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(54) AIRFOIL FOR A TURBINE SYSTEM

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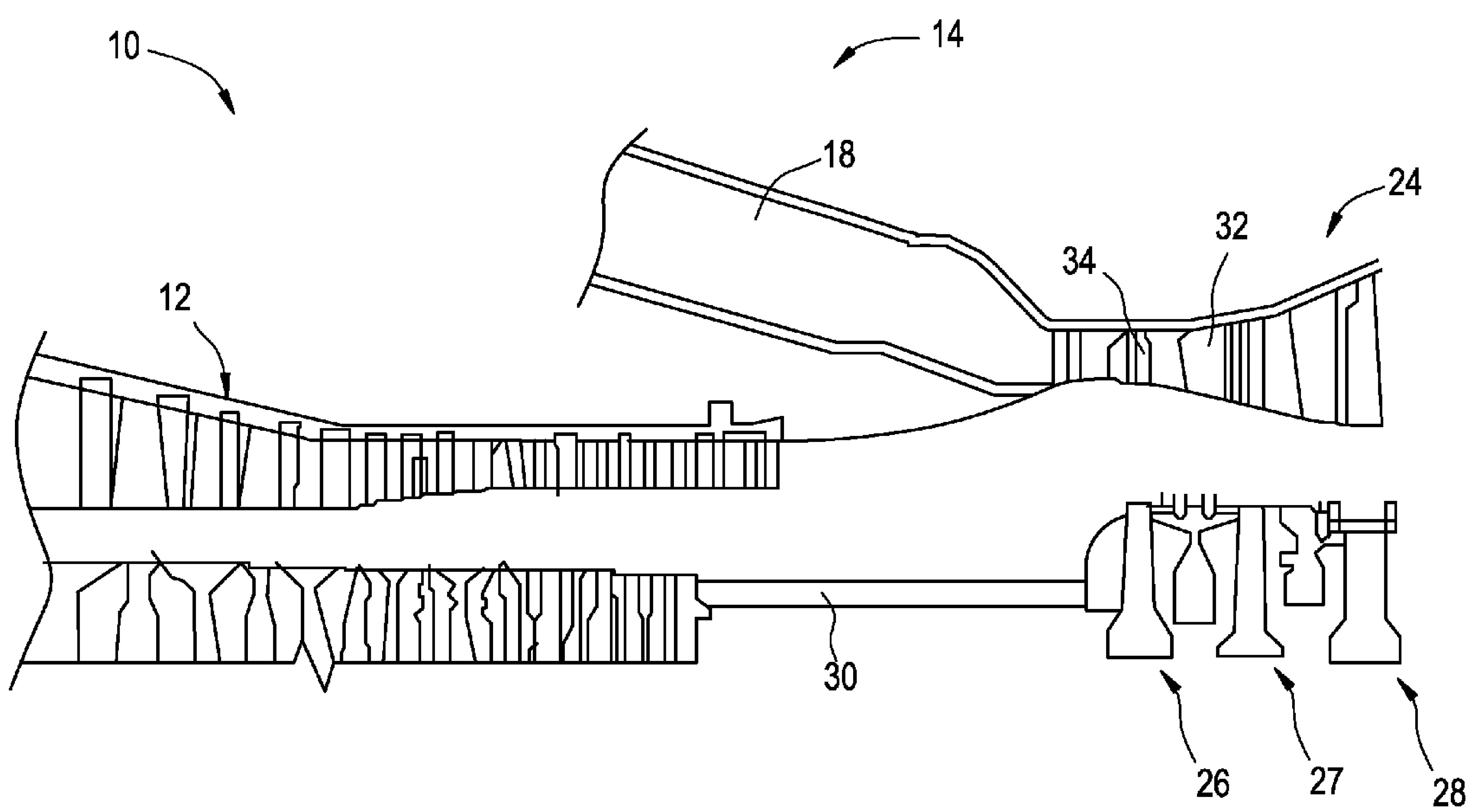
(57) ABSTRACT

An airfoil includes a main portion formed of a base material. Also included is a trailing edge region of the main portion. Further included is a trailing edge supplement structure comprising at least one pre-sintered preform (PSP) material operatively coupled to the base material proximate the trailing edge region.



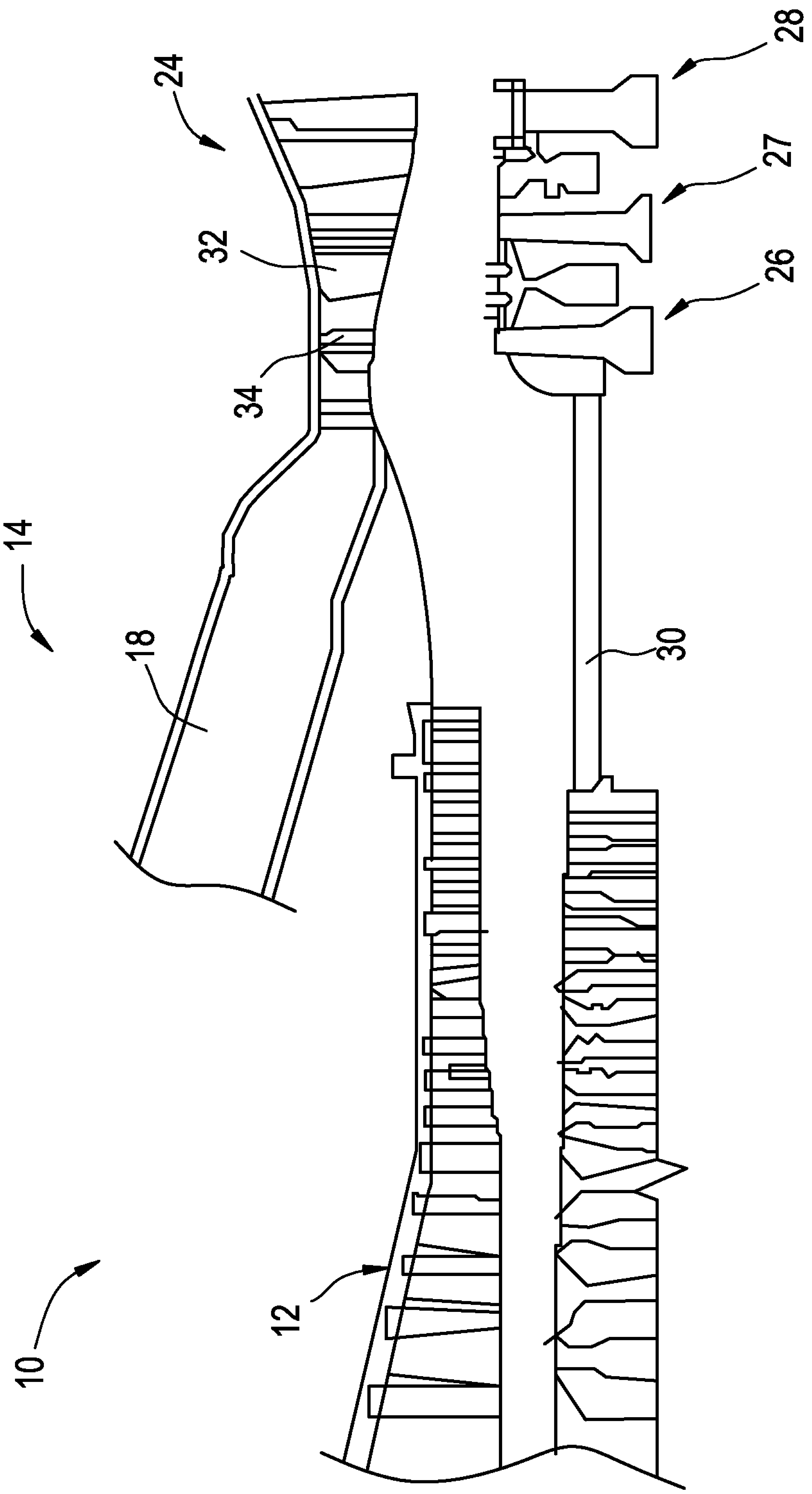


FIG. 1

FIG. 2

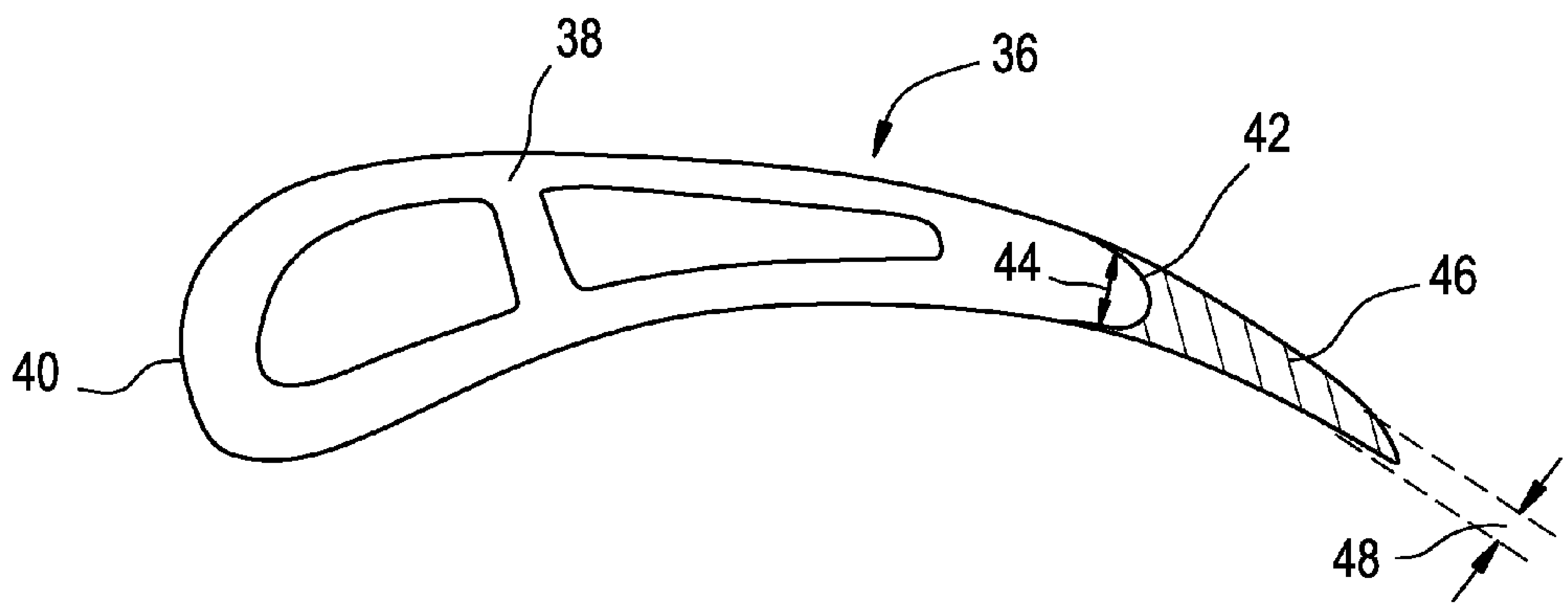


FIG. 3

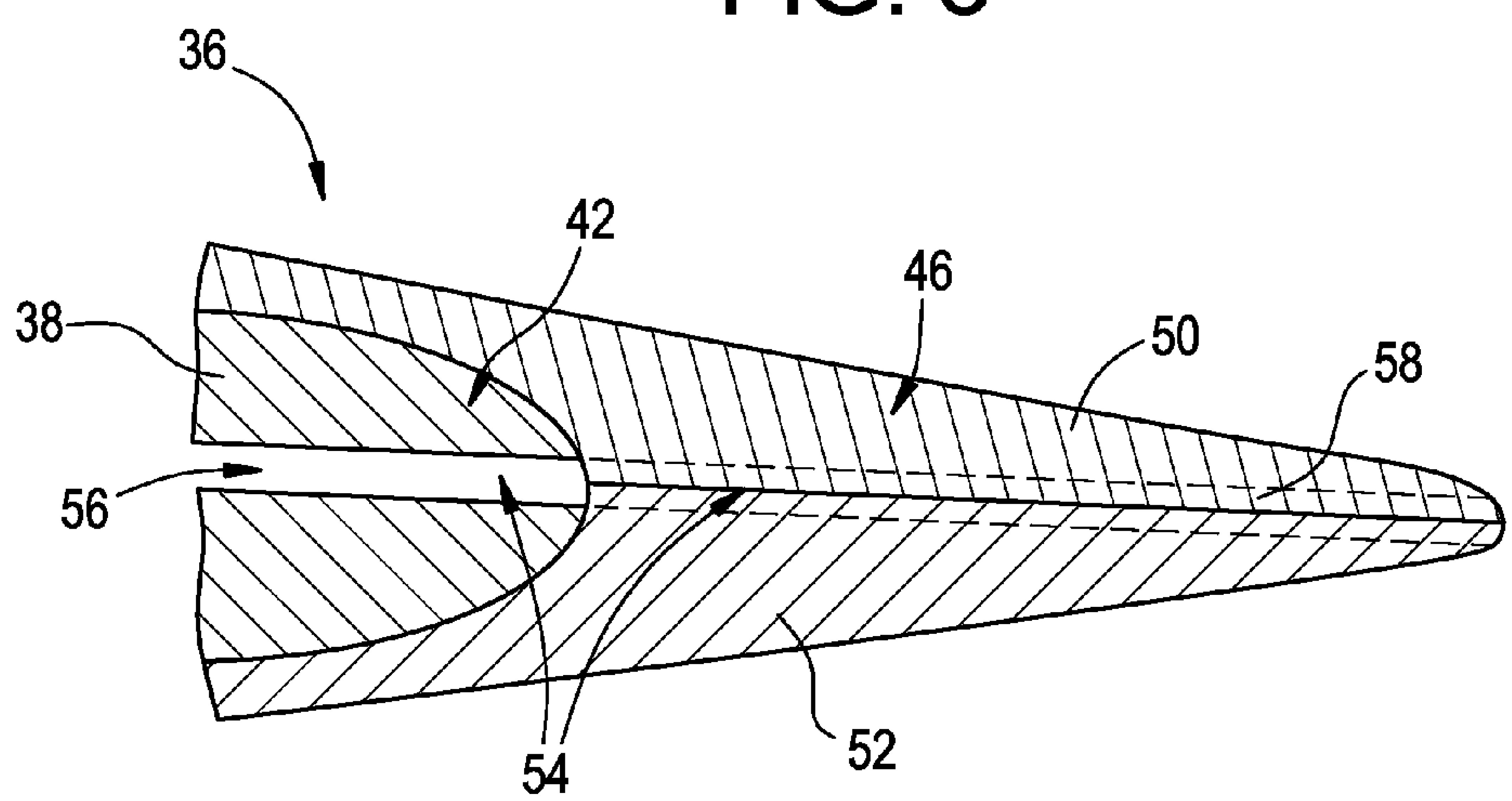


FIG. 4

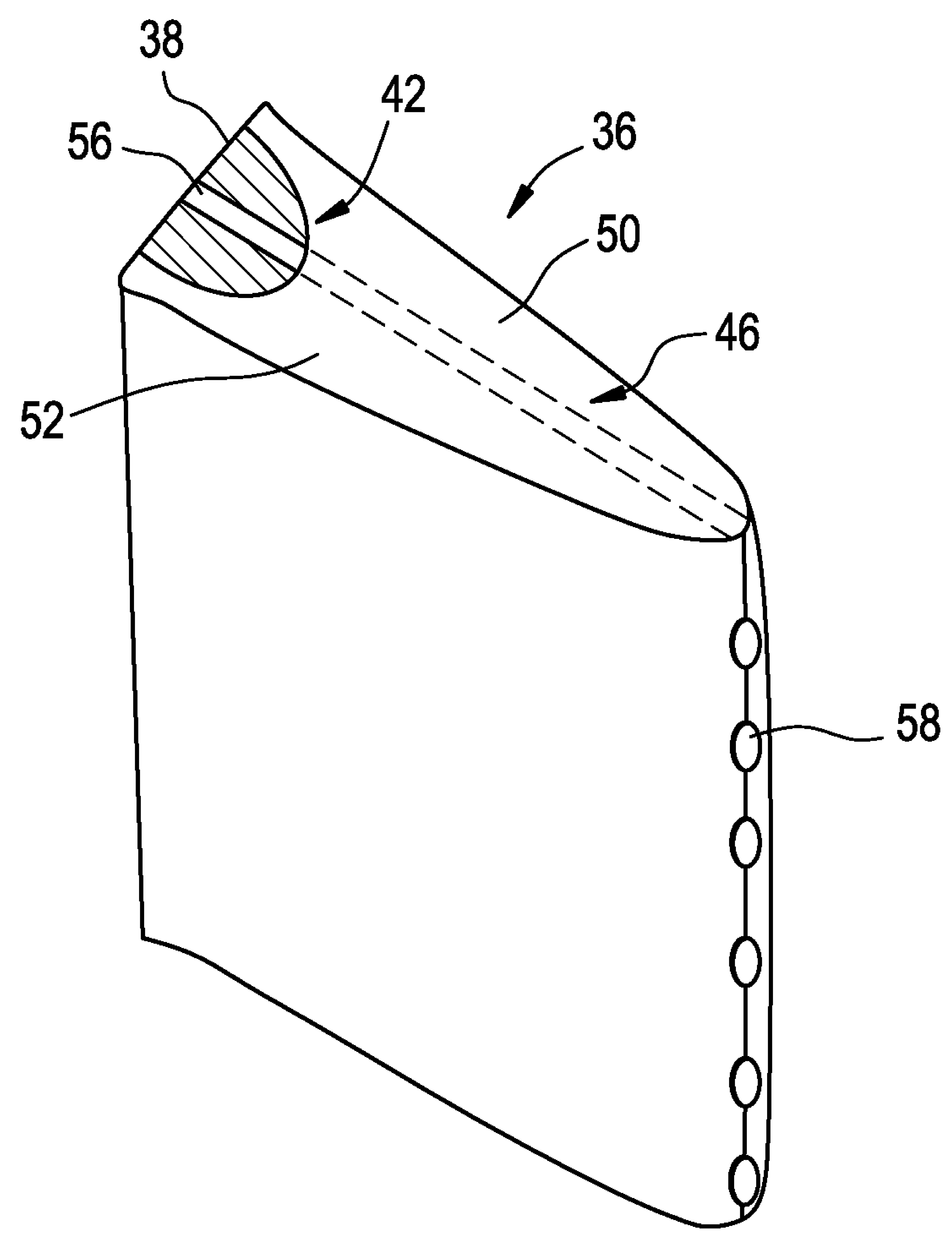
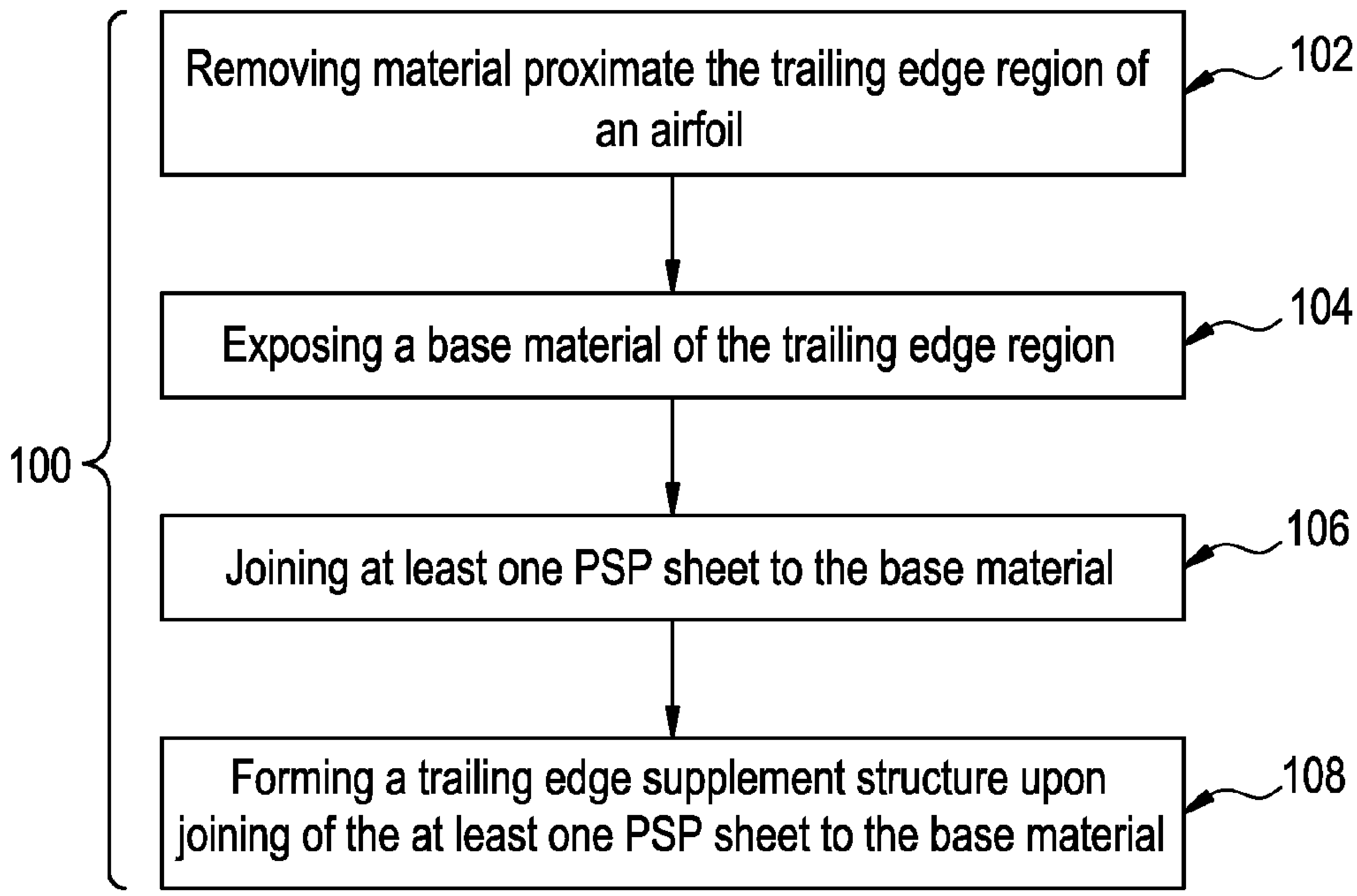


FIG. 5


Removing material proximate the trailing edge region of an airfoil
102
Exposing a base material of the trailing edge region
104
Joining at least one PSP sheet to the base material
106
Forming a trailing edge supplement structure upon joining of the at least one PSP sheet to the base material
108
100

AIRFOIL FOR A TURBINE SYSTEM

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to airfoils, and more particularly to a trailing edge supplement structure for airfoils, particularly those in turbine systems.

[0002] Airfoils employed in various turbine systems are formed as buckets and nozzles. A working fluid such as hot gas or steam is typically forced across the airfoils, with the buckets coupled to a rotor of the turbine system. The force of the working fluid on the buckets causes the buckets, and therefore the coupled body of the rotor to rotate. As such, aerodynamic geometry of the airfoils impacts the overall system performance of the turbine system. Various manufacturing processes, such as casting, may be employed to form the airfoils, but such processes are limiting in certain respects, with one limitation relating to the aerodynamic characteristics of the manufactured airfoils.

[0003] The airfoils are typically formed of nickel, cobalt or iron-based superalloys with desirable mechanical and environmental properties for withstanding turbine operating temperatures and conditions. Because the efficiency of a turbine system is dependent on its operating temperatures, there is a demand for the airfoils to be capable of withstanding increasingly higher temperatures. As the maximum local temperature of a superalloy component approaches the melting temperature of the superalloy, forced air cooling becomes necessary. For this reason, airfoils of gas turbine buckets and nozzles often require complex cooling schemes in which steam or air, typically bleed air, is forced through internal cooling passages within the airfoil and then discharged through cooling holes at the airfoil surface to transfer heat from the component. As noted above, the processes used to manufacture airfoils is somewhat limiting and this impacts the cooling passage precision, with respect to both location and dimension.

BRIEF DESCRIPTION OF THE INVENTION

[0004] According to one aspect of the invention, an airfoil includes a main portion formed of a base material. Also included is a trailing edge region of the main portion. Further included is a trailing edge supplement structure comprising at least one pre-sintered preform (PSP) material operatively coupled to the base material proximate the trailing edge region.

[0005] According to another aspect of the invention, a turbine system includes an airfoil. Also included is a main portion of the airfoil extending from a leading edge to a trailing edge region and formed of a base material. Further included is a trailing edge supplement structure comprising a first PSP material and a second PSP material, the first PSP material and the second PSP material joined to the base material of the main portion proximate the trailing edge region. Yet further included is at least one cooling passage within the trailing edge supplement structure.

[0006] According to yet another aspect of the invention, a method of repairing a trailing edge region of an airfoil is provided. The method includes removing material proximate the trailing edge region of the airfoil. The method also includes exposing a base material of the trailing edge region. The method further includes joining at least one PSP material to the base material. The method yet further includes forming a trailing edge supplement structure upon joining of the at least one PSP material to the base material.

[0007] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The subject matter, which is regarded as the invention, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0009] FIG. **1** is a schematic illustration of a turbine system;

[0010] FIG. **2** is a top plan view of an airfoil;

[0011] FIG. **3** is a cross-sectional view of a trailing edge region of the airfoil;

[0012] FIG. **4** is a perspective view of a trailing edge supplement structure; and

[0013] FIG. **5** is a flow diagram illustrating a method of repairing the trailing edge region of the airfoil.

[0014] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Referring to FIG. **1**, a turbine system **10** constructed in accordance with an exemplary embodiment of the invention, is schematically illustrated. The turbine system **10** illustrated comprises a gas turbine engine, but it is to be appreciated that embodiments described herein may be employed in alternative systems, such as a steam turbine, for example. For purposes of illustration and discussion, the gas turbine engine is referenced.

[0016] The gas turbine engine **10** includes a compressor section **12** and a plurality of combustor assemblies arranged in a can annular array, one of which is indicated at **14** and includes a combustion section **18**. It should be appreciated that this invention is independent of the details of the combustion system, and the can annular system is referenced for purposes of discussion. Fuel and compressed air are passed into the combustion section **18** and ignited to form a high temperature, high pressure combustion product or air stream that is used to drive a turbine section **24**. The turbine section **24** includes a plurality of stages **26**-**28** that are operationally connected to the compressor section **12** through a rotor **30**. In particular, each of the plurality of stages **26**-**28** includes a nozzle **32** and a bucket **34**, with the bucket **34** operatively coupled to the rotor **30**. The nozzle **32** and the bucket **34** of each of the plurality of stages **26**-**28** are airfoils that that working fluid (e.g., air-fuel mixture) passes over. Although three stages are identified, one can appreciate that more or less stages may be present.

[0017] Referring now to FIG. **2**, an airfoil **36** representing either the nozzle **32** or the bucket **34** is illustrated in greater detail. The airfoil **36** includes a main portion **38** that extends from a leading edge **40** to a trailing edge region **42**. The main portion **38** is formed of a base material that may vary depending on the particular application. In some embodiments, the base material comprises a nickel-, cobalt-, or iron-based superalloy. The main portion **38** may be formed as an equiaxed, directionally solidified (DS), or single crystal (SX) casting to withstand the high temperatures and stresses to which it is subjected, such as within a gas turbine engine, for example. The trailing edge region **42** is relatively rounded and includes a trailing edge region aft width **44**.

[0018] The airfoil **36** also includes a trailing edge supplement structure **46** that is operatively coupled to the main portion **38** proximate a surface of the trailing edge region **42**. As shown, relative to the main portion **38**, the trailing edge supplement structure **46** tapers to a thinner, more acute end portion, the dimension referred to herein as a trailing edge supplement structure aft width **48**.

[0019] Referring to FIGS. **3** and **4**, the trailing edge region **42** of the main portion **38** and the trailing edge supplement structure **46** are illustrated in greater detail. In the illustrated embodiment, the trailing edge supplement structure **46** includes a first PSP material, referred to herein as a PSP sheet **50** and a second PSP material, referred to herein as a PSP sheet **52** that are each pre-sintered preform (PSP) structures. The PSP sheets, namely the first PSP sheet **50** and the second PSP sheet **52**, each comprise a mixture of particles comprising a first alloy and a second alloy that have been sintered together at a temperature below their melting points to form an agglomerate and somewhat porous mass. Suitable particle size ranges for the powder particles include **150** mesh, or even **325** mesh or smaller to promote rapid sintering of the particles and reduce porosity in the PSP sheets to about 10 volume percent or less.

[0020] The first alloy of the first PSP sheet **50** and the second PSP sheet **52** comprises any composition such as one similar to the base material of the main portion **38** to promote common physical properties between the PSP sheets and the main portion **38**. For example, in some embodiments, the first alloy and the base material share a common composition (i.e., they are the same type of material). In some embodiments, the first alloy comprises a nickel-based superalloy or a cobalt-based superalloy. In some embodiments, the properties for the first alloy include chemical and metallurgical compatibility with the base material, such as high fatigue strength, low tendency for cracking, oxidation resistance and/or machinability.

[0021] The second alloy may also have a composition similar to the base material of the main portion **38**, but further contains a melting point depressant to promote sintering of the first alloy and the second alloy particles and enable bonding of the PSP sheets to the trailing edge region **42** of the main portion **38** at temperatures below the melting point of the base material. For example, in some embodiments the melting point depressant comprises boron and/or silicon.

[0022] The PSP sheets comprise any relative amounts of the first alloy and the second alloy that are sufficient to provide enough melting point depressant to ensure wetting and bonding (e.g., diffusion/brazing bonding) of the particles of the first alloy and the second alloy to each other and to the trailing edge region **42** of the main portion **38** of the airfoil **36**. For example, in some embodiments the second alloy comprises at least about 10 weight percent of each of the first PSP sheet **50** and the second PSP sheet **52**. In one embodiment, the second alloy comprises about 70 weight percent of each of the PSP sheets, with the first alloy comprising about 30 weight percent of each of the PSP sheets, thereby resulting in a mixed weight ratio of the first alloy to the second alloy of about 30:70. In another embodiment, a mixed weight ratio of the first alloy to the second alloy of about 40:60 is employed.

[0023] The above-described embodiments of the trailing edge supplement structure **46** are illustrated and described as having two PSP sheets. However, it is to be understood that a single PSP sheet may be employed and operatively coupled to the trailing edge region **42** of the main portion **38**. Furthermore, more than two PSP sheets may be employed to form the trailing edge supplement structure **46**.

[0024] Irrespective of the precise number of PSP sheets employed, the sheet(s) are operatively coupled to the trailing edge region **42** of the main portion **38**. In one embodiment, the PSP sheets are brazed to the trailing edge region **42**. The PSP sheets are formed of materials configured to be brazed to the trailing edge region **42** without the need for application of a braze paste. In this way, the PSP sheets, such as the first PSP sheet **50** and the second PSP sheet **52**, are positioned in a desirable location in an abutting manner with the trailing edge region **42** within a furnace and heated to a necessary temperature to facilitate brazing of the PSP sheets to the main portion **38**. In addition to brazing, it is contemplated that alternative coupling techniques may be employed, including, but not limited to, welding, diffusion bonding or mechanical fastening.

[0025] Formation of the PSP sheets as the trailing edge supplement structure **46** enables thinner trailing edge portions of the airfoil **36**, which effectively reduces aerodynamic blockage, thereby improving overall turbine system performance.

[0026] To provide effective cooling of the airfoil **36**, a cooling arrangement **54** is implemented within the trailing edge region **42** of the main portion **38** and throughout the trailing edge supplement structure **46**. The trailing edge region **42** of the main portion **38** includes at least one cooling channel **56** that is in fluid communication with at least one, but typically a plurality of cooling passages **58** disposed in the trailing edge supplement structure **46**. The plurality of cooling passages **58** may be formed in a variety of manners and at a variety of times throughout the manufacturing process. Specifically, the plurality of cooling passages **58** may be formed prior to coupling of the trailing edge supplement structure **46** to the main portion **38** or subsequent to coupling.

[0027] Formation of the plurality of cooling passages **58** prior to coupling of the trailing edge supplement structure **46** to the main portion **38** may include formation of negative grooves, slots or the like into at least one of the PSP sheets during formation of the PSP sheets themselves, such that the PSP sheets are still in their pliable green state before initial sintering. The grooves, slots or the like may be formed in both of the first PSP sheet **50** and the second PSP sheet **52**, such that alignment of the grooves, slots, etc. is necessary to form the plurality of cooling passages **58**. Alternatively, the plurality of cooling passages **58** may be machined (i.e., removal of some material from the PSP sheet(s)) via any suitable material removal operation, including, but not limited to, milling, grinding, wire electrical discharge machining (EDM), milled EDM, plunge EDM, electro-chemical machining (ECM), water-jet trenching, laser trenching, or combinations thereof. It is contemplated that the material removal process may occur prior to coupling of the trailing edge supplement structure **46** to the main portion or after such coupling. Regardless of the time of formation of the plurality of cooling passages **58**, the plurality of cooling passages **58** are in fluid communication with the at least one cooling channel **56**. It is contemplated that the above-described embodiments may be incorporated into new or existing airfoils of various turbine systems.

[0028] As illustrated in the flow diagram of FIG. **5**, and with reference to FIGS. **1-4**, a method of repairing a trailing edge region of an airfoil **100** is also provided. The turbine system **10** and the trailing edge supplement structure **46** of the airfoil **36** have all been previously described and specific structural components need not be described in further detail. The method of repairing a trailing edge region of an airfoil **100** includes removing material proximate the trailing edge region of the airfoil **102**. A base material of the trailing edge region is exposed **104** and at least one PSP sheet is joined to the base material **106**. A trailing edge supplement structure is formed upon joining of the at least one PSP sheet to the base material **108**. The method of repairing a trailing edge region of an airfoil **100** also includes forming at least one cooling passage that is in fluid communication with the at least one cooling channel **56** of the main portion **38**, as described in detail above.

[0029] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

1. An airfoil comprising:

a main portion formed of a base material;

a trailing edge region of the main portion; and

a trailing edge supplement structure comprising at least one pre-sintered preform (PSP) material operatively coupled to the base material proximate the trailing edge.

2. The airfoil of claim **1**, wherein the trailing edge supplement structure is brazed to the trailing edge region.

3. The airfoil of claim **1**, further comprising at least one cooling channel formed in the base material of the main portion.

4. The airfoil of claim **3**, further comprising at least one cooling passage formed in the trailing edge supplement structure, the at least one cooling passage in fluid communication with the at least one cooling channel.

5. The airfoil of claim **1**, further comprising a trailing edge supplement structure aft width and a trailing edge region aft width, wherein the trailing edge supplement structure aft width is less than the trailing edge region aft width.

6. The airfoil of claim **1**, wherein the at least one PSP material comprises a first alloy and a second alloy.

7. The airfoil of claim **6**, wherein the first alloy and the second alloy are mixed together at a weight ratio of about 30:70.

8. The airfoil of claim **1**, wherein the at least one PSP material comprises a first PSP material and a second PSP material operatively coupled together.

9. The airfoil of claim **8**, wherein at least one of the first PSP material and the second PSP material includes a slot, wherein operative coupling of the first PSP material and the second PSP material forms at least one cooling passage.

10. The airfoil of claim **9**, wherein the at least one cooling passage is in fluid communication with at least one cooling channel formed in the base material of the main portion.

11. A turbine system comprising:

an airfoil;

a main portion of the airfoil extending from a leading edge to a trailing edge and formed of a base material;

a trailing edge supplement structure comprising a first PSP material and a second PSP material, the first PSP material and the second PSP material joined to the base material of the main portion proximate the trailing edge; and

at least one cooling passage within the trailing edge supplement structure.

12. The turbine system of claim **11**, wherein at least one of the first PSP material and the second PSP material includes a slot, wherein operative coupling of the first PSP material and the second PSP material forms the at least one cooling passage.

13. The turbine system of claim **11**, wherein the at least one cooling passage is in fluid communication with at least one cooling channel formed in the base material of the main portion.

14. The turbine system of claim **11**, further comprising a trailing edge supplement structure aft width and a trailing edge region aft width, wherein the trailing edge supplement structure aft width is less than the trailing edge region aft width.

15. The turbine system of claim **11**, wherein each of the first PSP material and the second PSP material comprises a first alloy and a second alloy.

16. The turbine system of claim **15**, wherein the first alloy and the second alloy are mixed together at a weight ratio of about 30:70.

17. A method of repairing a trailing edge region of an airfoil comprising:

removing material proximate the trailing edge region of the airfoil;

exposing a base material of the trailing edge region;

joining at least one PSP material to the base material; and

forming a trailing edge supplement structure upon joining of the at least one PSP material to the base material.

18. The method of claim **17**, further comprising forming at least one cooling passage within the at least one PSP material prior to joining the at least one PSP material to the base material.

19. The method of claim **17**, further comprising forming at least one cooling passage within the at least one PSP material after joining the at least one PSP material to the base material.

20. The method of claim **17**, wherein the trailing edge supplement structure comprises a first PSP material and a second PSP material, the method further comprising forming at least one cooling passage within the trailing edge supplement structure by aligning a first slot of the first PSP material and a second slot of the second PSP material.

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