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United States Patent Application Publication	20250257875
Kind Code	A1
Publication Date	August 14, 2025
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MULTI-FUEL COMBUSTION SYSTEM

Abstract

A multi-fuel combustion system for a turbine engine, the multi-fuel combustion system having a combustion chamber formed by a combustor liner. The combustion chamber defines a first combustion zone and a second combustion zone. A first fuel system is fluidly coupled with the first combustion zone, where a rotary fuel slinger provides a first fuel to the first combustion zone. A second fuel system is fluidly coupled with the second combustion zone, where a gaseous fuel injector provides a second fuel to the second combustion zone.

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Family ID: **94382898**

Appl. No.: **18/441297**

Filed: **February 14, 2024**

Publication Classification

Int. Cl.: **F23R3/34** (20060101); **F23R3/36** (20060101)

U.S. Cl.:

CPC **F23R3/346** (20130101); **F23R3/36** (20130101);

Background/Summary

TECHNICAL FIELD

[0001] The present subject matter relates generally to a turbine engine having a multi-fuel combustion system.

BACKGROUND

[0002] Turbine engines are driven by a flow of combustion gases passing through the engine to rotate a multitude of turbine blades, which, in turn, rotate a compressor to provide compressed air to the combustor for combustion. A combustor can be provided within the turbine engine and is fluidly coupled with a turbine into which the combusted gases flow.

[0003] Historically, fuels are used in the combustor of a turbine engine. Generally, air and fuel are fed to a combustion chamber, the air and fuel are mixed, and then the fuel is burned in the presence of the air to produce hot gas. The hot gas is then fed to a turbine to produce power.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] In the drawings:

[0005] FIG. **1** is a schematic cross-sectional view of a turbine engine having a compressor section, a combustion section with a multi-fuel combustion system, and a turbine section in accordance with various aspects described herein.

[0006] FIG. **2** is a schematic cross-sectional view the multi-fuel combustion system of FIG. **1** in accordance with various aspects described herein.

[0007] FIG. **3** is the schematic cross-sectional view the multi-fuel combustion system of FIG. **2** further illustrating fuel and air flows in accordance with various aspects described herein.

[0008] FIG. **4** is a flow chart illustrating a method of operating the turbine engine having the multi-fuel combustion system of FIG. **1** in accordance with various aspects described herein.

[0009] FIG. **5** is a variation of the schematic cross-sectional view of FIG. **2**, in accordance with various aspects described herein.

[0010] FIG. **6** is another variation of the schematic cross-sectional view of FIG. **2** and FIG. **4**, in accordance with various aspects described herein.

DETAILED DESCRIPTION

[0011] Aspects of the disclosure described herein are directed to a multi-fuel combustion system. The multi-fuel combustion system includes a combustion chamber defined, in part, by a combustor liner. The combustor liner can have a forward liner and an aft liner. The forward liner at least partially defines a first combustion zone and the aft liner at least partially defines a second combustion zone within the combustion chamber.

[0012] A first fuel system includes a rotary fuel slinger which provides a first fuel to the first combustion zone. The rotary fuel slinger is rotationally driven and can atomize the first fuel received by rapid spinning and spraying of the first fuel. That is, the first fuel can be centrifuged radially outward within a portion of the rotary fuel slinger and another portion of the rotary fuel slinger can receive and discharge the first fuel as a collection of droplets.

[0013] The exhaust from the first combustion zone enters the second combustion zone. That is, the second combustion zone is fluidly downstream of the first combustion zone. The second combustion zone is provided with a second fuel from a gaseous fuel injector of a second fuel system. The second fuel burns faster, hotter, cleaner or any combination thereof when compared to the first fuel. Burning the exhaust from the first combustion zone in the second combustion zone reduces total emissions from the combustion chamber.

[0014] For purposes of illustration, the present disclosure will be described with respect to a turbine engine. It will be understood, however, that aspects of the disclosure described herein are not so limited and that a combustor as described herein can be implemented in engines, including but not limited to turbojet, turboprop, turboshaft, and turbofan engines. Aspects of the disclosure discussed herein may have general applicability within non-aircraft engines having a combustor, such as other mobile applications and non-mobile industrial, commercial, and residential applications.

[0015] The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any implementation described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other implementations. Additionally, unless specifically identified otherwise, all embodiments described herein should be considered exemplary.

[0016] As may be used herein, the terms “first” and “second” may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components.

[0017] The terms “forward” and “aft” refer to relative positions within a turbine engine or a vehicle, and refer to the normal operational attitude of the turbine engine or vehicle. For example, with regard to a turbine engine, forward refers to a position closer to an engine inlet and aft refers to a position closer to an engine exhaust.

[0018] As used herein, the term “upstream” refers to a direction that is opposite the fluid flow direction, and the term “downstream” refers to a direction that is in the same direction as the fluid flow.

[0019] The term “fluid” may be a gas or a liquid, or a combination thereof. The term “fluidly coupled” means that a fluid is capable of making the connection between the areas specified. The term “fluidly exposed” means that one or more portions of an object is contacted by a fluid.

[0020] Additionally, as used herein, the terms “radial” or “radially” refer to a direction away from a common center. For example, in the overall context of a turbine engine, radial refers to a direction along a ray extending between a center longitudinal axis of the engine and an outer engine circumference.

[0021] All directional references (e.g., radial, axial, upper, lower, left, right, front, back, top, bottom, above, below, vertical, horizontal, upstream, downstream, forward, aft, etc.) are only used for identification purposes to aid the reader's understanding of the present disclosure, and do not create limitations, particularly as to the position, orientation, or use of aspects of the disclosure described herein. Connection references (e.g., attached, coupled, and connected) are to be construed broadly and can include intermediate structural elements between a collection of elements and relative movement between elements unless otherwise indicated. As such, connection references do not necessarily infer that two elements are directly connected and in fixed relation to one another. The exemplary drawings are for purposes of illustration only. The dimensions, positions, order, and relative sizes reflected in the drawings attached hereto can vary.

[0022] The term “perpendicular” refers to generally perpendicular, where the angle between a first line and a second line is in a range of 85° to 95°. The term “parallel” refers to generally parallel, where first and second lines extend such that a third line can be drawn that crosses the first and second line, wherein the third line in a range of 85° to 95° to both the first line and the second line.

[0023] The singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise. Furthermore, as used herein, the term “set” or a “set” of elements can be any number of elements, including only one.

[0024] Uses of “and” and “or” are to be construed broadly. For example, and without limitation, uses of “and” do not necessarily require all elements or features listed, and uses of “or” are inclusive unless such a construction would be illogical.

[0025] As used herein, a “controller”, for example, “control module”, “regulator module”, “integrator module” can include a component configured or adapted to provide instruction, control, operation, or any form of communication for operable components to affect the operation thereof. Such controllers or modules can include any known processor, microcontroller, or logic device, including, but not limited to: Field Programmable Gate Arrays (FPGA), a Complex Programmable Logic Device (CPLD), an Application-Specific Integrated Circuit (ASIC), a Full Authority Digital

Engine Control (FADEC), a Proportional Controller (P), a Proportional Integral Controller (PI), a Proportional Derivative Controller (PD), a Proportional Integral Derivative Controller (PID), a hardware-accelerated logic controller (e.g. for encoding, decoding, transcoding, etc.), the like, or a combination thereof. While described herein as comprising separate elements, in non-limiting aspects such controllers and modules can be incorporated on one or more devices including a common device, such as a single processor or microcontroller. Non-limiting examples of such controllers or module can be configured or adapted to run, operate, or otherwise execute program code to effect operational or functional outcomes, including carrying out various methods, functionality, processing tasks, calculations, comparisons, sensing or measuring of values, or the like, to enable or achieve the technical operations or operations described herein. The operation or functional outcomes can be based on one or more inputs, stored data values, sensed or measured values, true or false indications, or the like. While “program code” is described, non-limiting examples of operable or executable instruction sets can include routines, programs, objects, components, data structures, algorithms, etc., that have the technical effect of performing particular tasks or implement particular abstract data types. In another non-limiting example, a controller, a controller module, regulator module, or integrator module can also include a data storage component accessible by the processor, including memory, whether transition, volatile or non-transient, or non-volatile memory. Additional non-limiting examples of the memory can include Random Access Memory (RAM), Read-Only Memory (ROM), flash memory, or one or more different types of portable electronic memory, such as discs, DVDs, CD-ROMs, flash drives, Universal Serial Bus (USB) drives, the like, or any suitable combination of these types of memory. In one example, the program code can be stored within the memory in a machine-readable format accessible by the processor. Additionally, the memory can store various data, data types, sensed or measured data values, inputs, generated or processed data, or the like, accessible by the processor in providing instruction, control, or operation to effect a functional or operable outcome, as described herein. In another non-limiting example, a controller can compare a first value with a second value, and operating or controlling operations of additional components based on the satisfying of that comparison. For example, when a sensed, measured, or provided value is compared with another value, including a stored or predetermined value, the satisfaction of that comparison can result in actions, functions, or operations controllable by the controller. As used, the term “satisfies” or “satisfaction” of the comparison is used herein to mean that the first value satisfies the second value, such as being equal to or less than the second value, or being within the value range of the second value. It will be understood that such a determination may easily be altered to be satisfied by a positive/negative comparison or a true/false comparison. Example comparisons can include comparing a sensed or measured value to a threshold value or threshold value range.

[0026] Also, as used herein, while sensors can be described as “sensing” or “measuring” a respective value, sensing or measuring can include determining a value indicative of or related to the respective value, rather than directly sensing or measuring the value itself. The sensed or measured values can further be provided to additional components. For instance, the value can be provided to a controller or processor, and the controller or processor can perform processing on the value to determine a representative value or an electrical characteristic representative of said value.

[0027] FIG. **1** is a schematic view of a turbine engine **10**. As a non-limiting example, the turbine engine **10** can be used with an aircraft. The turbine engine **10** can include, at least, a compressor section **12**, a combustion section **14**, and a turbine section **16** in a serial flow arrangement. A drive shaft **18** rotationally couples the compressor section **12** and turbine section **16**, such that rotation of one affects the rotation of the other, and defines an engine centerline **20** for the turbine engine **10**.

[0028] The compressor section **12** can include a low-pressure (LP) compressor **22**, and a high-pressure (HP) compressor **24** serially fluidly coupled to one another. The turbine section **16** can include an HP turbine **26** and an LP turbine **28** serially fluidly coupled to one another. The drive shaft **18** can operatively couple the LP compressor **22**, the HP compressor **24**, the HP turbine **26** and the LP turbine **28** together. Alternatively, the drive shaft **18** can include an LP drive shaft and an HP drive shaft. The LP drive shaft can couple the LP compressor **22** to the LP turbine **28**, and the HP drive shaft can couple the HP compressor **24** to the HP turbine **26**. An LP spool can be defined as the combination of the LP compressor **22**, the LP turbine **28**, and the LP drive shaft such that the rotation of the LP turbine **28** can apply a driving force to the LP drive shaft, which in turn can rotate the LP compressor **22**. An HP spool can be defined as the combination of the HP compressor **24**, the HP turbine **26**, and the HP drive shaft such that the rotation of the HP turbine **26** can apply a driving force to the HP drive shaft which in turn can rotate the HP compressor **24**.

[0029] The compressor section **12** can include a plurality of axially spaced stages. Each stage includes a set of circumferentially-spaced rotating blades and a set of circumferentially-spaced stationary vanes. The compressor blades for a stage of the compressor section **12** can be mounted to a disk, which is mounted to the drive shaft **18**. Each set of blades for a given stage can have its own disk. The vanes of the compressor section **12** can be mounted to a casing which can extend circumferentially about the turbine engine **10**. It will be appreciated that the representation of the compressor section **12** is merely schematic and that there can be any number of blades, vanes, and stages. Further, it is contemplated that there can be any number of other components within the compressor section **12**.

[0030] Similar to the compressor section **12**, the turbine section **16** can include a plurality of axially spaced stages, with each stage having a set of circumferentially-spaced, rotating blades and a set of circumferentially-spaced, stationary vanes. The turbine blades for a stage of the turbine section **16** can be mounted to a disk which is mounted to the drive shaft **18**. Each set of blades for a given stage can have its own disk. The vanes of the turbine section can be mounted to a casing in a circumferential manner. It is noted that there can be any number of blades, vanes, and turbine stages, as the illustrated turbine section is merely a schematic representation. Further, it is contemplated that there can be any number of other components within the turbine section **16**.

[0031] The combustion section **14** can be provided serially between the compressor section **12** and the turbine section **16**. The combustion section **14** can be fluidly coupled to at least a portion of the compressor section **12** and the turbine section **16** such that the combustion section **14** at least partially fluidly couples the compressor section **12** to the turbine section **16**. As a non-limiting example, the combustion section **14** can be fluidly coupled to the HP compressor **24** at an upstream end of the combustion section **14** and to the HP turbine **26** at a downstream end of the combustion section **14**.

[0032] A slinger multi-fuel combustion system or a multi-fuel combustion system **30** is included in the combustion section **14**. The multi-fuel combustion system **30** can receive a rotatable output from the drive shaft **18**. That is, a portion of the multi-fuel combustion system **30** is rotatably coupled to the drive shaft **18** which illustrates, by way of example, the LP drive shaft, the HP drive shaft, or both. The multi-fuel combustion system **30** can be fluidly coupled to a portion of the drive shaft **18** to receive a liquid fuel.

[0033] Additionally, or alternatively, an engagement assembly **32** can selectively fluidly connect or disconnected the multi-fuel combustion system **30** from a fuel source. By way of non-limiting example, the fuel source can be liquid fuel, hydrogen fuel, gaseous fuel, or any combination thereof. In other words, the liquid fuel can be “turned off” or disconnected by the engagement assembly **32**, while the engagement assembly **32** can be providing hydrogen fuel or other gaseous fuels, or vice versa.

[0034] During operation of the turbine engine **10**, ambient or atmospheric air is drawn into the compressor section **12** via a fan upstream of the compressor section **12**, where the air is compressed, defining a pressurized air. The pressurized air can then flow into the combustion section **14** where the pressurized air is mixed with fuel and ignited, thereby generating combustion gases. Some work is extracted from these combustion gases by the HP turbine **26**, which drives the

HP compressor **24**. The combustion gases are discharged into the LP turbine **28**, which extracts additional work to drive the LP compressor **22**, and the exhaust gas is ultimately discharged from the turbine engine **10** via an exhaust section downstream of the turbine section **16**. The driving of the LP turbine **28** drives the LP spool to rotate the fan and the LP compressor **22**.

[0035] One or more components of the turbine engine **10**, such as, but not limited to, an engine starter or one or more portions of the turbine section **16**, provide rotational energy to the drive shaft **18**. The drive shaft **18** can provide a rotatable output to a portion of the multi-fuel combustion system **30** as further discussed in FIG. **2**.

[0036] FIG. **2** is a schematic cross-sectional view of the multi-fuel combustion system **30**. The multi-fuel combustion system **30** includes a combustor liner **34** with a forward liner **40** and an aft liner **42**, spaced axially from the forward liner **40**. A combustion chamber **44** can be formed by the combustor liner **34**. The combustion chamber **44** can be an annular chamber. Alternately, in another non-limiting example, the combustion chamber **44** can be a plurality of circumferentially spaced combustion chambers.

[0037] The combustion chamber **44** includes a radially-extending portion **46** and an axially-extending portion **48**. The radially-extending portion **46** can include a first combustion zone **50**. The axially-extending portion **48** can include a second combustion zone **52**. In other words, the combustion chamber **44** includes at least two combustion zones, the first combustion zone **50** and the second combustion zone **52**, separated, by way of example, by a dotted line. It should be understood that the dotted line can be curved and located anywhere in the combustion chamber **44** that separates the combustion chamber **44** into two combustion zones. As used herein, a combustion zone includes a non-luminous zone where air and fuel are mixed to produce combustion. A first flame can be located in a first region **54** within the first combustion zone **50**. A second flame can be located in a second region **56** within the second combustion zone **52**.

[0038] A first fuel system **60** is fluidly coupled to the first combustion zone **50**. The first fuel system **60** includes a liquid fuel injector or nozzle having a slinger, illustrated as a rotary fuel slinger **62**, for providing a first fuel **58** to the first combustion zone **50**.

[0039] The rotary fuel slinger **62** is operably coupled to the drive shaft **18**. That is, as the drive shaft **18** rotates, a rotor portion **64** of the rotary fuel slinger **62** can rotate. While illustrated as permanently coupled or formed with the drive shaft **18**, it is contemplated in a different and non-limiting example that the rotary fuel slinger **62** can be selectively operably coupled to the drive shaft **18**.

[0040] The first fuel system **60** can include a fuel passage **66**. As illustrated, by way of example, the fuel passage **66** can be defined by the drive shaft **18**. Additionally, or alternatively, a first conduit **68**, illustrated in dashed line, can provide the first fuel **58** to the rotary fuel slinger **62**, where the first conduit **68** is located axially along and radially outward of the drive shaft **18**. The first conduit **68** can be coupled to the first fuel system **60** via the engagement assembly **32** (FIG. **1**).

[0041] A first fuel outlet, illustrated as an outlet **70**, of the rotary fuel slinger **62** emits the first fuel **58** into the radially-extending portion **46** or the first combustion zone **50** of the combustion chamber **44**. A slinger injector centerline **72** can be defined by the outlet **70**. The slinger injector centerline **72** can be perpendicular to the engine centerline **20**. That is, slinger injector centerline **72** can form an angle with the engine centerline **20** in a range from 85° to 95°. Alternatively, the slinger injector centerline **72** can form an angle with the engine centerline **20** in a range from 20° to less than 85°.

[0042] A first ignitor **78** can be located in the first combustion zone **50**. The first ignitor **78** is illustrated, by way of example, as located in the forward liner **40**. Additionally, or alternatively, the first ignitor **78** for the first fuel in the first combustion zone **50** can be located at the aft liner **42**. While the first ignitor **78** is illustrated as a single ignitor, multiple igniters are contemplated.

[0043] A second fuel system **80** is fluidly coupled to the second combustion zone **52**. The second fuel system **80** includes a fuel injector illustrated as a gaseous fuel injector **82** and a fuel supply passage illustrated as a gaseous fuel supply passage **84** terminating in an outlet illustrated as a gaseous fuel injector outlet **86**. The gaseous fuel injector **82** provides a second fuel **74** to the second combustion zone **52**. The second fuel can be provided to the gaseous fuel injector **82** by the gaseous fuel supply passage **84**. That is, the gaseous fuel supply passage **84** is fluidly coupled to the gaseous fuel injector **82**.

[0044] While illustrated as a single gaseous fuel injector, the gaseous fuel injector **82** can be a set of circumferentially spaced gaseous fuel injectors. The set of circumferentially spaced gaseous fuel injectors can be circumferentially spaced about the engine centerline **20**.

[0045] Optionally, a valve **88** can control the flow of the second fuel **74** into the gaseous fuel injector **82** from the gaseous fuel supply passage **84**. The valve **88** can be located at or upstream of the intersection of the gaseous fuel supply passage **84** and the gaseous fuel injector **82**.

[0046] A gaseous fuel injector centerline **92** can be defined by the gaseous fuel injector outlet **86**. The gaseous fuel injector centerline **92** can be perpendicular to the engine centerline **20**. Alternatively, the gaseous fuel injector centerline **92** can form an angle with the engine centerline **20** in a range from 20° to less than 85°, as further illustrated in FIGS. **5-6**.

[0047] A second ignitor **94** can be located in the second combustion zone **52**. The second ignitor **94** is located, by way of example, at the forward liner **40**. Additionally, or alternatively, the second ignitor **94** for the second fuel in the second combustion zone **52** can be located at the aft liner **42**. While the second ignitor **94** is illustrated as a single ignitor, multiple igniters are contemplated. It is further contemplated that the first ignitor **78** and the second ignitor **94** can be a single ignitor. That is, the combustion chamber **44** includes at least one ignitor, illustrated, by way of example as the first ignitor **78** and the second ignitor **94**.

[0048] A set of dilution holes **96** can be provided in the combustor liner **34**. The set of dilution holes **96** are located in the second combustion zone **52** and are configured to direct air from an exterior **98** of the combustion chamber **44** into the second combustion zone **52**. The set of dilution holes **96** can be adjacent the gaseous fuel injector outlet **86** for temperature control, flame shaping, fuel-air mixing, or the like. That is, the set of dilution holes **96** can be circumferentially spaced about the gaseous fuel injector outlet **86**. Any number of dilution holes can be provided in the set of dilution holes **96**. The set of dilution holes **96** can have any suitable patterning or arrangement including linear rows, irregular groups, variable hole diameters, or the like, or combinations thereof.

[0049] As used herein, the term “adjacent” means within an axial distance that is six times the diameter of the gaseous fuel injector outlet **86** or less. That is, the axial distance from the gaseous fuel injector outlet **86** to at least one or more of the set of dilution holes **96** is equal to or less than 600% of the diameter of the gaseous fuel injector outlet **86**. The set of dilution holes **96** are closer to the gaseous fuel injector outlet **86** than dilution holes of a traditional fuel outlet that would provide traditional liquid fuels to a combustion chamber. The set of dilution holes **96** are closer to the gaseous fuel injector outlet **86**, as the reactions with the second fuel **74** will happen much faster than traditional fuels.

[0050] A dilution hole centerline **100** can be defined by each dilution hole of the set of dilution holes **96**. An angle **102** defined as the intersection of the dilution hole centerline **100** and the gaseous fuel injector centerline **92** can be in a range of greater than 0° and less than 90°.

[0051] The dilution hole centerline **100** can be parallel to the slinger injector centerline **72**. Alternatively, an angle between the slinger injector centerline **72** and the dilution hole centerline **100** is non-zero. Optionally, the gaseous fuel injector outlet **86** can be axially aft of the rotary fuel slinger **62** or the slinger injector centerline **72**. Alternatively, in different and non-limiting examples, a portion of the gaseous fuel injector outlet **86** can be axially forward or axially align with at least a portion of the rotary fuel slinger **62** or the slinger injector centerline **72**.

[0052] FIG. **3** further illustrates the multi-fuel combustion system **30** during one or more portions of a cycle of operation of the turbine engine **10** (FIG. **1**). The cycle of operation can include, but is not limited to, start-up, idle, take-off, cruise, decent or land, and shut-down. Referring to FIG. **1**, during start-up the turbine engine **10** is provided with mechanical energy to begin the rotation of the drive shaft **18** and one or more portions of the compressor section **12** or the turbine section **16**. Once started, air is channeled into the LP compressor **22**, which then supplies pressurized airflow to the HP compressor **24**, which further pressurizes the air.

[0053] Referring again to FIG. **3**, a portion of the pressurized airflow from the HP compressor **24** (FIG. **1**) is mixed with the first fuel **58**, the second fuel **74**, or both in the multi-fuel combustion system **30** and ignited, thereby generating combustion gases. Some work can be extracted from these gases by the HP turbine **26** (FIG. **1**), which drives the HP compressor **24** (FIG. **1**). The combustion gases are discharged into the LP turbine **28** (FIG. **1**), which can extract additional work to drive the LP compressor **22** (FIG. **1**).

[0054] More specifically, the fuel passage **66**, the first conduit **68**, or a combination of both provides the first fuel **58** to the rotor portion **64** of the rotary fuel slinger **62**. The first fuel **58** can be a liquid fuel that includes, for example, kerosene or petroleum. The first fuel **58** has a residence time in the combustion chamber **44** in a range from 3 milliseconds to 7 milliseconds. By way of non-limiting example, the first fuel **58** can have a residence time in a range from 3 milliseconds to 5 milliseconds. Residence time can be calculated for the first fuel **58** in the first combustion zone **50** or in the first combustion zone **50** and at least a portion of the second combustion zone **52**. Residence time can be estimated by dividing the volume of the combustion chamber or zone by the volumetric flow rate of the fuel stream. In other words, the residence time is the time needed in a combustion chamber or zone to evaporate fuel (as needed), mix fuel and air, and burn or otherwise complete the chemical reactions of the fuel-air mixture. The estimate can further be refined by including swirl of the fuel-air mixture.

[0055] The outlet **70** of the rotary fuel slinger **62** emits the first fuel **58** as an atomized liquid fuel **118** into the radially-extending portion **46** or the first combustion zone **50** of the combustion chamber **44**. The first fuel **58** is atomized using centrifugal force from the drive shaft **18**. In other words, because of the rotating rotor portion **64**, the first fuel **58** moves radially outward towards the outlet **70** due to the inertia of the first fuel **58** within the rotating drive shaft **18** and the rotor portion **64**. The first fuel **58** exits the outlet **70** as tiny droplets. The first fuel **58** experiences pressure as it moves towards the outlet **70** within the rotor portion **64**, causing pressure atomization of the first fuel **58**. The pressure atomization of the first fuel **58** provides an even distribution of the first fuel **58** into the first combustion zone **50**.

[0056] Optionally, an atomizing air flow **120** can be provided and oriented to shear the first fuel **58** as it passes through the outlet **70** and into the first combustion zone **50**. The atomizing air flow **120** can atomize the first fuel **58** in addition to the pressure atomization provided by the rotor portion **64** to provide the atomized liquid fuel **118** to the first combustion zone **50**.

[0057] Independent or concurrent with the flow of the first fuel **58** to the rotary fuel slinger **62**, the second fuel **74** can be provided to the gaseous fuel injector **82** via the gaseous fuel supply passage **84**. The flow of the second fuel **74** can be controlled by a controller **122** in communication with, for example, the valve **88**. It is also contemplated that the flow of the first fuel **58** can be controlled by the controller **122** or another controller or device.

[0058] The second fuel **74** can be a gaseous fuel including a hydrocarbon fuel, hydrogen fuel, or a mixture of differing fuel types. The second fuel **74** has a residence time in the combustion chamber **44** in a range from 0.2 milliseconds to 4 milliseconds. By way of non-limiting example, the second fuel **74** in the second combustions zone **52** can have a residence time in a range from 1 millisecond to 3 milliseconds. The residence time for the second fuel **74** can be calculated for the in the second combustion zone **52** or in the second combustion zone **52** and at least a portion of the first combustion zone **50**.

[0059] Optionally, the gaseous fuel injector **82** can include one or more of a swirler, an air inlet, multiple fuel injectors, a premixer vortex generator, or other fuel-air mixing devices arranged in

discrete clusters or groups such that the fuel-air mixture has a non-zero swirl at the gaseous fuel injector outlet **86**.
[0060] The second fuel **74** or a mixture of air and the second fuel **74** can exit the gaseous fuel injector **82** at the gaseous fuel injector outlet **86**. The second fuel **74**, that includes hydrogen, can burn faster or hotter than traditional fuels such as, for example, the first fuel **58**. The set of dilution holes **96** can provide an air flow **124** that, for example, provide temperature control, flame shaping, and fuel-air mixing in the second combustion zone **52**. The set of dilution holes **96** can provide cooling for the combustor liner **34**, however, the primary benefit of the air flow **124** adjacent the gaseous fuel injector outlet **86** is to control the temperature, provide flame shaping, and fuel-air mixing for the flame or combustion in the second region **56**.
[0061] Additional dilution holes can provide air flow **104**, indicated by arrows, which direct air from the exterior **98** of the combustion chamber **44** to the first combustion zone **50**, the second combustion zone **52**, or both. The additional dilution holes can provide temperature control, flame shaping for one or both of the first region **54** or the second region **56**, fuel-air mixing, or the like.
[0062] Compressed air for the set of dilution holes **96**, the additional dilution holes, the air flow **124**, or other film holes that extend through the combustor liner **34** can come from the compressor section **12** (FIG. **1**). The compressor section **12** (FIG. **1**) provides a compressed air flow **108**, illustrated as an arrow, to an air passage compressor **110**, which can further compress the air flow. That is, the compressed air flow **108** flows through the air passage compressor **110** where it becomes a further compressed airflow **112**. An air passage diffuser **114** is fluidly coupled to and downstream of the air passage compressor **110**. The further compressed air flow **112** exhausts into the air passage diffuser **114** and exits into the exterior **98** of the multi-fuel combustion system **30** as a desired air flow **116**. The air flow **116** from the exterior **98** of the multi-fuel combustion system **30** can pass into the combustion chamber **44** as the atomizing air flow **120**, the air flow **104** from the additional dilution holes indicated by arrows, the air flow **124** from the set of dilution holes **96**, or any combination thereof.
[0063] Additionally, or alternatively, the air flow **116** provided to the exterior **98** of the multi-fuel combustion system **30** can be provided to the first fuel system **60** upstream of the outlet **70**, the second fuel system **80** upstream of the gaseous fuel injector outlet **86**, or a combination thereof.
[0064] Once fuel and compressed air are provided to the multi-fuel combustion system **30**, the turbine engine **10** (FIG. **1**) can then move through the different portions of the cycle of operation by increasing, decreasing, or maintaining the amount of the first fuel **58** provided to the rotary fuel slinger **62** and the amount of the second fuel **74** provided to the gaseous fuel injector **82**. Additionally, or alternative, the turbine engine **10** can then move through the different portions of the cycle of operation by increasing, decreasing, or maintaining the rotational speed of one or more components.
[0065] The rotary fuel slinger **62** can be designed for maximum fuel flow and can be optimized for cruising to improve the combustion efficiency and reduce emissions from the first combustion zone **50** such as, but not limited to, nitrogen oxides (NO.sub.x) emissions during a cruising portion of the cycle of operation. The cycle of operation can include, but is not limited to, start-up, idle, take-off, cruse, decent or landing, and shut-down.
[0066] During, for example, idling, when the rotary fuel slinger **62** rotates at a lower speed than during cruising, the first combustion zone **50** can have increased emissions when compared to the emissions during cruising. To reduce or eliminate the emissions from the first combustion zone **50** during start-up, idle, take-off, cruse, decent or landing, shut-down, or any combination thereof, the second fuel **74** can be provided to the gaseous fuel injector **82**. The emissions from the first combustion zone **50** are exhausted to the second combustion zone **52**, which, when ignited, combusts or otherwise eliminates at least a portion of the emissions from the first combustion zone **50**.
[0067] The second fuel **74**, being a hydrogen-based fuel, reduces the environmentally unwanted

byproducts. Hydrogen or hydrogen mixed with another element has a higher flame temperature than traditional fuels. That is, hydrogen or a hydrogen mixed fuel typically has a wider flammable range and a faster burning velocity than traditional hydrocarbon-based fuels.

[0068] In a different and non-limiting example, the multi-fuel combustion system **30** can operate the turbine engine **10** using the first fuel **58**, the second fuel **74**, or both the first fuel **58** and second fuel **74**. This allows for a variation in fuel types available at different locations globally. For example, an airport can only have the first fuel **58** or the second fuel **74** available for refueling. The turbine engine **10** (FIG. **1**) can complete a cycle of operation using just the first fuel **58** or the second fuel **74**.

[0069] FIG. **4** illustrates a method **300** of operating a turbine engine **10** (FIG. **1**) having a multi-fuel combustion system **30**. The method **300** can include, at **302**, providing mechanical energy to begin rotation of at least the drive shaft **18** and a portion of the compressor section **12** to start the turbine engine **10**.

[0070] At **304**, compressed air flows into the exterior **98** (FIG. **3**) of the multi-fuel combustion system **30** (FIG. **3**). The compressed air flow **108** from the exterior **98** of the multi-fuel combustion system **30** can pass into the combustion chamber **44** (FIG. **3**).

[0071] During start-up, idle, take-off, cruise, decent or land, shut-down, or any combination thereof, the amount of the first fuel **58** (FIG. **3**) provided to the rotary fuel slinger **62** (FIG. **3**) and the second fuel **74** (FIG. **3**) provided to the gaseous fuel injector **82** (FIG. **3**) can be varied. That is, during the cycle of operation at **306** the amount of the first fuel **58** and the second fuel **74** is varied or controlled during one or more stages or between stages of the cycle of operation.

[0072] The first ignitor **78** (FIG. **3**), the second ignitor **94** (FIG. **3**), or a combination thereof can ignite or begin combustion of the fuel-air in the combustion chamber **44**. The ignition, amount, and type of fuel delivered to create the fuel-air mixtures in the combustion chamber **44** can be controlled by a controller, such as controller **122** (FIG. **3**). The controller can be in communication with the valve **88** (FIG. **3**).

[0073] More specifically, during start-up or idle the second fuel **74** can be provided to the gaseous fuel injector **82** and ignited by the second ignitor **94**. During take-off the first fuel **58** and the second fuel **74** can be provided to the rotary fuel slinger **62** and the gaseous fuel injector **82**, respectively. Optionally, the first ignitor **78** can ignite the fuel-air mixture exiting the rotary fuel slinger **62** in the first combustion zone **50**.

[0074] During cruising, the first fuel **58** can be provided to the rotary fuel slinger **62** and the amount of second fuel **74** provided to the gaseous fuel injector **82** can decrease or cease. Alternatively, in a different and non-limiting example, the amount of second fuel **74** provided to the gaseous fuel injector **82** can increase when the liquid fuel is depleted or is reduced for other reasons to maintain cruising.

[0075] During landing, the first fuel **58** and the second fuel **74** can be provided to the rotary fuel slinger **62** and the gaseous fuel injector **82**, respectively. Optionally, the second ignitor **94** can restart combustion in the second combustion zone **52**.

[0076] During shut-down, the first fuel **58** can decrease and cease to be provided to the rotary fuel slinger **62** and concurrently or sequentially, the second fuel **74** can decrease and cease to be provided to the gaseous fuel injector **82**.

[0077] Further, the amount of the liquid fuel and the amount of gaseous fuel can vary based on external conditions, desired thrust, or a combination thereof during any portion of the operation of the turbine engine.

[0078] FIG. **5** is a variation of a schematic cross-sectional view of FIG. **2**, wherein FIG. **5** illustrates a multi-fuel combustion system **430**, that can be used in the turbine engine **10** (FIG. **1**).

[0079] The multi-fuel combustion system **430** is similar to the multi-fuel combustion system **30** (FIG. **2**), therefore, like parts will be identified with like numerals increased by four hundred (**400**), with it being understood that the description of the like parts of the multi-fuel combustion system

30 applies to the multi-fuel combustion system **430**, unless otherwise noted.

[0080] Similar to the multi-fuel combustion system **30**, the multi-fuel combustion system **430** rotatably couples to a drive shaft **418** that rotates about an engine centerline **420**. Further, the multi-fuel combustion system **430** includes a combustor liner **434** with a forward liner **440**, an aft liner **442**, a combustion chamber **444**, a first combustion zone **450**, a second combustion zone **452**, a first fuel system **460** including a rotary fuel slinger **462** having an outlet **470** for providing a first fuel **458**, a slinger injector centerline **472** defined by the outlet **470**, a first ignitor **478**, a second fuel system **480**, a gaseous fuel injector **482** having a gaseous fuel injector outlet **486** for providing a second fuel **474**, a gaseous fuel injector centerline **492** defined by the gaseous fuel injector outlet **486**, a second ignitor **494**, and a set of dilution holes **496**.

[0081] The gaseous fuel injector centerline **492** can form an angle with the engine centerline **420** in a range from 20° to less than 85°. An angle **481** can be defined as the angle between the gaseous fuel injector centerline **492** and the slinger injector centerline **472**. The angle **481** can be in a range from 0° to 90°. For example, the angle **481** can be in a range of 5° to 40°. A non-zero angle **481** can lengthen fuel-air mixing and/or help direct the exhaust from the second combustion zone **52**.

[0082] A first radial distance **483** is measured radially outward from the engine centerline **420** to the outlet **470**. A second radial distance **485** is measured radially outward from the engine centerline **420** to the gaseous fuel injector outlet **486**. The second radial distance **485** is greater than the first radial distance **483**.

[0083] The gaseous fuel injector outlet **486** can be axially aft of the outlet **470**. An axial outlet distance **487** can be defined as the axial distance, measured parallel to the engine centerline **420**, between the gaseous fuel injector outlet **486** and the outlet **470**.

[0084] While illustrated as greater than the first radial distance **483**, it is contemplated that the axial outlet distance **487** can be less than the first radial distance **483**.

[0085] Locating the gaseous fuel injector outlet **486** axially aft of the outlet **470** and angling the gaseous fuel injector centerline **492** in the forward direction would allow for increase in residence time.

[0086] FIG. **6** is another variation of a schematic cross-sectional view of FIG. **2**, wherein FIG. **6** illustrates a multi-fuel combustion system **530**, that can be used in the turbine engine **10** (FIG. **1**).

[0087] The multi-fuel combustion system **530** is similar to the multi-fuel combustion system **30** (FIG. **2**), **430** (FIG. **5**), therefore, like parts will be identified with like numerals further increased by a hundred, with it being understood that the description of the like parts of the multi-fuel combustion system **30**, **430** applies to the multi-fuel combustion system **530**, unless otherwise noted.

[0088] Similar to the multi-fuel combustion system **30**, **430**, the multi-fuel combustion system **530** rotatably couples to a drive shaft **518** that rotates about an engine centerline **520**. Further, the multi-fuel combustion system **530** includes a combustor liner **534** having a forward liner **540**, an aft liner **542**, a combustion chamber **544**, a first combustion zone **550**, a second combustion zone **552**, a first fuel system **560** including a rotary fuel slinger **562** having an outlet **570** for providing a first fuel **558**, a slinger injector centerline **572** defined by the outlet **570**, a first ignitor **578**, a second fuel system **580**, a gaseous fuel injector **582** having a gaseous fuel injector outlet **586** for providing a second fuel **574**, a gaseous fuel injector centerline **592** defined by the gaseous fuel injector outlet **586**, a second ignitor **594**, and a set of dilution holes **596**.

[0089] A first radial distance **583** is measured radially outward from the engine centerline **520** to the outlet **570**. A second radial distance **585** is measured radially outward from the engine centerline **520** to the gaseous fuel injector outlet **586**. The second radial distance **585** is greater than the first radial distance **583**.

[0090] The gaseous fuel injector outlet **586** can be axially forward of the outlet **570**. An axial outlet distance **587** can be defined as the axial distance, measured parallel to the engine centerline **520**, between the gaseous fuel injector outlet **586** and the outlet **570**.

[0091] The axial outlet distance **587**, while illustrated as less than the first radial distance **583**, it is contemplated that the axial outlet distance **587** can be greater than the first radial distance **583**.
[0092] Locating the gaseous fuel injector outlet **586** axially forward of the outlet **570** and angling the gaseous fuel injector centerline **592** in the forward direction would allow for increase in residence time.
[0093] Benefits of aspects described herein provide a multi-fuel combustion system disclose a combustor that operates utilizing liquid or traditional fuels, gaseous fuel, such as hydrogen, other sustainable aviation fuels, or any combination thereof.
[0094] Additional benefits of the multi-fuel combustion system include improved emissions. The multi-fuel combustion system includes a slinger combustor where the liquid fuel or first fuel is provided to a first combustion zone using a rotary fuel slinger. The rotary fuel slinger can be designed for maximum fuel flow and can be optimized for cruising to improve the combustion efficiency and reduce emissions from the first combustion zone.
[0095] The multi-fuel combustion system further includes a gaseous fuel injector providing the gaseous fuel or the second fuel to a second combustion zone. The gaseous fuel or the second fuel burns cleaner than the liquid fuel or the second fuel.
[0096] When operating using both fuels, the second combustion zone receives the emissions of the first combustion zone. The second combustion zone then combusts the emissions from the first combustion zone using a faster, hotter, and cleaner burning fuel. This results in the total emissions from the multi-fuel combustion system being reduced.
[0097] Gaseous fuel, including hydrogen, spreads/disperses at a faster rate than atomized liquid fuel, which can involve less mixing time for the gaseous fuel and the flame from the gaseous fuel may be more likely to spread farther and faster, which can increase the risk of flashback and increase the impact of controlling the flame and limiting flame spread by controlling the dispersion of the gaseous fuel.
[0098] Gaseous fuel may not be provided at every airport. Similarly, traditional fuels or liquid fuels may not be provided at every airport. As long as the aircraft can be provided with a predetermined amount of the first fuel (liquid fuel) or the second fuel (hydrogen-based fuel), a cycle of operation can be completed.
[0099] Dilution holes adjacent the gaseous fuel injector help contain gaseous fuel-air mixtures that have lower densities and higher velocities than liquid fuels. For example, flame shaping formations, such as the set of dilution holes, can contain the gaseous fuel-air mixtures such that the flame velocity matches the flow velocity to provide a stable flame.
[0100] Further aspects are provided by the subject matter of the following clauses:
[0101] A multi-fuel combustion system for a turbine engine, the multi-fuel combustion system comprising a combustion chamber formed by a combustor liner, the combustion chamber defining a first combustion zone and a second combustion zone, a first fuel system fluidly coupled with the first combustion zone, wherein the first fuel system includes a rotary fuel slinger for providing a first fuel to the first combustion zone, and a second fuel system fluidly coupled with the second combustion zone, wherein the second fuel system includes a gaseous fuel injector for providing a second fuel to the second combustion zone, wherein the second fuel is a gaseous fuel.
[0102] A multi-fuel combustion system for a turbine engine, the multi-fuel combustion system comprising a combustion chamber formed by a combustor liner, the combustion chamber defining a first combustion zone and a second combustion zone, a first fuel system fluidly coupled with the first combustion zone, wherein the first fuel system includes a rotary fuel slinger for providing a first fuel to the first combustion zone, and a second fuel system fluidly coupled with the second combustion zone, wherein the second fuel system includes a fuel injector for providing a second fuel to the second combustion zone, wherein the second fuel is a hydrogen-based fuel.
[0103] The multi-fuel combustion system of any preceding clause, wherein the rotary fuel slinger includes an outlet a first radial distance from an engine centerline and the gaseous fuel injector

includes an outlet at a second radial distance from the engine centerline, wherein the first radial distance is less than the second radial distance.
[0104] The multi-fuel combustion system of any preceding clause, wherein the first fuel has a residence time in a range from 3 milliseconds to 5 milliseconds.
[0105] The multi-fuel combustion system of any preceding clause, wherein the first fuel includes kerosene or petroleum.
[0106] The multi-fuel combustion system of any preceding clause, wherein the second fuel has a residence time in a range from 1 millisecond to 3 milliseconds.
[0107] The multi-fuel combustion system of any preceding clause, wherein the second fuel includes hydrogen.
[0108] The multi-fuel combustion system of any preceding clause, wherein the second combustion zone is fluidly downstream of the first combustion zone, and wherein the gaseous fuel injector is axially aft of the rotary fuel slinger.
[0109] The multi-fuel combustion system of any preceding clause, wherein the second fuel system is fluidly downstream of the first fuel system, and wherein the gaseous fuel injector is axially forward of the rotary fuel slinger.
[0110] The multi-fuel combustion system of any preceding clause, wherein the second fuel system is fluidly downstream of the first fuel system, and wherein a portion of the gaseous fuel injector is axially aligned with at least a portion of a slinger injector centerline.
[0111] The multi-fuel combustion system of any preceding clause, wherein the gaseous fuel injector is a set of circumferentially spaced gaseous fuel injectors.
[0112] The multi-fuel combustion system of any preceding clause, wherein the rotary fuel slinger includes an outlet defining a slinger injector centerline and the gaseous fuel injector includes an outlet defining a gaseous fuel injector centerline, wherein an angle measured between the slinger injector centerline and the gaseous fuel injector centerline is in a range from 5° to 40°.
[0113] The multi-fuel combustion system of any preceding clause, wherein an angle measured between the slinger injector centerline and an engine centerline is in a range from 85° to 95°.
[0114] The multi-fuel combustion system of any preceding clause, further comprising a set of dilution holes located adjacent an outlet of the gaseous fuel injector.
[0115] The multi-fuel combustion system of any preceding clause, wherein the combustion chamber is an annular chamber.
[0116] The multi-fuel combustion system of any preceding clause, further comprising a gaseous fuel supply passage fluidly coupled to the gaseous fuel injector.
[0117] The multi-fuel combustion system of any preceding clause, wherein a turbine engine includes a compressor section, a combustion section, and a turbine section in a serial flow arrangement, wherein the multi-fuel combustion system is located in the combustion section of the turbine engine.
[0118] The multi-fuel combustion of any preceding clause, wherein a turbine engine comprises a drive shaft rotationally coupled to the compressor section and turbine section, and wherein the drive shaft defines an engine centerline for the turbine engine.
[0119] The multi-fuel combustion of any preceding clause, further comprising a fuel passage defined by a portion of the drive shaft, wherein the fuel passage is fluidly coupled to the rotary fuel slinger.
[0120] The multi-fuel combustion system of any preceding clause, wherein an angle measured between the slinger injector centerline and an engine centerline is in a range from 20° to less than 85°.
[0121] A slinger multi-fuel combustion system for a turbine engine comprising a compressor section, combustion section, and turbine section in a serial flow arrangement and a drive shaft coupled to one or more portions of the compressor section or the turbine section, the drive shaft defining an engine centerline, the slinger multi-fuel combustion system comprising a combustion

chamber having a radially-extending portion and an axially-extending portion, a liquid fuel injector having a slinger operably coupled to the drive shaft and having an outlet emitting atomized liquid fuel into the radially-extending portion of the combustion chamber using centrifugal force from rotation of the drive shaft, and a gaseous fuel injector having a gaseous fuel injector outlet emitting gaseous fuel into the combustion chamber downstream of the outlet.
[0122] The slinger multi-fuel combustion system of any preceding clause, further comprising a fuel passage defined by a portion of the drive shaft, wherein the fuel passage is fluidly coupled to the liquid fuel injector.
[0123] The slinger multi-fuel combustion system of any preceding clause, further comprising a gaseous fuel supply passage fluidly coupled to the gaseous fuel injector, wherein a valve controls flow of the gaseous fuel into the gaseous fuel injector.
[0124] The slinger multi-fuel combustion system of any preceding clause, further comprising a set of dilution holes located adjacent an outlet of the gaseous fuel injector, wherein a dilution hole centerline is defined by a dilution hole of the set of dilution holes, and wherein the dilution hole centerline forms a non-zero angle with a gaseous fuel injector centerline defined by the gaseous fuel injector outlet.
[0125] The slinger multi-fuel combustion system of any preceding clause, wherein the liquid fuel injector includes an outlet defining a slinger injector centerline and the gaseous fuel injector includes an outlet defining a gaseous fuel injector centerline, wherein an angle measured between the slinger injector centerline and the gaseous fuel injector centerline is in a range from 5° to 40°, and wherein an angle measured between the slinger injector centerline and the engine centerline is in a range from 85° to 95°.
[0126] A method of operating a turbine engine comprising a compressor section, combustion section having a multi-fuel combustion system, and turbine section is serial flow arrangement and a drive shaft coupled to one or more portions of the compressor section or the turbine section, the drive shaft defining an engine centerline, the method comprising rotating at least the drive shaft and a portion of the combustion section to start the turbine engine, flowing compressed air from the compressor section to an exterior of the multi-fuel combustion system, flowing a portion of the compressed air from the exterior of the multi-fuel combustion system into a combustion chamber defined by a combustor liner of the multi-fuel combustion system, varying an amount of a liquid fuel provided to a first combustion zone of the combustion chamber, wherein the liquid fuel is provided by a rotary fuel slinger, and varying an amount of a gaseous fuel provided to a second combustion zone of the combustion chamber, wherein the gaseous fuel is provided by a gaseous fuel injector downstream of the rotary fuel slinger.
[0127] The method of any previous clause further comprising igniting, with a first ignitor or a second ignitor, a fuel-air mixture in the combustion chamber.
[0128] The method of any previous clause wherein the varying the amount of the liquid fuel and the varying the amount of the gaseous fuel includes providing both the liquid fuel and the gaseous fuel at take-off.
[0129] The method of any previous clause wherein the varying the amount of the gaseous fuel includes reducing or ceasing the gaseous fuel during cruising.
[0130] The method of any previous clause wherein the varying the amount of the liquid fuel and the varying the amount of the gaseous fuel includes providing both the liquid fuel and the gaseous fuel at landing.
[0131] The method of any previous clause further comprising restarting combustion via the second combustion zone during landing.
[0132] While described with respect to a turbine engine, it should be appreciated that the combustor as described herein can be for any engine with a having a combustor. It should be appreciated that application of aspects of the disclosure discussed herein are applicable to engines with propeller sections or fan and booster sections along with turbojets, turbo engines, and

turboshaft engines in aviation, marine, and stationary applications as well.
[0133] To the extent not already described, the different features and structures of the various embodiments can be used in combination, or in substitution with each other as desired. That one feature is not illustrated in all of the embodiments is not meant to be construed that it cannot be so illustrated, but is done for brevity of description. Thus, the various features of the different embodiments can be mixed and matched as desired to form new embodiments, whether or not the new embodiments are expressly described.
[0134] This written description uses examples to describe aspects of the disclosure described herein, including the best mode, and also to enable any person skilled in the art to practice aspects of the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of aspects of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims 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 languages of the claims.

Claims

1. A multi-fuel combustion system for a turbine engine, the multi-fuel combustion system comprising: a combustion chamber formed by a combustor liner, the combustion chamber defining a first combustion zone and a second combustion zone; a first fuel system fluidly coupled with the first combustion zone, wherein the first fuel system includes a rotary fuel slinger for providing a first fuel to the first combustion zone; and a second fuel system fluidly coupled with the second combustion zone, wherein the second fuel system includes a gaseous fuel injector for providing a second fuel to the second combustion zone, wherein the second fuel is a gaseous hydrogen fuel; a first ignitor extending through the combustor liner into the first combustion zone to ignite the first fuel; and a second ignitor extending through the combustor liner into the second combustion zone.
2. The multi-fuel combustion system of claim 1, wherein the rotary fuel slinger includes an outlet at a first radial distance from an engine centerline and the gaseous fuel injector includes an outlet at a second radial distance from the engine centerline, wherein the first radial distance is less than the second radial distance.
3. The multi-fuel combustion system of claim 1, wherein the first fuel has a residence time in a range from 3 milliseconds to 5 milliseconds.
4. The multi-fuel combustion system of claim 3, wherein the first fuel includes kerosene or petroleum.
5. The multi-fuel combustion system of claim 3, wherein the second fuel has a residence time in a range from 1 millisecond to 3 milliseconds.
6. (canceled)
7. The multi-fuel combustion system of claim 1, wherein the second combustion zone is fluidly downstream of the first combustion zone; wherein combustion of the second fuel in the second combustion zone is at a higher temperature than combustion of the first fuel in the first combustion zone such that combustion of the second fuel in the second combustion zone eliminates at least a portion of emissions from combustion of the first fuel in the first combustion zone to reduce total emissions from the multi-fuel combustion system, and wherein the gaseous fuel injector is axially aft of the rotary fuel slinger.
8. The multi-fuel combustion system of claim 1, wherein the second fuel system is fluidly downstream of the first fuel system such that combustion of the second fuel in the second combustion zone eliminates at least a portion of emissions from combustion of the first fuel in the first combustion zone to reduce total emissions from the multi-fuel combustion system, and wherein the gaseous fuel injector is axially forward of the rotary fuel slinger.

9. The multi-fuel combustion system of claim 1, wherein the second fuel system is fluidly downstream of the first fuel system, and wherein a portion of the gaseous fuel injector is axially aligned with at least a portion of a slinger injector centerline.
10. The multi-fuel combustion system of claim 1, wherein the gaseous fuel injector is a set of circumferentially spaced gaseous fuel injectors.
11. The multi-fuel combustion system of claim 1, wherein the rotary fuel slinger includes an outlet defining a slinger injector centerline and the gaseous fuel injector includes an outlet defining a gaseous fuel injector centerline, wherein an angle measured between the slinger injector centerline and the gaseous fuel injector centerline is in a range from 5° to 40°.
12. The multi-fuel combustion system of claim 11, wherein an angle measured between the slinger injector centerline and an engine centerline is in a range from 85° to 95°.
13. The multi-fuel combustion system of claim 1, further comprising a set of dilution holes located adjacent an outlet of the gaseous fuel injector.
14. (canceled)
15. (canceled)
16. A slinger multi-fuel combustion system for a turbine engine comprising a compressor section, combustion section, and turbine section in a serial flow arrangement and a drive shaft coupled to one or more portions of the compressor section or the turbine section, the drive shaft defining an engine centerline, the slinger multi-fuel combustion system comprising: a combustion chamber having a radially-extending portion and an axially-extending portion; a liquid fuel injector having a slinger operably coupled to the drive shaft and having an outlet for emitting atomized liquid fuel into the radially-extending portion of the combustion chamber using centrifugal force from rotation of the drive shaft; and a gaseous fuel injector having a gaseous fuel injector outlet for emitting gaseous hydrogen fuel into the combustion chamber downstream of the outlet of the liquid fuel injector such that combustion of the gaseous hydrogen fuel eliminates at least a portion of emissions from combustion of the atomized liquid fuel to reduce total emissions from the slinger multi-fuel combustion system.
17. The slinger multi-fuel combustion system of claim 16, further comprising a fuel passage defined by a portion of the drive shaft, wherein the fuel passage is fluidly coupled to the liquid fuel injector.
18. The slinger multi-fuel combustion system of claim 17, further comprising a gaseous fuel supply passage fluidly coupled to the gaseous fuel injector, wherein a valve controls flow of the gaseous hydrogen fuel into the gaseous fuel injector.
19. The slinger multi-fuel combustion system of claim 16, further comprising a set of dilution holes located adjacent an outlet of the gaseous fuel injector, wherein a dilution hole centerline is defined by a dilution hole of the set of dilution holes, and wherein the dilution hole centerline forms a non-zero angle with a gaseous fuel injector centerline defined by the gaseous fuel injector outlet.
20. The slinger multi-fuel combustion system of claim 16, wherein the liquid fuel injector includes an outlet defining a slinger injector centerline and the gaseous fuel injector includes an outlet defining a gaseous fuel injector centerline, wherein an angle measured between the slinger injector centerline and the gaseous fuel injector centerline is in a range from 5° to 40°, and wherein an angle measured between the slinger injector centerline and the engine centerline is in a range from 85° to 95°.
21. The slinger multi-fuel combustion system of claim 16, further comprising a first ignitor and a second ignitor; wherein the combustion chamber is defined by a combustor liner; wherein the combustion chamber defines a first combustion zone and a second combustion zone downstream of the first combustion zone; wherein the liquid fuel injector is fluidly coupled with the first combustion zone; wherein the first ignitor extends through the combustor liner into the first combustion zone to ignite the atomized liquid fuel in the first combustion zone; wherein the gaseous fuel injector is fluidly coupled with the second combustion zone; wherein the second

ignitor extends through the combustor liner into the second combustions zone to ignite the gaseous hydrogen fuel in the second combustion zone to eliminate at least the portion of the emissions from combustion of the atomized liquid fuel in the first combustion zone.

22. The multi-fuel combustion system of claim 7, wherein the combustion in the second combustion zone includes the second fuel burning faster and hotter than the first fuel in the combustion in the first combustion zone.

23. A method of operating a gas turbine engine of an aircraft, the gas turbine engine comprising a compressor section, combustion section, and turbine section in a serial flow arrangement and a drive shaft coupled to one or more portions of the compressor section or the turbine section, the drive shaft defining an engine centerline, the combustion section including a combustor liner defining a combustion chamber, the method comprising: operating a liquid fuel injector having a slinger operably coupled to the drive shaft to emit liquid fuel into a first combustion zone of the combustion chamber using centrifugal force from rotation of the drive shaft; operating a first ignitor to combust the liquid fuel in the first combustion zone such that first emissions are generated, the first ignitor extending through the combustor liner into the first combustion zone; operating a gaseous fuel injector to emit gaseous hydrogen fuel into a second combustion zone of the combustion chamber downstream of the first combustion zone; and combusting the gaseous hydrogen fuel in the second combustion zone to eliminate at least a portion of the first emissions and reduce total emissions from the gas turbine engine; wherein the combustion of the gaseous hydrogen fuel is at a higher temperature than the combustion of the liquid fuel.