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(54) CYLINDER LINER HAVING COOLANT FLOW BALANCER AND ENGINE POWER ASSEMBLY USING SAME

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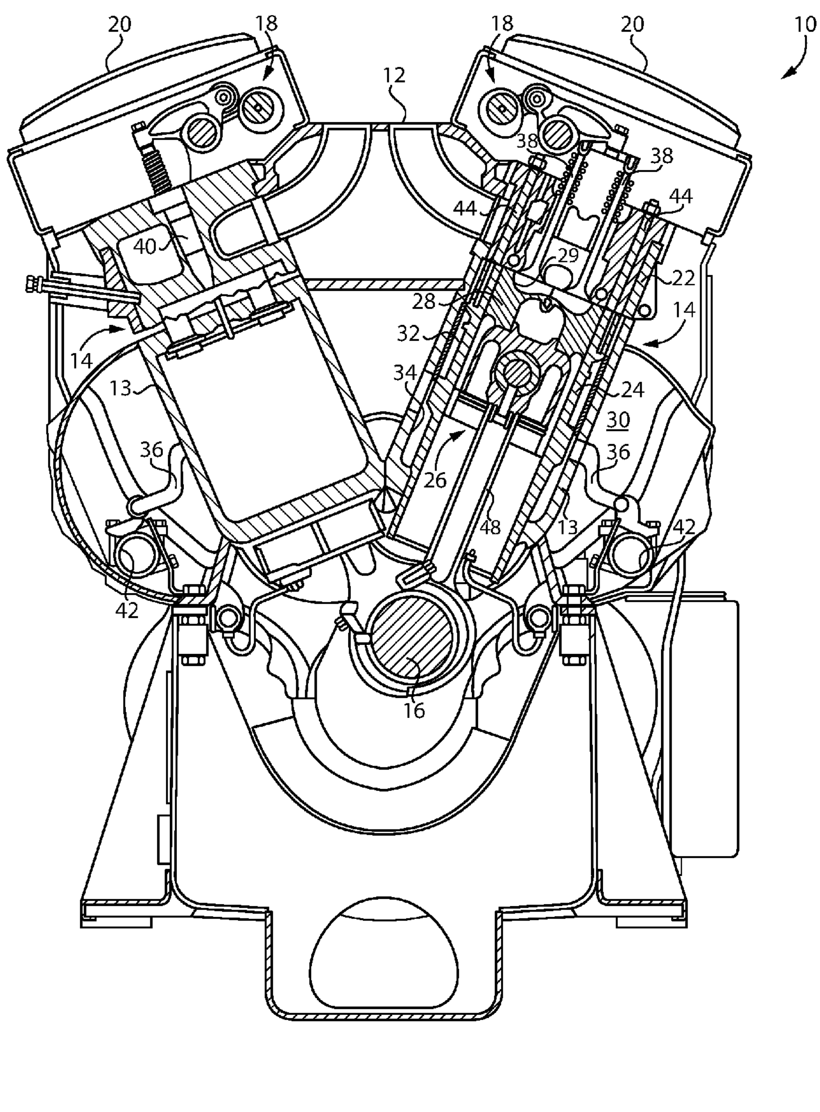
(57) **ABSTRACT**

A cylinder liner in a power assembly for an engine includes an elongate liner body including a water jacket surface and a plurality of combustion air ports extending from an outer liner surface to an inner liner surface. A coolant supply passage extends from a coolant inlet formed in an outer liner surface, to a water jacket feed outlet spaced axially from the plurality of combustion air ports. A flow balancer for coolant is positioned in a coolant flow path extending in an axial direction along the water jacket surface from the water jacket feed outlet. The cylinder liner may form, in service in an engine, an upper water jacket, and a lower air annulus. The flow balancer assists in normalizing a flow and pressure of coolant through the water jacket.



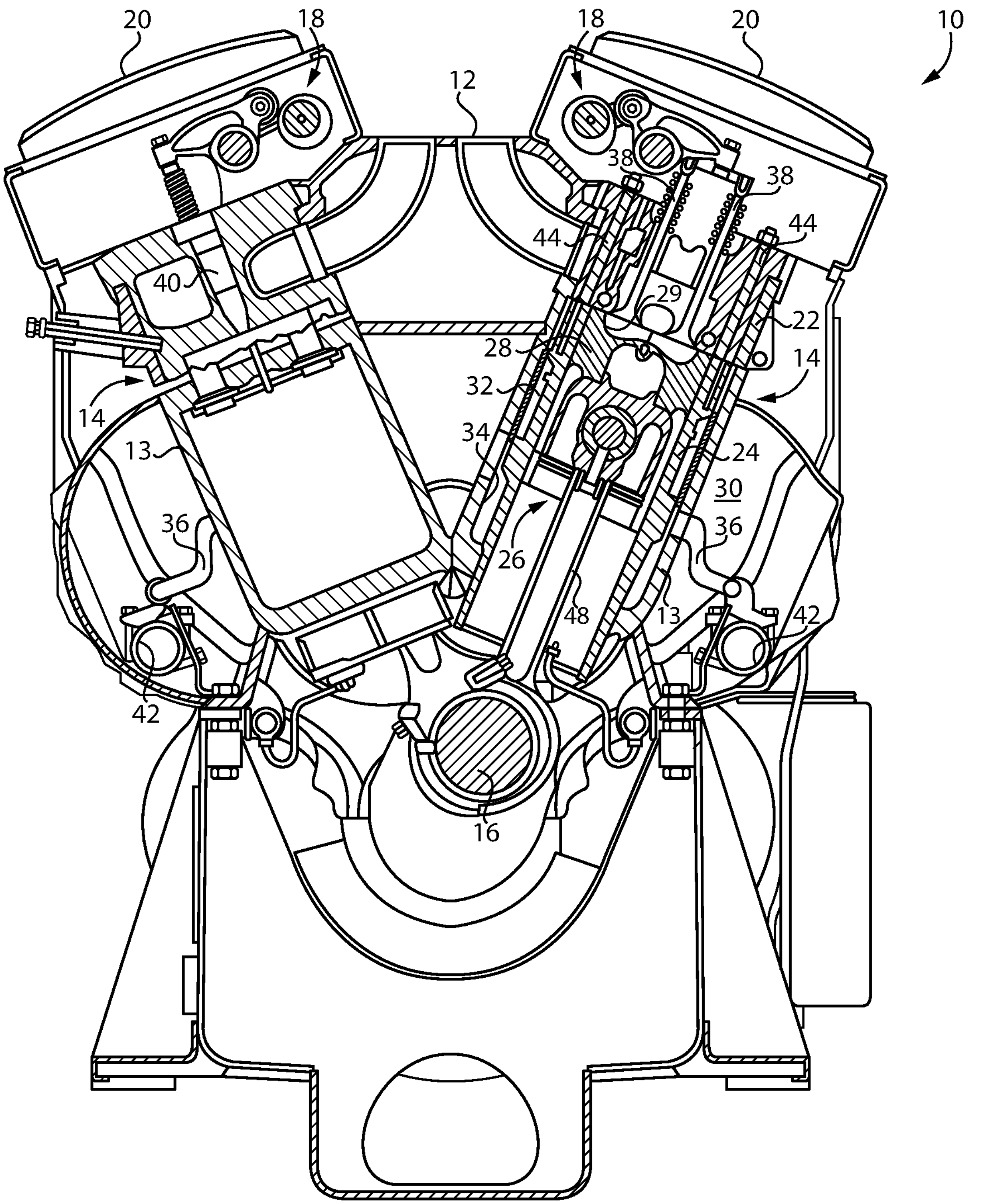

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FIG. 1

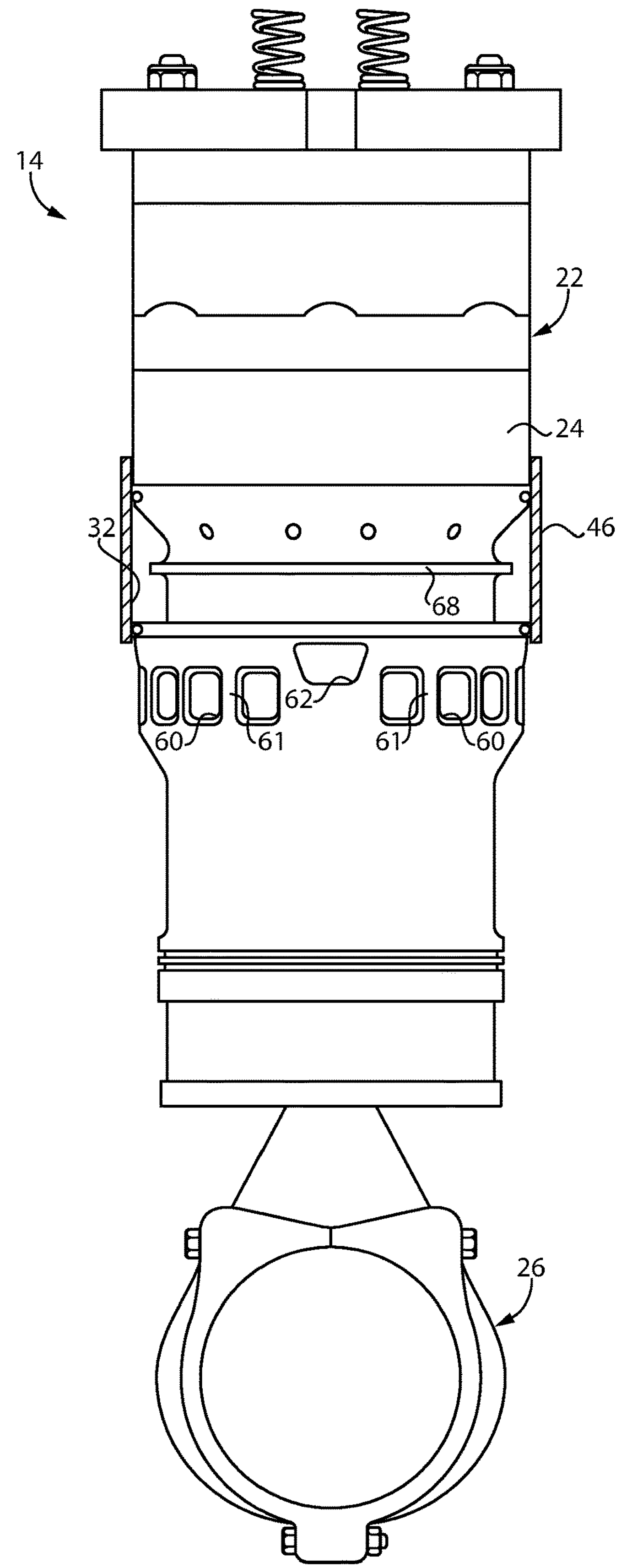

FIG. 2

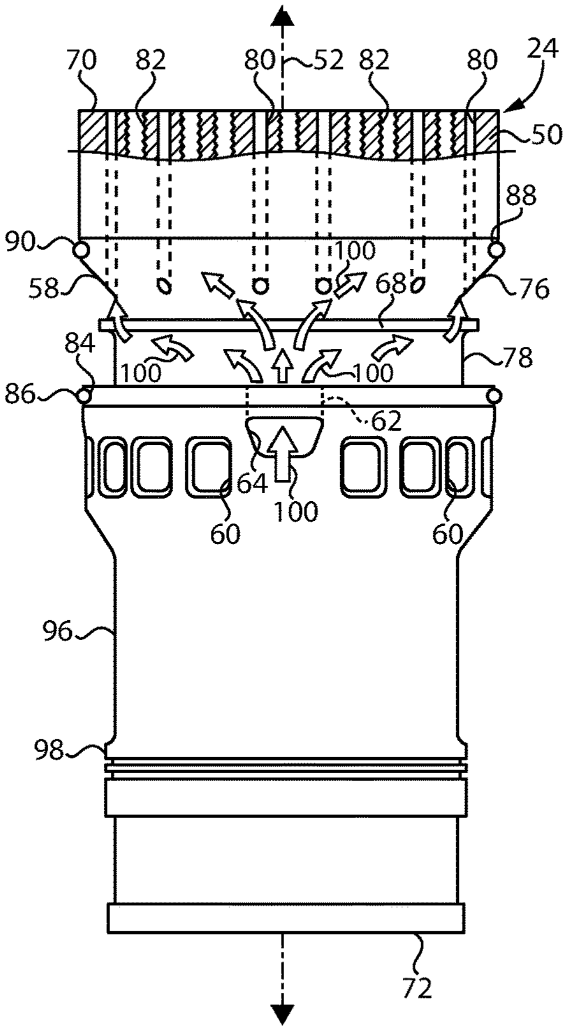

FIG. 3

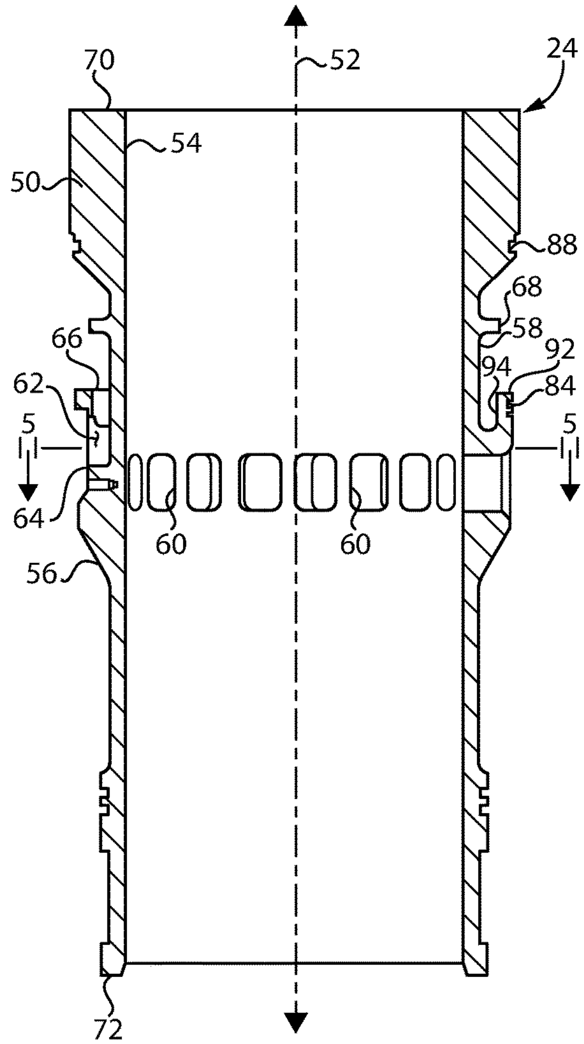

FIG. 4

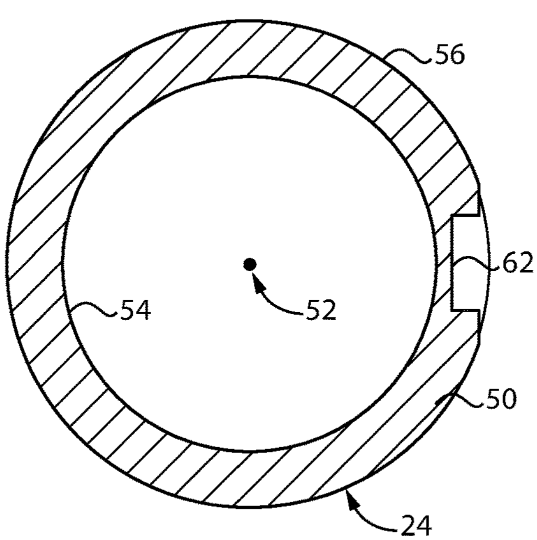

FIG. 5

CYLINDER LINER HAVING COOLANT FLOW BALANCER AND ENGINE POWER ASSEMBLY USING SAME

TECHNICAL FIELD

[0001] The present disclosure relates generally to a cylinder liner in an engine power assembly, and more particularly to a cylinder liner having a flow balancer for coolant flow in an upper water jacket.

BACKGROUND

[0002] Internal combustion engines are used globally for diverse purposes ranging from vehicle propulsion to operation of pumps, compressors, and electric generator equipment. In a typical implementation, fuel and air are delivered into a combustion chamber in the engine, and ignited to produce a rapid temperature and pressure rise that drives a piston coupled to a crankshaft operating a load. In a traditional four-stroke engine cycle, the piston moves up and down between a top dead center position and a bottom dead center position to execute each of an intake stroke, a compression stroke, an expansion stroke, and an exhaust stroke, for each full revolution of the crankshaft. In a two-stroke engine cycle the piston moves up and down only once for a full revolution of the crankshaft to perform intake, compression, expansion, and exhaust.

[0003] The combustion process generates significant heat necessitating relativity sophisticated cooling apparatus in most engine applications. In so-called water-cooled engines a coolant liquid, typically mostly water, is circulated through an engine housing to carry away heat. Air cooling of certain systems and subsystems of engines is also widely used. Cylinder liners are conventionally employed in many engines to form the combustion chamber itself in conjunction with a piston and a cylinder head. The cylinder liner is typically installed in an engine housing and commonly configured to participate in the liquid-cooling and sometimes air-cooling processes, as well as provision of engine oil for lubrication and additional cooling of the associated piston. Cylinder liners typically have a limited service life and can be swapped out for new cylinder liners periodically. One known two-stroke internal combustion engine is set forth in U.S. Pat. No. 8,938,350 B2 to Silvers et al. Engineers are continually seeking new and improved strategies for engine construction and operation relating to heat management, manufacturability, and other factors.

SUMMARY

[0004] In one aspect, a cylinder liner includes an elongate liner body defining a longitudinal axis, and including an inner liner surface, an outer liner surface having a water jacket surface extending circumferentially around the longitudinal axis, and a plurality of combustion air ports extending from the outer liner surface to the inner liner surface. The cylinder liner further includes a coolant supply passage extending from a coolant inlet formed in the outer liner surface, to a water jacket feed outlet spaced axially from the plurality of combustion air ports, and a flow balancer for coolant, formed on the outer liner surface, positioned in a coolant flow path extending in an axial direction along the water jacket surface from the water jacket feed outlet.

[0005] In another aspect, a power assembly for an engine includes a cylinder head assembly having a cylinder head, a cylinder liner coupled to the cylinder head assembly and defining a longitudinal axis, and a piston assembly including a piston. The cylinder liner includes an inner liner surface forming, together with the cylinder head and the piston, a combustion chamber, an outer liner surface including a water jacket surface extending circumferentially around the longitudinal axis, and a plurality of combustion air ports for conveying combustion air into the combustion chamber. The cylinder liner further includes a flow balancer formed on the water jacket surface.

[0006] In still another aspect, an engine includes an engine housing forming an air box, and a power assembly supported in the engine housing and including a cylinder liner, the cylinder liner having formed therein a plurality of combustion air ports fluidly connected to the air box. The cylinder liner includes an outer water jacket surface extending between the plurality of combustion air ports and an upper liner end, and an outer air annulus surface extending between the plurality of combustion air ports and a lower liner end. The power assembly further includes a jacket piece attached to the cylinder liner and forming, together with the outer water jacket surface, an upper water jacket, and an air annulus formed between the outer air annulus surface and the engine housing and fluidly connected to the air box.

BRIEF DESCRIPTION OF DRAWINGS

[0007] FIG. **1** is a sectioned diagrammatic view of an engine, according to one embodiment;

[0008] FIG. **2** is a diagrammatic view of a power assembly for an engine, according to one embodiment;

[0009] FIG. **3** is a partially sectioned diagrammatic view of a cylinder liner, according to one embodiment;

[0010] FIG. **4** is a sectioned diagrammatic view of a cylinder liner, according to one embodiment; and

[0011] FIG. **5** is a sectioned view taken along line **5**-**5** of FIG. **4**.

DETAILED DESCRIPTION

[0012] Referring to FIG. **1**, there is shown an internal combustion engine **10**, according to one embodiment. Engine **10** includes an engine housing **12** including a crankcase **13**, and a plurality of engine power assemblies **14** each supported in engine housing **12** and received within crankcase **13**. Engine housing **12** forms an air box **30** in a generally conventional manner, extending around engine power assemblies **14**. Each engine power assembly **14**, hereinafter referred to at times in the singular, includes a cylinder head or cylinder head assembly **22**, a cylinder liner **24** coupled to cylinder head assembly **22**, and a piston assembly **26** including a piston **28**. Engine power assembly **14** will be coupled to a crankshaft **16** by way of a connecting rod **48** of piston assembly **26** in a generally known manner. A valvetrain **18** including suitable rocker arms coupled to a camshaft, for example, is coupled to engine power assembly **14** to actuate components also in a generally conventional manner. FIG. **1** illustrates engine **10** having a V-configuration, however, it will be appreciated that engine power assemblies according to the present disclosure may be arranged in any suitable manner. A valve cover **20** is also coupled to engine power assembly **14**.

[0013] Engine **10** may be operated similarly to certain known engines, including in a two-stroke engine cycle where combustion air is admitted into a combustion chamber **29** defined by cylinder liner **24**, piston **28**, and cylinder head assembly **22**, and exhaust conveyed out by way of exhaust valves **38**. In the engine power assembly **14**, part of which is shown, on the left-hand side of FIG. **1** a fuel injector **40** is visible. Engine **10** can be direct-injected and operated on a suitable compression-ignition liquid fuel, such as a diesel distillate fuel. Other engine configurations and operating strategies are within the scope of the present disclosure, however, including a four-stroke engine cycle, port injection, spark-ignition, and various alternative fuels including liquid fuels and/or or gaseous fuels. Engine **10** can be applied in a range of applications including for vehicle propulsion, including for operating a drivetrain or an electric generator in a locomotive.

[0014] Cylinder head assembly **22** can be attached to cylinder liner **24** by way of a plurality of head bolts **44**. Also in the illustrated embodiment, a water jacket **32** is formed around cylinder liner **24**, as well as a lower air annulus **34**. Water jacket **32** may be understood as an upper water jacket whereby coolant liquid is conveyed along and through cylinder liner **24** and into cylinder head assembly **22**. Air annulus **34** may extend circumferentially around cylinder liner **24** and conveys air from air box **30** around cylinder liner **24**. In contrast to certain known engine and engine power assembly configurations no lower water jacket at all may be used, and cooling achieved by way of liquid coolant in water jacket **32** and air in air annulus **34** at least principally. FIG. **1** also illustrates a water inlet manifold **42**, and a water jumper line **36** that extends to cylinder liner **24** from water inlet manifold **32** to provide a flow of liquid coolant to feed the respective water jacket and cylinder head assembly as further discussed herein.

[0015] Referring also now to FIG. **2** there are shown features of engine power assembly **14** in additional detail, showing piston assembly **26** extending into cylinder liner **24**, which is in turn attached to cylinder head assembly **22**. A jacket piece **46** is attached to liner **24** and forms water jacket **32** together with cylinder liner **24** as further discussed herein. Jacket piece **46** may including a cylindrical spinning or the like having, for example, a wall thickness less than a wall thickness of cylinder liner **24**. Those skilled in the art will be familiar with engine power assemblies sold as replacement parts installed in place of used engine power assemblies in an engine. Engine power assembly **14** may thus be sold as a standalone after market system. Individual components of engine power assembly **14**, including cylinder liner **24**, may also be provided for installation in a new engine or a used engine returned from service, in place of a used cylinder liner.

[0016] Referring also now to FIGS. **3-5**, there are shown still further features of cylinder liner **24**. Cylinder liner **24** includes an elongate liner body **50** defining a longitudinal axis **52**, and including an inner liner surface **54**, an outer liner surface **56** including an outer water jacket surface **58** extending circumferentially around longitudinal axis **52**, and a plurality of combustion air ports **60**. Outer liner surface **56** also includes an air annulus surface extending circumferentially around longitudinal axis **52**. Combustion air ports **60** extend from outer liner surface **56** to inner liner surface **54** and are fluidly connected to air box **30** to convey combustion air into combustion chamber **29**. Combustion air ports **60** may be formed in an alternating arrangement with a plurality of struts **61**, circumferentially around longitudinal axis **52**, and generally receive a radially inward flow of air for combustion from airbox **30** when piston **28** is positioned low enough in cylinder liner **24** to permit admission of the air.

[0017] Liner body **50** further includes an upper liner end **70** and a lower liner end **72**. Water jacket surface **58** extends axially between combustion air ports **60** and upper liner end **70**. Air annulus surface extends axially between combustion air ports **60** and lower liner end **72**. Water jacket **32** is formed between water jacket surface **58** and jacket piece **46** and located axially between combustion air ports **60** and upper liner end **70**. Air annulus **34** is formed between air annulus surface **96** and engine housing **14**, typically crankcase **13**. Water jacket surface **58** may be necked-down between upper liner end **70** and combustion air ports **60**, providing a volume or cavity for a flow of coolant liquid as further discussed herein. Air annulus surface **96** may be necked-down between lower liner end **72** and combustion air ports **60**, providing a cavity or potentially open space entirely for conveyance of air from air box **30** around cylinder liner **24**.

[0018] Cylinder liner **24** also includes a coolant supply passage **62** extending from a coolant inlet **64** formed in outer liner surface **56**, to a water jacket feed outlet **68** spaced axially from combustion air ports **60**. Cylinder liner **24** also includes a flow balancer **68** for coolant, formed on outer liner surface **56**, and positioned in a coolant flow path extending in an axial direction along water jacket surface **58** from water jacket feed outlet **66**. When placed in service, all of the coolant liquid to be conveyed into and through water jacket **32** may be supplied by way of coolant supply passage **62**.

[0019] It has been discovered that the provision of a singular coolant feed location can, unless addressed by balancing coolant liquid flow, result in an undesired lack of mixing and/or undesired pressure properties of coolant flowing through water jacket **32**. As best shown in FIG. **3**, water jacket surface **58** may include a conical upper surface **76** and a cylindrical lower surface **78**. Flow balancer **68** may be formed on cylindrical lower surface **78**. Cylinder liner **24** may also include a plurality of coolant passages **80** each opening in water jacket surface **58**, for example in conical upper surface **76**, and also opening in upper liner end **70**. FIG. **3** illustrates a plurality of coolant passages **80** extending to and opening in upper liner end **70** as well as a plurality of threaded bolting bores **82** opening in upper liner end **70** to receive head bolts **44**. Flow balancer **68** may be positioned so as to be impinged upon by a flow of coolant liquid from water jacket feed outlet **68** to coolant passages **80**. In FIG. **3** arrows **100** illustrate an approximate and example flow of coolant that impinges upon flow balancer **68** and causes the coolant to spread circumferentially from outlet **66** so as to more uniformly feed relatively cold, fresh coolant into coolant passages **80**.

[0020] In the illustrated embodiment, flow balancer **68** is fully circumferential of longitudinal axis **52** and projects radially outward. Also in the illustrated embodiment, flow balancer **68** has the form of a rib. Embodiments are contemplated where a flow balancer is only partially circumferential of a cylinder liner longitudinal axis. Still other variations can include multiple flow balancers at different axial locations, flow balancers formed by radially inward geometry of outer liner surface **56**, fins, nodules, surface texturing, channels, or various other geometries including combination of those listed. In a practical implementation, a flow balancer will include at least one surface that extends radially relative to longitudinal axis **52**.

[0021] Cylinder liner **24** may further include a seal groove **84** extending circumferentially around longitudinal axis **52** at a location axially between coolant inlet **64** and water jacket feed outlet **66**. A first seal **86** may be seated in seal groove **84**. Cylinder liner **24** may also include a second seal groove **88** extending circumferentially around longitudinal axis **52** at a location axially between conical upper surface **76** and upper liner end **70**. A second seal **90** may be seated in second seal groove **88**. One or more additional grooves **98** may be formed closer to lower liner end **72** to receive additional seals or other hardware that serves to seal around and/or locate cylinder liner **24** in engine **10** and/or power assembly **14**.

[0022] Cylinder liner **24** may further include a lip protrusion **92** extending circumferentially around longitudinal axis **52** and having seal groove **84** formed therein. In the illustrated embodiment, lip protrusion **92** includes an upturned lip protrusion upturned in a direction of upper liner end **70**. Alternative embodiments are within the scope of the present disclosure. A coolant annulus **94** extends radially inward of lip protrusion **92**, and coolant supply passage **62** extends through lip protrusion **92** as best shown in FIG. **4**.

INDUSTRIAL APPLICABILITY

[0023] Operating engine **10** can include reciprocating piston **28** within cylinder liner **24**, receiving a flow of air for combustion via combustion air ports **60** when piston **28** passes combustion air ports **60** in a downward stroke, and pressurizing the air when piston **28** is moved in an upward stroke past combustion air ports **60**. At a desired timing, fuel is injected via fuel injector **40** and compression-ignited in combustion chamber **29**, with the resulting pressure and temperature rise driving position **28** once again downward. Exhaust valves **38** are opened at appropriate timings to permit conveyance of exhaust out of combustion chamber **29**.

[0024] Meanwhile, coolant is supplied by way of water jumper **36** so as to flow through coolant passage **62** into water jacket **32**. The flow of coolant through water jacket **32** and along water jacket surface **58** encounters flow balancer **68**, causing the flow of coolant to spread and the coolant mix as coolant flows upwardly to enter coolant passages **80**. Coolant flows through coolant passages **80** and into cylinder head assembly **22** for recirculation typically passing through a radiator.

[0025] As noted above, certain known engine configurations included both an upper water jacket and a lower water jacket around a cylinder liner. Known cylinder liners are commonly machined from a static iron casting. According to the present disclosure, certain of the feature changes relative to the state of the art can facilitate alternative manufacturing strategies including centrifugal casting. In particular, in some traditional designs the passage of coolant between a lower water jacket and an upper water jacket in a cylinder liner required holes or passages to be formed in struts of the cylinder liner separating the combustion air ports. Such a strategy was generally poorly suited to centrifugal casting. According to the present disclosure, the elimination of passages through struts **61** assists in improved suitability of the design for centrifugal casting. In addition, prior designs utilizing cooled passages through struts tended to naturally balance a flow of coolant around the liner. Thus, elimination of coolant passages in struts generated additional challenges respecting cooling flow balancing, addressed by way of flow balancer **68**.

[0026] The present description is for illustrative purposes only, and should not be construed to narrow the breadth of the present disclosure in any way. Thus, those skilled in the art will appreciate that various modifications might be made to the presently disclosed embodiments without departing from the full and fair scope and spirit of the present disclosure. Other aspects, features and advantages will be apparent upon an examination of the attached drawings and appended claims. As used herein, the articles "a" and "an" are intended to include one or more items, and may be used interchangeably with "one or more." Where only one item is intended, the term "one" or similar language is used. Also, as used herein, the terms "has," "have," "having," or the like are intended to be open-ended terms. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise.

1. A cylinder liner comprising:

an elongate liner body defining a longitudinal axis, and including an inner liner surface, an outer liner surface including a water jacket surface extending circumferentially around the longitudinal axis, and a plurality of combustion air ports extending from the outer liner surface to the inner liner surface;

a coolant supply passage extending from a coolant inlet formed in the outer liner surface, to a water jacket feed outlet spaced axially from the plurality of combustion air ports; and

a flow balancer for coolant, formed on the outer liner surface, positioned in a coolant flow path extending in an axial direction along the water jacket surface from the water jacket feed outlet, and the flow balancer including at least one surface extending in a radial direction and facing in opposition to a flow of coolant in the coolant flow path.

2. The cylinder liner of claim **1** wherein the elongate liner body includes an upper liner end and a lower liner end, and the water jacket surface is necked-down between the upper liner end and the plurality of combustion air ports.

3. The cylinder liner of claim **2** wherein the outer liner surface includes an air annulus surface that is necked-down between the lower liner end and the plurality of combustion air ports.

4. The cylinder liner of claim **2** wherein the water jacket surface includes a conical upper surface and a cylindrical lower surface, and the flow balancer is formed on the cylindrical lower surface.

5. The cylinder liner of claim **4** further comprising a plurality of coolant passages each opening in the conical upper surface and in the upper liner end.

6. The cylinder liner of claim **5** further comprising a seal groove extending circumferentially around the longitudinal axis at a location axially between the coolant inlet and the water jacket feed outlet.

7. The cylinder of claim **6** further comprising an upturned lip protrusion extending circumferentially around the longitudinal axis and having the seal groove formed thereon, and the coolant supply passage extends through the upturned lip protrusion.

8. The cylinder liner of claim **6** further comprising a second seal groove extending circumferentially around the longitudinal axis at a location axially between the conical upper surface and the upper liner end.

9. The cylinder liner of claim **1** wherein the flow balancer is at least partially circumferential of the longitudinal axis.

10. The cylinder liner of claim **9** wherein the flow balancer projects radially outward.

11. The cylinder liner of claim **10** wherein the flow balancer includes a rib and is fully circumferential of the longitudinal axis.

12. A power assembly for an engine comprising:

a cylinder head assembly including a cylinder head;

a cylinder liner coupled to the cylinder head assembly and defining a longitudinal axis;

a piston assembly including a piston;

the cylinder liner including an inner liner surface forming, together with the cylinder head and the piston, a combustion chamber, an outer liner surface including a water jacket surface extending circumferentially around the longitudinal axis, and a plurality of combustion air ports for conveying combustion air into the combustion chamber; and

the cylinder liner further including a flow balancer formed on the water jacket surface;

wherein the water jacket surface includes a conical upper surface and a cylindrical lower surface, and the flow balancer is formed on the cylindrical lower surface.

13. The power assembly of claim **12** wherein the flow balancer includes a rib projecting radially outward.

14. The power assembly of claim **12** wherein the cylinder liner further includes a coolant supply passage extending from a coolant feed inlet formed in the outer liner surface to a water jacket feed outlet formed in the outer liner surface.

15. The power assembly of claim **14** wherein the cylinder liner further includes a lip protrusion including therein a seal groove located axially between the coolant feed inlet and the water jacket feed outlet.

16. The power assembly of claim **15** wherein a coolant annulus extends circumferentially around the longitudinal axis and radially inward from the lip protrusion.

17. The power assembly of claim **15** wherein the cylinder liner further includes a second seal groove located axially between the water jacket surface and an upper liner end, and the power assembly further comprising a first seal seated in the seal groove, a second seal seated in the second seal groove, and a jacket piece in contact with the first seal and the second seal such that an upper water jacket is formed between the jacket piece and the water jacket surface.

18. The power assembly of claim **12** further comprising a plurality of coolant passages opening in the water jacket surface, and the flow balancer is arranged fluidly between the water jacket feed outlet and the plurality of coolant passages.

19. The power assembly of claim **12** wherein the water jacket surface includes a conical upper surface and a cylindrical lower surface, and the flow balancer is formed on the cylindrical lower surface.

20. An engine comprising:

an engine housing forming an air box;

a power assembly supported in the engine housing and including a one-piece cylinder liner, the cylinder liner defining an axis and having formed therein a plurality of combustion air ports fluidly connected to the air box, and including an outer water jacket surface extending between the plurality of combustion air ports and an upper liner end, and an outer air annulus surface extending between the plurality of combustion air ports and a lower liner end;

the power assembly further including a jacket piece attached to the cylinder liner and forming, together with the outer water jacket surface, an upper water jacket; and

an air annulus formed between the outer air annulus surface and the engine housing and fluidly connected to the air box;

a flow balancer for coolant, formed on the outer liner surface at a flow balancer axial location relative to the axis; and

the power assembly further including a piston movable between a first position in the cylinder liner where the piston is positioned below the flow balancer axial location and low enough in the cylinder liner to permit admission of air through the plurality of combustion air ports, and a second position where the piston is positioned at least partially above the flow balancer axial location.

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