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(54) **ENGINE SYSTEM HAVING RADIAL FUEL INJECTION**

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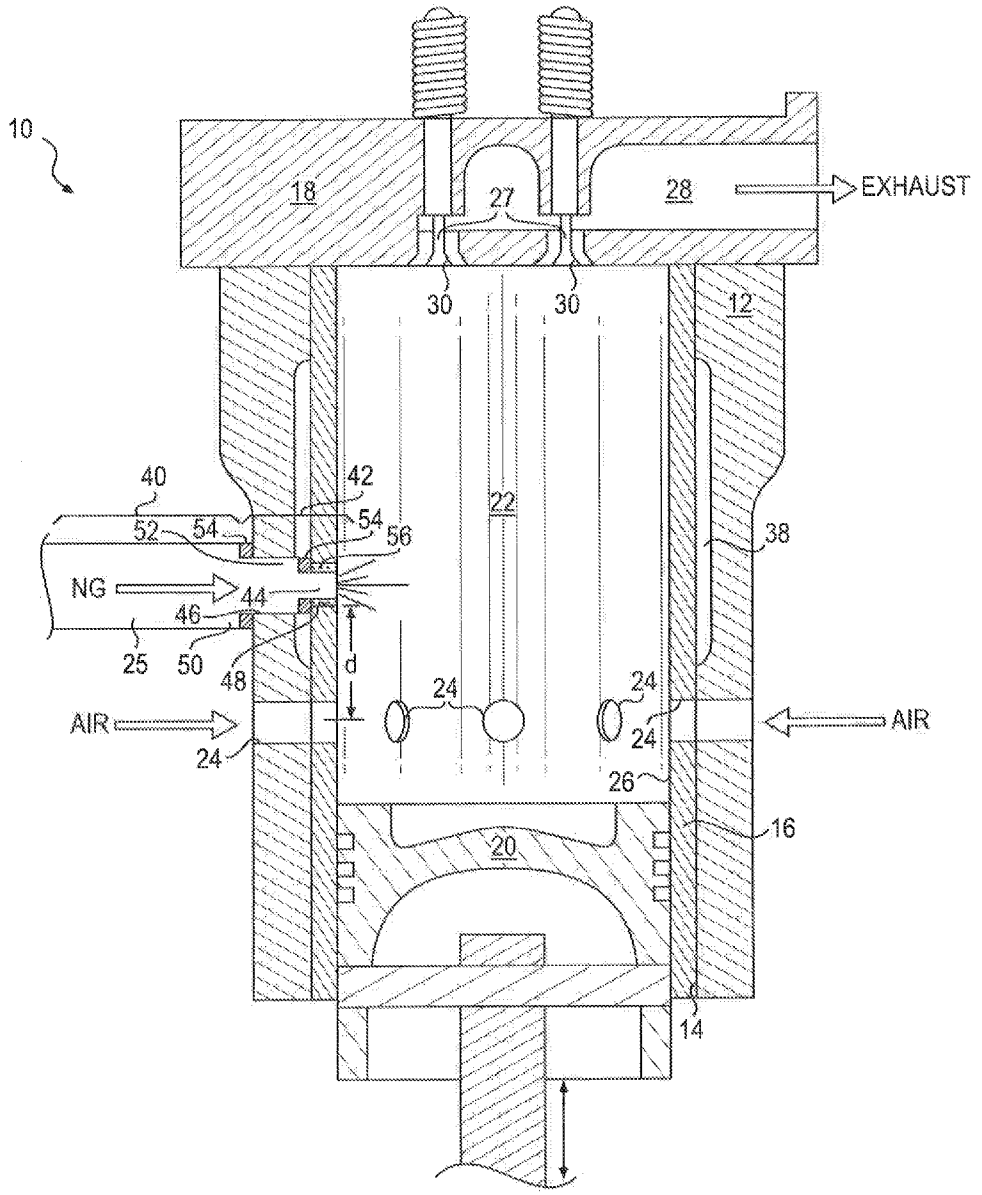
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(57) **ABSTRACT**

An engine system is disclosed. The engine system may have an engine block at least partially defining a cylinder bore, and a cylinder liner disposed within the cylinder bore. The engine system may also include a fuel injector configured to pass radially through the cylinder bore and threadingly engage the cylinder liner.



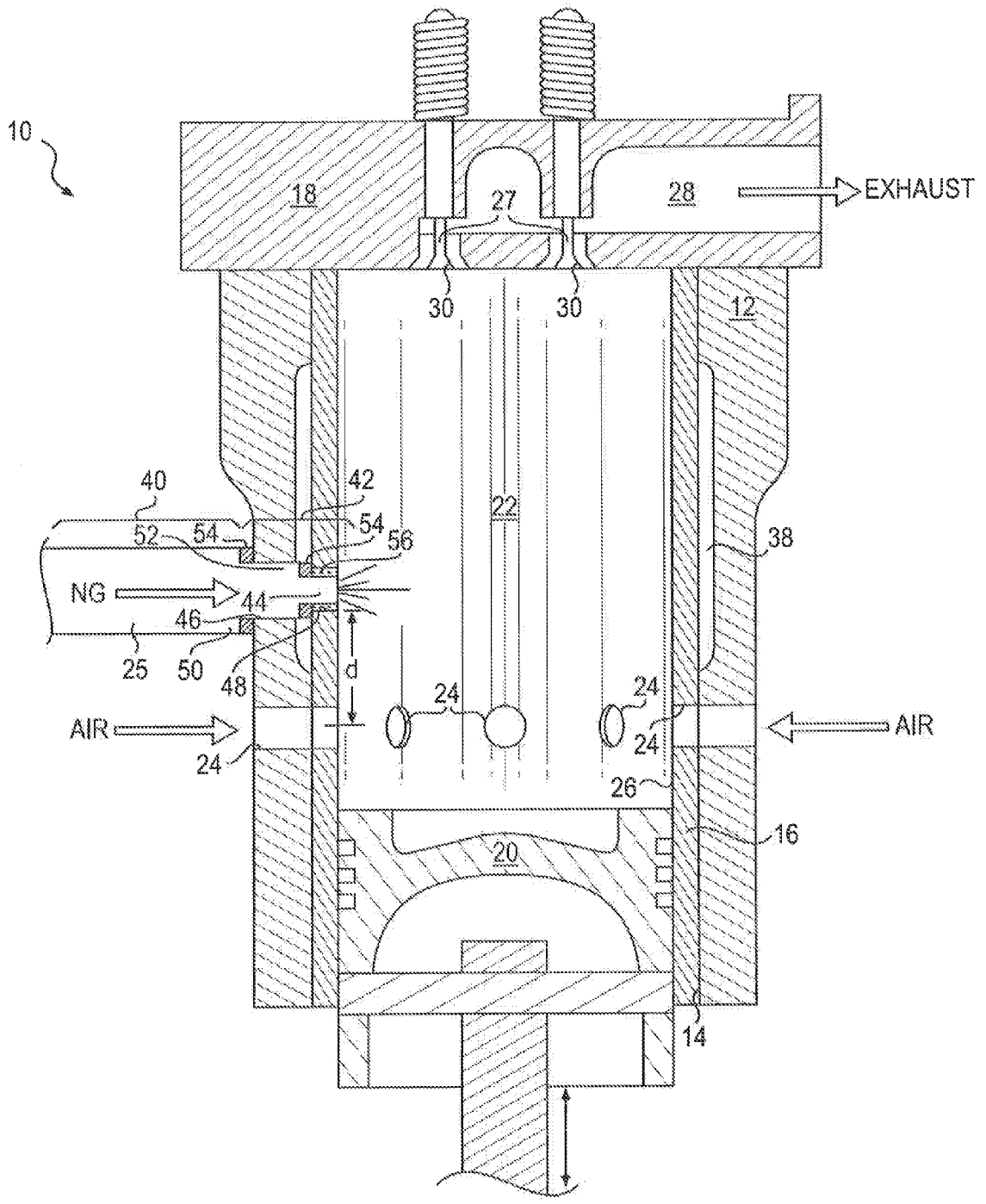

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FIG. 1

ENGINE SYSTEM HAVING RADIAL FUEL INJECTION

TECHNICAL FIELD

[0001] The present disclosure relates generally to an engine system and, more particularly, to an engine system having radial fuel injection.

BACKGROUND

[0002] Gaseous fuel-powered engines are common in locomotive applications. For example, the engine of a locomotive can be powered by natural gas (or another gaseous fuel) alone or by a mixture of natural gas and diesel fuel. Natural gas may be more abundant and, therefore, less expensive than diesel fuel. In addition, natural gas may burn cleaner in some applications.

[0003] Natural gas has traditionally been introduced radially into an engine's cylinders, to mix with air therein as an associated piston moves toward a top-dead-center (TDC) position. In some applications, a natural gas nozzle is situated to inject gaseous fuel through an existing air inlet port located within an annular surface of the engine's cylinder liner. Although somewhat effective, injecting gaseous fuel at this location can also be inefficient. In particular, some of the injected gaseous fuel may pass back out through the same air inlet port (or back out through another air inlet port) into an associated air box. In addition, injecting at this location results in advanced injection timing that can allow some of the injected fuel to exit the cylinder via still open exhaust valves. In either situation, some of the gaseous fuel is being wasted.

[0004] An exemplary dual-fuel natural gas/diesel engine is disclosed in U.S. Pat. No. 5,035,206 of Welch et al. that issued on Jul. 30, 1991 ("the '**206** patent"). The engine includes a cylinder, a piston in the cylinder, and inlet ports around the cylinder that are uncovered by downward movement of the piston. A blower forces air through the inlet ports, and an injector is provided for injecting natural gas into the cylinder once during each cycle. The injector has a delivery conduit that opens into the cylinder at a location above the air inlet ports. When the piston is descending, the piston completely uncovers the delivery conduit before beginning to uncover the air inlet ports. In this configuration, the natural gas is timed for injection as late as possible, preferably after the piston reaches bottom-dead-center (BDC), and continues until after air entry has been stopped by upward movement of the piston. This provision ensures that a large portion of air will have filled the cylinder before the entry of natural gas, so as to minimize the escape and loss of natural gas.

[0005] Although the engine of the '**206** patent may help to reduce the loss of natural gas, it may only be applicable to air-cooled engines and/or newly manufactured engines. In particular, the delivery conduit of the '**206** patent may not be compatible with a liquid-cooled engine having a water jacket formed around the cylinder. Further, the '**206** patent provides no way to retrofit an existing engine with the delivery conduit. In addition, injecting gaseous fuel during air introduction may still lead to reverse flow of the gaseous fuel out of the inlet ports.

[0006] The engine system of the present disclosure solves one or more of the problems set forth above and/or other problems in the art.

SUMMARY

[0007] In one aspect, the present disclosure is directed to an engine system. The engine system may include an engine block at least partially defining a cylinder bore, and a cylinder liner disposed within the cylinder bore. The engine system may also include a fuel injector configured to pass radially through the cylinder bore and threadingly engage the cylinder liner.

[0008] In another aspect, the present disclosure is directed to another engine system. This engine system may include an engine block at least partially defining a cylinder bore, a cylinder liner disposed within the cylinder bore, and a water jacket located between the cylinder bore and the cylinder liner. The engine system may also include a cylinder head configured to close off an end of the cylinder bore, at least one intake air port formed within the cylinder liner, and a piston reciprocatingly disposed within the cylinder liner. The engine system may also include a fuel injector configured to pass radially through the water jacket and the cylinder bore to threadingly engage the cylinder liner at an axial location between the at least one intake air port and the cylinder head. The fuel injector is configured to begin injecting fuel when the at least one intake air port is closed off by the piston at about 100° before the piston reaches top-dead-center, and to stop injecting fuel when the piston covers up a tip of the fuel injector at about 120° before the piston reaches top-dead-center.

[0009] In another aspect, the present disclosure is directed to a method of retrofitting an engine with a fuel injector. The method may include radially drilling a first bore through an engine block into a cylinder bore, and radially drilling a second bore through a cylinder liner. The method may also include tapping the second bore, and threadingly engaging the fuel injector with the second bore.

BRIEF DESCRIPTION OF THE DRAWING

[0010] FIG. **1** is a cross-sectional illustration of an exemplary disclosed engine system.

DETAILED DESCRIPTION

[0011] FIG. **1** illustrates a portion of an exemplary internal combustion engine **10**. Although engine **10** is shown and described as a two-stroke gaseous fueled engine, it is contemplated that engine **10** may be another type of engine (e.g., a four-stroke gaseous fueled-engine or a two-or four-stroke dual fuel engine). Engine **10** may include, among other things, an engine block **12** defining at least one cylinder bore **14**. A cylinder liner **16** may be disposed within cylinder bore **14**, and a cylinder head **18** may be connected to engine block **12** to close off an end of cylinder bore **14**. A piston **20** may be slidably disposed within cylinder liner **16**, and piston **20** together with cylinder liner **16** and cylinder head **18** may define a combustion chamber **22**. It is contemplated that engine **10** may include any number of combustion chambers **22** and that combustion chambers **22** may be disposed in an "in-line" configuration, in a "V" configuration, in an opposing-piston configuration, or in any other suitable configuration.

[0012] Piston **20** may be configured to reciprocate within cylinder liner **16** between TDC and BDC. In particular, piston **20** may be pivotally connected to a crankshaft (not shown), which is rotatably disposed within engine block **12**. In this configuration, a sliding motion of each piston **20** within cyl-

inder liner **16** may result in a rotation of the crankshaft. Similarly, a rotation of the crankshaft may result in a sliding motion of piston **20**. As the crankshaft rotates through about 180°, piston **20** may move through two full strokes (i.e., from TDC to BDC to TDC). Engine **10** (as a two-stroke engine) may undergo a complete combustion cycle within this time that includes a power/exhaust/intake stroke (CDC to BDC) and an intake/compression stroke (BDC to TDC).

[0013] During a final phase of the intake stroke, air may be drawn and/or forced into combustion chamber **22** via one or more intake ports **24** located within an annular surface **26** of cylinder liner **16**. In particular, as piston **20** moves downward within cylinder liner **16**, a position will eventually be reached at which intake ports **24** are no longer blocked by piston **20** and instead are fluidly communicated with combustion chamber **22**. When intake ports **24** are in fluid communication with combustion chamber **22** and a pressure of air at intake ports **24** is greater than a pressure within combustion chamber **22**, air will pass through intake ports **24** into combustion chamber **22**.

[0014] Gaseous fuel (e.g., natural gas) may be mixed with the air before, during, and/or after the air enters combustion chamber **22**. In the disclosed embodiment, a single radial fuel injector **25** is located an axial distance d above intake ports **24** (i.e., between intake ports **24** and cylinder head **18**). It is contemplated however, that any number of injectors **25** may be utilized. The distance d may be selected to provide a desired injection timing relative to the opening and/or closing of intake ports **24** during the movement of piston **20**. In the disclosed embodiment, the distance d may be about 25-40 mm and injector **25** may be timed to inject fuel at about 100-120° before piston **20** reaches its TDC position. And for a cylinder having an internal diameter of about 200-250 mm, a ratio of the axial distance d to relative to the diameter may be about 1:5-10. As will be explained in more detail below, this unique ratio may provide for desired conditions (e.g., injection timings, pressures, temperatures, etc.) within combustion chamber **22** that promote efficiency and low emissions. The gaseous fuel from injector **25** may mix with the air from intake ports **24** to form a fuel/air mixture within combustion chamber **22**.

[0015] During the beginning of the compression stroke described above, air may still be entering combustion chamber **22** via intake ports **24** as piston **20** starts its upward stroke to mix any residual gas with air and fuel in combustion chamber **22**. Eventually, intake ports **24** may be blocked by piston **20**, and further upward motion of piston **20** may compress the mixture. As the mixture within combustion chamber **22** is compressed, the mixture will increase in pressure and temperature until it combusts and releases chemical energy. This may result in a further and significant increase in the pressure and temperature within combustion chamber **22**. It should be noted that, in a dual-fuel engine, an injection of liquid fuel (e.g., of diesel fuel) may be necessary to cause the mixture within combustion chamber **22** to ignite.

[0016] After piston **20** reaches TDC, the increased pressure caused by combustion may force piston **20** downward, thereby imparting mechanical power to the crankshaft. During an end portion of this movement, one or more exhaust valves **27** located within cylinder head **18** may open to allow pressurized exhaust within combustion chamber **22** to exit into an associated exhaust manifold **28** via a corresponding exhaust port **30**. In particular, as piston **20** moves upward within cylinder liner **16**, a position will eventually be reached at which exhaust valves **27** move to fluidly communicate combustion chamber **22** with exhaust ports **30**. When combustion chamber **22** is in fluid communication with exhaust ports **30** and a pressure in combustion chamber **22** is greater than a pressure at exhaust ports **30**, exhaust will pass from combustion chamber **22** through exhaust ports **30** into exhaust manifold **28**. In the disclosed embodiment, movement of exhaust valve(s) **27** may be cyclically controlled, for example by way of a cam (not shown) or other device that is mechanically connected to the crankshaft. It is contemplated, however, that movement of exhaust valve(s) **27** may alternatively be controlled in a non-cyclical manner, if desired. It is also contemplated that exhaust port(s) **30** could alternatively be located within cylinder liner **18**, with their openings and closings dictated by the motion of piston **20** (i.e., exhaust valves **27** could be omitted), such as in a loop-scavenged two-stroke engine. Although operation of a two-stroke engine **10** has been described with reference to FIG. **1**, one skilled in the art would understand that fuel may be combusted and exhaust may be generated in a similar manner in a four-stroke engine.

[0017] Heat from the combustion process described above that could damage engine **10**, if unaccounted for, may be dissipated from cylinder bore **14** by way of a water jacket **38**. Water jacket **38** may be located between an internal wall of cylinder bore **14** and an external wall of cylinder liner **16**. For example, water jacket **38** may be formed by a recess within engine block **12** at the internal wall of cylinder bore **14** and/or within the external wall of cylinder liner **16**. It is also contemplated that water jacket **38** may be formed completely within engine block **12** around cylinder liner **16**, formed completely within cylinder liner **16**, and/or formed by a hollow sleeve (not shown) that is brazed to either one of engine block **12** or cylinder liner **16**, as desired. Water, glycol, or a blended mixture may be directed through water jacket **38** to absorb heat from engine block **12** and cylinder liner **16**.

[0018] Gaseous fuel injector **25** may pass through water jacket **38**. Specifically, gaseous fuel injector **25** may include a base **40**, and a nozzle **42** having a tip **44**; and engine block **12** and cylinder liner **16** may include bores **46** and **48** that are configured to receive nozzle **42** and tip **44**, respectively. Bore **46** may be larger than bore **48**, such that external access to bore **48** may be provided by way of bore **46**. A first shoulder **50** may be located at a base of nozzle **42**, and a second shoulder **52** may be located at a base of tip **44**. Shoulder **50** may be configured to abut a face machined into engine block **12** (or a different external surface of water jacket **38**), while shoulder **52** may be configured to abut a face machined into an external wall of cylinder liner **16** (or a different internal surface of water jacket **38**). A seal (e.g, an elastomeric o-ring) **54** may be located at each of these abutments. Tip **44** may include threads **56** that engage cylinder liner **16**, such that as injector **25** is rotated, first and second shoulders **50**, **52** may be drawn inward to compress seals **54** against the faces of engine block **12** and cylinder liner **16**. In this configuration, seals **54** may inhibit coolant from leaking out of water jacket **38** and into combustion chamber **22** (e.g., via bore **48**) or into a crankcase (not shown) connected below engine block **12** (e.g., via bore **46**).

[0019] Gaseous fuel injector **25** may be oriented at an angle relative to a central axis of cylinder bore **14**, and a plane that is generally perpendicular to the central axis. Specifically,

nozzle **42** may be tilted to inject downward toward piston **20** or upward toward cylinder head **18**, for example by about ±10°. Similarly, nozzle **42** may be offset to one side of the central axis so as to create swirl inside combustion chamber **22**. This offset angle may be, for example, about ±10°. In one embodiment, tip **44** may be have a generally round cross-section, with a diameter of about 16-24 mm. In another embodiment, tip **44** may have a generally rectangular cross-section, with a width of about 20-30 mm, and a height (aligned with the central axis of cylinder bore **14**) of about 10-16 mm.

INDUSTRIAL APPLICABILITY

[0020] The disclosed engine system may be used in any machine or power system application where it is beneficial to reduce emissions of harmful gases, while also delivering inexpensive power output. The disclosed engine system finds particular applicability within mobile machines, such as locomotives, which can be subjected to large variations in load and emissions requirements. The disclosed engine system may provide an efficient way to deliver gaseous fuel known to produce lower levels of regulated exhaust constituents.

[0021] By injecting fuel at the disclosed timings, a greater amount of the gaseous fuel may be retained within combustion chamber **22**. Specifically, the fuel injections may not start until after air inlet ports **24** are already closed by the upward motion of piston **20**. And injector **25** may be positioned axially high enough to allow all of the required gaseous fuel to be injected before tip **44** of injector **25** is covered by piston **20**. The axial location of injector **25** may still be low enough within cylinder liner **16** for sufficient mixing of the gaseous fuel prior to ignition.

[0022] Existing engines may be retrofitted to accept gaseous fuel injector **25**. Specifically, any engine may be modified such that gaseous fuel can be radially injected into the engine's cylinders at a location associated with the timings described above. These modifications may include the drilling of bores **46** and **48** into engine block **12** and cylinder liner **16**, respectively, and the machining of sealing faces around bores **46** and **48**. Bore **46** may be larger than bore **48** and drilled first, with bore **48** being drilled by way of bore **46**. The faces against which seals **54** are compressed may be machined before or after the formation of bores **46**, **48**. Thereafter, bore **48** may be tapped to form threads **56**. Injector **25** (together with seals **54**) may then be passed through bore **46** to thread into bore **48** and against the sealing faces. In some applications, this retrofitting of an existing engine with injector **25** may be accomplished without ever having to open combustion chamber **22** (e.g., by removing cylinder head **18**) or removing cylinder liner **16** and piston **20**. This may allow for a lower cost retrofit process and also result in less potential contamination of the engine. It should be noted that injector **25** may also be installed into an engine not having water jacket **38**, if desired. In this application, seals **54** may be omitted.

[0023] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed engine systems without departing from the scope of the disclosure. Other embodiments of the engine systems will be apparent to those skilled in the art from consideration of the specification and practice of the engine systems disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims and their equivalents.

1. An engine system, comprising:
an engine block at least partially defining a cylinder bore;
a cylinder liner disposed within the cylinder bore;
a fuel injector configured to pass radially through the cylinder bore and threadingly engage the cylinder liner;
a cylinder head configured to close off an end of the cylinder bore;
at least one intake air port formed within the cylinder liner; and
a piston reciprocatingly disposed within the cylinder liner;
wherein the fuel infector is configured to:
threadingly engage the cylinder liner at a location between the cylinder head and the at least one intake air port and at an axial distance away from a center of the at least one intake air port that is approximately 1:5-10 of an internal diameter of the cylinder liner;
begin injecting gaseous fuel when the at least one intake air port is closed off by piston approximately 100° before the piston reaches top-dead-center and to stop injecting fuel when the piston covers up a tip of the fuel injector approximately 120° before the piston reaches top-dead-center; and
wherein the cylinder liner has an internal diameter of approximately 200-250 mm.

2. The engine system of claim **1**, further including a water jacket located between the cylinder bore and the cylinder liner, wherein the fuel injector passes through the water jacket.

3. The engine system of claim **2**, wherein the water jacket is formed between an internal wall of the cylinder bore and an external wall of the cylinder liner.

4. The engine system of claim **2**, wherein the fuel injector includes:
a base; and
a nozzle connected at an end of the base and having a tip threaded to engage the cylinder liner.

5. The engine system of claim **4**, wherein the fuel injector includes;
a first shoulder located at a base of the nozzle, the first shoulder configured to abut the engine block; and
a second shoulder located at a base of the tip, the second shoulder configured to abut the cylinder liner.

6. The engine system of claim **5**, further including seals located at the first and second shoulders, wherein threaded engagement of the tip with the cylinder liner causes the first and second shoulders to compress the seals.

7. The engine system of claim **6**, wherein:
the engine block and the cylinder liner include machined faces, and bores that pass through the machined faces;
the fuel injector is configured to be received by the bores; and
the threaded engagement of the tip with the cylinder liner causes the first and second shoulders to compress the seals against the machined faces.

8. The engine system of claim **6**, wherein the seals are elastomeric o-ring seals.

9-13. (canceled)

14. An engine system, comprising:
an engine block at least partially defining a cylinder bore;
a cylinder liner disposed within the cylinder bore;

a water jacket located between the cylinder bore and the cylinder liner;

a cylinder head configured to close off an end of the cylinder bore;

at least one intake air port formed within the cylinder liner;

a piston reciprocatingly disposed within the cylinder liner; and

a fuel injector configured to pass radially through the water jacket and the cylinder bore to threadingly engage the cylinder liner at an axial location between the at least one intake air port and the cylinder head,

wherein the fuel injector is configured to begin injecting fuel when the at least one intake air port is closed off by the piston approximately 100° before the piston reaches top-dead-center and to stop injecting fuel when the piston covers up a tip of the fuel injector approximately 120° before the piston reaches top-dead-center;

wherein the fuel injector configured to threadingly engage the cylinder liner an axial distance away from a center of the at least one intake air port that is approximately 1:5-10 of an internal diameter of the cylinder liner; and

wherein the cylinder liner has an internal diameter of approximately 200-250 mm.

16-20. (canceled)

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