US 20160258627A1

(19) **United States**

(12) **Patent Application Publication**

Cheung et al.

(10) **Pub. No.: US 2016/0258627 A1**

(43) **Pub. Date: Sep. 8, 2016**

(54) **LOW NET-SWIRL CONFIGURATIONS FOR GAS TURBINE ENGINE COMBUSTORS**

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(21) Appl. No.: **14/636,689**

(22) Filed: **Mar. 3, 2015**

Publication Classification

(51) **Int. Cl.**

F23R 3/14 (2006.01)

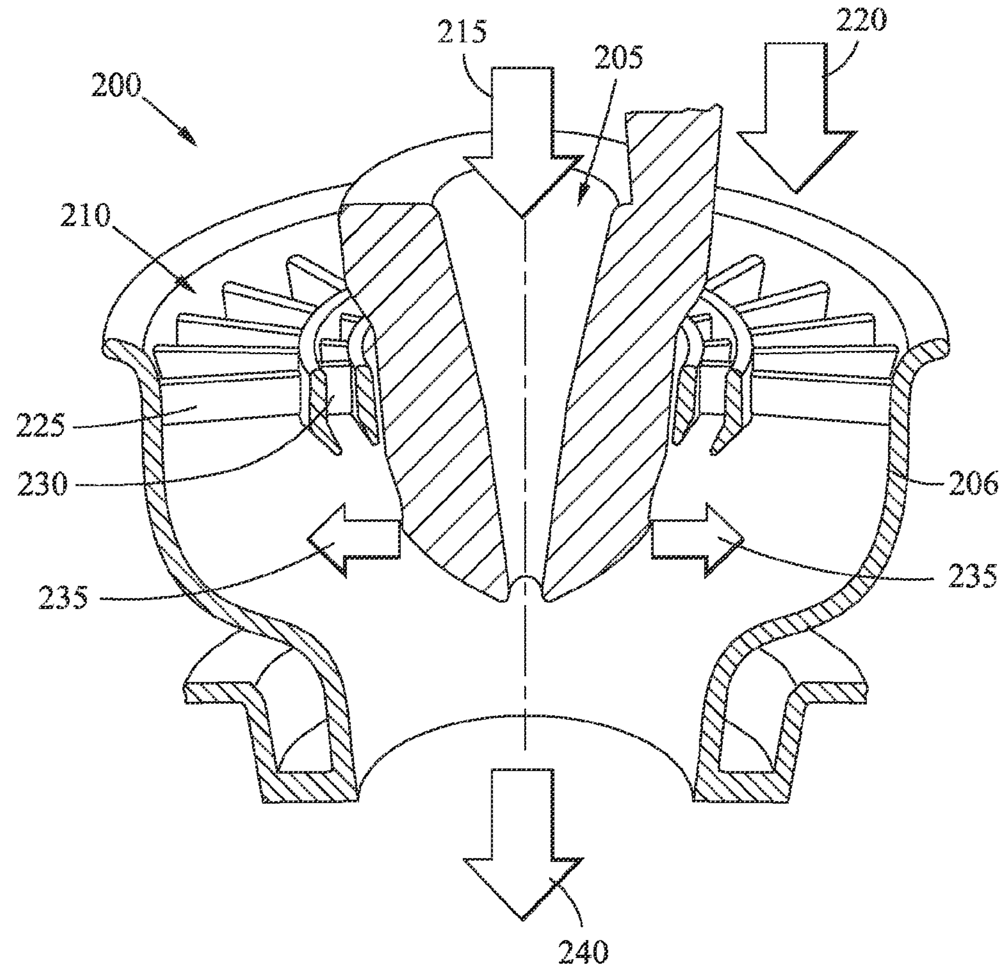
F23R 3/28 (2006.01)

(52) **U.S. Cl.**

CPC .. *F23R 3/14* (2013.01); *F23R 3/286* (2013.01)

(57) **ABSTRACT**

The present disclosure relates to gas turbine engines, and in particular to combustor swirlers and swirler configurations. In one embodiment, a swirler includes an inner passage for receiving a fuel injector and a plurality of outer passages concentrically arranged around the inner passage. The plurality of outer passages include an outer vane assembly including a plurality of vane elements arranged at a first angle and a first middle vane assembly include a plurality of vane elements arranged at a second angle, wherein the outer vane assembly is concentrically arranged around the first middle vane assembly, and wherein the outer vane assembly and first middle vane assembly are configured to produce a low net-swirl to control the penetration depth and improve premixing of a fuel air mixture for the fuel injector. According to another embodiment, the swirler includes a second middle vane assembly include a plurality of vane elements arranged at a third angle.



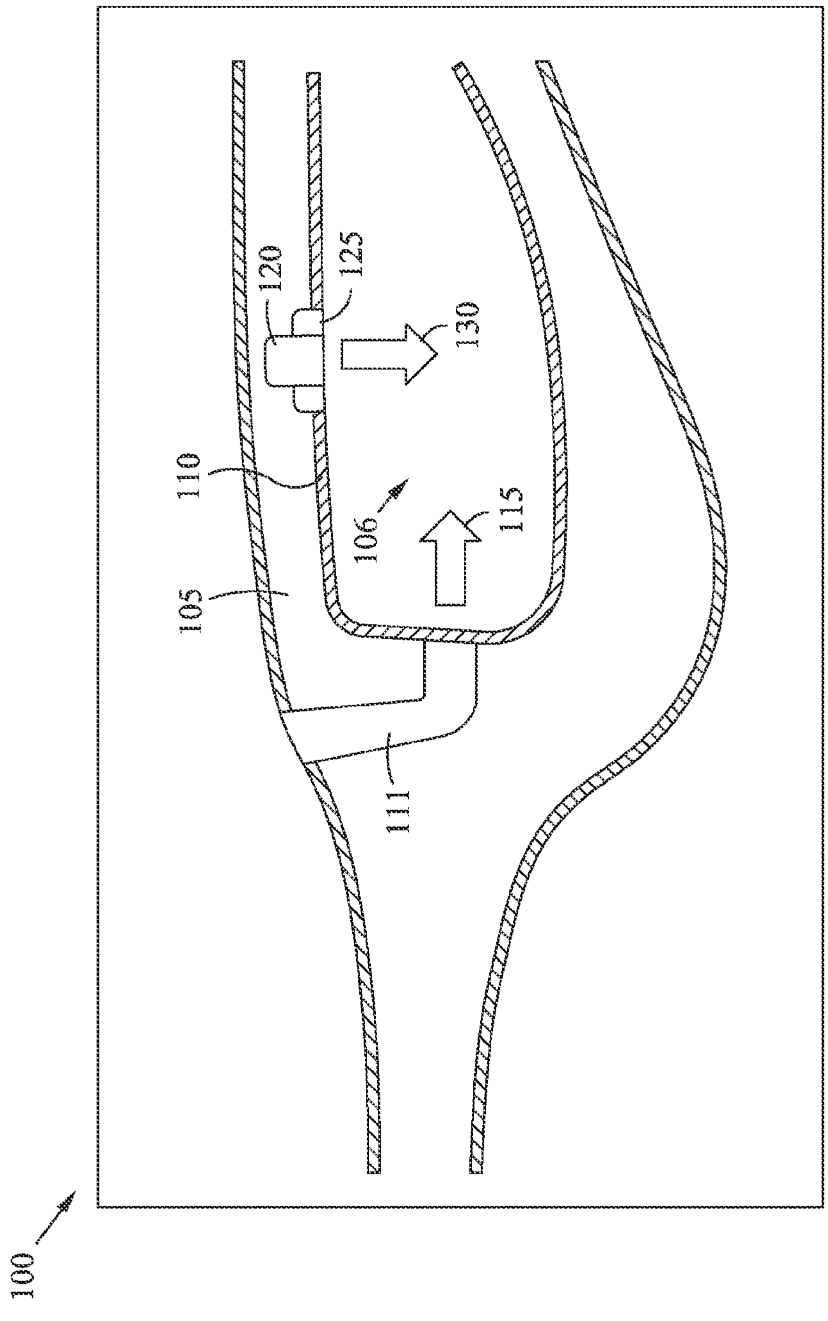


FIG. 1

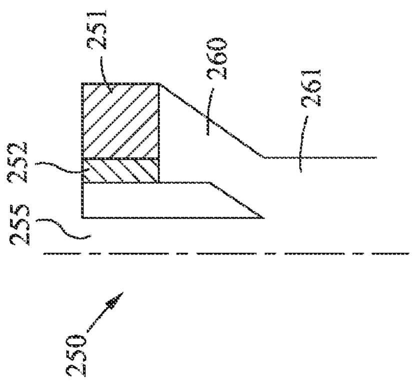


FIG. 2B

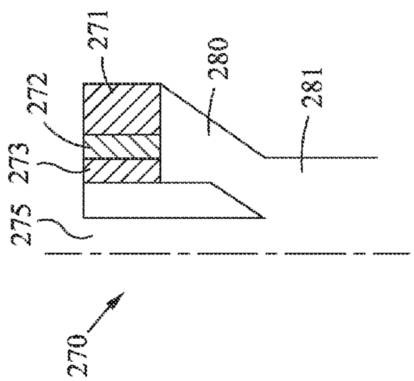


FIG. 2C

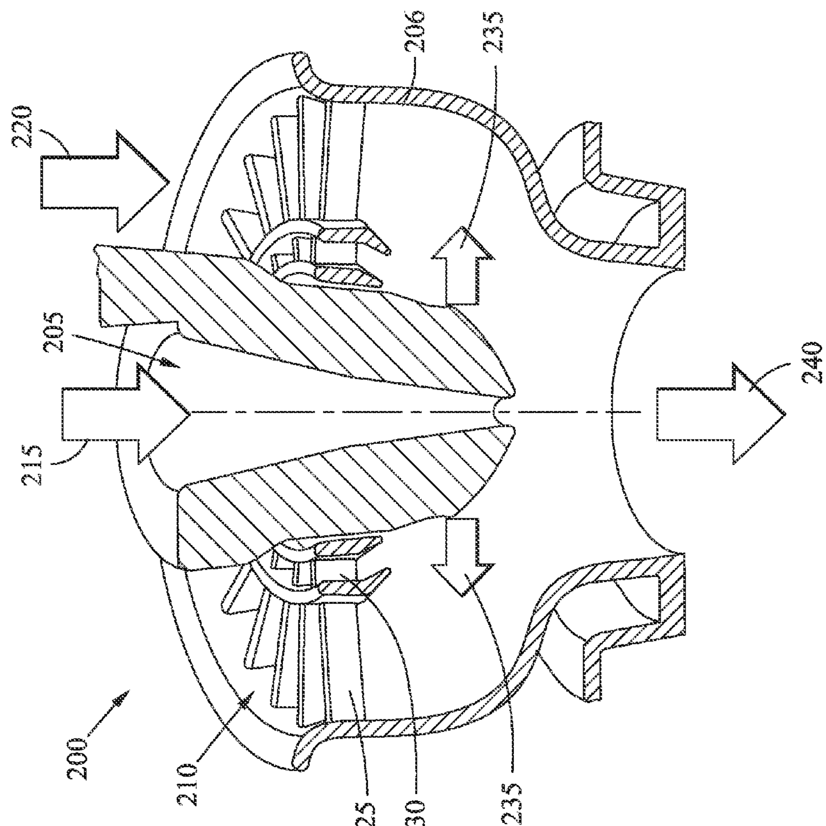


FIG. 2A

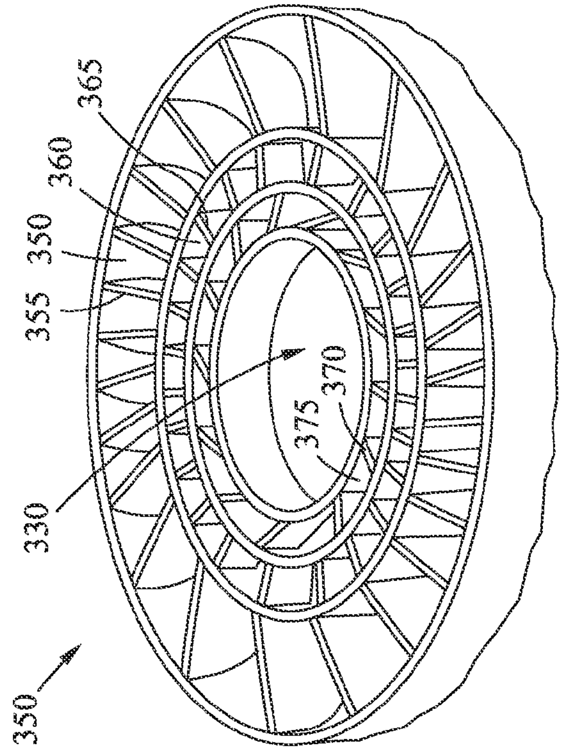


FIG. 3B

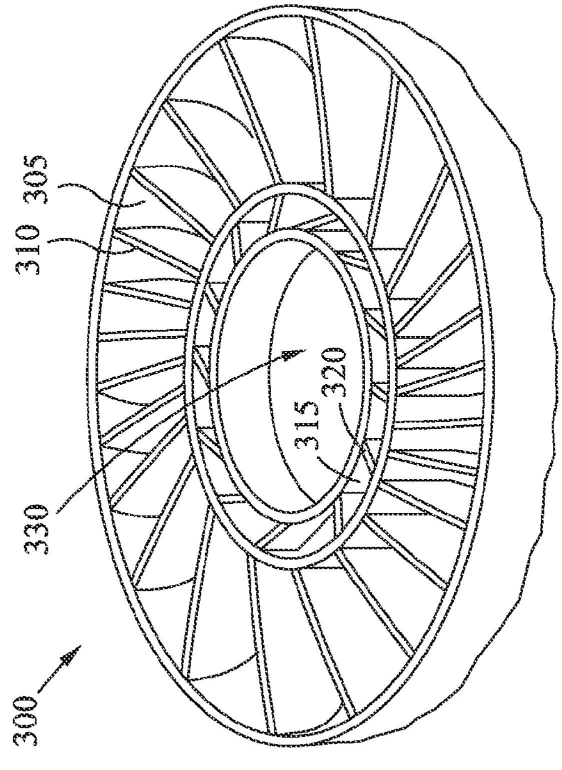


FIG. 3A

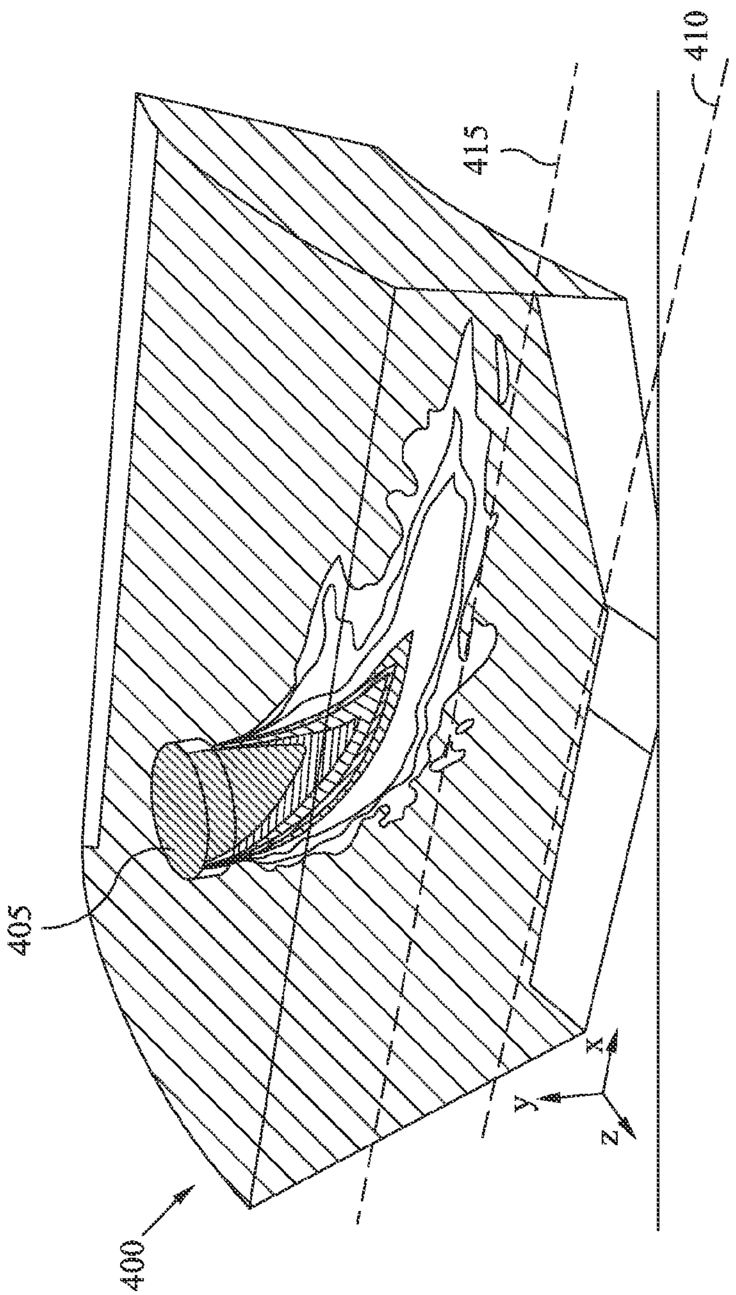


FIG. 4

LOW NET-SWIRL CONFIGURATIONS FOR GAS TURBINE ENGINE COMBUSTORS

STATEMENT OF FEDERALLY FUNDED RESEARCH

[0001] This invention was made with Government support under contract number NNC13TA45T awarded by the National Aeronautics and Space Administration (NASA). The Government has certain rights in the invention.

FIELD

[0002] The present disclosure relates to combustion systems for gas turbine engines and, in particular, low net-swirl configurations for a combustor.

BACKGROUND

[0003] Gas turbine engines, such as those used to power modern aircraft, to power sea vessels, to generate electrical power, and in industrial applications, include a compressor for pressurizing a supply of air, a combustor for burning a fuel in the presence of the pressurized air, and a turbine for extracting energy from the resultant combustion gases. Generally, the compressor, combustor, and turbine are disposed about a central engine axis with the compressor disposed axially upstream or forward of the combustor and the turbine disposed axially downstream of the combustor. In operation of a gas turbine engine, fuel is injected into and combusted in the combustor with compressed air from the compressor thereby generating high-temperature combustion exhaust gases, which may contain pollutant gases or smoke.

[0004] Accordingly, there is a desire to provide configurations that improve fuel and air mixing within combustors. There is also a desire to improve the configurations of gas turbine engines and combustor assemblies to reduce unwanted pollutant emission such as NOx and smoke.

BRIEF SUMMARY OF THE EMBODIMENTS

[0005] Disclosed and claimed herein are swirlers and swirler configurations for combustors of gas turbine engines. One embodiment is directed to a swirler including an inner passage for receiving a fuel injector and a plurality of outer passages concentrically arranged around the inner passage. The plurality of outer passages include an outer vane assembly including a plurality of vane elements arranged at a first angle and a first middle vane assembly include a plurality of vane elements arranged at a second angle. The outer vane assembly is concentrically arranged around the first middle vane assembly, and the outer vane assembly and first middle vane assembly are configured to produce a low net-swirl to control the penetration depth of a fuel air mixture for the fuel injector.

[0006] In one embodiment, the swirler is configured to generate an air and fuel mixture downstream of a combustor pilot flow and improve premixing of the fuel air mixture.

[0007] In one embodiment, vanes of the outer vane assembly are angled within the range of +45 to +60 degrees.

[0008] In one embodiment, vanes of the outer vane assembly are arranged and configured to handle within 50 to 70 percent of the airflow received by the swirler.

[0009] In one embodiment, vanes of the first middle vane assembly are angled within the range of 0 to −25 degrees.

[0010] In one embodiment, vanes of the first middle vane assembly are arranged and configured to handle within 20 to 40 percent of the airflow received by the swirler.

[0011] In one embodiment, the penetration depth relates to the penetration depth within a combustor cavity.

[0012] In one embodiment, the swirler generates a low net-swirl by co-swirling airflow associated with the outer vane assembly and first middle vane assembly.

[0013] In one embodiment, the swirler includes a second middle vane assembly include a plurality of vane elements arranged at a third angle, and wherein the first middle vane assembly is arranged concentrically around the first middle vane assembly.

[0014] In one embodiment, vanes of the outer vane assembly are angled in a direction opposite to vanes of the first middle vane assembly.

[0015] Another embodiment is directed to a swirler including an inner passage for receiving a fuel injector and a plurality of outer passages concentrically arranged around the inner passage. The plurality of outer passages include an outer vane assembly including a plurality of vane elements arranged at a first angle, a first middle vane assembly include a plurality of vane elements arranged at a second angle, and a second middle vane assembly include a plurality of vane elements arranged at a third angle. The first middle vane assembly is concentrically arranged around the second middle vane assembly. The outer vane assembly is concentrically arranged around the first middle vane assembly and second middle assembly, and wherein the outer vane assembly, first middle vane assembly and second middle vane assembly are configured to produce a low net-swirl to control the penetration depth of a fuel air mixture for the fuel injector.

[0016] In one embodiment, the swirler is configured to generate an air and fuel mixture downstream of a combustor pilot flow and improve premixing of the fuel air mixture.

[0017] In one embodiment, vanes of the outer vane assembly are angled within the range of +45 to +60 degrees.

[0018] In one embodiment, vanes of the outer vane assembly are arranged and configured to handle within 45 to 65 percent of the airflow received by the swirler.

[0019] In one embodiment, vanes of the first middle vane assembly are angled within the range of −10 to −30 degrees and vanes of the second middle assembly are angled within the range of +10 to +30 degrees.

[0020] In one embodiment, vanes of the first middle vane assembly are arranged and configured to handle within 15 to 25 percent of the airflow received by the swirler wherein vanes of the second middle vane assembly are arranged and configured to handle within 15 to 25 percent of the airflow received by the swirler.

[0021] In one embodiment, the penetration depth relates to the penetration depth within a combustor cavity.

[0022] In one embodiment, the swirler generates a low net-swirl by co-swirling airflow associated with the outer vane assembly and first middle vane assembly.

[0023] In one embodiment, the swirler includes a second middle vane assembly include a plurality of vane elements arranged at a third angle, and wherein the first middle vane assembly is arranged concentrically around the first middle vane assembly.

[0024] In one embodiment, vanes of the outer vane assembly and second middle vane assembly are angled in a direction opposite to vanes of the first middle vane assembly

[0025] Other aspects, features, and techniques will be apparent to one skilled in the relevant art in view of the following detailed description of the embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The features, objects, and advantages of the present disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

[0027] FIG. **1** depicts a cross-sectional representation of a combustor for a gas turbine engine according to one or more embodiments;

[0028] FIGS. **2**A-**2**C depict graphical representations of swirler configurations according to one or more embodiments;

[0029] FIGS. **3**A-**3**B depict graphical representations of swirler configurations according to one or more embodiments; and

[0030] FIG. **4** depicts a graphical representation of swirler penetration according to one or more embodiments.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Overview and Terminology

[0031] One aspect of this disclosure relates to configurations for a gas turbine engine and in particular a swirler for a combustor. According to one embodiment, a swirler configuration can include two or more outer passages with vane elements configured to provide a fuel-air mixture with low net-swirl. Based on the amount of swirl, the penetration depth of the fuel-air mixture may be controlled to in order to increase the efficiency of fuel burn within the combustor. According to one or more embodiments,

[0032] As used herein, the terms “a” or “an” shall mean one or more than one. The term “plurality” shall mean two or more than two. The term “another” is defined as a second or more. The terms “including” and/or “having” are open ended (e.g., comprising). The term “or” as used herein is to be interpreted as inclusive or meaning any one or any combination. Therefore, “A, B or C” means “any of the following: A; B; C; A and B; A and C; B and C; A, B and C”. An exception to this definition will occur only when a combination of elements, functions, steps or acts are in some way inherently mutually exclusive.

[0033] Reference throughout this document to “one embodiment,” “certain embodiments,” “an embodiment,” or similar term means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of such phrases in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner on one or more embodiments without limitation.

Exemplary Embodiments

[0034] Referring now to the figures, FIG. **1** depicts a cross-sectional representation of a combustor for a gas turbine engine according to one or more embodiments. Gas turbine engine **100** is shown including combustor **105** and annular structure **110**. Combustor **105** extends along a portion of a gas turbine engine **100** providing a gas-flow path within combustor cavity **106**. According to one embodiment, combustor **105** may be an axially controlled stoichiometry combustor. Combustor **105** includes fuel nozzle **111** which may be configured as a pilot fuel injector in the front end of the combustor and may provide a pilot fuel-air mixture **115** for cavity **106**. Combustor **105** may include a second or main fuel injector downstream of fuel nozzle **111**. According to one embodiment, combustor **105** includes swirler **120** configured to mix air and fuel for the second or main fuel injector associated with secondary fuel-air mixture **130** for combustor **105**.

[0035] According to one embodiment, swirler **120** may include a plurality of passages **125** to provide low net-swirl and as a result control the penetration depth and improve premixing of fuel-air mixture **130**. By controlling the penetration depth of fuel-air mixture **130**, swirler can provide a fuel-air mixture that improves the fuel burning ability of fuel-air mixture **130** by pilot fuel-air mixture **115**. In that fashion, NOx (e.g., nitric oxide and nitrogen dioxide) emissions of the combustor **105** and gas turbine engine **100** may be reduced.

[0036] Swirler **120** may be configured for one or more fuel injectors to control the penetration of a fuel air mixture and to control premixing of the fuel air mixture. According to one embodiment, swirler **120** improves fuel and air mixing within combustor **105** due to premixing. In addition, swirler **120** reduces unwanted pollutant emission such as NOx and smoke by controlling the penetration depth of the fuel air mixture and by combustion of substantially all fuel.

[0037] FIGS. **2**A-**2**B depict graphical representations of swirler configurations according to one or more embodiments. According to one embodiment, swirler **200** includes an inner passage **205** configured to receive air flow and one or more swirl passages shown as **210**. Inner passage **205** is configured to receive and channel air flow **215**. Inner passage **205** may be configured to receive a fuel injector. According to one embodiment, swirler **200** includes guide structure **206** configured to channel swirler airflow with fuel output by a fuel injector within inner passage **205**.

[0038] Swirl passages include outer passages concentrically arranged around the inner passage **205**, wherein the plurality of outer passages include an outer vane assembly **225** and first middle vane assembly **230**. Outer vane assembly **225** includes a plurality of vane elements arranged at a first angle. First middle vane assembly **230** includes a plurality of vane elements arranged at a second angle. As shown in FIG. **2**A, outer vane assembly **225** is concentrically arranged around the first middle vane assembly **230**. Outer vane assembly **225** and first middle vane assembly **230** are configured to produce a low net-swirl to control the penetration depth of a fuel air mixture for the fuel injector, such as a main fuel injector. Outer vane assembly **225** and first middle vane assembly **230** may also produce a low net-swirl to improve premixing of the fuel air mixture for the fuel injector. Although FIG. **2**A, is shown and described as having a two passage swirl arrangement above formed by outer vane assembly **225** and first middle vane assembly **230** swirler **200** may include a second middle vane assembly.

[0039] According to one embodiment, a fuel injector within inner passage **205** may spray fuel axially as shown by **235**. Axial fuel spray **235** is mixed with air output by outer vane assembly **225** and first middle vane assembly **230** as fuel-air mixture **240**. Fuel-air mixture may be characterized as having a low net-swirl that allows for the penetration depth of fuel-air mixture **240** to be controlled with respect to an annular structure of a combustor.

[0040] FIG. **2**B depicts a partial representation of a two pass outer passage for a swirler according to one or more embodiments. Swirler configuration **250** includes outer passage (e.g., vane assembly) **251**, middle passage (e.g., vane assembly) **252**, and inner passage **255**. Outer passage **260** may be configured with a plurality of vanes are angled within the range of +45 to +60 degrees. Vanes of the outer passage **260** are arranged and configured to handle within 50 to 70 percent of the airflow received by the swirler. Vanes of the middle passage **252** are angled within the range of 0 to −25 degrees and may be configured to handle within 20 to 40 percent of the airflow received by the swirler Inner passage **255** may be configured receive 5 to 20 percent of the airflow received by the swirler.

[0041] Air flow output by inner passage **255** and inner passage **255** co-swirls in fuel spray location **260** and joins airflow of inner passage **255** at exit **261** of the swirler.

[0042] FIG. **2**C depicts a partial representation of a three pass outer passage for a swirler according to one or more embodiments. Swirler configuration **270** includes outer passage (e.g., vane assembly) **271**, middle passage (e.g., vane assembly) **272**, second middle passage (e.g., vane assembly) **273**, and inner passage **275**. Outer passage **271** may be configured with a plurality of vanes are angled within the range of +45 to +60 degrees. Vanes of the outer passage **271** are arranged and configured to handle within 45 to 65 percent of the airflow received by the swirler. Vanes of the middle passage **272** are angled within the range of −10 to −30 degrees and vanes of the second middle assembly are angled within the range of +10 to +30 degrees. Vanes of the first middle vane assembly **272**, and similarly vanes of the second middle vane assembly **273** are arranged and configured to handle within 15 to 25 percent of the airflow received by the swirler. Inner passage **275** may be configured receive 5 to 20 percent of the airflow received by the swirler.

[0043] Air flow output by inner passage **275** and inners passage **272**, **273** co-swirls in fuel spray location **280** and joins airflow of inner passage **275** at exit **281** of the swirler.

[0044] FIGS. **3**A-**3**B depict graphical representations of swirler configurations according to one or more embodiments. FIG. **3**A depicts a two pass swirler including vane elements according to one or more embodiments. Swirler **300** includes outer passage **305** including vanes **310** and middle passage **315** including vanes **320**. Inner passage of swirler **300** is shown as **330**. Swirler **300** is an annular structure including vanes of each passage angled in opposite directions.

[0045] FIG. **3**B depicts a three pass swirler including vane elements according to one or more embodiments. Swirler **350** includes outer passage **350** including vanes **355**, middle passage **360** including vanes **365** and middle passage **370** including vanes **375**. Inner passage of swirler **350** is shown as **330**. Swirler **350** is an annular structure including vanes of each passage angled in opposite directions.

[0046] FIG. **4** depicts a graphical representation of swirler penetration according to one or more embodiments. According to one embodiment, one or more swirler elements may be included around the circumference of an annular combustor. FIG. **4** depicts a combustor **400** and fuel-air mixture **405** controlled by a swirler relative to the inner diameter **410** of the combustor structure. According to one embodiment, the amount of penetration of fuel-air mixture **405** may be controlled to a depth **415** above the inner diameter panel. According to another embodiment, premixing of fuel-air mixture **405** may improved by the swirler configuration to reduce unwanted pollutant emissions such as NOx and smoke.

[0047] While this disclosure has been particularly shown and described with references to exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the claimed embodiments.

What is claimed is:

1. A swirler for a combustor of a gas turbine engine, the swirler comprising:
- an inner passage for receiving a fuel injector;
- a plurality of outer passages concentrically arranged around the inner passage, wherein the plurality of outer passages include
  - an outer vane assembly including a plurality of vane elements arranged at a first angle; and
  - a first middle vane assembly include a plurality of vane elements arranged at a second angle,
- wherein the outer vane assembly is concentrically arranged around the first middle vane assembly, and wherein the outer vane assembly and first middle vane assembly are configured to produce a low net-swirl to control the penetration depth of a fuel air mixture for the fuel injector.

2. The swirler of claim **1**, wherein the swirler is configured to generate an air and fuel mixture downstream of a combustor pilot flow and improve premixing of the fuel air mixture.

3. The swirler of claim **1**, wherein vanes of the outer vane assembly are angled within the range of +45 to +60 degrees.

4. The swirler of claim **1**, wherein vanes of the outer vane assembly are arranged and configured to handle within 50 to 70 percent of the airflow received by the swirler.

5. The swirler of claim **1**, wherein vanes of the first middle vane assembly are angled within the range of 0 to −25 degrees.

6. The swirler of claim **1**, wherein vanes of the first middle vane assembly are arranged and configured to handle within 20 to 40 percent of the airflow received by the swirler.

7. The swirler of claim **1**, wherein the penetration depth relates to the penetration depth within a combustor cavity.

8. The swirler of claim **1**, wherein the swirler generates a low net-swirl by co-swirling airflow associated with the outer vane assembly and first middle vane assembly.

9. The swirler of claim **1**, further comprising a second middle vane assembly include a plurality of vane elements arranged at a third angle, and wherein the first middle vane assembly is arranged concentrically around the first middle vane assembly.

10. The swirler of claim **1**, wherein vanes of the outer vane assembly are angled in a direction opposite to vanes of the first middle vane assembly.

11. A swirler for a combustor of a gas turbine engine, the swirler comprising:
- an inner passage for receiving a fuel injector;
- a plurality of outer passages concentrically arranged around the inner passage, wherein the plurality of outer passages include
  - an outer vane assembly including a plurality of vane elements arranged at a first angle;
  - a first middle vane assembly include a plurality of vane elements arranged at a second angle; and

a second middle vane assembly include a plurality of vane elements arranged at a third angle, wherein the first middle vane assembly is concentrically arranged around the second middle vane assembly,

wherein the outer vane assembly is concentrically arranged around the first middle vane assembly and second middle assembly, and wherein the outer vane assembly, first middle vane assembly and second middle vane assembly are configured to produce a low net-swirl to control the penetration depth of a fuel air mixture for the fuel injector.

12. The swirler of claim **11**, wherein the swirler is configured to generate an air and fuel mixture downstream of a combustor pilot flow and improve premixing of the fuel air mixture.

13. The swirler of claim **11**, wherein vanes of the outer vane assembly are angled within the range of +45 to +60 degrees.

14. The swirler of claim **11**, wherein vanes of the outer vane assembly are arranged and configured to handle within 45 to 65 percent of the airflow received by the swirler.

15. The swirler of claim **11**, wherein vanes of the first middle vane assembly are angled within the range of −10 to −30 degrees and vanes of the second middle assembly are angled within the range of +10 to +30 degrees.

16. The swirler of claim **11**, wherein vanes of the first middle vane assembly are arranged and configured to handle within 15 to 25 percent of the airflow received by the swirler wherein vanes of the second middle vane assembly are arranged and configured to handle within 15 to 25 percent of the airflow received by the swirler.

17. The swirler of claim **11**, wherein the penetration depth relates to the penetration depth within a combustor cavity.

18. The swirler of claim **11**, wherein the swirler generates a low net-swirl by co-swirling airflow associated with the outer vane assembly and first middle vane assembly.

19. The swirler of claim **11**, further comprising a second middle vane assembly include a plurality of vane elements arranged at a third angle, and wherein the first middle vane assembly is arranged concentrically around the first middle vane assembly.

20. The swirler of claim **11**, wherein vanes of the outer vane assembly and second middle vane assembly are angled in a direction opposite to vanes of the first middle vane assembly.

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