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(54) GAS TURBINE ENGINE

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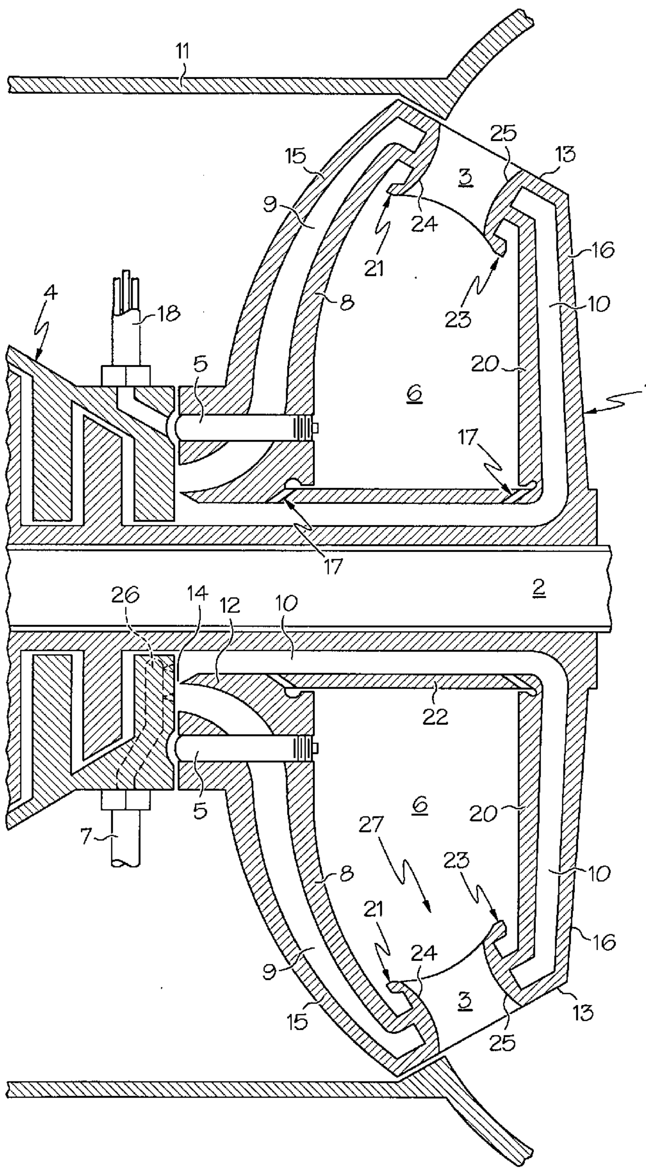
(57) **ABSTRACT**

A gas turbine engine for highly efficient fuel consumption includes as elements a rotor, a stator and a spindle. The rotor includes a system of passageways, a combustion chamber, and a plurality of exhaust ports. The system of passageways comprises a plurality of axial passageways and radial passageways configured to receive a precombustion air-fuel mixture and transport the precombustion air-fuel mixture to the combustion chamber. The exhaust ports provide fluid communication of postcombustion gas between the combustion chamber and the exterior of the rotor.



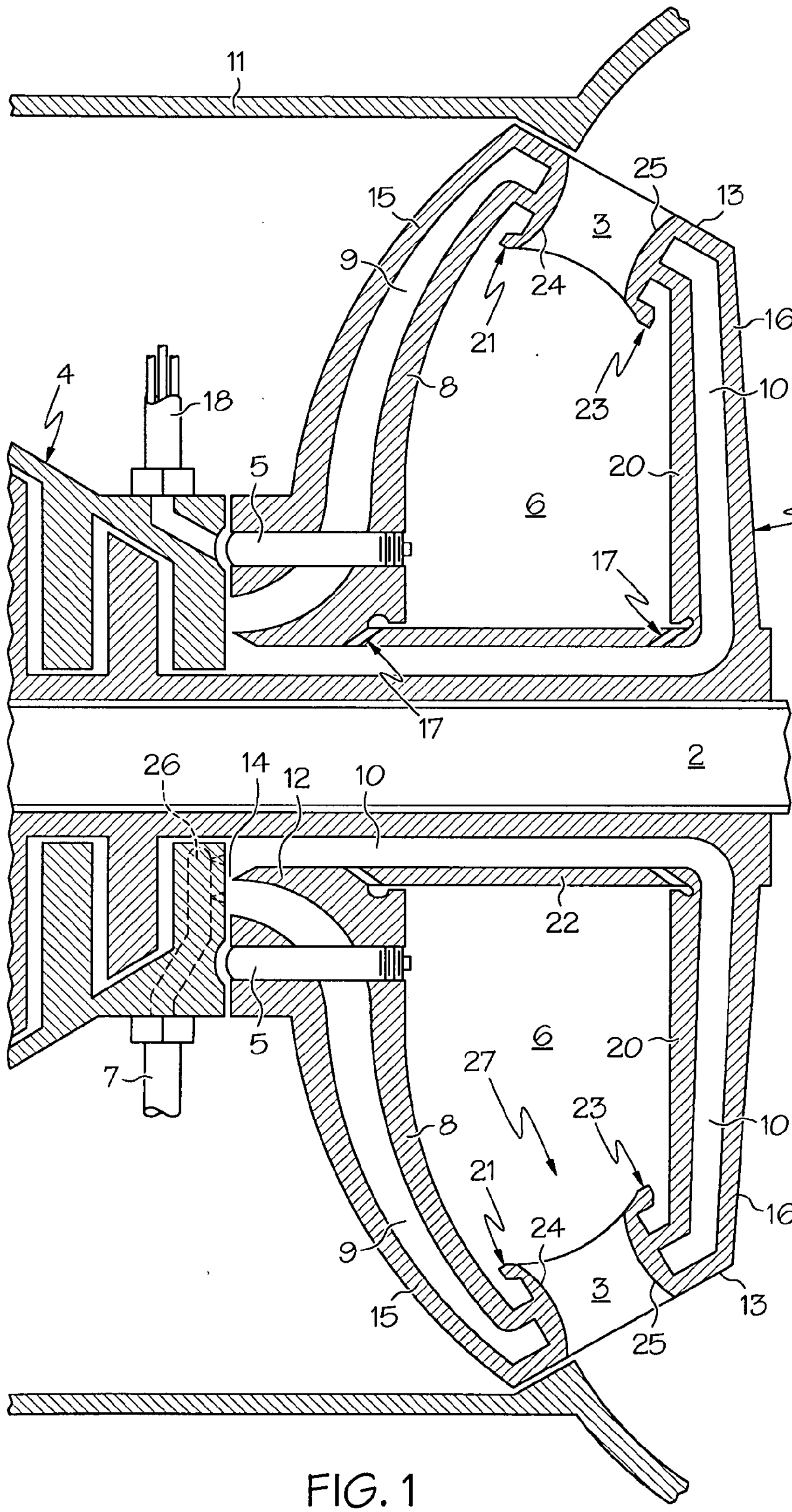

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FIG. 1

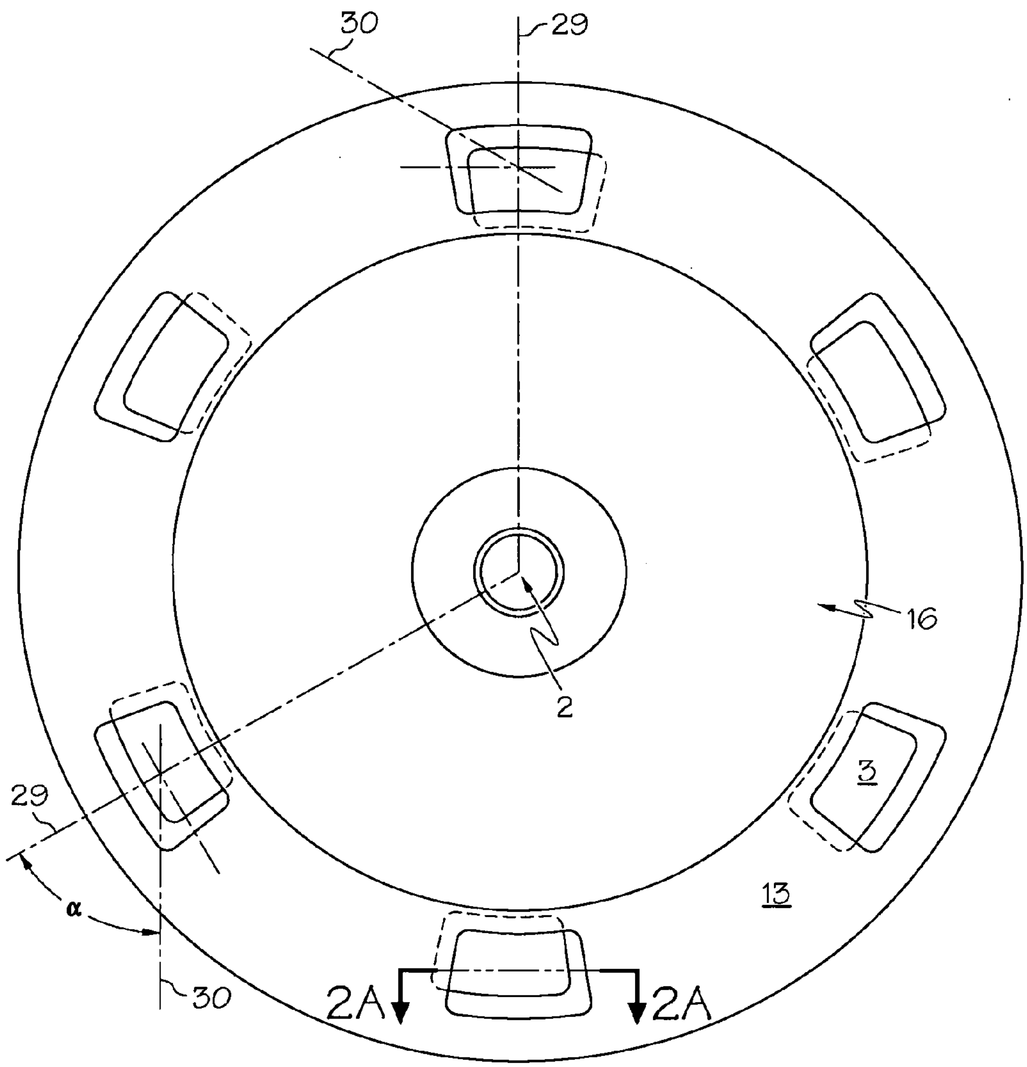

FIG. 2

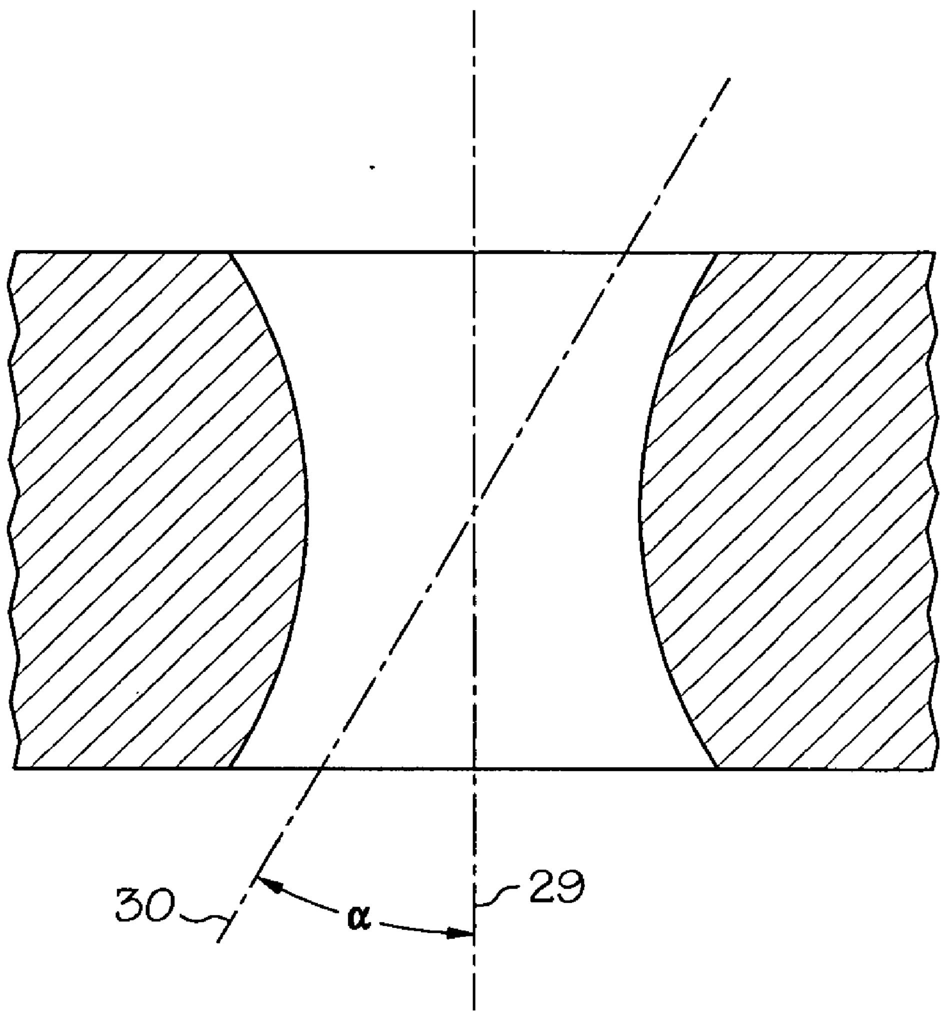

FIG. 2A

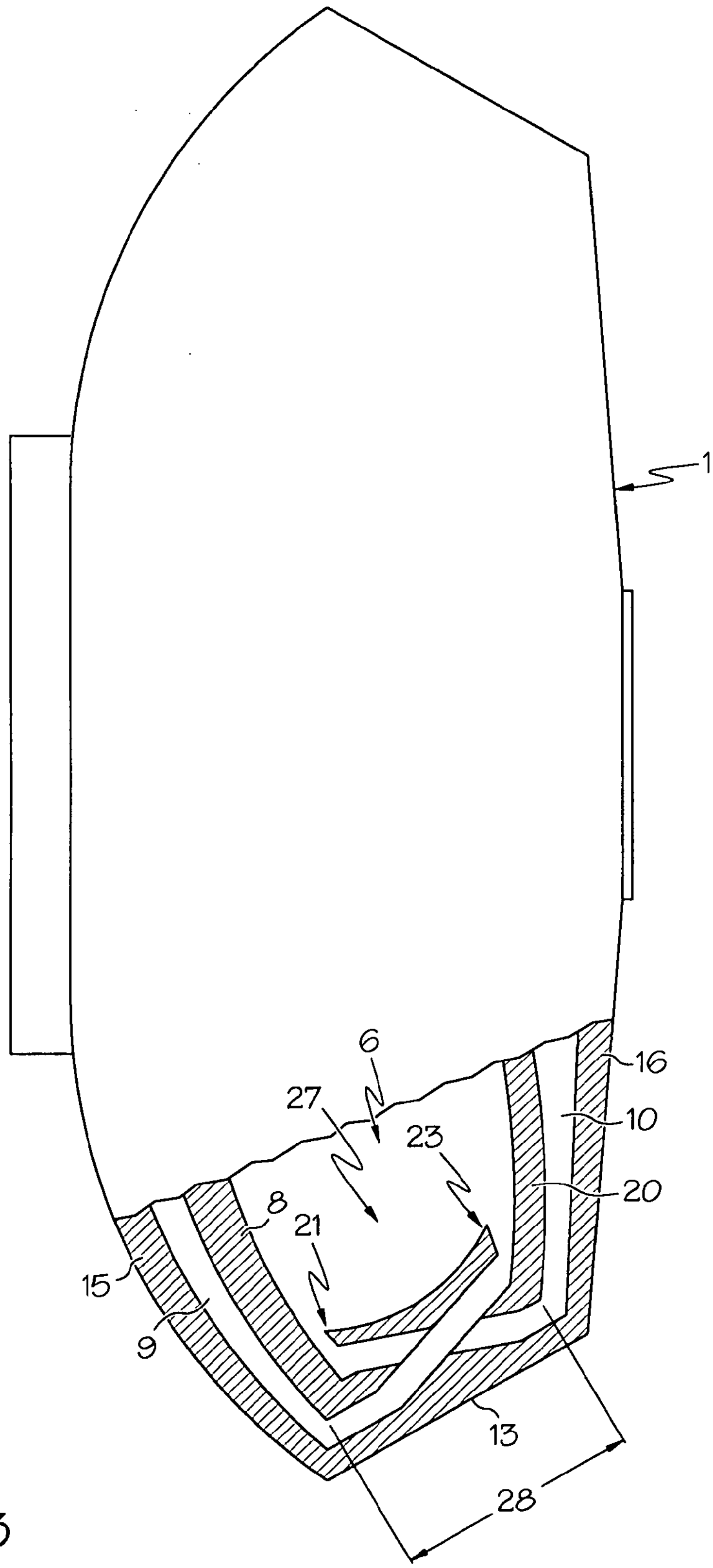

FIG. 3

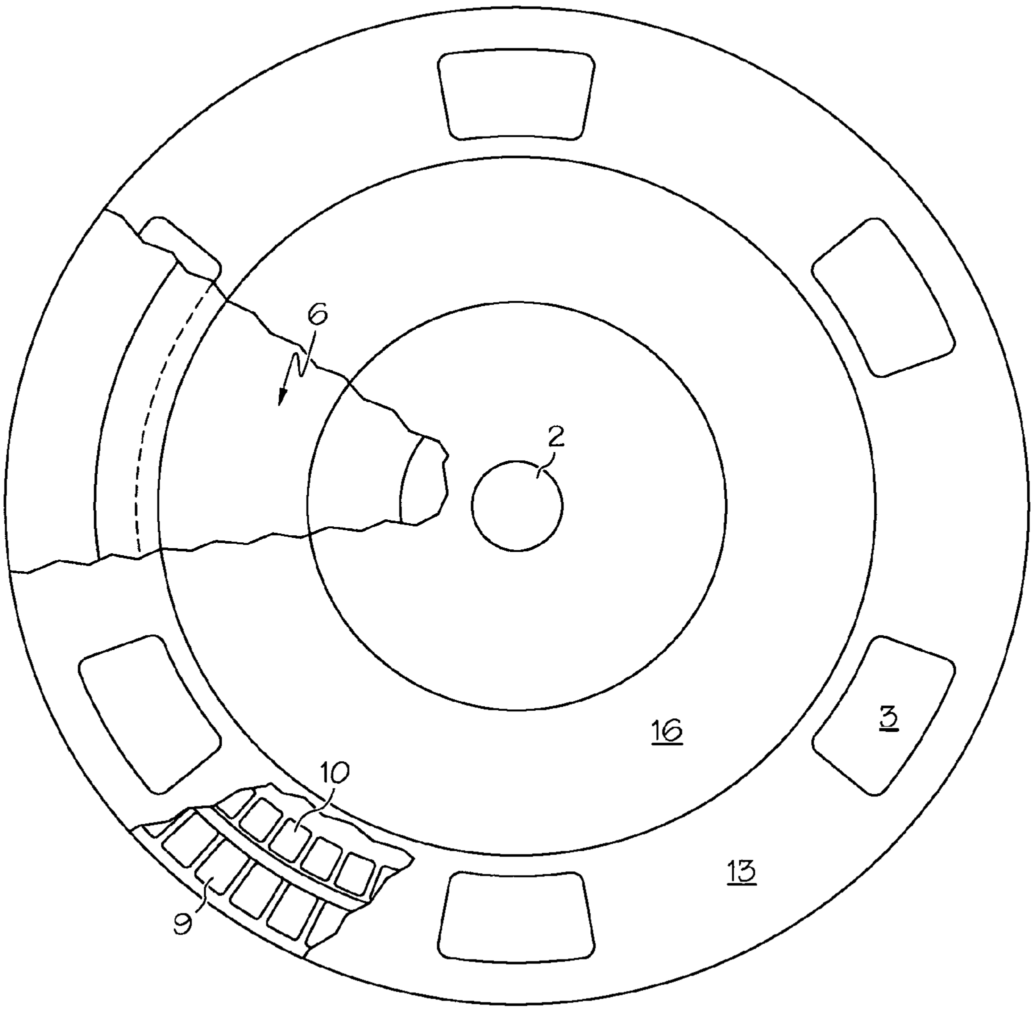

FIG. 4

GAS TURBINE ENGINE

FIELD OF THE INVENTION

[0001] The present invention relates to jet propelled, rotary engines, such as gas turbine engines. More particularly the invention relates to a combustor for use in a gas turbine engine, and in particular, but not exclusively to a combustor operating at highly stoichiometric conditions.

BACKGROUND OF THE INVENTION

[0002] Gas turbine engines of various designs are widely used in many industrial applications. Typically a gas turbine engine uses a fluid flow in which air enters from an upstream position and flows through a compression stage or stages. Fuel is added to the air stream to create a precombustion air-fuel mixture. The air-fuel mixture undergoes combustion in a combustion chamber. The exhaust from combustion typically passes through a turbine stage. The turbine stage is connected to the compressor stage or stages by a shaft such that rotational force from the turbine stage is used to drive the compressor stage or stages. Where forward thrust for jet propulsion is not a primary need, gas turbine engines have additional downstream turbine stages used to power generators or auxiliary power units.

[0003] The uses of gas turbine engines are various and widespread. For example they are used in a variety of propulsion and power generation applications. There is an ongoing need to conceive and develop improvements in the design of gas turbine engines. It is desirable to develop a turbine design that has improved energy output and/or efficiency. In a specific example, it is desirable for a turbine engine design to provide a stoichiometric or near stoichiometric combustion of fuel. Stoichiometric combustion of fuel is advantageous in that it minimizes the flow of air through the system to only that required for combustion.

[0004] Temperature is also an important factor in engine performance. Generally higher temperature in combustion promotes full combustion at high efficiency. Such combustion makes efficient use of fuel. During periods of high fuel cost, it is desirable to provide an engine that minimizes the fuel carried by an aircraft. A high temperature turbine engine can minimize fuel usage with the added benefit of reducing the amount of fuel required to be carried. However, the high temperature necessary for full combustion also is known to cause material failure. An engine that performs at high temperature and near stoichiometric combustion should also have uniform temperature and stress throughout its core to avoid or delay material failure.

[0005] There has been identified, then, a need to provide an improved design for gas turbine engines. It is desirable to develop a turbine engine with high efficiency, near stoichiometric combustion and high temperature performance, while minimizing or avoiding material failure. The present invention addresses one or more of these needs.

SUMMARY OF THE INVENTION

[0006] In accordance with one aspect of the present invention, and by way of example only, there is provided a gas turbine for highly efficient fuel consumption, that includes as elements:

[0007] a rotor, a stator, and a spindle, wherein the stator and the spindle are a unitary piece or are assembled from component pieces, and wherein the rotor is positioned on the spindle such that the rotor rotates about the spindle;

[0008] wherein the rotor includes a system of passageways, a combustion chamber and a plurality of exhaust ports;

[0009] wherein the system of passageways includes one or more axial passageways and one or more radial passageways configured to receive precombustion air-fuel mixture and transport the precombustion air-fuel mixture to the combustion chamber;

[0010] wherein the combustion chamber is defined by one or more chamber walls and a combustion chamber inlet; the combustion chamber inlet including the distal ends of the axial and radial passageways and first and second flanges configured to disperse precombustion air-fuel mixture against forward and aft chamber walls, respectively; and

[0011] wherein the exhaust ports provide for egress of post-combustion gas between the combustion chamber and the exterior of the rotor.

[0012] In one embodiment of the invention, the one or more axial passageways comprise a series of a plurality of passageways extending initially axially along the combustion chamber, and wherein the series encircles the spindle.

[0013] In another embodiment of the invention, the one or more axial passageways comprise a single, continuous passageway extending initially axially and encircling the spindle.

[0014] In another embodiment of the invention, the one or more radial passageways comprise a series of a plurality of passageways extending radially outward along the combustion chamber and wherein the series encircles the spindle and at least a portion of the combustion chamber.

[0015] In another embodiment of the invention, the one or more radial passageways comprise a single, continuous passageway extending radially and encircling at least a portion of the combustion chamber.

[0016] As used herein, "axial" means, as respecting the axial passageways, extending in substantial part generally in the direction of the axis of rotation of the rotor. The term "radial" means, as respecting the radial passageways, extending in substantial part generally radially outward from the axis of rotation of the rotor albeit not necessarily perpendicular to that axis.

[0017] In another aspect of the present invention, and by way of example only, the stator is configured to receive fuel and transmit precombustion air-fuel mixture to the rotor.

[0018] In yet another aspect of the present invention, still by way of example only, the system of passageways also includes an inlet passageway configured to receive precombustion air-fuel mixture and a splitter configured to direct precombustion air-fuel mixture to the axial and radial passageways.

[0019] In a further aspect of the present invention, and again by way of example only, the exhaust ports define a deLaval nozzle, and the exhaust ports are further characterized by an exhaust port central axis, which is positioned at an offset angle relative to a line extending radially from the center of the spindle.

[0020] In still a further aspect of the present invention, by way of example only, the combustion chamber includes an ignition source or sources.

[0021] In yet still another aspect of the present invention, and still by way of example only, the combustion chamber is further configured to receive a coolant at one or more points along the perimeter of said combustion chamber.

[0022] Other independent features and advantages of the gas turbine engine will become apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. **1** is a fragmentary cross sectional view of a rotor, a stator, and a spindle according to an embodiment of the invention.

[0024] FIG. **2** is an aft elevation view of a rotor including exhaust ports and a nozzle deck, according to an embodiment of the invention.

[0025] FIG. **2**A is a fragmentary cross-section view taken along the line **2**A-**2**A depicted in FIG. **2**, according to an embodiment of the invention.

[0026] FIG. **3** is a side elevation view of a rotor, broken away in part to expose a combustion chamber inlet, according to an embodiment of the invention.

[0027] FIG. **4** is an aft elevation view of a rotor including the exhaust ports and the nozzle deck, with broken away portions to show the axial and radial passageways, according to an embodiment of the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0028] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description of the invention. Reference will now be made to exemplary embodiments of the invention in detail, examples of which are illustrated in the accompanying drawings.

[0029] Referring initially to FIG. **1**, there is shown a first embodiment of a gas turbine engine assembly. The gas turbine engine assembly includes a rotor **1**, a stator **4**, and a spindle **2** within an engine casing **11**.

[0030] The rotor **1** will rotate around the spindle **2**, which is positioned generally in a central axial position, as is known in the art of gas turbine engine design. In the preferred embodiment the stator **4** and the spindle **2** may be either a unitary piece or assembled from components. In another preferred embodiment of the present invention, the stator **4** includes a fuel inlet **7** for receiving a fuel and a fuel injection system, shown in part at **26**, for transmitting a mixture of compressed air and atomized fuel to the rotor **1** as is known in the art, the fuel injection system **26** containing two or more injection points. The fuel supplied to the fuel inlet **7** can be gasoline, kerosene, propane, alcohol, liquefied natural gas, compressed natural gas, diesel, or any other fuel known in the art of gas turbine engine design.

[0031] The rotor **1** includes a system of passageways including one or more axial passageways **10**, one or more radial passageways **9**, and one or more inlet passageways **14**, each with a splitter **12**. The rotor **1** further includes a combustion chamber inlet **27** (partially shown in FIG. **1**, more fully shown in FIG. **3**), a combustion chamber **6**, exhaust ports **3**, and ignition sources **5**. The rotor **1** may be a unitary piece or assembled from components.

[0032] As illustrated in FIG. **1**, precombustion air-fuel mixture passes through the inlet passageway **14** and is divided by the splitter **12**. A portion of the precombustion air-fuel mixture is forced through the radial passageway **9** such that the precombustion air-fuel mixture moves from a generally central axial position toward a more radially outward position. The other portion of the precombustion air-fuel mixture is forced through the axial passageway **10** such that the precombustion air-fuel mixture moves axially parallel to the spindle toward a more distal position. To promote enhanced heat exchange, the radial passageway **9** is defined primarily by a forward chamber wall **8** and a forward rotor wall **15**, and the axial passageway **10** is defined primarily by an aft chamber wall **20** and an aft rotor wall **16**.

[0033] By varying the location of the splitter **12** a designer can select the relative proportions of precombustion air-fuel mixture to be directed in each direction. In a preferred embodiment, it is generally desired to obtain an approximately equal split between the two streams of precombustion air-fuel mixture. In this way precombustion air-fuel mixture enters the combustion chamber **6** in approximately equal proportions from each side of the combustion chamber **6**. The precombustion air-fuel mixture that is supplied to the inlet passageway **14** can be any mixture of compressed air and an atomized fuel that is added thereto by an injector such as is known in the art of gas turbine engine design.

[0034] As illustrated in FIG. **3**, at the distal end of each radial passageway **9**, the radial passageway **9** curves subsurface to the nozzle deck **13** and directs the precombustion air-fuel mixture through the combustion chamber inlet **27** into the combustion chamber **6**. At the distal end of each axial passageway **10**, the axial passageway **10** curves subsurface to the nozzle deck **13** and directs the precombustion air-fuel mixture through the combustion chamber inlet **27** into the combustion chamber **6**.

[0035] Certain details of combustion chamber inlet **27** are now described. As demonstrated in FIG. **3**, the combustion chamber inlet **27** includes the distal ends of the axial and radial passageways **10** and **9** as well as a first flange **21** and a second flange **23**, which provide enhanced dispersion of precombustion air-fuel mixture against combustion chamber walls. In one embodiment of the present invention, the distal ends of the axial and radial passageways **10** and **9** pass each other in a crossing manner for enhanced heat exchange. The precombustion air-fuel mixture from the axial passageway **10** exits the distal end of passageway **10** and contacts the first flange **21** for dispersion against the forward chamber wall **8**. Likewise, the precombustion air-fuel mixture from the radial passageway **9** exits the distal end of passageway **9** and contacts the second flange **23** for dispersion against the aft chamber wall **20**. The length dimension **28** of the combustion chamber inlet **27** can be selected with a variety of criteria in mind including gas fluid flow, cooling, and the desired volume of the combustion chamber **6**.

[0036] While in operation, the rotor **1** is rotating about spindle **2**. Thus, in a preferred embodiment, the configuration of the rotor **1** and the dispersal of fuel as described achieves significant fuel mixing in the combustion chamber **6**. As fuel is dispersed from the first flange **21** against the forward chamber wall **8**, that portion of the fuel tends to both ricochet off the wall and to follow the wall toward a further interior position in combustion chamber **6**. A similar result occurs at the second flange **23** that is positioned opposite the first flange **21**. The engine rotation further serves to mix this material within the chamber **6**.

[0037] Both the axial and radial passageways **10** and **9** are hollow structures that allow fluid communication therethrough. In one embodiment, the axial passageways **10** and the radial passageways **9** are generally circular in cross-section. However, in other embodiments one or both of these passageways can be non-circular in cross-section. Additionally, one or both of the axial passageway and the radial passageway functions may be achieved by a single continuous passageway uninterrupted in its lateral direction encircling the central axis of the rotor, rather than being sets of individual passageways, as shown. In a preferred embodiment, as shown in FIG. **4**, both of the radial and axial passageways **9** and **10** are distributed in a pattern symmetrically encircling a central axis of the spindle **2**.

[0038] The combustion chamber **6** is a generally torus-shaped structure. It is limited by the forward chamber wall **8**, the aft chamber wall **20**, an inner chamber wall **22**, and the combustion chamber inlet **27**.

[0039] In an embodiment of the present invention, combustion chamber **6** is configured to receive coolant at one or more points along the perimeter of combustion chamber **6**. In the embodiment shown in FIG. **1**, the coolant is precombustion air-fuel mixture diverted through the inner chamber wall **22** to the combustion chamber **6** from the axial passageway **10** by one or more coolant channels **17**. In yet another embodiment of the present invention, the coolant is compressed air directed into combustion chamber **6** by other means.

[0040] In FIG. **1** the ignitors **5** are shown positioned extending into the combustion chamber **6** such that the ignitors **5** can provide ignition in the combustion chamber **6**. The ignitor **5** is but one ignition device example and other such devices may be used, if desired, to provide ignition within the combustion chamber **6**. In the embodiment of FIG. **1**, the stator **4** includes a system, partially shown at **18**, for providing electrical power to the ignitors **5**.

[0041] Referring generally to FIGS. **1** and **2**, it is noted that the rotor **1** includes exhaust ports **3** which provide egress passageways through which the postcombustion gas can pass out of the combustion chamber **6**. As is known in the art, the postcombustion gas can be directed and vented through other systems as desired, as for example, other turbines and nozzles. In the preferred embodiment shown, the rotor **1** includes a plurality of exhaust ports **3**, a preferred number being six. It is also preferred that the exhaust ports **3** are spaced equidistant around the perimeter of the rotor **1**. This equality of spacing provides for a balanced thrust from the combustion chamber. In yet another preferred embodiment, the exhaust ports are located on the nozzle deck **13** of the rotor **1**.

[0042] The cross-sectional area of exhaust ports **3** can be varied to obtain desired results such as fluid flow and pressure drop. In the preferred embodiment shown in FIG. **1**, the exhaust port **3** defines a deLaval nozzle. The deLaval nozzle includes a convergent wall portion **24** and a divergent wall portion **25**. The convergent wall portion **24** and the divergent wall portion **25** meet at a rounded middle location of the port. Further, the aperture of an exhaust port **3** can take varied shapes such as generally circular or oval. Preferably, however, the aperture of exhaust port **3** is substantially square or rectangular. Curved corners may be provided in the square or rectangular apertures.

[0043] As illustrated in FIG. **2** and FIG. **2**A, each exhaust port central axis **30** is set at an angle α relative to a radial line **29** extending from the center of the combustion chamber **6**. The central axes **30** represent the general thrust alignments of the exhaust ports **3**. The angle α between the exhaust port central axis **30** and the radial line **29** thus represents an important parameter in determining the angular thrust that will be developed by the gas turbine engine. Likewise, the area of the exhaust port **3** aperture, and the angular positioning of the nozzle deck **13** with respect to the forward rotor wall **15** and the aft rotor wall **16**, can be selected to achieve desired thrust and power objectives.

[0044] It has been found that the embodiment of the gas turbine engine described herein displays improved engine performance over prior art designs. The engines achieve combustion temperatures at steady state operation that are higher than combustion temperatures of other prior art designs. Testing of design prototypes has achieved temperatures of between 3000 and 4000° F. Additionally, the higher temperature provides for an improved fuel consumption. Fuel and air consumption at near stoichiometric ratios has been achieved.

[0045] While not wishing to be bound by any theory, it is believed that a combination of physical features and properties found in the engine embodiments according to the present invention promotes the improved engine performance. First, the design of the rotor **1** promotes thorough mixing of fuel and air which promotes complete and efficient combustion in the combustion chamber **6**. The design also provides for superior heat exchange and hence more uniform temperature and stresses throughout the rotor **1**. The heat exchange features of the embodiments promote heating of the precombustion air-fuel mixture which tends to promote good mixing and combustion, while drawing heat away from engine components where excess heat is undesirable. Further, the positioning of the axial passageways **10** and the radial passageways **9** relative to the combustion chamber **6** lessens or minimizes back pressure or blowback of combustion forces through those passageways, and as a result good fluid flow is promoted throughout the system and the postcombustion gases readily exit through exhaust ports **3**. Finally, the combination of physical features and properties described in the foregoing embodiments provides a gas turbine engine that is shorter, lighter, and more rigid than existing gas turbine engines.

[0046] While the invention has been described with reference to a preferred embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to a particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A gas turbine engine for highly efficient fuel consumption, comprising:

a rotor, a stator and a spindle;

the rotor including a system of passageways, a combustion chamber, and a plurality of exhaust ports;

the system of passageways comprises one or more axial and radial passageways configured to receive a precombustion air-fuel mixture and transport the precombustion air-fuel mixture to the combustion chamber;

the plurality of exhaust ports providing fluid communication of a postcombustion gas between the combustion chamber and an exterior of the rotor.

2. The gas turbine engine according to claim **1**, wherein the stator and the spindle are a unitary piece.

3. The gas turbine engine according to claim **1**, wherein the stator is configured to receive a fuel and transmit the precombustion air-fuel mixture to the rotor.

4. The gas turbine engine according to claim **1**, wherein the system of passageways further includes an inlet passageway configured to receive the precombustion air-fuel mixture, and a splitter located such that the precombustion air-fuel mixture passing through the inlet passageway comes into contact with the splitter, divides and moves into and through the axial and radial passageways.

5. The gas turbine engine according to claim **3**, wherein the splitter directs fluid equally into the axial and radial passageways.

6. The gas turbine engine according to claim **1**, wherein the combustion chamber is defined by one or more chamber walls and a combustion chamber inlet, wherein the combustion chamber inlet comprises the distal end of the axial passageway, the distal end of the radial passageway, a first flange and a second flange.

7. The gas turbine engine according to claim **1**, wherein the exhaust ports are defined by substantially circular or substantially rectangular apertures.

8. The gas turbine engine according to claim **1**, wherein the exhaust ports define deLaval nozzles.

9. The gas turbine engine according to claim **1**, further comprising an ignition source or sources positioned in the combustion chamber.

10. The gas turbine engine according to claim **9**, wherein the stator comprises a system for providing electrical power to the ignition source.

11. The gas turbine engine according to claim **1**, wherein each exhaust port is defined by one or more exhaust port walls, the exhaust port walls further comprising a convergent wall portion and a divergent wall portion.

12. The gas turbine engine according to claim **11**, wherein the convergent wall portion and the divergent wall portion meet at a rounded substantially middle location within the port.

13. The gas turbine engine according to claim **1**, having three or more exhaust ports.

14. The gas turbine engine according to claim **13**, wherein the three or more exhaust ports are positioned at substantially equal angular separation.

15. The gas turbine engine according to claim **1**, wherein the plurality of exhaust ports each have an exhaust port central axis positioned at an offset angle relative to a radial line beginning at the center of said spindle and extending radially.

16. The gas turbine engine according to claim **1**, wherein the axial passageways and the radial passageways are positioned proximate the combustion chamber such that heat exchange occurs between said passageways and said combustion chamber through the forward and aft chamber walls.

17. The gas turbine engine according to claim **1**, wherein the combustion chamber is configured to receive a coolant at one or more points along the perimeter of the combustion chamber.

18. A gas turbine engine assembly for receiving and combusting a precombustion air-fuel mixture, comprising:

a spindle;

a rotatable housing positioned on the spindle;

a combustion chamber defined by the rotatable housing;

wherein the rotatable housing defines one or more axial passageways and one or more radial passageways, the axial passageways configured to receive precombustion air-fuel mixture and transport the precombustion air-fuel mixture past a first flange and into the combustion chamber, said radial passageway configured to receive precombustion air-fuel mixture and transport said precombustion air-fuel mixture past a second flange and into the combustion chamber.

19. The gas turbine engine according to claim **18**, wherein the rotatable housing further comprises an inlet passageway and a splitter, the inlet passageway configured to receive precombustion air-fuel mixture, the splitter configured to divide and direct the precombustion air-fuel mixture down the axial and radial passageways in approximately equal portions.

20. The gas turbine engine according to claim **18**, wherein the one or more axial passageways comprise a series of a plurality of passageways extending axially along the combustion chamber, and where the series encircles the spindle.

21. The gas turbine engine according to claim **18**, wherein the one or more radial passageways comprise a series of a plurality of passageways extending radially outwardly along the combustion chamber, and wherein the series encircles the spindle and at least a portion of the combustion chamber.

22. The gas turbine engine according to claim **18**, wherein the one or more axial passageways comprise a single continuous passageway encircling the spindle.

23. The gas turbine engine according to claim **18**, wherein the one or more radial passageways comprise a single continuous passageway extending radially and encircling at least a portion of the combustion chamber.

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