STEAM POWER PLANT AND METHOD FOR OPERATING IT

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ABSTRACT

The invention relates to a method for operating a steam power plant, comprising a steam engine which is operated with a vaporous working medium, an evaporator for evaporating the working medium; a condenser for liquefying the working medium and a reservoir for the working medium. The invention is characterized in that a lubricant sump in a housing of the steam engine is heated to a temperature above the evaporating temperature of the working medium by means of a heating device during the starting phase of the steam engine.
Fig. 4
Fig. 6

Prior Art
STEAM POWER PLANT AND METHOD FOR OPERATING IT

[0001] The invention concerns a steam power plant and a method of operating the same, as well as a steam engine in particular for exhaust gas energy recovery of an internal combustion machine.

[0002] Steam power plants, which for instance are operated according to the Clausius-Rankine process, convert a heat flow into mechanical power. A possibility of application consists in the waste heat recovery of internal combustion machines of vehicles, whereas in particular the heat energy contained in the exhaust gas stream is used by means of a steam engine for supporting the propulsion or for feeding secondary drive units. Such steam power plants typically include a reservoir with a vapourisable working medium, from which a feed pump connected to a steam generator scoops working medium. The heat exchanger charged with the heat flow to be used evaporates the working medium which expands by way of a mechanical effect in the steam engine and consequently liquefies via a condenser and is returned to the reservoir.

[0003] Steam engines for steam power plants can for instance be designed as piston engines, in particular as reciprocating piston engines, which are operated according to the twostroke principle. Alternately, the expansion of the vaporous working medium can take place in a screw expander, irrespective of the type of the steam engine, the leakage of a portion of the working medium in the gap area between the moving components of the expansion chambers and the fixed side surface areas cannot be avoided completely. In the case of a reciprocating piston engine such as steam engine, said leakage occurs in the area of the structural necessary gap between the pistons, i.e. the piston rings and the cylinder running track, so that a certain quantity of working medium flows into the steam engine housing. This process designated as “blow-by” also exists in internal combustion engines. Accordingly, measures are seized for sealing the gap area along the cylinder running surfaces as far as possible. To do so, ring grooves generating turbulence on the piston skirt and/or on the cylinder wall come into play.

[0004] A further sealing of the cylinder chamber with respect to the crankcase of a reciprocating piston engine can be obtained moreover by means of a splitting bushing for which separate piston rings are provided. Additionally, the sealing can be improved by reducing the effect of the transverse forces on the piston. A solution suggested for that purpose consists in using a piston drive with a crosshead, whereas the drive connection takes place between piston and crank pin via a piston rod, which is connected in an articulated manner with a connecting rod. The pivot bearing between the connecting rod and the piston rod is supported typically by means of a slide shoe on a slide bearing wall for the crosshead. Such a crosshead is suggested by document DD 3411 A for reducing the blow-by of a steam engine, whereas the crosshead is connected fixedly to the piston bottom as regards a design which is as short as possible, so that a distinct piston rod can be omitted. The centric run of the piston can be improved by a crosshead guide bushing which is arranged in the range of the transition between cylinder and crankcase so that the blow-by of the working medium can be reduced by means of a labyrinth seal on the piston wall.

[0005] The shortcoming with a crosshead arrangement is however the additional structural means to be implemented in connection with a greater weight of the moving parts, which is particularly undesirable for fast running steam engines. Moreover, the blow-by cannot be avoided completely with the measures described previously, so as to prevent increasing saponification of the lubricant in the sump of the crankcase.

[0006] The blow-by generates an increasing pressure when operating the steam engine in the crankcase so that a crankcase ventilation unit should be provided. The ventilation unit known from internal combustion engines must represent a closed system, since an exhaust from the crankcase under normal operating conditions includes finely atomized lubricant. For internal combustion engines, the exhaust of the crankcase ventilation unit is guided through an oil filter, before the blow-by gases removed from the crank chamber are conveyed to the air intake box of the internal combustion engine. The oil filter returns the lubricant captured into the sump of the crankcase by means of an oil return channel. Such oil filters are known in different designs. One of the variations consists in providing a settling chamber in which the oil mist precipitates. Alternately, the oil separating element can operate according to the centrifugal principle and be designed in the form of a cyclone. See for instance document DE 1 164 158 A. Alternately, deflector plates in combination with several sharp deflection elements can be used for the gas flow. For that purpose, document DE 10 2006 056 789 A1 can be mentioned by way of example. Additional embodiments include coils, knitted wire meshes or yams as well as fleece as oil separators. Moreover, document DE 102 03 274 A1 describes a plastic granulate for an oil separating system. A further variation consists in using for oil separation an electric filter such as described for instance in document DE 197 01 463 C1.

[0007] A further problem for oil separators of internal combustion engines relates to the reliable function at low temperatures. An electrical heating system for an oil separator for cleaning crankcase gases is disclosed in document DE 10 2009 005 550 A1, which is used for frost resistance. Additionally, document DE 10 2004 031 499 B4 discloses a heating device at the intake of the crankcase ventilation pipe into the air intake box of an internal combustion engine, in order to prevent said area from freezing up.

[0008] The object of the invention is to offer a steam engine and a method for its operation, the method which reduces the saponification of a lubricating medium in the housing of the steam engine due to the introduction of working medium resulting from the blow-by effect. The method and the system should be characterised by simple construction and manufacturing technique.

[0009] The object mentioned above is solved by the features of the independent claims.

[0010] In the case of the steam engine according to the invention, any enrichment of the working medium introduced from the expansion chamber into the lubricant by the blow-by effect, inside the steam engine housing, is reduced in such a way that the lubricant sump inside the steam engine housing is brought to a temperature above the evaporating temperature of the working medium. To do so, the steam engine according to the invention includes a heating device to reach as quickly as possible the necessary temperature in the lubricant sump after starting the plant. Vaporous working medium is evacuated with the oil mist via a housing ventilation unit fitted with an oil separator for creating a pressure compensation and then preferably conveyed from the gas extractor to the reservoir for the working medium of the steam power plant after separation of the medium.
The heating device for the lubricant in the lubricant sump of the steam engine housing is in the case of a reciprocating piston steam engine preferably arranged in the crankcase. To do so, an electric heating resistor can be considered. Alternately or additionally, heat sources inside the steam power plant, possibly a steam heating system for the heating device or a condensate heating unit, or external heat sources, for example from the exhaust gas stream of an internal combustion engine or from its oil system, can be used. It may also be contemplated to provide a heat accumulator, possibly a latent heat accumulator for the heating device.

The heating device for the lubricant is deactivated after sufficient operating time of the steam engine as soon as, in the lubricant sump of the steam engine housing, a temperature above the evaporating temperature of the working medium will be reliably maintained by the steam throughput in the expansion chambers. To do so, the steam engine is preferably coated with a thermal insulation. An upper temperature limit is established by the decomposition temperature of the lubricating medium so that a lubricant cooling system is activated in continuous operation, whereas the lubricant temperature may not fall below the evaporating temperature of the working medium.

In accordance with a further embodiment, the oil separator is additionally arranged in the hot area of the steam engine in such a way that it reaches a temperature above the evaporating temperature of the working medium during operation. In a preferred alternative design the oil separator contains a separate heating device, for heating the areas transporting the gas and the particle the lubricant separating element to a temperature above the evaporating temperature of the working medium. Moreover, in a preferred embodiment, the line link transporting gas between the steam engine housing and the oil separator is thermally insulated or heated separately to reach as quickly as possible an operating temperature above the evaporating temperature of the working medium.

For the method according to the invention, the lubricant sump in the steam engine housing is brought to such a temperature or maintained at a temperature ensuring evaporation of the working medium of the steam engine. Consequently, the temperature at hand preferably exhibits a temperature interval ΔT=10⁰C and in particular preferably ΔT=20⁰C above the evaporating temperature of the working medium. A steam engine housing ventilation pipe then contains a discharge which consists of a mixture of oil mist and evaporated working medium.

It is further advantageous to carry out the oil separation before the working medium condenses. For that purpose, a further embodiment of the invention, the exhaust channels up to the oil separator as well as the oil separator are tempered or arranged inside the thermal sheath of the steam engine, whereas the temperature is sufficiently high to maintain the working medium in the steam condition. In the oil separator, the lubricant components of the discharge present in droplet form are removed as far as possible from the steam engine housing, while the vaporous working medium passes through the oil separator essentially unimpeded. After the oil separator, the residue of the discharge is conveyed from the steam engine housing into the circuit of the working medium of the steam engine, whereas after the oil separator, there may be condensation of the working medium. Most preferably an introduction is provided on the condenser for the working medium, whereas it is ensured by means of a suitable pump and valve system that the working medium does not recirculate to the oil separator.

Accordingly, the residual exhaust from the steam engine housing is conveyed to the reservoir for the working medium via the condenser. In an alternative embodiment the bypassing of the condenser and the direct supply into the working reservoir can also be considered, whereas after the oil separator, there may be condensation of the working medium in all areas of the supply network. Also a condensation immediately in the reservoir of the working medium is possible due to the relatively small volume stream of working medium from the housing ventilation unit.

In a further embodiment of the invention, the steam engine described previously forms with a lubricant sump and an oil separator for the housing ventilation unit at a temperature above the evaporating temperature of the working medium, a portion of a steam power plant. In a preferred embodiment, an additional oil separator is provided in the reservoir for the working medium to counteract an accumulation of lubricant which is not completely removed by the oil separator of the housing ventilation unit. This oil separator situated on the reservoir side is connected to the sump of the lubricating medium in the steam engine housing, so as to return the lubricant scooped out of the reservoir to the steam engine.

The invention will subsequently be described in more detail using exemplary embodiments with reference to the figures. There in details is shown:

FIG. 1 shows an embodiment of the invention with a reciprocating piston steam engine and an electrical heating resistor as a heating device for heating the lubricant sump in the crankcase as a schematic diagram.

FIG. 2 shows an alternative embodiment of the invention with a condensate heating system as a heating device for heating the lubricant sump.

FIG. 3 shows an exemplary embodiment with a steam heating unit as a heating device for heating the lubricant sump.

FIG. 4 shows a further embodiment of the invention with an oil separator integrated in the thermal shell of the steam engine.

FIG. 5 shows an alternative embodiment of the invention with a separate oil separator heating unit.

FIG. 6 shows a hybrid drive according to the prior art for a vehicle including an internal combustion engine and a steam power device.

FIG. 6 shows a schematically simplified drive system corresponding to the prior art for a vehicle fitted with a hybrid motor which contains an internal combustion engine as well as a steam power plant. The engine output generated by the internal combustion engine is transferred via a transmission to the drive wheels and. In so doing, the exhaust gas generated when operating the internal combustion engine is conveyed to the evaporator of the steam power plant via the exhaust gas pipe. A vaporisable working medium which is kept in a reservoir for the working medium flows towards said evaporator via the feed pump. The vaporous working medium is conveyed to the steam engine and expands by way of mechanical work. In the embodiment shown, the mechanical power output of the steam engine serves for driving an electric generator which feeds secondary devices which are not illustrated in detail. In an alternative embodiment not shown in the Figures,
The power generated by the steam engine 2 can be used for supporting the propulsion of the vehicle and can be, for instance, coupled to the drive train in the area of the transmission 9. A condenser 7 which absorbs and condenses the waste steam of the steam engine 2 is represented as a further component of the steam power plant 1 in FIG. 6. The condensate of the working medium then flows back to the reservoir 4.

[0026] FIG. 1 shows a steam power plant 1 designed according to the invention with a steam engine 2 comprising a steam engine housing 30. Details, such as a thermal insulation enclosing the steam engine housing 30, are not represented for improved clarity. A reciprocating piston engine with both reciprocating pistons 12.1, 12.2 is used as a steam engine 2 in the arrangement shown. These pistons drive a crankshaft 15 via piston rods 14.1, 14.2 which is mounted in a crankcase 16 with a lubricant sump 17. Between the envelope surfaces of the reciprocating pistons 12.1, 12.2 and the cylinder walls 13.1, 13.2 during operation of the steam engine 2 a leakage flow of the working medium (blow-by) is present which leads into the inside of the crankcase 16. To avoid saponification of the lubricant in the lubricant sump 17 of the crankcase 16 and to counteract any pressure due to the blow-by, a housing ventilation unit in the form of a crankcase ventilation unit 18 is provided. Said unit comprises an oil separator 19 which in this instance is fitted with a settling chamber. Further embodiments can be contemplated, and in particular, cyclone separators, filter elements in the form of knitted fabrics or granules and electrically operated oil separators 19 can be considered.

[0027] For heating the lubricant in the lubricant sump 17, a heating device 35 is provided in the area of the crankcase 16. Said device includes in this case an electric heating resistor 36 which is connected to a power source 37. Moreover, there is also provided a temperature sensor 38 in direct thermal contact with the lubricant sump 17, which sensor co-operates with a switching circuit 39 and a control unit 20 for processing the sensor signals and adjusting the flow of current through the electric heating resistor 36 to the heating control unit. When starting the steam power plant 1 or after a longer operating pause, the lubricant in the lubricant sump 17 is brought by the electric heating resistor 36 to a temperature above the evaporating temperature of the working medium so that a discharge is possible via the crankcase ventilation unit before saponification of the lubricant occurs.

[0028] In a preferred embodiment, the lubricant separated in the oil separator 19 from the gas vent, coming out of the crankcase 16, is guided via the lubricant return line 23.1 back to the lubricant sump 17 in the crankcase 16. The residual discharge of the crankcase ventilation unit extensively separated from the lubricant, designated hereafter as lubricant-free discharge 24 is, in the embodiment shown in this instance, conveyed via the condenser 7 to the reservoir for the working medium 4. Alternatively, a separate collective reservoir can be considered for the lubricant-free discharge 24, however such a configuration is not represented in detail in FIG. 1.

[0029] In the diagrammatic example of this embodiment, an oil separator 25 situated on the reservoir side is used in the reservoir for the working medium 4. Said separator can for instance be designed as a membrane separator. Said separator serves for separating the working medium from the lubricant introduced, which flows back via the lubricant return line 23.2 into the lubricant sump 17 of the crankcase 16.

[0030] FIG. 2 shows an alternative embodiment of the invention with a heating device 35 for the lubricant in the lubricant sump 17 of the crankcase 16 in the form of a condensate heating unit 40. To that end, the still evaporating working medium, arriving in the condenser 7, is conveyed via a bypass, not illustrated in detail, to a meandering pipe system 41, arranged inside the crankcase 16, a system on which the outlet side is connected to the reservoir 4 for the working medium. The condensation of the working medium takes place inside the meandering pipe system 41. In the case that only essentially vaporous working medium flows back to the condenser 7, the lubricant sump 17 has reached an operating temperature above the evaporating temperature of the working medium and the by-pass connection is closed inside the condenser and the heating device 35 is hence switched off.

[0031] A further exemplary embodiment with a steam heating system 43 as a heating device 35 is shown in FIG. 3. There, a 2-way steam valve 42 is arranged in the steam pipe after the evaporator 6 which co-operates with a control unit, non-illustrated in detail, processing the signals of the temperature sensor 38 in the crankcase 16. To obtain an operating condition with a temperature in the lubricant sump 17 below the evaporating temperature of the working medium, vaporous working medium is guided from the 2-way steam valve 42 through the meandering pipe system 41 of the heating device 35 directly to the condenser 7 so that the lubricant sump 17 can be heated up.

[0032] FIG. 4 shows another embodiment based on the embodiment shown in FIG. 1. Said embodiment consists in arranging the oil separator 19 inside the thermal insulation 44 of the steam engine 2 so that the latter ends up in the hot area. For clarification purposes, a portion of the thermal insulation 44 of the steam engine 2 is represented, which insulation surrounds the reciprocating pistons 12.1, 12.2 and the crankcase 16. Preferably, the oil separator 19 is situated inside the crankcase 16 so that said separator essentially adopts the temperature of the lubricant sump 17 and so that hence it is guaranteed during operation that the working medium remains vaporous in the inside thereof.

[0033] A separate oil separator heating unit 22 is provided on the oil separator 19 itself in the alternative embodiment shown in FIG. 5. Moreover, the connection between the outlet for the crankcase ventilation unit 18 on the crankcase 16 and the oil separator 19 contains a separate flow channel heating unit 21.

[0034] Further embodiments of the invention can be contemplated, for which the steam engine is designed as a reciprocating piston machine instead of a reciprocating piston machine. Moreover, alternative embodiments of the steam engine 2, such as screw expanders are included. There is no crankshaft 15 in a crankcase 16 for such versions. Subsequently, in the context of the invention, the blow-by is guided from the expansion chambers inside the steam engine housing with a housing ventilation unit, which includes an oil separator as well as a system for securing the evaporation of the working medium inside the steam engine housing. Further, a temperature above the evaporating temperature of the working medium is preferably maintained in the housing ventilation unit including the oil separator.

LIST OF REFERENCE NUMERALS

[0035] 1 Steam power plant
[0036] 2 Steam engine
[0037] 3 Electrical generator
[0038] 4 Reservoir for the working medium
[0039] 5 Feed pump
[0040] 6 Evaporator
[0041] 7 Condenser
[0042] 8 Internal combustion engine
[0043] 9 Transmission
[0044] 10.1, 10.2 Drive wheel
[0045] 11 Exhaust gas pipe
[0046] 12.1, 12.2 Reciprocating piston
[0047] 13.1, 13.2 Cylinder wall
[0048] 14.1, 14.2 Connecting rod
[0049] 15 Crankshaft
[0050] 16 Crankcase
[0051] 17 Lubricant sump
[0052] 18 Crankcase ventilation unit
[0053] 19 Oil separator
[0054] 20 Control system
[0055] 21 Flow channel heating unit
[0056] 22 Oil separator heating unit
[0057] 23.1, 23.2 Lubricant return line
[0058] 24 Lubricant-free discharge
[0059] 25 Oil separator situated on the reservoir side
[0060] 30 Steam engine housing
[0061] 35 Heating device
[0062] 36 Electric heating resistor
[0063] 37 Power source
[0064] 38 Temperature sensor
[0065] 39 Switching circuit
[0066] 40 Condensate heating unit
[0067] 41 Meandering pipe system
[0068] 42 2-way-steam valve
[0069] 43 Steam heating
[0070] 44 Thermal insulation

1-11. (canceled)

12. A method for operating a steam power plant, including a steam engine, which is operated with a vaporous working medium, an evaporator for evaporating the working medium; a condenser for liquefying the working medium and a reservoir for the working medium, characterised in that a lubricant sump in a housing of the steam engine is heated to a temperature above the evaporating temperature of the working medium by means of a heating device during the starting phase of the steam engine.

13. The method of claim 12, characterised in that a gas discharge is fed to an oil separator for ventilating the housing of the steam engine, which when operating the steam engine is brought to a temperature above the evaporating temperature of the working medium due to the arrangement inside the thermal insulation of the steam engine and/or through a separate oil separator heating unit.

14. A steam engine including:
a steam engine housing with a lubricant sump enclosed inside the steam engine housing;
an expansion chamber for a vaporous working medium driving the steam engine, which is situated inside the steam engine housing; characterised in that
a housing ventilation unit with an oil separator is fitted on the steam engine housing and a heating device is associated with the lubricant sump, that brings the lubricant sump to a temperature above the evaporating temperature of the working medium.

15. The steam engine according to claim 14, characterised in that the heating device comprises an electrical heating resistor or a steam heating unit or a condensate heating unit using the working medium.

16. The steam engine according to claim 14, characterised in that the oil separator is arranged inside a thermal insulation for the steam engine.

17. The steam engine according to claim 15, characterised in that the oil separator is arranged inside a thermal insulation for the steam engine.

18. The steam engine according to claim 14, characterised in that a separate oil separator heating unit is associated with the oil separator.

19. The steam engine according to claim 15, characterised in that a separate oil separator heating unit is associated with the oil separator.

20. The steam engine according to claim 16, characterised in that a separate oil separator heating unit is associated with the oil separator.

21. The steam engine according to claim 17, characterised in that a separate oil separator heating unit is associated with the oil separator.

22. The steam engine according to claim 14, characterised in that the housing ventilation unit includes a flow channel heating unit for a connection line between the steam engine housing and the oil separator, which maintains a temperature in the connection line above the evaporating temperature of the working medium.

23. The steam engine according to claim 15, characterised in that the housing ventilation unit includes a flow channel heating unit for a connection line between the steam engine housing and the oil separator, which maintains a temperature in the connection line above the evaporating temperature of the working medium.

24. The steam engine according to claim 16, characterised in that the housing ventilation unit includes a flow channel heating unit for a connection line between the steam engine housing and the oil separator, which maintains a temperature in the connection line above the evaporating temperature of the working medium.

25. The steam engine according to claim 17, characterised in that the housing ventilation unit includes a flow channel heating unit for a connection line between the steam engine housing and the oil separator, which maintains a temperature in the connection line above the evaporating temperature of the working medium.

26. The steam engine according to claim 18, characterised in that the housing ventilation unit includes a flow channel heating unit for a connection line between the steam engine housing and the oil separator, which maintains a temperature in the connection line above the evaporating temperature of the working medium.

27. The steam engine according to claim 19, characterised in that the housing ventilation unit includes a flow channel heating unit for a connection line between the steam engine housing and the oil separator, which maintains a temperature in the connection line above the evaporating temperature of the working medium.

28. The steam engine according to claim 14, characterised in that the steam engine comprises a reciprocating piston which drives a crankshaft via a piston rod, and a lubricant sump in a crankcase accommodating the crankshaft, which is part of the steam engine housing, and the housing ventilation unit is designed in the form of a crankcase ventilation unit.
29. A steam power plant comprising the steam engine according to claim 14, the steam power plant including:
an evaporator for the working medium; and
a condenser and a reservoir for the working medium,
whereas the oil separator in the housing ventilation unit of the steam engine is connected at least indirectly to the
reservoir for the working medium.
30. The steam power plant according to claim 29, characterised in that the evaporator is interposed between the oil
separator and the reservoir for the working medium.
31. The steam power plant according to claim 29, characterised in that an oil separator situated on the reservoir side is
associated with the reservoir for the working medium, which is connected to the lubricant sump in the steam engine housing via a lubricant return line.

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