(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 900 907 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.03.2008 Bulletin 2008/12

(51) Int Cl.:
F01D 11/22 *(2006.01)*

(21) Application number: **07113096.7**

(22) Date of filing: **25.07.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **08.09.2006 US 518018**

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(54) **Turbine blade tip gap reduction system for a turbine engine**

(57) A turbine blade gap control system (10) configured to move a vane carrier (22) and attached ring segments (16) of a turbine engine (18) axially relative to a turbine blade assembly (28) to reduce the gaps (12) between the tips (20) of the turbine blades (14) and the ring segments (16) to increase the efficiency of the turbine engine (18) once operating in a steady state condition. The turbine blade assembly (28) may be formed from a plurality rows (30) of turbine blades (14) extending radially from a rotor (32), wherein each row (30) may be formed from a plurality of turbine blades (14) and wherein the turbine blades (14) may have tips (20) positioned at an acute angle (24) relative to a rotational axis (26) of the turbine blade assembly (28). A vane carrier (22) may be positioned concentric with the rotor (32) and positioned radially outward from the turbine blades (14), and a plurality of ring segments (16) may be attached to the vane carrier (22).

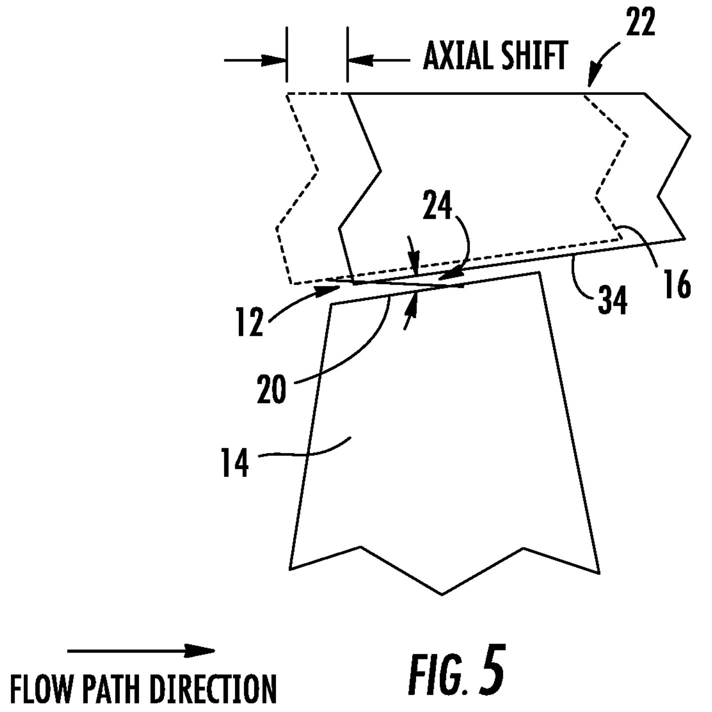

FIG. 5

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Description

FIELD OF THE INVENTION

[0001] This invention is directed generally to turbine engines, and more particularly to systems for reducing the gap between the tips of rotatable turbine blades attached to a rotary turbine blade assembly and ring segments attached to a vane carrier when the turbine engine is operating at steady state conditions.

BACKGROUND

[0002] 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 configurations expose turbine blade assemblies to these high temperatures. As a result, turbine blades must be made of materials capable of withstanding such high temperatures. Turbine blades and other components often contain cooling systems for prolonging the life of the blades and reducing the likelihood of failure as a result of excessive temperatures.

[0003] Turbine blades typically extend radially from a rotor assembly and terminate at a tip within close proximity of the ring segments attached to a vane carrier. The ring segments may be exposed to the hot combustion gases and, similar to the turbine blades, the ring segments often rely on internal cooling systems to reduce stress and increase the life cycle. The ring segments are spaced radially from the turbine blade tips to create a gap therebetween to prevent contact of the turbine blade tips with the ring segments as a result of thermal expansion of the turbine blades. During conventional startup processes in which a turbine engine is brought from a stopped condition to a steady state operating condition, turbine blades and ring segments pass through a pinch point at which the gap between the turbine blade tips and the ring segments is at a minimal distance due to thermal expansion. The turbine blade tips of many conventional configurations contact or nearly contact the ring segments. Contact of the turbine blade tips may cause damage to the blades. Furthermore, designing the gap between the turbine blade tips and the ring segments for the pinch point often results in a gap at steady state conditions that is larger than desired because the gap and combustion gases flowing therethrough adversely affect performance and efficiency.

[0004] One conventional system includes moving the rotor axially to reduce the gap. however, moving the rotor axially within the turbine engine causes an increase in the gaps at the compressor blade tips, thereby increasing inefficiencies in the compressor. Thus, a need exists for a more effective way of enabling turbine blade tips to pass through the pinch point without contacting the ring segments, yet reduce the size of the gap at steady state operating conditions.

SUMMARY OF THE INVENTION

[0005] This invention is directed to a turbine blade gap control system for reducing a gap formed between turbine blades and ring segments in turbine engines. Reducing the gap increases the efficiency of the turbine engine by reducing the amount of combustion gases flowing around the turbine blades rather than through the blades. The turbine blade gap control system may be configured to enable the turbine engine to go through start up conditions, through a pinch point in the start up process before steady state operation where the tips of the turbine blades are closest to the ring segments and into a steady state condition. The turbine blade gap control system may be configured to reduce the size of the gap at steady state operating conditions by moving a vane carrier to which the ring segments are attached axially. Such axial movement may reduce the gap between the tips of turbine blades and ring segments in turbine engines in which the tips of the turbine blades are positioned at an acute angle relative to a rotational axis and the ring segments are positioned in a similar manner.

[0006] The turbine engine may include a turbine blade assembly formed from a plurality rows of turbine blades extending radially from a rotor. Each row may be formed from a plurality of turbine blades. The turbine blades may have tips positioned at an acute angle relative to a rotational axis of the turbine blade assembly. The turbine engine may also include a vane carrier concentric with the rotor and positioned radially outward from the turbine blades. A plurality of ring segments may be attached to the vane carrier and positioned between the vane carrier and the tips of the turbine blades in each row. An inner surface of each of the ring segments may be offset radially outward from the tips of the turbine blades creating gaps so that the turbine blades may rotate without contact. The ring segments may be positioned at an acute angle substantially equal to the acute angle at which the turbine blade tips are positioned.

[0007] The turbine engine may also include a turbine blade gap control system configured to move the vane carrier and attached ring segments axially relative to the turbine blade assembly to reduce the gaps between the tips of the turbine blades and the ring segments. In one embodiment, the turbine blade gap control system may include one or more hydraulic arms attached to the vane carrier for moving the vane carrier axially relative to the turbine blade assembly. The hydraulic arm may be attached to an outer cylinder or other turbine engine support structure positioned radially outward from the vane carrier. In one embodiment, the hydraulic arm may be formed from four hydraulic arms positioned around the outer cylinder. The hydraulic arms may be positioned generally 90 degrees from each other around the outer cylinder.

[0008] The invention may also include a method of reducing gaps between tips of turbine blades in a turbine engine and adjacent ring segments. The method may include operating a turbine engine by bringing the turbine engine to a steady state operating condition and reducing the gaps between the tips of the turbine blades and the ring segment by using the turbine blade gap control system to move the vane carrier axially relative to the turbine blade assembly. Operating a turbine engine may include using a turbine blade gap control system including one or more hydraulic arms attached to the vane carrier for moving the vane carrier axially relative to the turbine blade assembly. The hydraulic arm may be attached to an outer cylinder or other turbine engine support structure positioned radially outward from the vane carrier. In one embodiment, the hydraulic arm may include four hydraulic arms positioned around the outer cylinder and may be spaced generally 90 degrees from each other around the outer cylinder.

[0009] During use, the turbine engine may be started and brought up to a steady state operating condition. At start up, the turbine blade gap control system may have the carrier vane and attached ring segments moved axially away from the tips of the turbine blades. In this position, the turbine engine may go from start up through a pinch point at which the turbine blade tips are closest to the ring segments without contact occurring. The turbine blades and other turbine engine components may heat up to a steady state operating temperature at which the turbine blades have ceased growing due to thermal expansion. Once the steady state operating conditions are reached, the turbine blade gap control system may be used to reduce the size of the gap by moving the vane carrier axially along the rotational axis relative to the turbine blade assembly. The hydraulic arms may be used to move the vane carrier axially relative to the turbine blade assembly.

[0010] An advantage of this invention is that the turbine blade gap control system enables turbine blades to be brought through a pinch point without the turbine blade tips contacting the ring segments and enables the gaps between the turbine blades tips and the ring segments to be reduced at steady state operating conditions to increase the efficiency of the engine.

[0011] Another advantage of this invention is that the turbine blade gap control system enables the gaps between the turbine blades tips and the ring segments to be reduced at steady state operating conditions to increase the efficiency of the engine without negatively affecting the compressor. The net effect on the turbine engine is an increase in efficiency.

[0012] These and other embodiments are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] 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 cross-sectional view of a turbine engine having aspects of this invention.

Figure 2 is a partial cross-sectional view of the turbine engine shown in Figure 1 taken along line 2-2.

Figure 3 is a detailed partial cross-sectional view of a turbine blade gap control system shown in Figure 2 taken along line 3-3.

Figure 4 is a detailed view of the turbine blade assembly shown in Figure 1 along line 4-4 before vane carrier shift.

Figure 5 is a detailed view of the turbine blade assembly shown in Figure 2 along line 5-5 with the vane carrier shifted axially relative to the turbine blade assembly.

DETAILED DESCRIPTION OF THE INVENTION

[0014] As shown in Figures 1-5, this invention is directed to a turbine blade gap control system 10 for reducing a gap 12 formed between turbine blades 14 and ring segments 16 in turbine engines 18. Reducing the gap 12 increases the efficiency of the turbine engine 18 by reducing the amount of combustion gases flowing around the turbine blades 14 rather than through the blades 14. The turbine blade gap control system 10 may be configured to enable the turbine engine 18 to go through start up conditions, through a pinch point in the start up process before steady state operation where the tips 20 of the turbine blades 14 are closest to the ring segments 16 and into a steady state condition. The turbine blade gap control system 10 may be configured to reduce the size of the gap 12 at steady state operating conditions by moving a vane carrier 22 to which the ring segments 16 are attached axially. Such axial movement may reduce the gap 12 between the tips 20 of turbine blades 14 and ring segments 16 in turbine engines 18 in which the tips 20 of the turbine blades 14 are positioned at an acute angle 24 relative to a rotational axis 26 and the ring segments 16 are positioned in a similar manner.

[0015] As shown in Figure 1, the turbine engine 18 may include a turbine blade assembly 28 formed from a plurality rows 30 of turbine blades 14 extending radially outward from a rotor 32. The rotor 32 may be any conventional rotor configured to rotate about the rotational axis 26. Each row 30 may be formed from a plurality of turbine blades 14 extending radially outward from the rotor 32. The turbine blades 14 of a row may all extend substantially equal distances from the rotor 32 such that the tips 20 are positioned within close proximity of the ring segments 16, yet offset to form the gap 12. During operation, the rotor 32 rotates as combustion gases pass by the turbine blades 14.

[0016] The turbine blades 14 may have tips 20 positioned at an acute angle 24 relative to a rotational axis

26 of the turbine blade assembly 28. In at least one embodiment, as shown in Figures 1, 4 and 5, the tips 20 of the turbine blades 14 may be positioned at an acute angle 24 of about 20 degrees. The ring segments 16 may include inner surfaces 34 that are positioned at substantially at the acute angle 24 relative to the rotational axis 26. The ring segments 16 may be positioned between the vane carrier 22 and the tips 20 of the turbine blades 14 in each row, wherein an inner surface 34 of each of the ring segments 16 is offset radially outward from the tips 20 of the turbine blades 14. The ring segments 16 may be attached to the vane carrier 22. The vane carrier 22 may be concentric with the rotor 32 and positioned radially outward from the turbine blades 14. In such a position, axial movement of the vane carrier 22 causes a reduction in the size of the gap 12. In at least one embodiment, the vane carrier 22 may be move axially between about 4 millimeters and about 5 millimeters, which results in a reduction of the gap 12 of about 1 millimeter.

[0017] The turbine blade gap control system 10 may be configured to move the vane carrier 22 and attached ring segments 16 axially relative to the turbine blade assembly 28 to reduce the size of the gaps 12 between the tips 20 of the turbine blades 14 and the ring segments 16. The turbine blade gap control system 10 may be formed from any device capable of moving the vane carrier 22 relative to the turbine blade assembly 28, and in particular, relative to the tips 20 of the turbine blades 14. In at least one embodiment, as shown in Figures 2 and 3, the turbine blade gap control system 10 may comprise at least one hydraulic arm 36 attached to the vane carrier 22 for moving the vane carrier 22 axially relative to the turbine blade assembly 28. The hydraulic arm 36 may be attached to an outer cylinder 38 or other support structure positioned radially outward from the vane carrier 22. As shown in Figure 3, the hydraulic arm 36 may include four hydraulic arms 36 positioned around the outer cylinder 38. The hydraulic arms 36 may be positioned generally 90 degrees from each other around the outer cylinder 38. In other embodiments, the turbine blade gap control system 10 may include other numbers of hydraulic arms 36, and the hydraulic arms may be positioned in other configurations.

[0018] During use, the turbine engine 18 may be started and brought up to a steady state operating condition. At start up, the turbine blade gap control system 10 may have the carrier vane 22 and attached ring segments 16 positioned axially away from the tips 20 of the turbine blades 14. In this position, the turbine engine 18 may go from start up through a pinch point at which the turbine blade tips 20 are closest to the ring segments 16 without contact occurring. The turbine blades 14 and other turbine engine components may heat up to a steady state operating temperature at which the turbine blades 14 have ceased thermal expansion. Once the steady state operating conditions are reached, the turbine blade gap control system 10 may be used to reduce the size of the gap 12 by moving the vane carrier 22 axially along the rotational axis 26 relative to the turbine blade assembly 28. The hydraulic arms 36 may be used to move the vane carrier 22 axially relative to the turbine blade assembly 28.

[0019] The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of this invention. Modifications and adaptations to these 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

1. A turbine engine (18), **characterized in that**:

   a turbine blade assembly (28) formed from a plurality rows (30) of turbine blades (14) extending radially from a rotor (32), wherein each row (30) is formed from a plurality of turbine blades (14) and wherein the turbine blades (14) have tips (20) positioned at an acute angle (24) relative to a rotational axis (26) of the turbine blade assembly (28);

   a vane carrier (22) concentric with the rotor (32) and positioned radially outward from the turbine blades (14);

   a plurality of ring segments (16) attached to the vane carrier (22) and positioned between the vane carrier (22) and the tips (20) of the turbine blades (14) in each row (30), wherein an inner surface of each of the ring segments (16) is offset radially outward from the tips (20) of the turbine blades (14) creating gaps (12) and wherein the ring segments (16) are positioned at an acute angle (24) substantially equal to the acute angle (24) at which the turbine blade tips (20) are positioned; and

   a turbine blade gap control system (10) configured to move the vane carrier (22) and attached ring segments (16) axially relative to the turbine blade assembly (28) to reduce the gaps (12) between the tips (20) of the turbine blades (14) and the ring segments (16).

2. The turbine engine (18) of claim 1, **characterized in that** the turbine blade gap control system (10) comprises at least one hydraulic arm (36) attached to the vane carrier (22) for moving the vane carrier (22) axially relative to the turbine blade assembly (28).

3. The turbine engine (18) of claim 2, **characterized in that** the at least one hydraulic arm (36) is attached to an outer cylinder (38) positioned radially outward from the vane carrier (22).

4. The turbine engine (18) of claim 3, **characterized**

in that the at least one hydraulic arm (36) comprises four hydraulic arms (36) positioned around the outer cylinder (38).

5. The turbine engine (18) of claim 4, **characterized in that** the hydraulic arms (36) are positioned generally 90 degrees from each other around the outer cylinder (38).

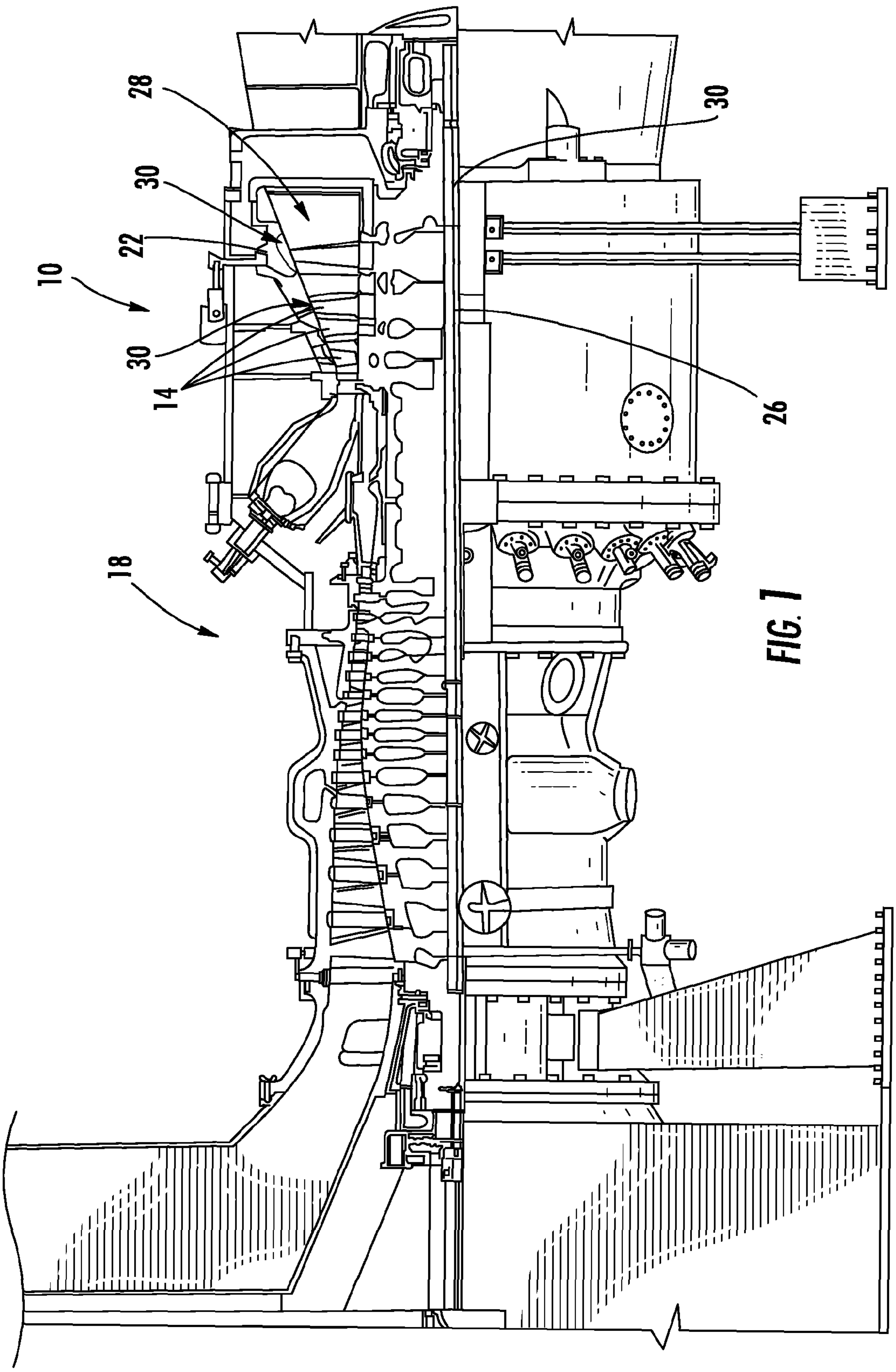

FIG. 1

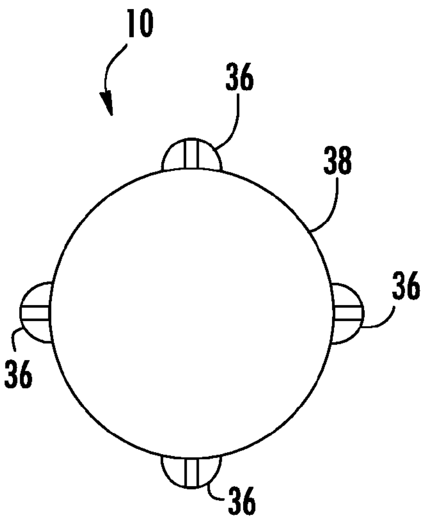

FIG. 2

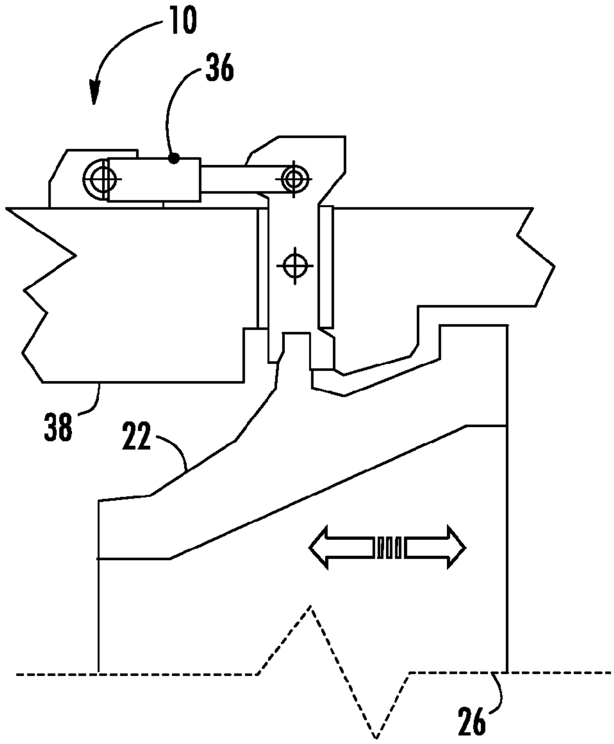

FIG. 3

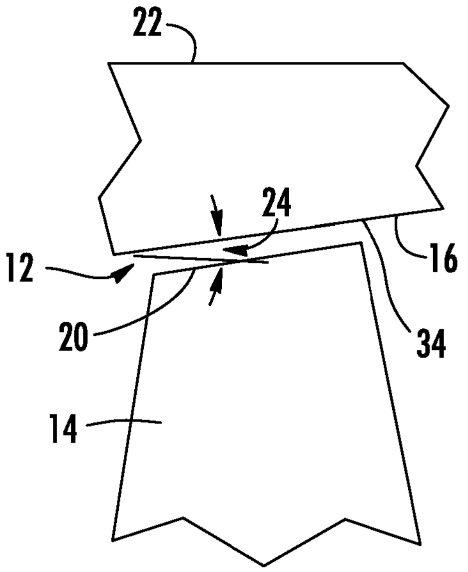

FIG. 4

FLOW PATH DIRECTION

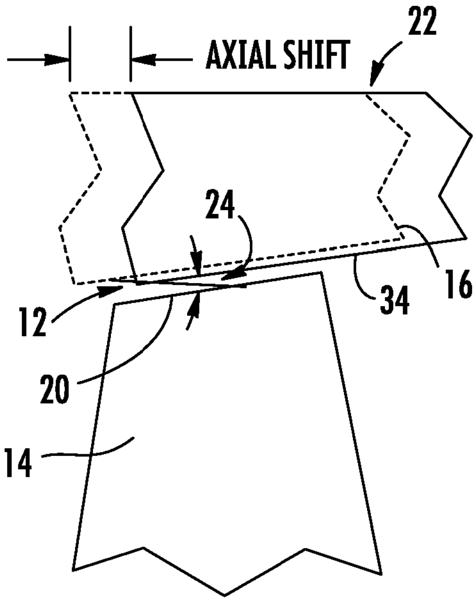

FIG. 5