forming a tip member from a pre-consolidated composite material, the tip member having a second engagement surface generally conforming to the first engagement surface. The method includes directing the second engagement surface to the first engagement surface. The method includes consolidating the component preform and tip member. The ceramic matrix composite component is formed having a desired geometry and the tip member stays in place in the cavity during operation of the ceramic matrix composite component.



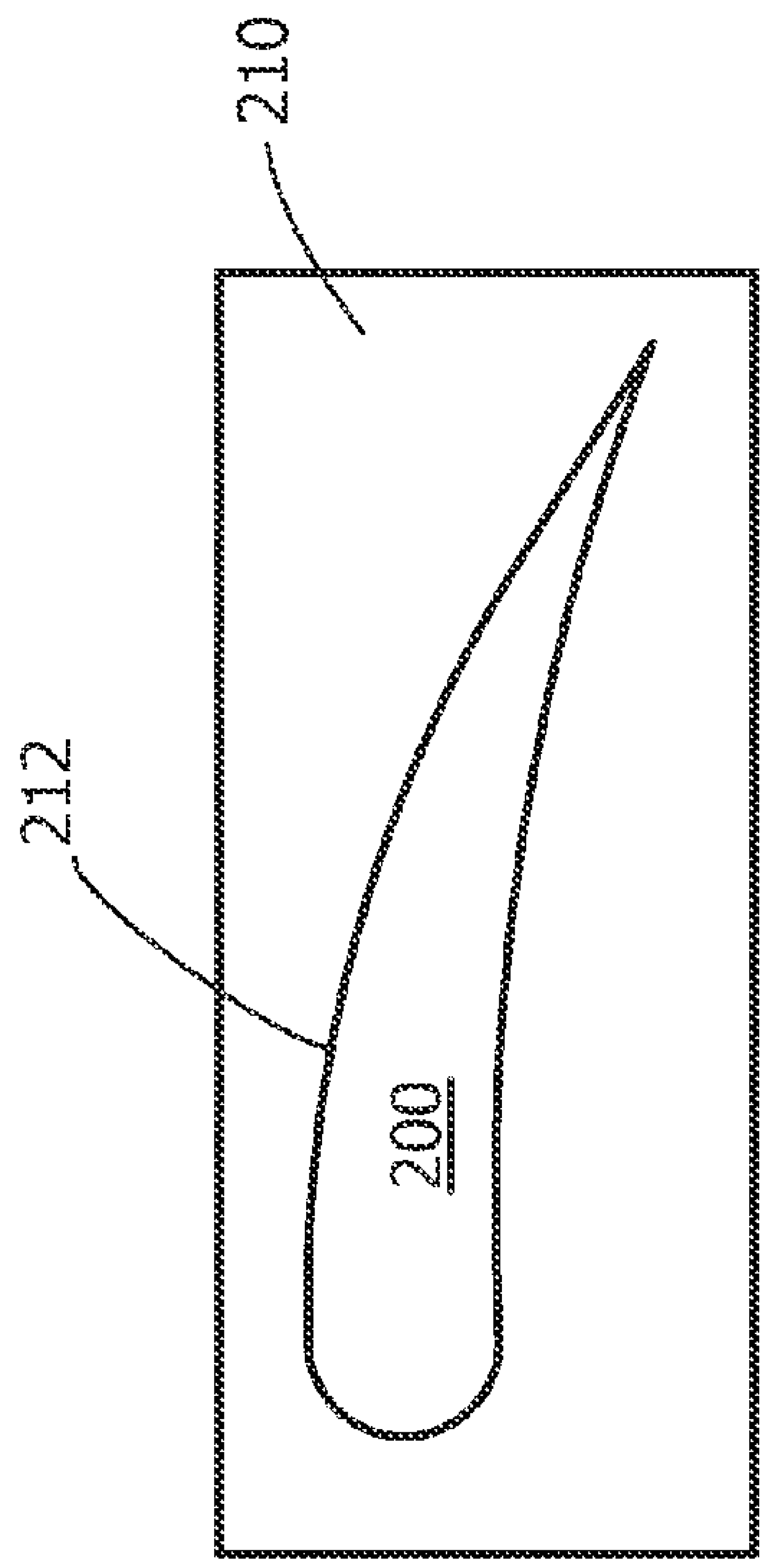


FIG. 2

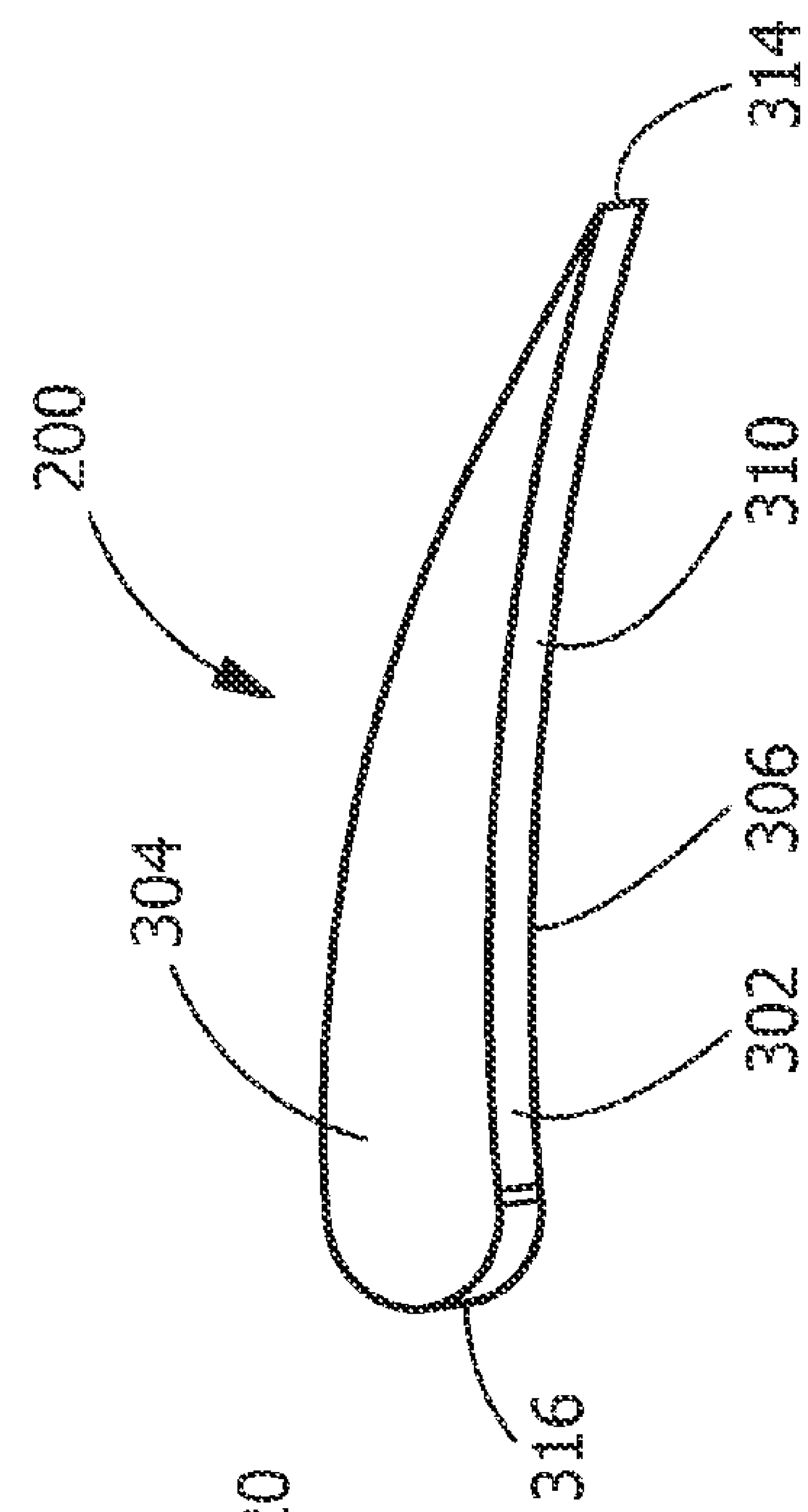


FIG. 3

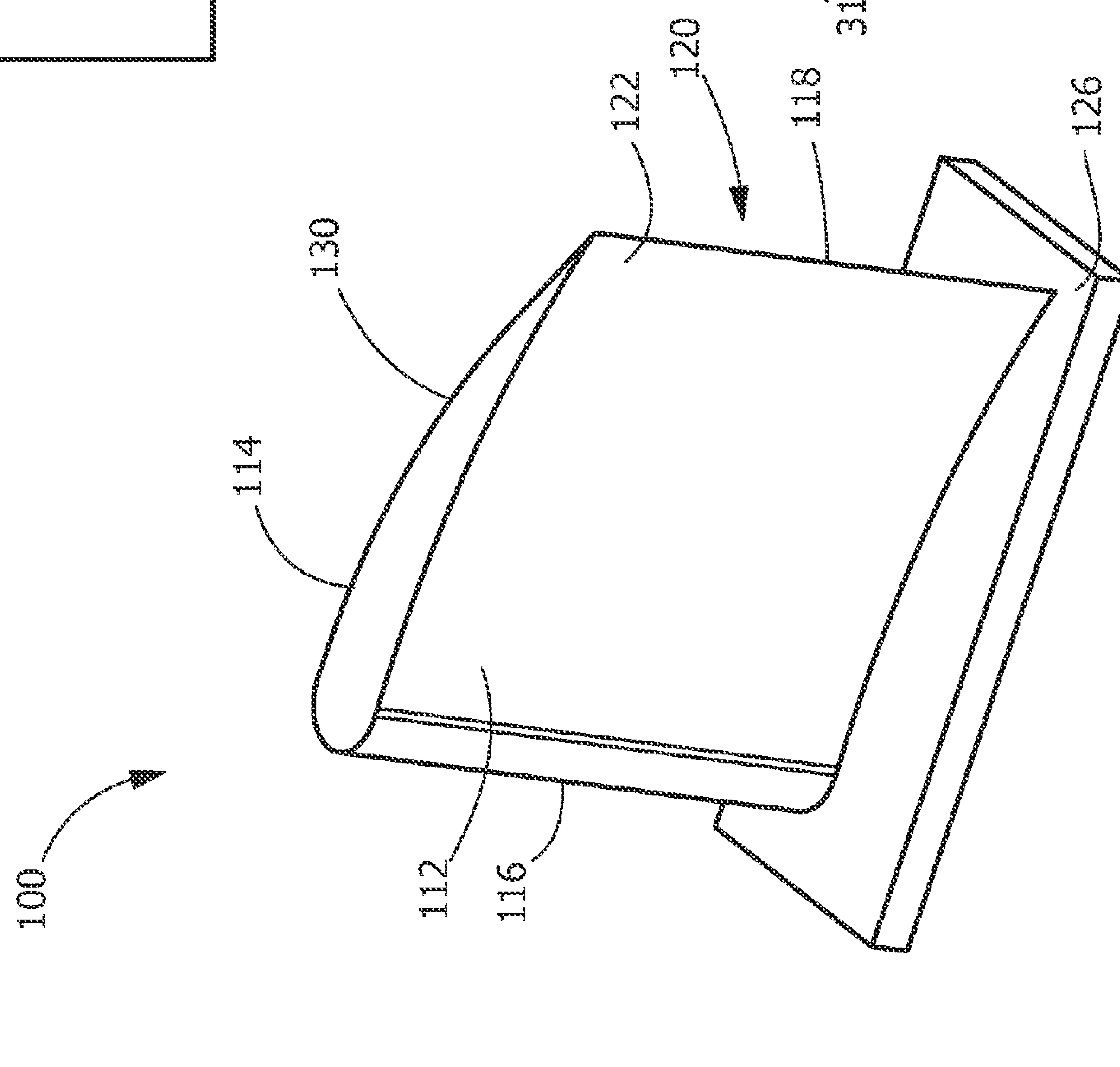


FIG. 1

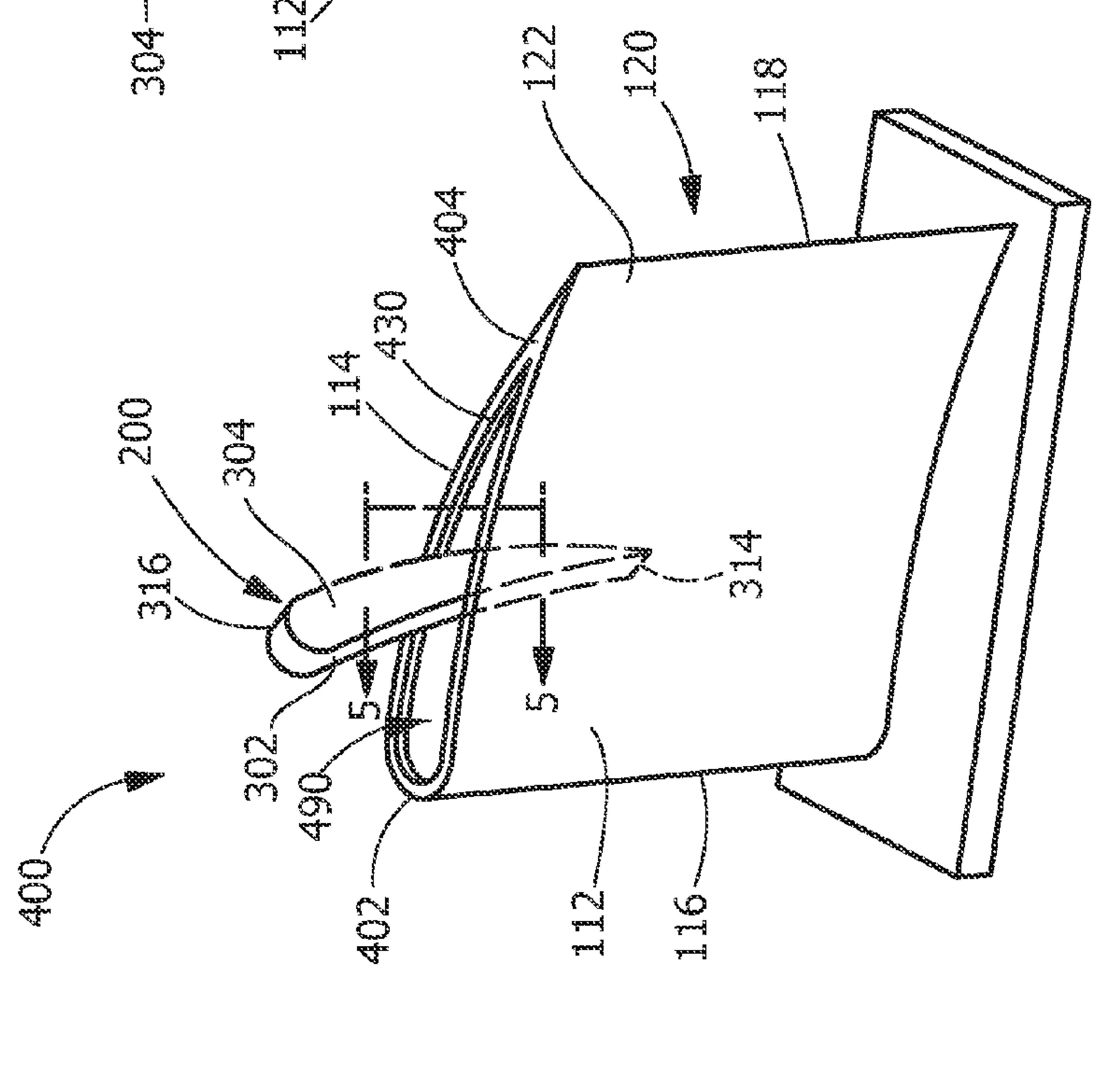


FIG. 4

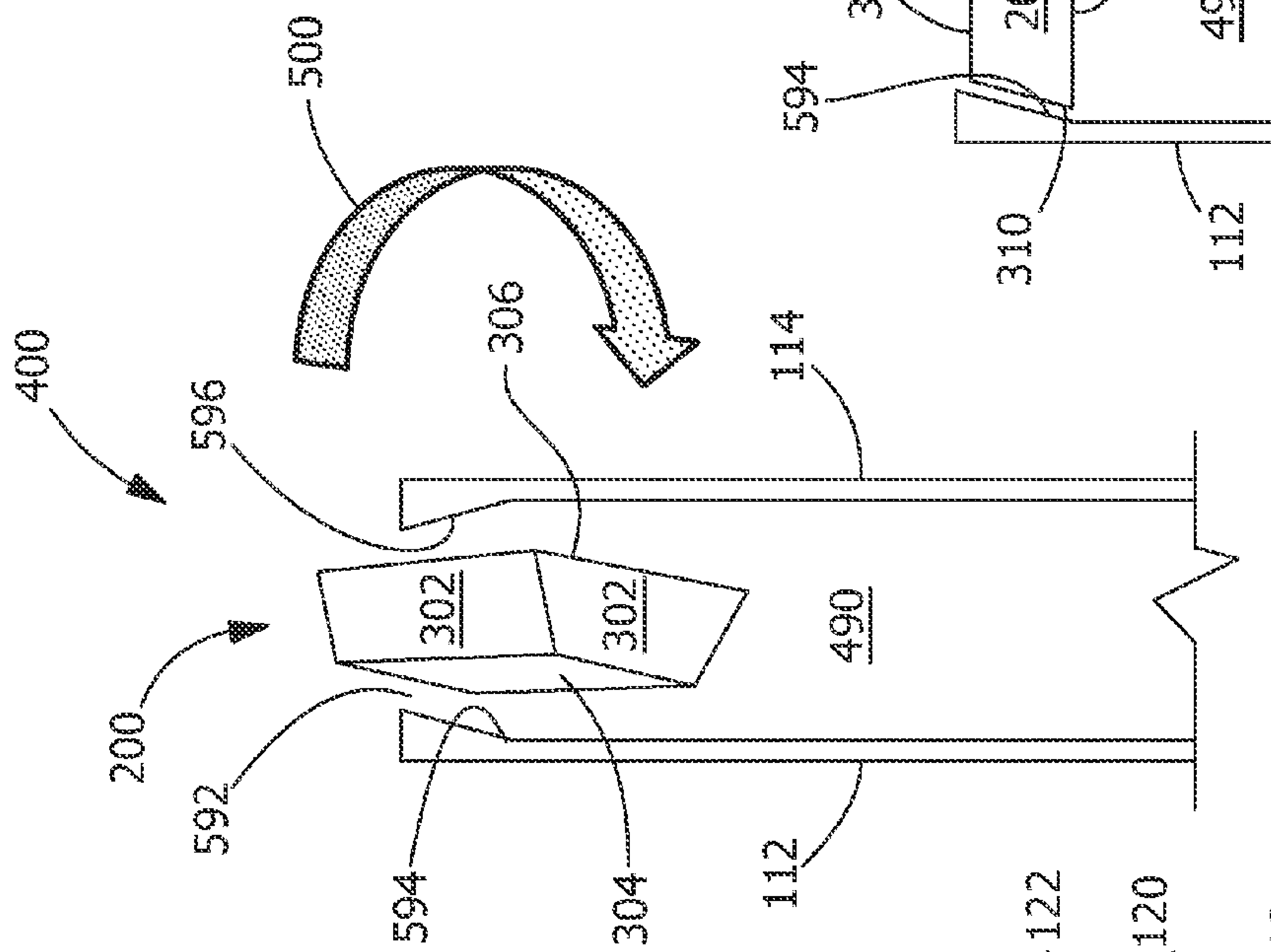


FIG. 5

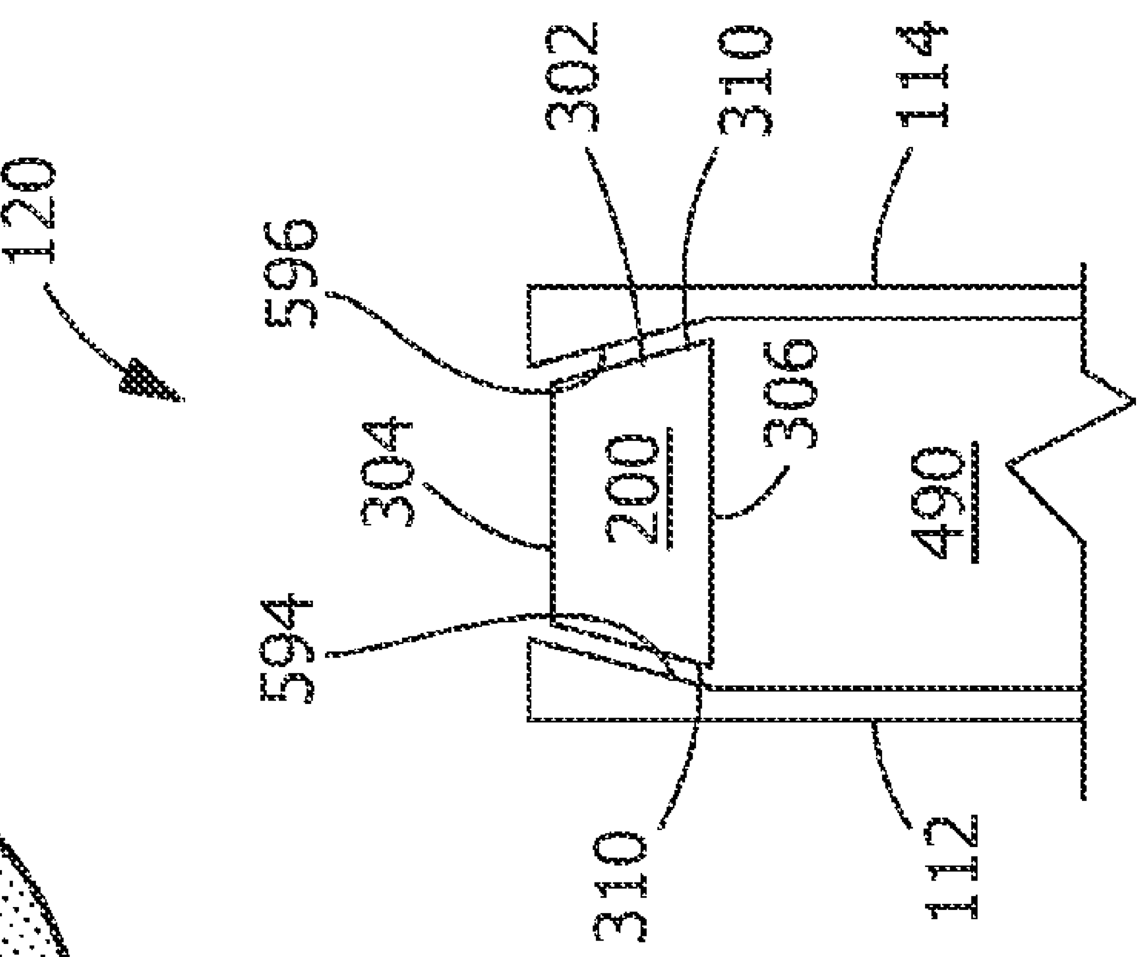


FIG. 6

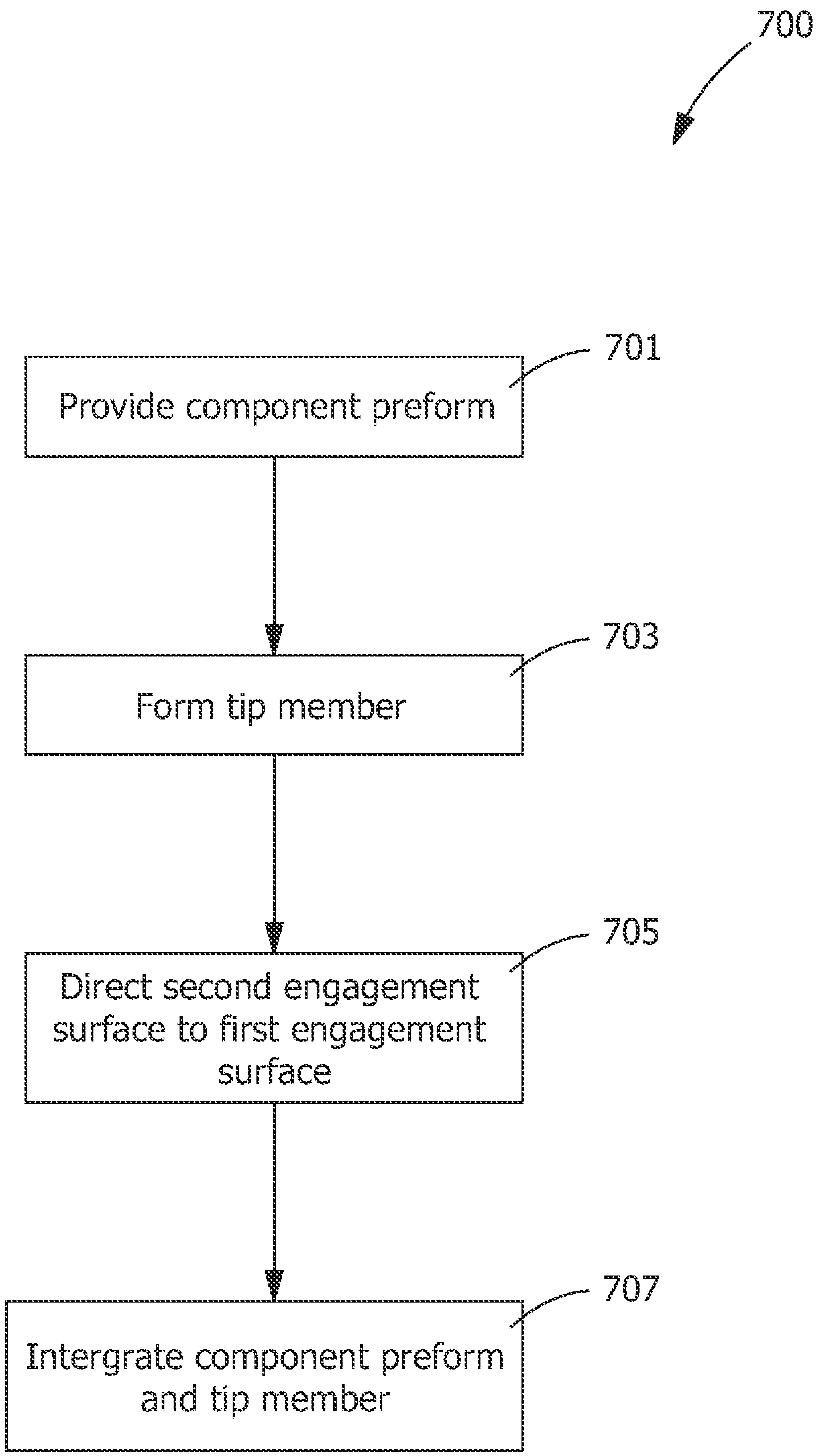

700
701
Provide component preform
703
Form tip member
705
Direct second engagement surface to first engagement surface
707
Intergrate component preform and tip member

FIG. 7

METHOD OF FORMING A CERAMIC MATRIX COMPOSITE COMPONENT, A CERAMIC MATRIX COMPOSITE COMPONENT AND A TIP MEMBER

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0001] This invention was made with Government support under contract number DE-FC26-05NT42643 awarded by the Department of Energy. The Government has certain rights in the invention.

FIELD OF THE INVENTION

[0002] The present invention relates generally to gas turbines for power generation and, more specifically, to a method of forming ceramic matrix composite components, a ceramic matrix composite component and a tip member for gas turbines.

BACKGROUND OF THE INVENTION

[0003] Like turbine blades and vanes formed from more conventional superalloy materials, CMC blades and vanes usually include cavities and cooling passages to reduce weight, reduce centrifugal load, and reduce operating temperatures of the components. These features are typically formed in CMC components using a combination of removable and expendable tooling.

[0004] Forming CMC component with a cavity includes a number of steps, including using pre-forms. First, a plurality of ceramic plies, some of which can include reinforcing material or are pre-impregnated with matrix, are laid up on a mandrel or mold in a pre-determined pattern to provide desired final or near-net-shape and desired mechanical properties of component. The mandrel is generally selected from various polymers, or other meltable materials. The laid-up plies may be pre-impregnated (pre-preg) with matrix material, such as SiC or impregnated with matrix after lay-up of the plies. Prior to rigidization of the CMC pre-form, the mandrel is removed through a burn-out cycle. In the burn-out cycle, the mandrel forming materials, such as, various polymers, or other meltable materials are melted out or decomposed to gaseous products.

[0005] After the burn-out cycle, the CMC pre-form blade is very fragile due to burn-off of the volatile substances of the composite. The open tip area of the CMC pre-form requires capping or closing before use in gas turbines. In known processes, to close the open tip area of the CMC pre-form, a tip cap is inserted into the fragile open tip area. The tip cap can be formed from of a CMC laminate part having a number of plies, and shaped as the open tip area to fill the open tip area of the CMC pre-form. Forming the CMC laminate tip cap by cutting out the CMC plies to the desired shape and laying up the plies in the desired geometry is time and labor intensive. Challenges also arise with placing the CMC laminate having a number of plies into the open tip area. Additionally, because both the CMC laminate and pre-form blade are fragile prior to densification, these components can be easily damaged during assembly.

[0006] Therefore, a method of forming pre-form ceramic matrix composite cavity, a pre-form ceramic matrix composite cavity, and a method of forming ceramic matrix composite components that do not suffer from the above drawbacks is desirable in the art.

SUMMARY OF THE INVENTION

[0007] Certain embodiments commensurate in scope with the originally claimed invention are summarized below. These embodiments are not intended to limit the scope of the claimed invention, but rather these embodiments are intended only to provide a brief summary of possible forms of the invention. Indeed, the invention may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

[0008] According to an exemplary embodiment of the present disclosure, a method of forming a ceramic matrix composite component is provided. The method includes providing a component preform having a first end, a second end, and a cavity, the cavity having a pre-determined shape and a first engagement surface. A tip member is formed from a pre-consolidated composite material, the tip member having a second engagement surface generally conforming to the first engagement surface. The second engagement surface is directed to the first engagement surface. The component preform and tip member are consolidated. The ceramic matrix composite component is formed having a desired geometry and the tip member stays in place in the cavity during operation of the ceramic matrix composite component.

[0009] According to another exemplary embodiment of the present disclosure, a ceramic matrix composite component is provided. The ceramic matrix composite component includes a component preform having a first end, a second end, and a cavity, the cavity having a pre-determined shape and a first engagement surface. The ceramic matrix composite component includes a tip member formed from a pre-consolidated composite material, the tip member having a second engagement surface generally conforming to the first engagement surface. The ceramic matrix composite component has a desired geometry and the tip member stays in place in the cavity during operation of the ceramic matrix composite component.

[0010] According to another exemplary embodiment of the present disclosure, a tip member for a cavity in a ceramic matrix composite component is provided. The tip member is formed from a pre-consolidated composite material. The tip member has a geometry substantially similar to a pre-determined shape of a cavity and a second engagement surface that cooperates with a first engagement surface of the cavity of the ceramic matrix composite component.

[0011] Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** is a perspective view of a ceramic matrix composite (CMC) component of the present disclosure.

[0013] FIG. **2** is a top schematic view of a pre-consolidated sheet including an outline of a tip member of the present disclosure.

[0014] FIG. **3** is a perspective view of a tip member of the present disclosure.

[0015] FIG. **4** is a perspective view of a component preform and tip member of the present disclosure.

[0016] FIG. **5** is a cross-sectional view along line **5**-**5** of FIG. **4** of the component preform and tip member of the present disclosure.

[0017] FIG. **6** is a cross-sectional view of FIG. **4** with first engagement surface and second engagement surface aligned of the present disclosure.

[0018] FIG. **7** is a flow chart of the method of forming a ceramic matrix composite component.

[0019] Wherever possible, the same reference numbers will be used throughout the drawings to represent the same parts.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Provided is an economically viable method of forming a ceramic matrix composite (CMC) component, a CMC component, and a tip member that do not suffer from the drawbacks in the prior art. One advantage of an embodiment of the present disclosure includes a simpler method of forming tip members having a tapered cross section. Yet another advantage is a tip member that has a better fit tolerance within the ceramic matrix composite. Another advantage of an embodiment of the present disclosure includes a tip member that provides added mechanical load carrying capability compared to a vertically cut tip cap. Yet another advantage of the present embodiment is a lower cost in forming the tip member. Another advantage of the present embodiment is that there is a higher yield rate and easier reproducibility of tip members. Another advantage of an embodiment of the present disclosure includes a coated CMC article that limits the removal or loss of coating in the event of contact (e.g., tip rub) with another component in the system.

[0021] One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0022] When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0023] Systems used to generate power include, but are not limited to, gas turbines, steam turbines, and other turbine assemblies such as land based aero-derivatives used for power generation. In certain applications, the power generation systems, including the turbomachinery therein (e.g., turbines, compressors, and pumps) and other machinery may include components that are exposed to challenging conditions. For example, certain power generation system components, such as blades, buckets, casings, rotor wheels, shafts, shrouds, nozzles, and so forth, may operate in high heat and high revolution environments. These components are manufactured using ceramic matrix composites and these components may also include cooling passages. The present disclosure provides a method to form ceramic matrix composite (CMC) components including cooling passages. An exemplary embodiment of the disclosure is shown in FIGS. **1-6** as a turbine blade, but the present disclosure is not limited to the illustrated structure.

[0024] FIG. **1** is a perspective view of a CMC component **100**, such as, but not limited to, a turbine blade **120** or turbine vane. Turbine blade **120** is preferably formed of a ceramic matrix composite (CMC) material. Material for CMC component **100** includes, but is not limited to, an oxide based CMC, such as, but not limited to, alumina, mullite, boron nitride CMCs, boron carbide CMCs, sialons (silicon, aluminum, oxygen, and nitrogen) CMCs, intermetallic CMCs, and polymer based CMCs. Suitable examples of materials used to make CMC components **100**, include, but are not limited to, SiC fibers impregnated with a SiC and carbon matrix with various binders. Turbine blade **120** includes an airfoil **122** against which the flow of hot exhaust gas is directed. Turbine blade **120** is mounted to a turbine disk (not shown) by a dovetail (not shown) which extends downwardly from airfoil **122** and engages a slot on the turbine disk. A platform **126** extends laterally outwardly from the area where airfoil **122** is joined to dovetail. Turbine blade **120** includes at least one cavity **490** as shown in FIG. **4**, extending along the interior of airfoil **122**. During operation of power generation system, a flow of cooling air is directed through cavity **490** to reduce the temperature of airfoil **122**. Turbine blade **120** includes a pressure side **112** and a suction side **114** opposite pressure side **112**. Turbine blade **120** includes a first end **116**, the leading edge, and a second end **118**, the trailing edge.

[0025] FIG. **2** is a top schematic view of a pre-consolidated sheet **210** including an outline **212** of a tip member **200**. Pre-consolidated sheet **210** comprises a plurality of pre-preg ceramic unidirectional plies already aligned and ready to be cut. In one embodiment, pre-consolidated sheet **210** comprises pre-preg plies including epoxy/polymer based resins with carbon, fiberglass, and/or KEVLAR® fibers. In another embodiment, pre-consolidated sheet **210** comprises pre-preg plies including SiC fibers impregnated with a SiC and carbon matrix with various binders. In one embodiment, pre-consolidated sheet **210** has a thickness of about 0.254 millimeters (10 mils) to about 1 centimeter (394 mils), or alternatively about 0.5 millimeters to about 90 millimeters, or alternatively from about 1 millimeter to about 80 millimeters. As depicted in FIG. **2**, a cut-out or outline **212** of tip member **200** is shown in pre-consolidated sheet **210**. Suitable method used to cut out tip member **200** from pre-consolidated sheet **210**, include, but are not limited to, cutting, laser cutting, ultrasonic cutting, and waterjet cutting.

[0026] FIG. **3** illustrates tip member **200** cut from pre-consolidated sheet **210**. Tip member **200** includes a first end **314**, trailing edge, a second end **316**, leading edge, a top **304**, a bottom **306** and second engagement surface **302**. Second engagement surface **302** includes a tapered surface **310**. Second engagement surface **302** including tapered surface **310** cooperate with first engagement surface **594** of component preform **400** (see FIG. **4**). Geometry of tip member **200** is substantially similar to blade tip **430** of component preform **400**. As shown in FIG. **4**, first end **314** of tip member **200** is inserted into cavity **490** of component preform **400**. In one embodiment, depending on size of and shape of cavity **490** of component preform **400** about half of tip member **200** is inserted into cavity **490**.

[0027] As shown in the cross-section view of FIG. **5**, tip member **200** is rotated, as shown by arrow **500**, to allow second engagement surface **302** of tip member **200** to engage with first engagement surface **594** of preform component **400**, such that top **304** of tip member **200** is flush with end of blade tip **430** of preform component **400**. In one embodiment, second engagement surface **302** includes taper **310** generally conforming to taper **596** of first engagement surface **594**. In one embodiment, taper **596** of first engagement surface **594** is wider at the bottom, as shown in FIG. **5**. In one embodiment, as depicted in FIG. **5**, tip member **200** has a reverse taper **310** that cooperates with taper **596** of first engagement surface **594**. In an alternative embodiment, taper **596** of first engagement surface **594** is narrower at the bottom.

[0028] FIG. **6** depicts the tip member **200** situated within cavity **490** of component preform **400** with first engagement surface **594** and second engagement surface **302** being adjacent. Taper **310** of tip member **200** cooperates with taper **596** of component preform **400** to secure tip member **200** in cavity **490**.

[0029] FIG. **7** is a flow chart describing method **700** of forming ceramic matrix composite component **100**. Method **700** includes providing component preform **400** having first end **402**, second end **404**, and cavity **490** (see FIG. **4**), step **701**. As shown in FIG. **4**, cavity **490** has a pre-determined shape and first engagement surface **594**. Method **700** includes forming tip member **200** from pre-consolidated composite material **210** (see FIGS. **2** and **3**), step **703**. Tip member **200** has second engagement surface **302** generally conforming to first engagement surface **594** of component preform **400** (see FIGS. **5** and **6**). Method **700** includes directing second engagement surface **302** to first engagement surface **594** (see FIGS. **5** and **6**), step **705**. Step of directing, step **705**, generally includes placing first end **402** of tip member **200** in opening **592** of cavity **490** of component preform **400** with second end **316** of tip member **200** being above or outside cavity **490** (see FIGS. **4-5**). Step of directing, step **705**, includes rotating or flipping tip member **200**, as shown by arrow labeled **500**, such that first end **314** of tip member **200** engages with first end **402** of component preform **400** and second end **316** of tip member **200** engages with second end **404** of component preform **400** resulting in second engagement surface **302** engaging with first engagement surface **594**. Method **700** includes consolidating component preform **400** and tip member **200**, step **707**. The step of consolidating, step **707**, includes any suitable composite processing methods, such as, but not limited to, melt infiltration, bonding, brazing, chemical vapor infiltration, polymer impregnation and pyrolysis, and other known composite processing methods. Method **700** provides ceramic matrix composite component **100** having a desired geometry and with tip member **200** that stays in place in cavity **490** during operation of ceramic matrix composite component **100**.

[0030] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method of forming a ceramic matrix composite component comprising:

providing a component preform having a first end, a second end, and a cavity, the cavity having a pre-determined shape and a first engagement surface;

forming a tip member from a pre-consolidated composite material, the tip member having a second engagement surface generally conforming to the first engagement surface;

directing the second engagement surface to the first engagement surface; and

consolidating the component preform and tip member;

wherein the ceramic matrix composite component is formed having a desired geometry and the tip member stays in place in the cavity during operation of the ceramic matrix composite component.

2. The method of claim **1**, wherein the ceramic matrix composite component is a component selected from the group consisting of turbine blades, turbine nozzles, turbine buckets, and combinations thereof.

3. The method of claim **1**, wherein the pre-consolidated composite material comprises ceramic unidirectional plies, organic or inorganic based pre-preg plies, or organic or inorganic based cross-plies.

4. The method of claim **1**, wherein the pre-consolidated composite material has a thickness of about 0.254 millimeters to about 1 centimeter.

5. The method of claim **1**, wherein the step of forming includes cutting, laser cutting, waterjet cutting, and combinations thereof.

6. The method of claim **1**, wherein the first engagement surface includes a taper.

7. The method of claim **1**, wherein the taper of the first engagement surface forms a geometry that narrows toward an end of the cavity.

8. The method of claim **6**, wherein the second engagement surface includes a taper generally conforming to the taper of the first engagement surface.

9. A ceramic matrix composite component comprising:

a component preform having a first end, a second end, and a cavity, the cavity having a pre-determined shape and a first engagement surface;

a tip member formed from a pre-consolidated composite material, the tip member having a second engagement surface generally conforming to the first engagement surface; and

wherein the ceramic matrix composite component has a desired geometry and the tip member stays in place in the cavity during operation of the ceramic matrix composite component.

10. The ceramic matrix composite of claim **9**, wherein the ceramic matrix composite component is a component selected from the group consisting of turbine blades, turbine nozzles, turbine buckets, and combinations thereof.

11. The ceramic matrix composite of claim **9**, wherein the pre-consolidated composite material has a thickness of about 0.254 millimeters to about 6.35 millimeters.

12. The ceramic matrix composite of claim **9**, wherein the step of forming includes cutting, laser cutting, waterjet cutting, and combinations thereof.

13. The ceramic matrix composite of claim **9**, wherein the first engagement surface includes a taper.

14. The ceramic matrix composite of claim **13**, wherein the taper of the first engagement forms a geometry that narrows toward an end of the cavity.

15. The ceramic matrix composite of claim **9**, the second engagement surface of the tip member includes a taper generally conforming to the taper of the first engagement surface.

16. A tip member for a cavity in a ceramic matrix composite component, the tip member formed from a pre-consolidated composite material, the tip member having a geometry that conforms to a pre-determined shape of a cavity and a second engagement surface that cooperates with a first engagement surface of the cavity of the ceramic matrix composite component.

17. The tip member of claim **16**, wherein the first engagement surface includes a taper.

18. The tip member of claim **16**, wherein the second engagement surface of the tip member includes a taper generally conforming to the taper of the first engagement surface.

* * * * *