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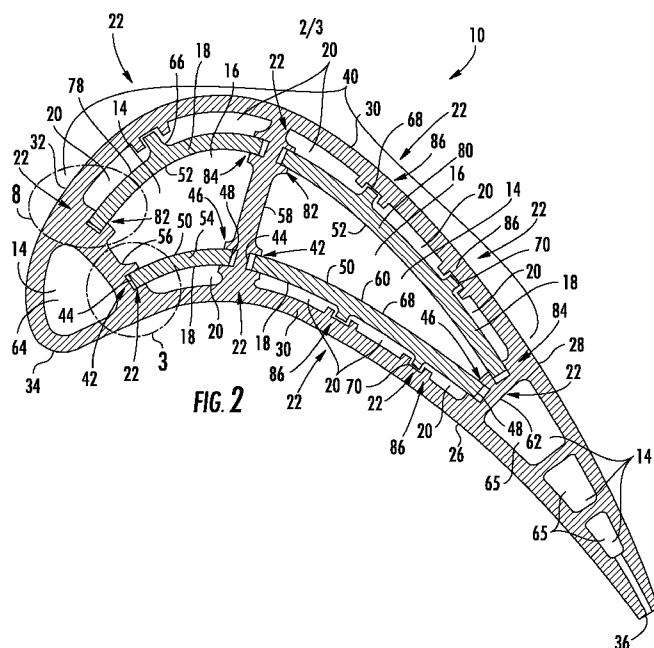
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(54) Title: TURBINE AIRFOIL WITH INTERNAL COOLING SYSTEM HAVING NEARWALL COOLING CHANNELS
FORMED FROM AN INNER WALL FORMED SEPARATELY FROM AN OUTER WALL FORMING THE TURBINE AIR-
FOIL

(57) Abstract: An airfoil (10) for a gas turbine engine is disclosed in which the airfoil (10) includes an internal cooling system (14) formed from one or more midchord cooling channels (16) with at least one inner wall (18) positioned within the midchord cooling channel (16) forming a nearwall cooling channel (20). The inner wall (18) may be held in place with an inner wall connection system (22). The inner wall connection system (22) may be configured such that the inner wall (18) can slide spanwise and may have a limited degree of freedom to move towards a pressure or suction side (26, 28), or both. With the inner wall (18) being positioned within the airfoil (10) and not being rigidly connected to the airfoil (10), there exists little, if any, thermal stress between the inner wall (18) and the outer wall (30) forming the airfoil (10). The inner wall (18) may be formed via a bi-cast process in which the inner wall (18) has a higher melting point than the airfoil (10).

**TURBINE AIRFOIL WITH INTERNAL COOLING SYSTEM HAVING NEARWALL
COOLING CHANNELS FORMED FROM AN INNER WALL FORMED
SEPARATELY FROM AN OUTER WALL FORMING THE TURBINE AIRFOIL**

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10 rights in this invention.

FIELD OF THE INVENTION

This invention is directed generally to gas turbine engines, and more
particularly to internal cooling systems for airfoils in gas turbine engines.

15 **BACKGROUND**

Typically, gas turbine engines include a compressor for compressing air, a
combustor for mixing the compressed air with fuel and igniting the mixture, and a
turbine blade assembly for producing power. Combustors often operate at high
temperatures that may exceed 2,500 degrees Fahrenheit. Typical turbine combustor
20 configurations expose turbine vane and blade assemblies to high temperatures. As
a result, turbine vanes and blades must be made of materials capable of
withstanding such high temperatures, or must include cooling features to enable the
component to survive in an environment which exceeds the capability of the material.
Turbine engines typically include a plurality of rows of stationary turbine vanes
25 extending radially inward from a shell and include a plurality of rows of rotatable
turbine blades attached to a rotor assembly for turning the rotor.

Typically, the turbine vanes are exposed to high temperature combustor
gases that heat the airfoil. The airfoils include internal cooling systems for reducing
the temperature of the airfoils. Some airfoils include a four wall design forming
30 nearwall cooling channels. Cooling air is passed through the nearwall cooling
channels to create higher concentrated cooling at the outer wall. However, the four
wall design has an inherent structural problem due to the significant differences in

operating temperatures between the outer and inner walls. The outer walls will operate at significantly higher temperatures than the inner walls because the outer walls are subjected to the hot gas path air whereas the inner walls are not contacted by the hot gas path air and operate near the temperature of the cooling air. This difference in operating temperature between the inner and outer walls creates high thermally induced stress in the walls and can greatly limit the life of the airfoils. Thus, a need exists for reducing thermal fight between the outer and inner walls of near-walled cooled gas turbine airfoils.

SUMMARY OF THE INVENTION

An airfoil for a gas turbine engine is disclosed in which the airfoil includes an internal cooling system formed from one or more midchord cooling channels with at least one inner wall positioned within the midchord cooling channel forming a nearwall cooling channel. The inner wall may be held in place with an inner wall connection system. The inner wall connection system may be configured such that the inner wall can slide in a spanwise direction and may have a limited degree of freedom to move towards a pressure or suction side, or both. With the inner wall being positioned within the airfoil and not being rigidly connected to the airfoil, there exists little, if any, thermal stress between the inner wall and the outer wall forming the airfoil. The inner wall may be formed via a bi-cast process in which the inner wall is formed from a material with a higher melting point than a material forming the outer wall of the airfoil.

In at least one embodiment, the turbine airfoil may be formed from a generally elongated hollow airfoil formed from an outer wall, and having a leading edge, a trailing edge, a pressure side, a suction side, and a cooling system positioned within interior aspects of the generally elongated hollow airfoil. The turbine airfoil may include one or more midchord cooling channels with at least one inner wall positioned within the midchord cooling channel forming a nearwall cooling channel. The turbine airfoil may include an inner wall connection system formed from one or more first end connections configured to limit movement of a first end of the inner wall towards the outer wall forming the generally elongated hollow airfoil and formed from one or more second end connections configured to limit movement of a second

end of the inner wall towards the outer wall forming the generally elongated hollow airfoil.

In at least one embodiment, the inner wall may be formed from a material having a higher melting temperature than a melting point of a material forming the outer wall of the generally elongated hollow airfoil. As such, the turbine airfoil may be formed from a bi-cast process. The inner wall may be first cast using a higher temperature capability metal that will not melt when being subjected to a second casting process. The inner wall fits in place in the overall airfoil structure, but the inner wall is structurally free from the outer wall, which greatly reduces, if not virtually eliminates, thermal stress between the inner wall and the outer wall. During operation, the inner wall may experience significantly lower temperatures than the outer wall because the inner wall is not exposed to direct contact with the combustor exhaust gases as the outer wall is. Consequently, the inner wall experiences significantly lower thermal growth than the outer wall. Because the inner wall may slide relative to the outer wall, the inner wall may not be subjected to high stresses that plague conventional inner and outer walls of airfoils in which the higher thermal growth of the outer walls severely stress the cooler inner walls.

In at least one embodiment, the inner wall may be formed from a pressure side inner wall positioned adjacent the outer wall forming the pressure side of the generally elongated hollow airfoil and may be formed from a suction side inner wall positioned adjacent the outer wall forming the suction side of the generally elongated hollow airfoil. The pressure side inner wall may be formed from a leading pressure side inner wall extending from a first rib to a second rib and a trailing pressure side inner wall extending from the second rib to a third rib. The leading pressure side inner wall may be coupled to the first rib via the first end connection and may be coupled to the second rib via the second end connection. The first and second end connections may enable limited movement of the leading pressure side inner wall towards the pressure and suction sides, yet prevent the leading pressure side inner wall from contacting pressure or suction sides. One or more leading standoff supports may extend from the leading pressure side inner wall toward the outer wall forming the pressure side to control movement of the leading pressure side inner

wall toward the outer wall forming the pressure side. The trailing pressure side inner wall may be configured similarly to the leading pressure side inner wall.

The suction side inner wall may be formed from a leading suction side inner wall extending from a first rib to a second rib and a trailing suction side inner wall
5 extending from the second rib to a third rib. The leading suction side inner wall may be configured similarly to the leading pressure side inner wall and the trailing suction side inner wall may be configured similarly to the trailing pressure side inner wall.

The inner wall connection system may include one or more radial movement limitation systems configured to limit movement of the at least one inner wall in a
10 spanwise direction, which may be in a radial direction. The radial movement limitation system may be formed from a first inner wall restriction surface extending from the inner wall and positioned radially inward of a first rib wall restriction surface positioned such that the first inner wall restriction surface and the first rib wall
15 restriction surface contact each other to limit movement of the at least one inner wall radially outward. The radial movement limitation system may be formed a second inner wall restriction surface extending from the inner wall and positioned radially outward of a second rib wall restriction surface positioned such that the second inner wall restriction surface and the second rib wall restriction surface contact each other to limit movement of the at least one inner wall radially inward. The radial movement
20 limitation system may be configured with lugs extending from the inner wall and from other components of the turbine airfoil. The lugs may have different configurations and are not limited to a single configuration for limiting movement of the at least one inner wall in a spanwise direction.

The inner wall connection system may include a number of different
25 configurations for the first and second end connections on the end of the inner wall. In at least one embodiment, the first end connection may be formed from a first receiver spanwise extending slot receiving the first inner wall. The first receiver spanwise extending slot may be formed from a first retaining protrusion on a first side of the inner wall and a second retaining protrusion on a second side of the inner
30 wall. In another embodiment, the first end connection may be formed from a first receiver spanwise extending slot positioned between first and second arms extending from the first rib, whereby the first receiver spanwise extending slot formed

from the first and second arms is sized to receive a protrusion. In yet another embodiment, the first receiver spanwise extending slot may be formed as a dovetail receiver. The protrusion may be formed as a dovetail with first and second sides that are nonparallel and nonorthogonal to form a dovetail having a base that is narrower than an outer tip.

An advantage of the internal cooling system is that the inner wall of the internal cooling system fits in place in the overall airfoil structure, but the inner wall is structurally free from the outer wall, which greatly reduces, if not virtually eliminates, thermal stress between the inner wall and the outer wall.

Another advantage of the internal cooling system is that because the inner wall may slide relative to the outer wall, the inner wall may not be subjected to high stresses that plague conventional inner and outer walls of airfoils in which the higher thermal growth of the outer walls severely stress the cooler inner wall.

Yet another advantage of the internal cooling system is that the inner wall of the internal cooling system may be formed from a material having a higher melting temperature than a melting point of a material forming the outer wall of the generally elongated hollow airfoil, thereby enabling the turbine airfoil to be formed from a bi-cast process.

Another advantage of the internal cooling system is that the clearance between the inner walls and the other components of the airfoil is maintained with tight clearances, thereby minimizing leakage.

These and other embodiments are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated 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 turbine airfoil.

Figure 2 is a cross-sectional view of the turbine airfoil taken at section line 2-2 in Figure 1 and displaying nearwall cooling channels formed from inner walls positioned near outer walls forming the pressure and suction sides of the airfoil.

Figure 3 is a cross-sectional, detail view of the inner wall connection system at the pressure side nearwall cooling channel taken at detail 3 in Figure 2.

Figure 4 is a cross-sectional, detail view of an alternative embodiment of the inner wall connection system at the pressure side nearwall cooling channel taken at detail 3 in Figure 2.

Figure 5 is a cross-sectional, detail view of another alternative embodiment of the inner wall connection system at the pressure side nearwall cooling channel taken at detail 3 in Figure 2.

Figure 6 is a cross-sectional, detail view of an alternative embodiment of the inner wall connection system at the pressure side nearwall cooling channel taken at detail 3 in Figure 2.

Figure 7 is a cross-sectional, detail view of the alternative embodiment of the radial movement limitation systems of the inner wall connection system at the pressure side nearwall cooling channel taken at section line 7-7 in Figure 6.

Figure 8 is a cross-sectional, detail view of the inner wall connection system at the suction side nearwall cooling channel taken at detail 8 in Figure 2.

Figure 9 is a cross-sectional, detail view of an alternative embodiment of the inner wall connection system at the suction side nearwall cooling channel taken at detail 8 in Figure 2.

Figure 10 is a cross-sectional, detail view of another alternative embodiment of the inner wall connection system at the suction side nearwall cooling channel taken at detail 8 in Figure 2.

DETAILED DESCRIPTION OF THE INVENTION

As shown in Figures 1-10, an airfoil 10 for a gas turbine engine is disclosed in which the airfoil 10 includes an internal cooling system 14 formed from one or more midchord cooling channels 16 with at least one inner wall 18 positioned within the midchord cooling channel 16 forming a nearwall cooling channel 20. The inner wall 18 may be held in place with an inner wall connection system 22. The inner wall connection system 22 may be configured such that the inner wall 18 can slide in a spanwise direction 24 and may have a limited degree of freedom to move towards a pressure or suction side 26, 28, or both. With the inner wall 18 being positioned

within the airfoil 10 and not being rigidly connected to the airfoil 10, there exists little, if any, thermal stress between the inner wall 18 and the outer wall 30 forming the airfoil 10. The inner wall 18 may be formed via a bi-cast process in which the inner wall 18 is formed from a material with a higher melting point than a material forming the outer wall 30 of the airfoil 10.

In at least one embodiment, as shown in Figures 1 and 2, the turbine airfoil 10 may be formed from a generally elongated hollow airfoil 32 formed from an outer wall 30, and having a leading edge 34, a trailing edge 36, a pressure side 26, a suction side 28, and an internal cooling system 14 positioned within interior aspects of the generally elongated hollow airfoil 32. The turbine airfoil 10 may have any appropriate configuration such that the turbine airfoil 10 may be usable in a turbine engine, such as, but not limited to, a gas turbine engine.

The turbine airfoil 10 may include one or more midchord cooling channels 16 with one or more inner walls 18 positioned within the midchord cooling channel 16 forming a nearwall cooling channel 20. The midchord cooling channel 16 may have any configuration to cool a midchord region 40 of the turbine airfoil 10 and is not limited to the configuration shown in the Figures. The turbine airfoil 10 may include one or more inner wall connection systems 22 formed from one or first end connections 42 configured to limit movement of a first end 44 of the inner wall 18 towards the outer wall 30 forming the generally elongated hollow airfoil 32. The inner wall connection system 22 may also include one or more second end connections 46 configured to limit movement of a second end 48 of the inner wall 18 towards the outer wall 30 forming the generally elongated hollow airfoil 32. The inner wall connection system 22 may be configured such that the inner wall 18 can slide in a spanwise direction 24 and may have a limited degree of freedom to move towards a pressure or suction side 26, 28, or both. The inner walls 18 may be constrained in place, such as, but not limited to, use of grooves but may not be rigidly attached to the structural walls of the airfoil 32, and therefore, can slide in the chordwise direction 72, which is the direction of the major differential thermal growth of between the outer and inner walls. Figures 3-10 show different embodiments of the inner wall connection system 22 for attaching the inner walls 18 to the airfoils 32. Clearance may exist between the inner walls 18 and the airfoils 32 such that the

inner walls 18 can slide relative to the outer walls 30 when at ambient temperatures and at operating temperatures.

The midchord cooling channel 16 between the inner walls 18 forming the nearwall cooling channel 20 may be used for a number of purposes. The midchord cooling channel 16 outside of the nearwall cooling channels 20 may be used to contain by-pass air, provide cooling fluid supply, such as, but not limited to, air, to one or more of the nearwall cooling channels 20, or may be configured as a dead cavity without air flow. The midchord cooling channel 16 may serve any of the purposes listed or other unlisted purposes.

In at least one embodiment, the inner wall 18 of the turbine airfoil 10 may be formed from a material having a higher melting temperature than a melting point of a material forming the outer wall 30 of the generally elongated hollow airfoil 32. In at least one embodiment, the turbine airfoil 10 may be formed from a bi-cast process. The inner wall 18 may be first cast using a higher temperature capability metal that will not melt when being subjected to a second casting process. The inner wall 18 may be formed by casting or formed from a high temperature wrought alloy, such as a wrought alloy with a melting point higher than a melting point of a material used to form the outer wall 30. In at least one embodiment, the inner wall 18 may be formed from a material, such as but not limited to, single crystal and directionally solidified alloys. Any combination of alloys may be used as long as the alloy forming the inner wall 18 has a higher melting temperature than the material, such as, but not limited to, an alloy used to form the rest of the turbine airfoil 10. The clearance between the inner walls 18 and the other components of the airfoil 10 is maintained via application of a thin ceramic coating on the first and second ends 44, 48 of the inner wall 18 which is leached away after casting. Application of the thin ceramic coating enables very tight clearances to be maintained between the inner wall 18 and inner wall connection system 22, thereby minimizing leakage. In at least one embodiment, the first cast component, which may be the inner wall 18, may be allowed to oxidize to create a layer to prevent the second cast component, which may be the outer wall 30 forming the generally elongated hollow airfoil 32, from sticking to the first cast component and therefore minimize leakage. It is permissible for the inner wall 18 sticks to other components of the generally elongated hollow airfoil 32 because as

soon as thermal stresses are created, the inner wall 18 would separate from being stuck to generally elongated hollow airfoil 32.

The inner wall 18 fits in place in the overall airfoil structure 32, but the inner wall 18 is structurally free from the outer wall 30, which greatly reduces, if not
5 virtually eliminates, thermal stress between the inner wall 18 and the outer wall 30. During operation, the inner wall 18 may experience significantly lower temperatures than the outer wall 30 because the inner wall 18 is not exposed to direct contact with the combustor exhaust gases as the outer wall 30 is. Consequently, the inner wall
10 18 experiences significantly lower thermal growth than the outer wall 30. Because the inner wall 18 may slide relative to the outer wall 30, the inner wall 18 may not be subjected to high stresses that plague conventional inner and outer walls of airfoils in which the higher thermal growth of the outer walls severely stress the cooler inner walls.

In at least one embodiment, as shown in Figure 2, the inner wall 18 may be
15 formed from a pressure side inner wall 50 positioned adjacent the outer wall 30 forming the pressure side 26 of the generally elongated hollow airfoil 32. The inner wall 18 may also be formed from a suction side inner wall 52 positioned adjacent the outer wall 30 forming the suction side 28 of the generally elongated hollow airfoil 32. The pressure side inner wall 50 may be formed from a leading pressure side inner
20 wall 54 extending from a first rib 56 to a second rib 58 and a trailing pressure side inner wall 60 extending from the second rib 58 to a third rib 62. The first rib 56 may extend between the outer walls 30 forming the pressure and suction sides 26, 28. The first rib 56 may also separate the midchord cooling channel 16 from a leading edge cooling channel 64. The leading edge cooling channel 64 may have any
25 appropriate configuration and is not limited to the configuration shown in the Figures. In at least one embodiment, the second rib 58 may extend between the outer walls 30 forming the pressure and suction sides 26, 28 and may divide the midchord cooling channel 16. The third rib 62 may extend between the outer walls 30 forming the pressure and suction sides 26, 28 and may separate the midchord cooling
30 channel 16 from a trailing edge cooling channel 65.

In at least one embodiment, as shown in Figure 2, the leading pressure side inner wall 54 may be coupled to the first rib 56 via the first end connection 42 and

may be coupled to the second rib 58 via the second end connection 46. The first and second end connections 42, 46 may enable limited movement of the leading pressure side inner wall 54 towards the pressure and suction sides 26, 28, yet prevent the leading pressure side inner wall 54 from contacting pressure or suction sides 26, 28. As shown in Figure 2, the turbine airfoil 10 may include one or more leading standoff supports 66 extending between the leading pressure side inner wall 54 and the outer wall 30 forming the pressure side 26 to control movement of the leading pressure side inner wall 54 toward the outer wall 30 forming the pressure side 26. In at least one embodiment, the turbine airfoil 10 may include one or more leading standoff supports 66 extending from the leading pressure side inner wall 54 toward the outer wall 30 forming the pressure side 26.

The trailing pressure side inner wall 60 may be coupled to the second rib 58 via the first end connection 42 and may be coupled to the third rib 62 via the second end connection 46. The first and second end connections 42, 46 enable limited movement of the leading pressure side inner wall 54 towards the pressure and suction sides 26, 28, yet prevent the leading pressure side inner wall 54 from contacting pressure or suction sides 26, 28. As shown in Figure 2, the turbine airfoil 10 may include one or more one trailing standoff supports 86 extending between the trailing pressure side inner wall 60 and the outer wall 30 forming the pressure side 26 to control movement of the trailing pressure side inner wall 60 toward the outer wall 30 forming the pressure side 26. In at least one embodiment, the turbine airfoil 10 may include one or more one trailing standoff supports 86 extending from the trailing pressure side inner wall 60 toward the outer wall 30 forming the pressure side 26. In at least one embodiment, as shown in Figure 2, the trailing standoff support 86 may be formed from a first trailing standoff support 68 separated in a chordwise direction 72 from a second trailing standoff support 70. The airfoil 10 may include more than two trailing standoff supports 66 in other embodiments.

As shown in Figure 2, the suction side inner wall 52 may be formed from a leading suction side inner wall 78 extending from a first rib 56 to a second rib 58 and a trailing suction side inner wall 80 extending from the second rib 58 to a third rib 62. The leading suction side inner wall 78 may be coupled to the first rib 56 via a first end connection 82 and is coupled to the second rib 58 via the second end

connection 84. The first and second end connections 82, 84 may enable limited movement of the leading suction side inner wall 78 towards the pressure and suction sides 26, 28, yet prevent the leading suction side inner wall 78 from contacting pressure or suction sides 26, 28. As shown in Figure 2, the turbine airfoil 10 may include one or more leading standoff supports 66 extending between the leading suction side inner wall 52 and the outer wall 30 forming the suction side 28 to control movement of the leading suction side inner wall 52 toward the outer wall 30 forming the suction side 28. In at least one embodiment, the turbine airfoil 10 may include one or more leading standoff supports 66 extending from the leading pressure side inner wall 78 toward the outer wall 30 forming the suction side 28. In at least one embodiment, one or more leading standoff supports 66 may be between the leading suction side inner wall 78 and the outer wall 30 forming the suction side 28 to control movement of the leading suction side inner wall 78 toward the outer wall 30 forming the suction side 28. In at least one embodiment, one or more leading standoff supports 66 may extend from the leading suction side inner wall 78 toward the outer wall 30 forming the suction side 28.

The trailing suction side inner wall 80 may be coupled to the second rib 58 via the first end connection 82 and may be coupled to the third rib 62 via the second end connection 84. The first and second end connections 82, 84 may enable limited movement of the trailing suction side inner wall 80 towards the pressure and suction sides 26, 28, yet prevent the trailing suction side inner wall 80 from contacting pressure or suction sides 26, 28. One or more trailing standoff supports 86 may extend from the trailing suction side inner wall 80 toward the outer wall 30 forming the suction side 28 to control movement of the trailing suction side inner wall 80 toward the outer wall 30 forming the suction side 28. In at least one embodiment, as shown in Figure 2, the trailing standoff support 86 may be formed from a first trailing standoff support 68 separated in a chordwise direction 72 from a second trailing standoff support 70. The airfoil 10 may include more than two trailing standoff supports 66 in other embodiments.

As shown in Figures 7 and 8, the inner wall connection system 22 may include one or more radial movement limitation systems 90 configured to limit movement of the inner wall 18 in a spanwise direction 24. The radial movement

limitation system 90 may be formed from a first inner wall restriction surface 92 extending from the inner wall 18 and positioned radially inward of a first rib wall restriction surface 94 positioned such that the first inner wall restriction surface 92 and the first rib wall restriction surface 94 contact each other to limit movement of the inner wall 18 radially outward. The radial movement limitation system 90 may also include a second inner wall restriction surface 96 extending from the inner wall 18 and positioned radially outward of a second rib wall restriction surface 98 positioned such that the second inner wall restriction surface 96 and the second rib wall restriction surface 98 contact each other to limit movement of the at least one inner wall radially inward. As such, the radial movement limitation system 90 limits movement in a radially inward direction and limits movement in a radially outward direction. The radial movement limitation system 90 of the inner wall connection system 22 may be included on one or more, or all of the first and second end connections 42, 46 of the pressure side inner wall 50 and the first and second end connections 82, 84 of the suction side inner wall 52.

In at least one embodiment of the radial movement limitation system 90, as shown in Figure 7, a first inner wall lug 100 may extend from the inner wall 18 and may contain the first inner wall restriction surface 92 and the second inner wall restriction surface 96. A first outer lug 102 may include the first rib wall restriction surface 94 and may be positioned radially outward of the first inner wall lug 100. A second outer lug 104 may include the second rib wall restriction surface 98 and may be positioned radially inward of the first inner wall lug 100.

In another embodiment of the radial movement limitation system 90, as shown in Figure 7, a first inner wall lug 100 may extend from the inner wall 18 and may contain the first inner wall restriction surface 92. A second inner wall lug 106 may extend from the inner wall 18 and may contain the second inner wall restriction surface 96. A first outer lug 102 may include the first rib wall restriction surface 94 and the second rib wall restriction surface 98. The first outer lug 102 may extend at least partially between the first and second inner wall lugs 100, 106.

In an embodiment of the inner wall connection system 22, as shown in Figures 3 and 8, the first end connection 42, 82 may be formed from a first receiver spanwise extending slot 110 receiving the first inner wall 18. The first receiver

spanwise extending slot 110 may be formed from a first retaining protrusion 112 on a first side 114 of the inner wall 18 and a second retaining protrusion 116 on a second side 118 of the inner wall 18. The first retaining protrusion 112 and the second retaining protrusion 116 forming the first receiver spanwise extending slot 110 may
5 extend from the first rib 56.

In another embodiment of the inner wall connection system 22, as shown in Figures 4 and 9, the first end connection 42, 82 may be formed from a first receiver spanwise extending slot 110 positioned between first and second arms 120, 122 extending from the inner wall 18. The first receiver spanwise extending slot 110
10 formed from the first and second arms 120, 122 may be sized to receive a protrusion 124. In at least one embodiment, the protrusion 124 extends from the first rib 56. These configurations of the radial movement limitation system 90 transfer centrifugal loads of the inner walls to the other aspects of the airfoil 32. In at least one embodiment, the lugs in the first and second end connections 42, 46, fit between
15 corresponding lugs in the mating part of the joint to provide radial fixity of the inner walls 18. In configurations where the radial movement limitation system 90 is not used, the centrifugal loads of the inner walls will be carried by the tip 134 of the blade 32 at the location where the inner walls 18 rest against the tip 134.

In another embodiment of the inner wall connection system 22, as shown in
20 Figures 5 and 10, the first receiver spanwise extending slot 110 may be formed as a dovetail receiver 126. The protrusion 124 may be formed as a dovetail 128 with first and second sides 114, 118 that are nonparallel and nonorthogonal to form a dovetail having a base 130 that is narrower than an outer tip 132. The dovetail receiver 126 may have clearance with the inner walls 18 but the joint may tighten up at operating
25 temperatures because of the higher thermal growth of the outer walls 30. Such configuration will minimize leakage of the cooling air that flows in the passages between the inner and outer walls 18, 30. In at least one embodiment, one or more, or all, of the connections of the inner wall connection system 22 may be configured with the dovetail receiver 126 and the dovetail 128. In another embodiment, the
30 dovetail receiver 126 and the dovetail 128 may only be used as the first and second end connections 42, 46.

During use, the inner wall 18 is positioned within the generally elongated hollow airfoil 32, but the inner wall 18 is structurally free from the outer wall 30, which greatly reduces, if not virtually eliminates, thermal stress between the inner wall 18 and the outer wall 30. The inner wall 18 may experience significantly lower
5 temperatures than the outer wall 30 because the inner wall 18 is not exposed to direct contact with the combustor exhaust gases. Consequently, the inner wall 18 experiences significantly lower thermal growth than the outer wall 30. Because the inner wall 18 may slide relative to the outer wall 30, the inner wall 18 may not be subjected to high stresses that plague conventional inner and outer walls of airfoils in
10 which the higher thermal growth of the outer walls severely stress the cooler inner walls.

The radial movement limitation system 90 including the the first inner wall restriction surface 92, the first rib wall restriction surface 94, the second inner wall restriction surface 96 and the second rib wall restriction surface 100 may be
15 configured to retain the inner wall 18 from movement in the spanwise direction 24. Retaining the inner walls 18 with the radial movement limitation system 90 described herein may carry the centrifugal loads generated by the inner walls 18 and prevent the inner walls 18 from contacting the tip 134 of the airfoil 32. In other embodiments in which the radial movement limitation system 90 is not used, the tip 134 of the
20 airfoil 32 will carry the centrifugal loads generated by the inner walls 18.

The clearance between the inner wall 18 and the various components of the inner wall connection system 22, such as, but not limited to, the first end connections 42, 82 and the second end connections 46, 84, may be sized such that during use, the inner walls 18 may be confined by the first end connections 42, 82 and the
25 second end connections 46, 84 yet able to slide in the chordwise direction 72 and have limited movement in the spanwise direction 24. Thus, when the outer wall 30 of the airfoil 32 is exposed hot combustion exhaust gases, the outer wall 30 thermally expands but does not cause the first end connections 42, 82 and the second end connections 46, 84 or other components of the systems described
30 herein to rigidly bind the inner wall 18 in place to create thermal stress between the outer wall 30 and inner walls 18. Therefore, the clearances between the first end

connections 42, 82 and the second end connections 46, 84 and the inner walls are maintained.

The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of this invention. Modifications and adaptations to these
5 embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of this invention.

CLAIMS

We claim:

1. A turbine airfoil (10), characterized in that:
 - a generally elongated hollow airfoil (32) formed from an outer wall (30), and having a leading edge (34), a trailing edge (36), a pressure side (26), a suction side (28), and a cooling system (14) positioned within interior aspects of the generally elongated hollow airfoil (32);
 - at least one midchord cooling channel (16) with at least one inner wall (18) positioned within the at least one midchord cooling channel (16) forming a nearwall cooling channel (20);
 - at least one inner wall connection system (22) formed from at least one first end connection (42) configured to limit movement of a first end (44) of the at least one inner wall (18) towards the outer wall (30) forming the generally elongated hollow airfoil (32) and formed from at least one second end connection (46) configured to limit movement of a second end (48) of the at least one inner wall (18) towards the outer wall (30) forming the generally elongated hollow airfoil (32).
2. The turbine airfoil (10) of claim 1, characterized in that the at least one inner wall (18) is formed from a material having a higher melting temperature than a melting point of a material forming the outer wall (30) of the generally elongated hollow airfoil (32).
3. The turbine airfoil (10) of claim 1, characterized in that the at least one inner wall (18) is formed from a pressure side inner wall (50) positioned adjacent the outer wall (30) forming the pressure side (26) of the generally elongated hollow airfoil (32) and is formed from a suction side inner wall (52) positioned adjacent the outer wall (30) forming the suction side (28) of the generally elongated hollow airfoil (32).
4. The turbine airfoil (10) of claim 3, characterized in that the pressure side inner wall (50) is formed from a leading pressure side inner wall (54) extending

from a first rib (56) to a second rib (58) and a trailing pressure side inner wall (60) extending from the second rib (58) to a third rib (62).

5. The turbine airfoil (10) of claim 4, characterized in that the leading pressure side inner wall (54) is coupled to the first rib (56) via the first end connection (42) and is coupled to the second rib (58) via the second end connection (46), wherein the first and second end connections (42, 46) enable limited movement of the leading pressure side inner wall (54) towards the pressure and suction sides (26, 28), yet prevent the leading pressure side inner wall (54) from contacting pressure or suction sides (26, 28).

6. The turbine airfoil (10) of claim 5, further characterized in that at least one leading standoff support (66) extending from the leading pressure side inner wall (54) toward the outer wall (30) forming the pressure side (26) to control movement of the leading pressure side inner wall (54) toward the outer wall (30) forming the pressure side (26).

7. The turbine airfoil (10) of claim 4, characterized in that the trailing pressure side inner wall (60) is coupled to the second rib (58) via the first end connection (42) and is coupled to the third rib (62) via the second end connection (46), wherein the first and second end connections (42, 46) enable limited movement of the leading pressure side inner wall (54) towards the pressure and suction sides (26, 28), yet prevent the leading pressure side inner wall (54) from contacting pressure or suction sides (26, 28).

8. The turbine airfoil (10) of claim 7, further characterized in that at least one trailing standoff support (86) extending from the trailing pressure side inner wall (60) toward the outer wall (30) forming the pressure side (26) to control movement of the trailing pressure side inner wall (60) toward the outer wall (30) forming the pressure side (26).

9. The turbine airfoil (10) of claim 3, wherein the suction side inner wall (52) is formed from a leading suction side inner wall (78) extending from a first rib (56) to a second rib (58) and a trailing suction side inner wall (80) extending from the second rib (58) to a third rib (62).

10. The turbine airfoil (10) of claim 9, characterized in that the leading suction side inner wall (78) is coupled to the first rib (56) via a first end connection (42) and is coupled to the second rib (58) via a second end connection (46), wherein the first and second end connections (42, 46) enable limited movement of the leading suction side inner wall (78) towards the pressure and suction sides (26, 28), yet prevent the leading suction side inner wall (78) from contacting pressure or suction sides (26, 28).

11. The turbine airfoil (10) of claim 10, further characterized in that at least one leading standoff support (66) extending from the leading suction side inner wall (78) toward the outer wall (30) forming the suction side (28) to control movement of the leading suction side inner wall (78) toward the outer wall (30) forming the suction side (28).

12. The turbine airfoil (10) of claim 9, characterized in that the trailing suction side inner wall (80) is coupled to the second rib (58) via the first end connection (42) and is coupled to the third rib (62) via the second end connection (46), wherein the first and second end connections (42, 46) enable limited movement of the trailing suction side inner wall (80) towards the pressure and suction sides (26, 28), yet prevent the trailing suction side inner wall (80) from contacting pressure or suction sides (26, 28).

13. The turbine airfoil (10) of claim 12, further characterized in that at least one trailing standoff support (86) extending from the trailing suction side inner wall (80) toward the outer wall (30) forming the suction side (28) to control movement of the trailing suction side inner wall (80) toward the outer wall (30) forming the suction side (28).

14. The turbine airfoil (10) of claim 1, characterized in that the at least one inner wall connection system (22) further comprises at least one radial movement limitation system (90) configured to limit movement of the at least one inner wall (18) in a spanwise direction (24).

15. The turbine airfoil (10) of claim 14, characterized in that the at least one radial movement limitation system (90) is formed from a first inner wall restriction surface (92) extending from the inner wall (18) and positioned radially inward of a first rib wall restriction surface (94) positioned such that the first inner wall restriction surface (92) and the first rib wall restriction surface (94) contact each other to limit movement of the at least one inner wall (18) radially outward and wherein the at least one radial movement limitation system (90) is formed from a second inner wall restriction surface (96) extending from the inner wall (18) and positioned radially outward of a second rib wall restriction surface (98) positioned such that the second inner wall restriction surface (96) and the second rib wall restriction surface (98) contact each other to limit movement of the at least one inner wall (18) radially inward.

16. The turbine airfoil (10) of claim 15, characterized in that a first inner wall lug (100) extends from the inner wall (18) and contains the first inner wall restriction surface (92) and the second inner wall restriction surface (96), wherein a first outer lug (102) includes the first rib wall restriction surface (94) and is positioned radially outward of the first inner wall lug (100) and wherein a second outer lug (104) includes the second rib wall restriction surface (98) and is positioned radially inward of the first inner wall lug (100).

17. The turbine airfoil (10) of claim 15, characterized in that a first inner wall lug (100) extends from the inner wall (18) and contains the first inner wall restriction surface (92), wherein a second inner wall lug (106) extends from the inner wall (18) and contains the second inner wall restriction surface (96), wherein a first outer lug (102) includes the first rib wall restriction surface (94) and the second rib

wall restriction surface (98) and wherein the first outer lug (102) extends at least partially between the first and second inner wall lugs (100, 106).

18. The turbine airfoil (10) of claim 1, characterized in that the at least one first end connection (42) is formed from a first receiver spanwise extending slot (110) receiving the first inner wall, wherein the first receiver spanwise extending slot (110) is formed from a first retaining protrusion (112) on a first side (114) of the inner wall (18) and a second retaining protrusion (116) on a second side (118) of the inner wall (18).

19. The turbine airfoil (10) of claim 1, characterized in that the at least one first end connection (42) is formed from a first receiver spanwise extending slot (110) positioned between first and second arms (120, 122) extending from the first rib (56), wherein the first receiver spanwise extending slot (110) formed from the first and second arms (120, 122) is sized to receive a protrusion (124).

20. The turbine airfoil (10) of claim 19, characterized in that the first receiver spanwise extending slot (110) is formed as a dovetail receiver (126) and wherein the protrusion (124) is formed as a dovetail (128) with first and second sides (114, 118) that are nonparallel and nonorthogonal to form a dovetail (128) having a base (130) that is narrower than an outer tip (132).

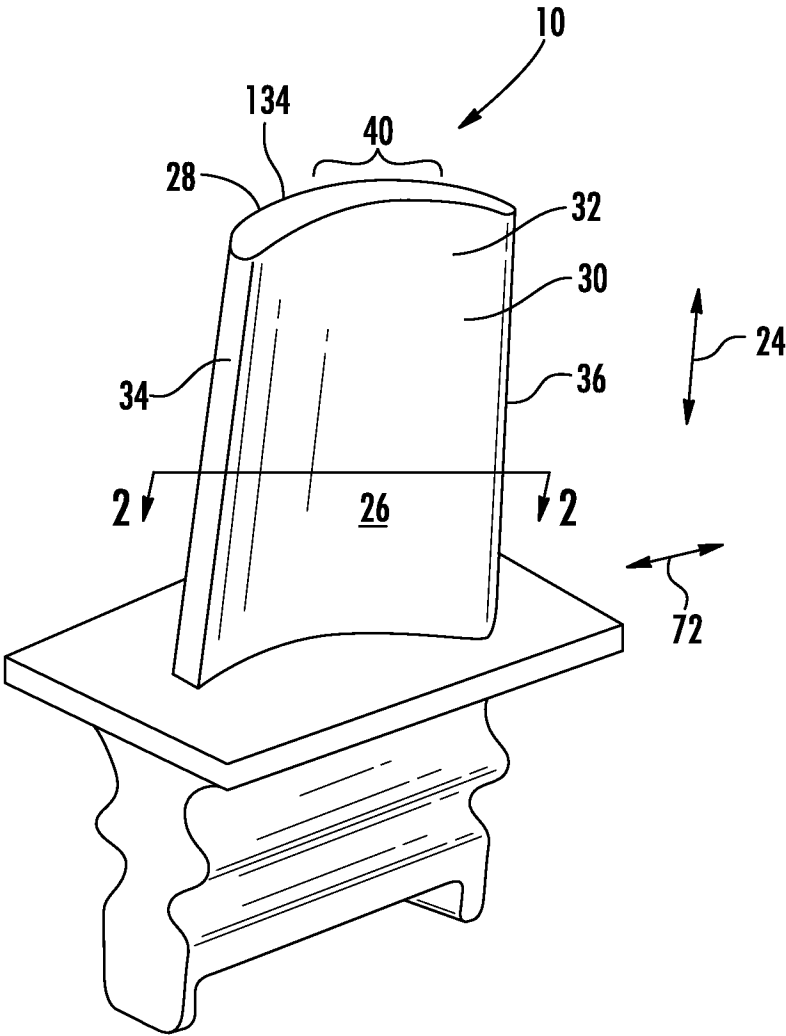
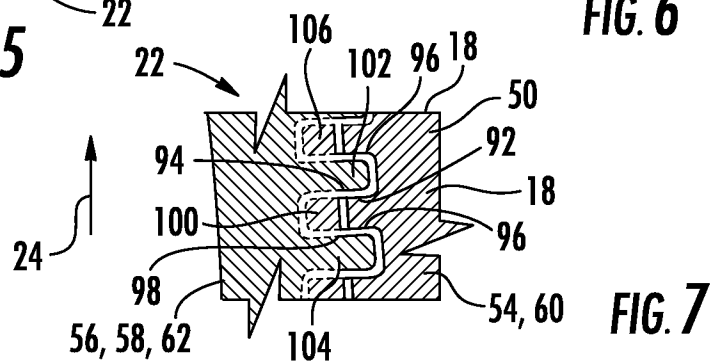
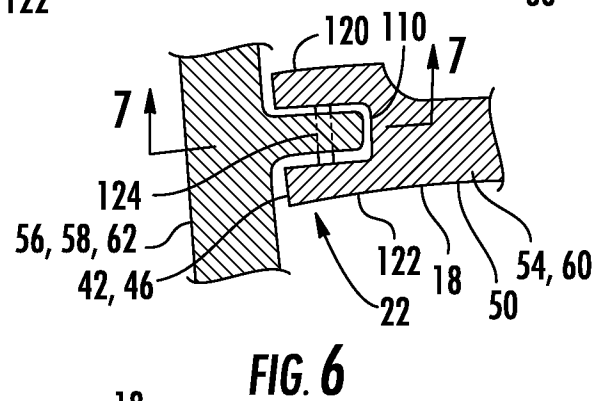
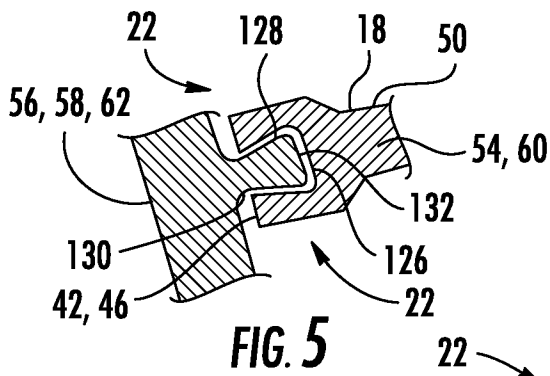
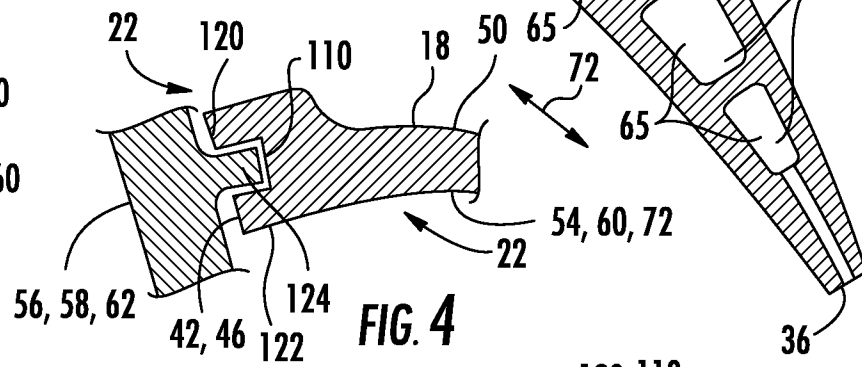
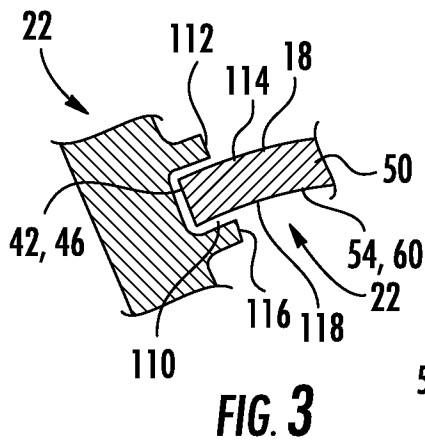
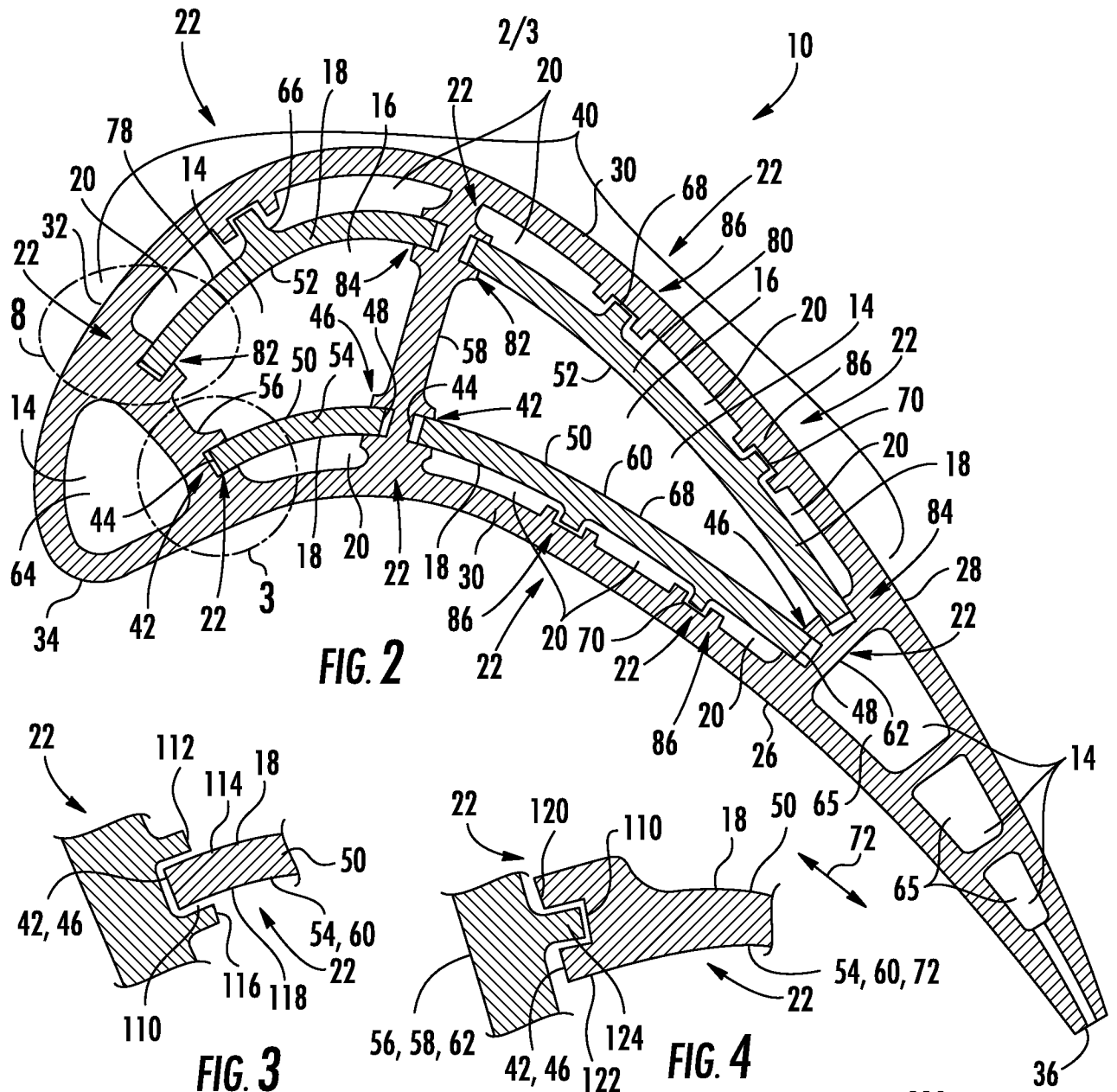


FIG. 1



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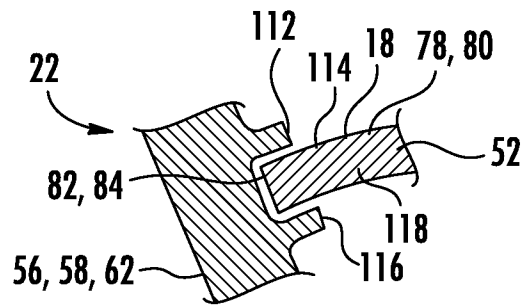


FIG. 8

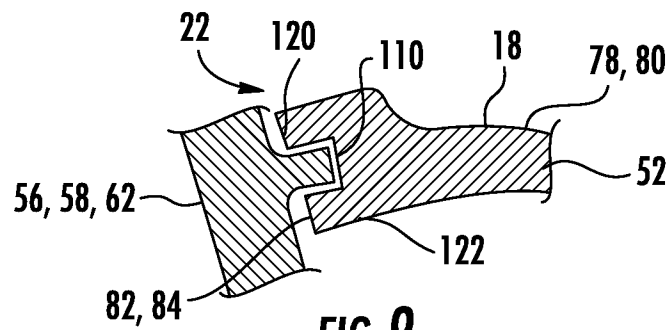


FIG. 9

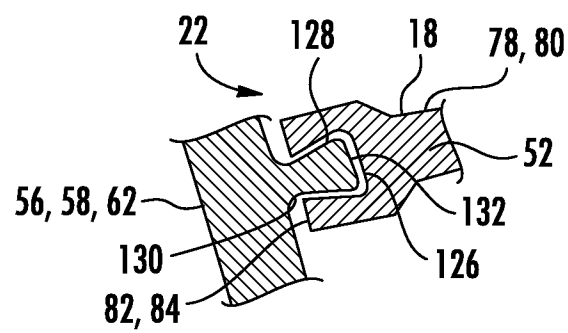


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/020921

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D5/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	----- GB 2 242 941 A (ROLLS ROYCE PLC [GB]) 16 October 1991 (1991-10-16) abstract; figure 3	1-20
X	----- EP 1 221 538 A2 (GEN ELECTRIC [US]) 10 July 2002 (2002-07-10) abstract; figure 3	1-20
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Y	abstract; figures 2,4,11,15,17,18 ----- -/-	3-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

1 December 2015

Date of mailing of the international search report

10/12/2015

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/020921

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	paragraph [0024]; figure 4 -----	3-20
Y	US 8 684 668 B1 (JONES RUSSELL B [US] ET AL) 1 April 2014 (2014-04-01) abstract; claims 1,4,7; figures 1,4,7,14,25,27 -----	3-20

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Information on patent family members

International application No

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