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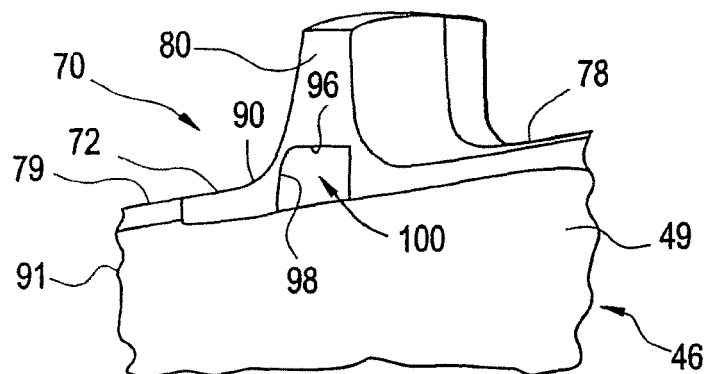
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(54) **Shroud assembly for a turbomachine**

(57) A rotating assembly (31) for a turbomachine (2) includes a plurality of rotating members (46) that extend radially outward from a central hub (47). Each of the plurality of rotating members (46) includes a base portion (48) detachably mounted to the central hub (47), a tip portion (49), a mid-span portion (50) that extends between the base portion (48) and the tip portion (49), and a shroud portion (60, 70) positioned at one of the tip por-

tion (49) and the mid-span portion (50). The shroud portion (60, 70) includes a pressure side (73) and a suction side (72). At least one hard face interface member (100, 120) is secured to at least one of the suction side (72) and the pressure side (73) of the shroud portion (60, 70). The at least one hard face interface member (100, 120) is both mechanically interlocked with, and metallurgically bonded to, the shroud portion (60, 70).

FIG. 4



Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to the art of turbomachines and, more particularly, to a rotating assembly for a turbomachine.

[0002] Turbomachines employ a number of rotating components or assemblies. Turbines, for example, employ compressor stages and turbine stages that rotate at high speed when the turbine is in operation. In general, a stage includes a plurality of free-floating blades that extend radially outward from a central hub. Some blades include a shroud that limits vibration within a stage. The shroud is typically positioned at a tip portion of the blade, a mid portion of the blade or at both the mid portion and the tip portion of the blade. The shrouds are designed such that at high or operational speeds, the free-floating blades interlock to form an integral rotating member. At lower speeds, such as on turbine turning gear, the blades do not interlock and will often times impact one another. Impacts between the blades can cause damage that will shorten service life of the turbomachine.

[0003] In order to minimize damage resulting from blade impacts, a hard face coating is applied to potential contact points. The hard face coating increases wear resistance of the potential contact points to increase both impact resistance and durability. Conventionally, the hard face coating is metallurgically bonded to the blade through, for example, a welding or brazing process. Using a welding process to bond the hard face interface to the blade inherently produces a great deal of localized heat which, if not properly controlled, can weaken the impact resistance and other metallurgical properties at the interface of the materials being joined. Excessive heat can also cause cracking in adjacent material during manufacture. Of particular concern is maintaining integrity in a Z-notch radius portion of the blade. The z-notch radius portion is subjected to high stresses and therefore subject to cracking causing a release of material. An additional failure mechanism can occur during high speed operation when tension and/or shear forces develop that over-stress the metallurgical bond. Over time, the metallurgical bond can fail and the hard face coating is released from the blade becoming foreign object debris (FOD) in the turbomachine. FOD flying around the turbomachine can damage the rotating components as well as inner surfaces of the turbine and lead to engine failure.

BRIEF DESCRIPTION OF THE INVENTION

[0004] In accordance with one exemplary embodiment of the present invention, a rotating assembly for a turbomachine includes a central hub and a plurality of rotating members that extend radially outward from a central hub. Each of the plurality of rotating members includes a base portion detachably mounted to the central hub, a tip portion, and a mid-span portion that extends

between the base portion and the tip portion. Each of the plurality of rotating members also includes a shroud portion that is positioned at one of the tip portion and the mid-span portion. The shroud portion includes a pressure side and a suction side. At least one hard face interface member is secured to at least one of the suction side and the pressure side of the shroud portion. The at least one hard face interface member is both mechanically interlocked with, and metallurgically bonded to, the shroud portion.

[0005] In accordance with another exemplary embodiment of the present invention, a method of securing a hard face interface member to a shroud portion of a rotating member for a turbomachine includes forming a rotating member having a base portion, a mid-span portion and a tip portion. A shroud portion is formed on at least one of the mid-span portion and the tip portion of the rotating member. The shroud portion includes a pressure side and a suction side. A hard face interface member is secured with both a mechanical interlock and a metallurgical bond to at least one of the pressure side and the suction side of the shroud portion.

[0006] There follows a detailed description of embodiments of the invention by way of example only with reference to the drawings, in which:

FIG. 1 is a partial, cross-sectional schematic illustration of a turbomachine including a rotating assembly constructed in accordance with an exemplary embodiment of the present invention;

FIG. 2 is a partial perspective view of a rotating assembly including a plurality of rotating components constructed in accordance with an exemplary embodiment of the present invention;

FIG. 3 is a perspective view of a rotating component of FIG. 2 including a tip shroud and a mid-span shroud;

FIG. 4 is a partial side view of a suction side of the tip shroud of FIG. 3 illustrating a hard face interface member mounted within a cavity formed in the tip shroud in accordance with an exemplary embodiment of the present invention;

FIG. 5 is a partial bottom view of the suction side of the tip shroud illustrated in FIG. 4 showing a plurality of dimples formed in the cavity for mechanically interlocking the hard face interface member;

FIG. 6 is a partial side view of a pressure side of the tip shroud of FIG. 3 illustrating a hard face interface member received within a cavity formed in the tip shroud in accordance with an exemplary embodiment of the present invention;

FIG. 7 is a partial bottom view of the pressure side

of the tip shroud illustrated in FIG 6 showing a plurality of dimples formed in the cavity for mechanically interlocking the hard face interface member;

FIG. 8 is a partial bottom view of the suction side of the tip shroud illustrated in FIG. 5 showing a plurality of continuous protuberances provided in the cavity for mechanically interlocking the hard face interface member;

FIG. 9 is a partial bottom view of the suction side of the tip shroud illustrated in FIG. 5 showing a plurality of continuous grooves formed in the cavity for mechanically interlocking the hard face interface member;

FIG. 10 is a partial bottom view of the suction side of the tip shroud illustrated in FIG. 5 showing a plurality of discontinuous grooves provided in the cavity for mechanically interlocking the hard face interface member;

FIG. 11 is a partial bottom view of the suction side of the tip shroud illustrated in FIG. 5 showing a plurality of discontinuous protuberances formed in the cavity for mechanically interlocking the hard face interface member;

FIG. 12 is a detail view of a suction side of the tip shroud of FIG 4 illustrating a cavity having a plurality of continuous protuberances for mechanically interlocking the hard face interface member in accordance with another exemplary embodiment of the present invention;

FIG. 13 is a detail view of a suction side of the tip shroud of FIG 4 illustrating a cavity having a plurality of discontinuous protuberances for mechanically interlocking the hard face interface member in accordance with yet another exemplary embodiment of the present invention;

FIG. 14 is a detail view of a suction side of the tip shroud of FIG 4 illustrating a cavity having a plurality of continuous grooves for mechanically interlocking the hard face interface member in accordance with still another exemplary embodiment of the present invention; and

FIG. 15 is a detail view of a suction side of the tip shroud of FIG 4 illustrating a cavity having a plurality of discontinuous grooves for mechanically interlocking the hard face interface member in accordance with a still further exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0007] With initial reference to FIGS. 1 and 2 a turbomachine, shown in the form of a gas turbine engine, constructed in accordance with an exemplary embodiment of the present invention is indicated generally at 2. Engine 2 includes a compressor 4 and a plurality of combustor assemblies arranged in a can annular array, one of which is indicated at 8. As shown, combustor assembly 8 includes an endcover assembly 9 that seals, and at least partially defines, a combustion chamber 12. A plurality of nozzles 14-16 are supported by endcover assembly 9 and extend into combustion chamber 12. Nozzles 14-16 receive fuel through a common fuel inlet (not shown) and compressed air from compressor 4. The fuel and compressed air are passed into combustion chamber 12 and ignited to form a high temperature, high pressure combustion product or air stream that is used to drive a turbine 30. Turbine 30 includes a plurality of rotating assemblies or stages 31-33 that are operationally connected to compressor 4 through a compressor/turbine shaft 34 (sometimes referred to as a rotor).

[0008] In operation, air flows into compressor 4 and is compressed into a high pressure gas. The high pressure gas is supplied to combustor assembly 8 and mixed with fuel, for example process gas and/or synthetic gas (syn-gas), in combustion chamber 12. The fuel/air or combustible mixture ignited to form a high pressure, high temperature combustion gas stream of approximately 538 degrees Celsius (°C) to 1593 °C (1000 degrees Fahrenheit (°F) to 2900 °F). Alternatively, combustor assembly 8 can combust fuels that include, but are not limited, to natural gas and/or fuel oil. In any event, combustor assembly 8 channels the combustion gas stream to turbine 30 which converts thermal energy to mechanical, rotational energy.

[0009] At this point it should be understood that each rotating assembly or stage 31-33 is similarly formed, thus reference will be made to FIGS. 2-3 in describing stage 31 constructed in accordance with an exemplary embodiment of the present invention with an understanding that the remaining stages, i.e., stages 32 and 33 have corresponding structure. Also it should be understood that the present invention could be employed in stages in compressor 4 or other rotating assemblies that require impact resistant surfaces. In any event, stage 31 is shown to include a plurality of rotating members, one of which is indicated at 46, which extend radially outward from a central hub 47. As best shown in Fig. 3, rotating member 46 includes a base portion 48, a tip portion 49 and a mid-span portion 50 that extends between base portion 48 and tip portion 49. In the exemplary embodiment shown, rotating member 46 includes a first or mid-span shroud 60 having a first or suction side 63 and a second or pressure side 64. Rotating member 46 is also shown to include a second or tip shroud 70 having a first or suction side 72 and a second or pressure side 73. In addition, tip shroud 70 includes first and second opposing wing

members 78 and 79 and a third wing member 80. Third wing member 80 extends perpendicularly relative to first and second wing members 78 and 79.

[0010] Tip shroud 70 covers a bucket or throat portion (not separately labeled) of rotating member 46. Tip shroud 70 is designed to receive, or nest with, tip shrouds on adjacent rotating members in order to form a continuous ring 81 that extends circumferentially about stage 31. Continuous ring 81 creates an outer flow path boundary that reduces gas path air leakage over top portions (not separately labeled) of stage 31 so as to increase stage efficiency and overall turbine performance. In a similar manner, mid-span shroud 60 is configured to receive, or nest within, mid-span shrouds on adjacent rotating members to form an inner ring indicated generally at 82 that further increases stage efficiency. At this point, it should be recognized that while rotating member 46 is shown with both mid-span shroud 60 and tip-shroud 70, each rotating member could alternatively be provided with a single shroud positioned either at tip portion 49 or mid-span portion 50. In the exemplary embodiment shown, during high or operational speeds, adjacent rotating members 46 interlock through mid-span shroud 60 and tip-shroud 70 by virtue of centrifugal forces created by the operation of turbine 30. However, during lower speeds such as, during turbine turning gear, the rotational force is not sufficient to establish the interlock and thus, often times adjacent rotating members impact one another. The impacts can create wear on the rotating members thereby lowering an overall service life of turbine 30. Towards that end, each mid-span shroud 60 and tip-shroud 70 is provided with a wear resistant/impact resistant member in a manner that will be described more fully below.

[0011] Reference will now be made to FIGS. 4 and 5 in describing suction side 72 of tip shroud 70. As shown, suction side 72 includes a first surface 90 and an opposing second surface 91. Second surface 91 includes a recess or cavity 94 having a base portion 96 and a peripheral wall portion 98. With this configuration, a hard face interface member 100, that in accordance with an exemplary embodiment of the present invention is formed from a pre-sintered, preformed (PSP) material, is positioned within cavity 94.

[0012] Hard face interface member 100 is mechanically interlocked with, and metallurgically bonded to, suction side 72 to provide an impact and wear resistant surface for tip shroud 70. In accordance with one aspect of the invention, hard face interface member 100 is positioned within cavity 94 and brazed to tip shroud 70. In this manner, cavity 94 provides a mechanical interlock, and brazing provides a metallurgical bond to tip shroud 70. The mechanical interlock at an outer radial position or z-notch radius portion of hard face interface member 100 establishes a secondary bond that resists compressive or tensile (depending of the relative position on tip-shroud 70) forces developed during the operation of stage 31. The mechanical interlock supplements the metallurgical bond

provided by brazing in order to create a more robust load path to establish a fail-safe attachment/retention mechanism for hard face interface member 100. In accordance with another aspect of the present invention, cavity 94 is provided with a plurality of surface elements, which, in the exemplary embodiment shown, take the form of dimples or indentations 105 formed on a base portion 96. Indentations 105 increase an overall surface area of cavity 94 so as to establish a more robust mechanical interlock for hard face interface member 100. In any event, after being mechanically interlocked with, and metallurgically bonded to tip shroud 70, hard face interface member 100 is machined so as to be substantially flush with second surface 91 to provide an overall finish for tip-shroud 70 that reduces localized airflow turbulences.

[0013] Reference will now be made to FIGS. 6 and 7 in describing pressure side 73 of tip shroud 70. In a manner similar to that described above, pressure side 73 includes a first surface 110 and an opposing second surface 111. Second surface 111 includes a recess or cavity 114 having a base portion 116 and a peripheral wall portion 118. A hard face interface member 120 is positioned within cavity 114. Hard face interface member 120, in accordance with an exemplary embodiment of the present invention, is formed from a PSP material and is mechanically interlocked with, and metallurgically bonded to, pressure side 73 to provide another impact and wear resistant surface for tip shroud 70. In a manner also similar to that described above, hard face interface member 120 is positioned within cavity 114 and brazed to tip shroud 70 to establish a metallurgical bond. In this manner, cavity 114 provides a mechanical interlock, and brazing provides a metallurgical bond to tip shroud 70. Recess 114 also includes a plurality of surface elements, which in the exemplary embodiment shown, take the form of dimples or indentations 124 formed on base portion 116. Indentations 124 increase an overall surface area of base portion 116 to increase the overall strength of the mechanical interlock. In any event, after being mechanically linked to, and metallurgically bonded with tip shroud 70, hard face interface member 120 is machined so as to be substantially flush with second surface 111 to provide an overall finish for tip-shroud 70 that reduces localized airflow turbulences.

[0014] At this point, it should also be understood that mid-span shroud 60 includes a first hard face interface member 130 positioned within a recess (not separately labeled) formed on suction side 63 and a second hard face interface member 140 provided within a recess (not separately labeled) provided on pressure side 64. With this arrangement, hard face interface members 100, 120, 130 and 140 provide localized wear/impact resistant surface enhancements that remain secured to rotating member 46 during the operation of stage 31. That is, the combination of the mechanical link or interlock and the metallurgical bond provides a fail-safe multiple-load path, attachment/retention mechanism that is resistant to multiple directional loading for hard face interface member

100. Moreover, the addition of the mechanical interlock provides a bond that makes up for any diminished metallurgical properties (most notable of which is impact resistance) of rotating member 46 created through the application of heat established during brazing. It should be understood that in addition to dimples or indentations, various other surface elements can be employed to enhance bonding between the hard face interface member and the blade. For example, FIG. 8 illustrates a plurality of continuous protuberances 200 arranged on base portion 96. FIG. 9 illustrates a plurality of continuous grooves 210 formed in base portion 96. FIG. 10 depicts base portion 96 with a plurality of discontinuous grooves 220 while FIG. 11 shows base portion 96 with a plurality of discontinuous or segmented protuberances 230. In any case, it should be apparent that various elements can be employed to enhance the mechanical bond between the hard face interface member and the blade.

[0015] Moreover, in addition to cavities 94 and 114, Tip and/or mid span shroud 70 and 60 can include a machined cavity or recess 300 having a radius portion 310 and a plurality of continuous protuberances 320 such as shown in FIG. 12. Recess 300 is formed by removing for example, approximately 1/10 " (2.54 mm) of a face portion of suction side 72. FIG. 13 illustrates a cavity or recess 360 having a radius portion 370 formed on a face portion of suction side 72. Recess 360 includes a plurality of discontinuous protuberances 380 for mechanically interlocking a hard face interface member. FIG. 14 illustrates a cavity or recess 400 having a radius portion 410 formed in suction side 72. Recess 400 includes a plurality of continuous grooves 420 for mechanically interlocking the hard face interface member. Finally, FIG. 15 illustrates a cavity or recess 460 having a radius 470 formed in suction side 72. Recess 460 includes a plurality of discontinuous grooves 480 for mechanically interlocking the hard face interface member. Of course, it should be understood, that the particular hard face interface member would include structure corresponding to the protuberances or grooves to facilitate the mechanical interlock.

[0016] In general, this written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may be includes other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the present invention if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

Claims

1. A rotating assembly for a turbomachine (2) compris-

ing:

a central hub (47);
a plurality of rotating members (46) extending radially outward from the central hub (47), each of the plurality of rotating members (46) including:

a base portion (48) detachably mounted to the central hub (47);
a tip portion (49);
a mid-span portion (50) extending between the base portion (48) and the tip portion (49);
a shroud portion (60, 70) positioned at one of the tip portion (49) and the mid-span portion (50), the shroud portion (60, 70) including a pressure side (73) and a suction side (72); and
at least one hard face interface member (100) secured to at least one of the suction side (72) and the pressure side (73) of the shroud portion (60, 70), the at least one hard face interface member (100) being both mechanically interlocked with, and metallurgically bonded to the shroud portion.

2. The rotating assembly according to claim 1, wherein the shroud portion (60, 70) includes at least one recess (94) formed in one of the pressure side (73) and suction side (72), the hard face interface member (100) being mechanically interlocked with the shroud portion (60, 70) in the at least one recess (94).
3. The rotating assembly according to claim 2, wherein the at least one recess (94) includes a first recess (94) formed in the pressure side (73) of the shroud portion (60, 70) and a second recess (114) formed in the suction side (72) of the shroud portion (60, 70).
4. The rotating assembly according to claim 3, wherein the at least one hard face interface member (100) includes a first hard face interface member (100) mechanically interlocked with and metallurgically bonded to the shroud portion (60, 70) in the first recess (94) and a second hard face interface member (120) mechanically interlocked with and metallurgically bonded to the shroud portion in the second recess (114).
5. The rotating assembly according to claim 2, wherein the at least one recess (94) includes a base portion (96) and a peripheral wall portion (98), the base portion (96) including a plurality of surface elements (105).
6. The rotating assembly according to claim 5, wherein the plurality of surface elements (105) are indentations formed in the base portion (96).

7. The rotating assembly according to claim 1, wherein the shroud portion (60) is mounted to the mid-span portion (50) of each of the plurality of rotating members (46). 5
8. The rotating assembly according to claim 1, wherein the shroud portion (60, 70) is mounted to the tip portion (49) of each of the plurality of rotating members (46). 10
9. The rotating assembly according to claim 1, wherein the shroud portion (60, 70) is mounted to both the mid-span portion (50) and the tip portion (49) of each of the plurality of rotating members (46). 15
10. The rotating assembly according to claim 1, wherein the hard face interface member (100, 120) is formed from a pre-sintered preformed material. 20
11. A method of securing a hard face interface member to a shroud portion of a rotating member for a turbomachine, the method comprising: 25
- forming a rotating member including a base portion, a mid-span portion and a tip portion; 25
- forming a shroud portion on at least one of the mid-span portion and the tip portion of the rotating member, the shroud portion including a pressure side and a suction side; and 30
- securing a hard face interface member to at least one of the pressure side and the suction side of the shroud portion, the hard face interface member being both mechanically interlocked with, and metallurgically bonded to, the shroud portion. 35
12. The method of claim 11, further comprising: 40
- forming at least one recess in the one of the pressure side and the suction side of the shroud portion; and 40
- securing the hard face interface member to the shroud portion at the recess.
13. The method of claim 11 or 12, further comprising: 45
- brazing the hard face interface member in the recess formed in the one of the pressure side and the suction side of the shroud portion to secure the hard face interface member to the shroud portion. 50
14. The method of claim 13, further comprising: 55
- machining the hard face interface member to establish a final finish. 55
15. The method of any of claims 11 to 14, further comprising: 55
- forming a plurality of indentations within the recess formed in the one of the pressure side and the suction side of the shroud portion, the indentations providing additional surface area in the recess to strengthen the mechanical interlock.

FIG. 1

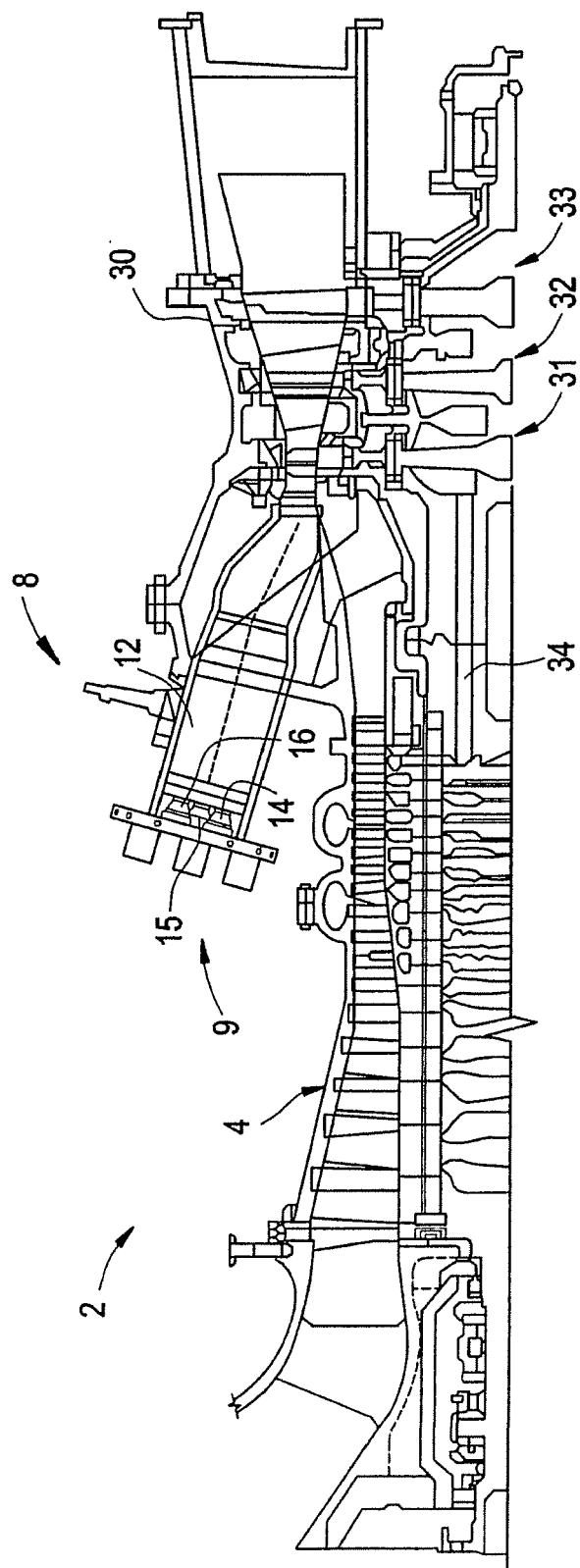


FIG. 2

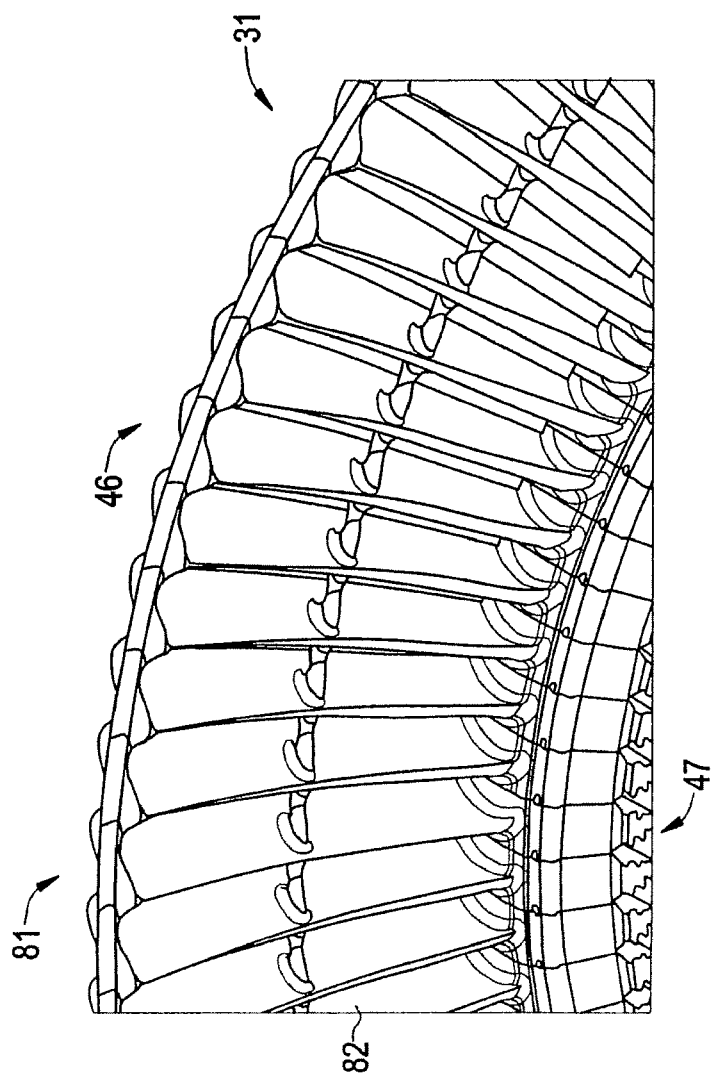


FIG. 3

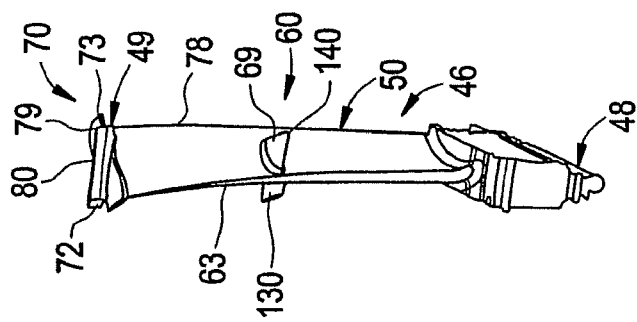


FIG. 4

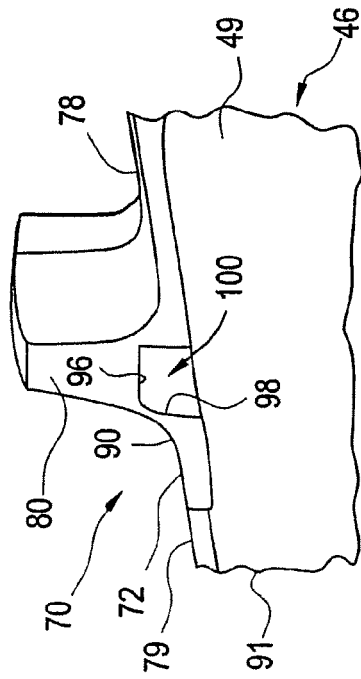


FIG. 5

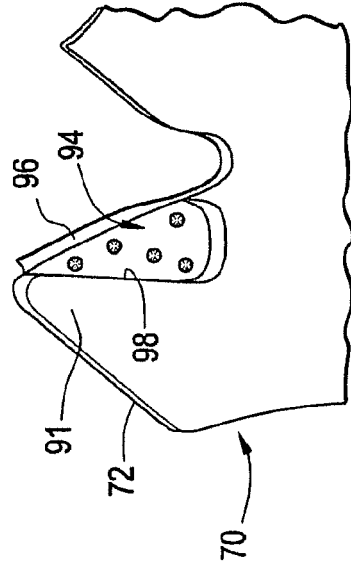


FIG. 6

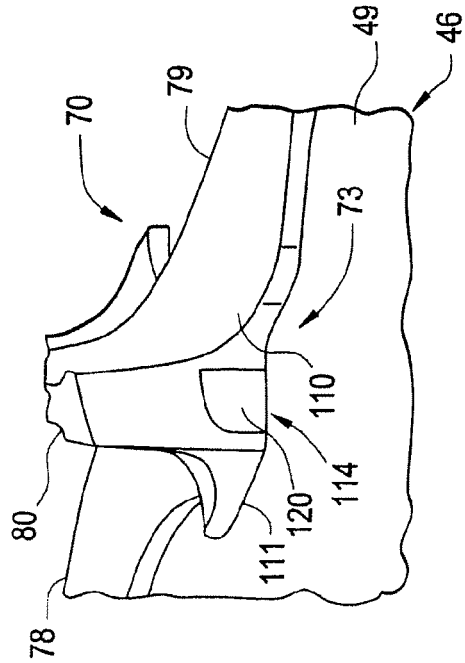


FIG. 7

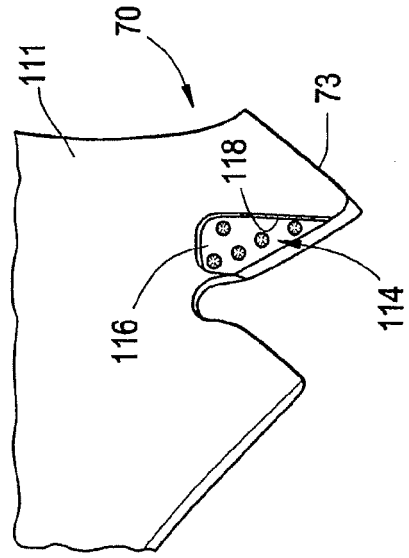


FIG. 8

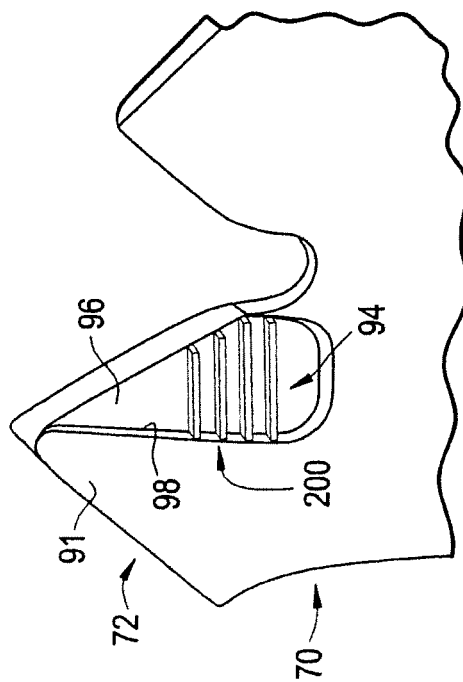


FIG. 9

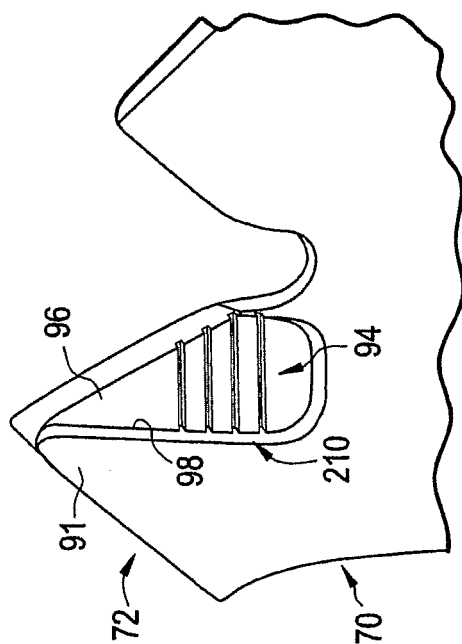


FIG. 10

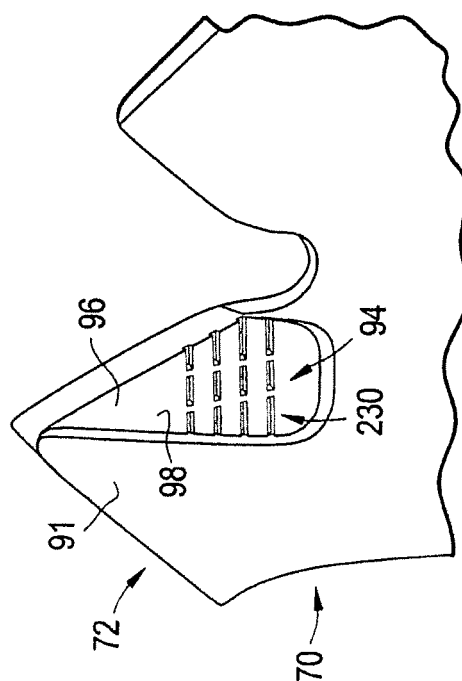
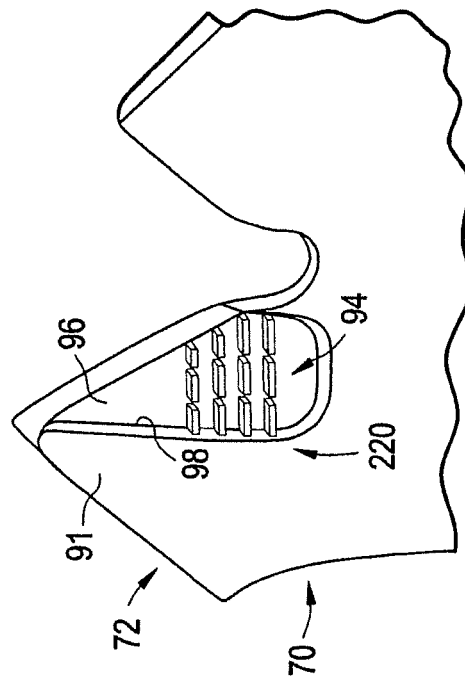


FIG. 11



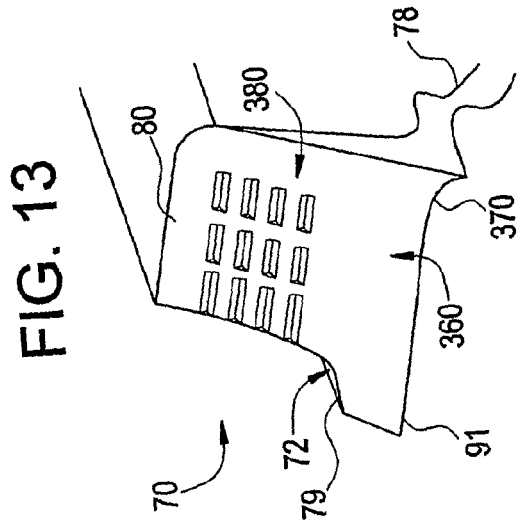


FIG. 15

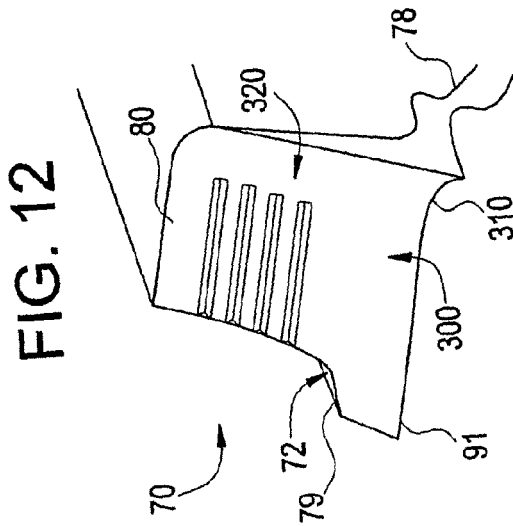
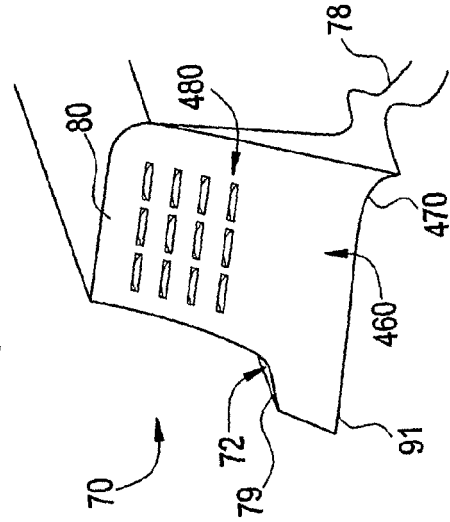


FIG. 14

