US 20140237993A1

(19) United States

(12) Patent Application Publication

Taylor et al.

(10) Pub. No.: US 2014/0237993 A1

(43) Pub. Date: Aug. 28, 2014

(54) **DIESEL ENGINE ARRANGEMENT AND METHOD FOR VARNISH BUILD-UP CONTROL**

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(21) Appl. No.: **14/350,364**

(22) PCT Filed: **Nov. 16, 2011**

(86) PCT No.: **PCT/US2011/060887**

§ 371 (c)(1), (2), (4) Date: **Apr. 8, 2014**

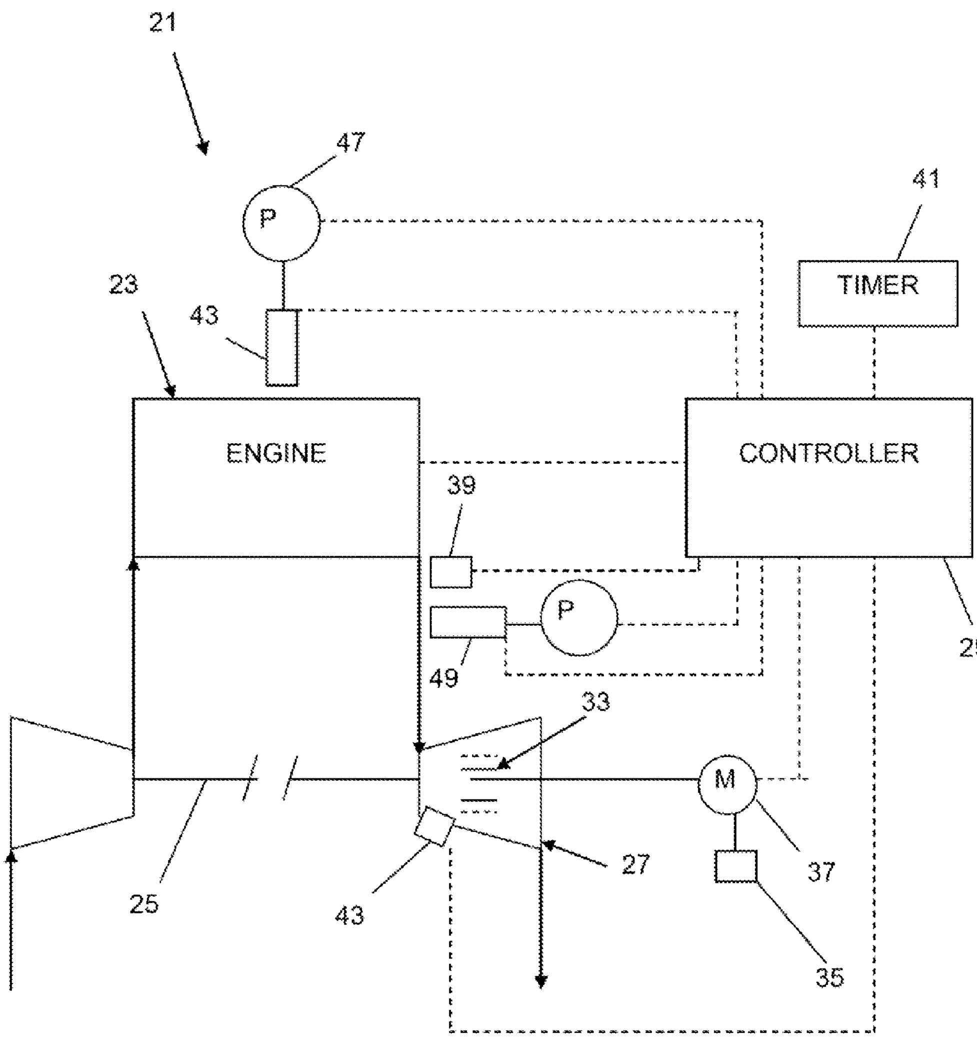
Publication Classification

(51) **Int. Cl.**
F01N 3/10 (2006.01)

(52) **U.S. Cl.**
CPC ***F01N 3/10*** (2013.01)
USPC **60/274**; 60/320

(57) **ABSTRACT**

A method is provided for controlling varnish build-up in a variable geometry turbine (VGT) of a diesel engine turbocharger. According to the method, it is determined whether an operation parameter is at a level established for initiating a varnish build-up control sequence. Upon determining that the operation parameter is at the established level, the varnish build-up control sequence is initiated. The sequence comprises increasing exhaust temperature upstream of the VGT to a first exhaust temperature, and changing an opening size of a VGT nozzle between a smaller and a larger opening size in association with increasing the exhaust temperature to the first exhaust temperature. A diesel engine arrangement is also provided.



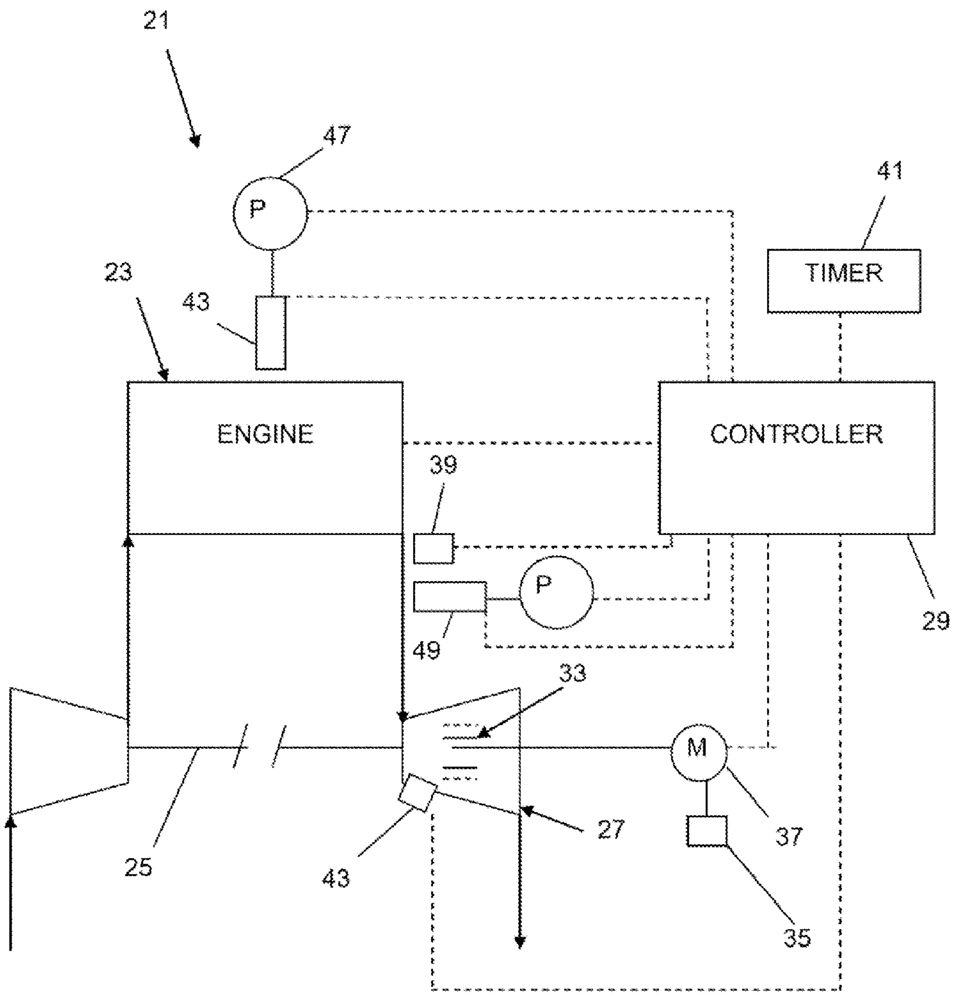

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FIG. 1

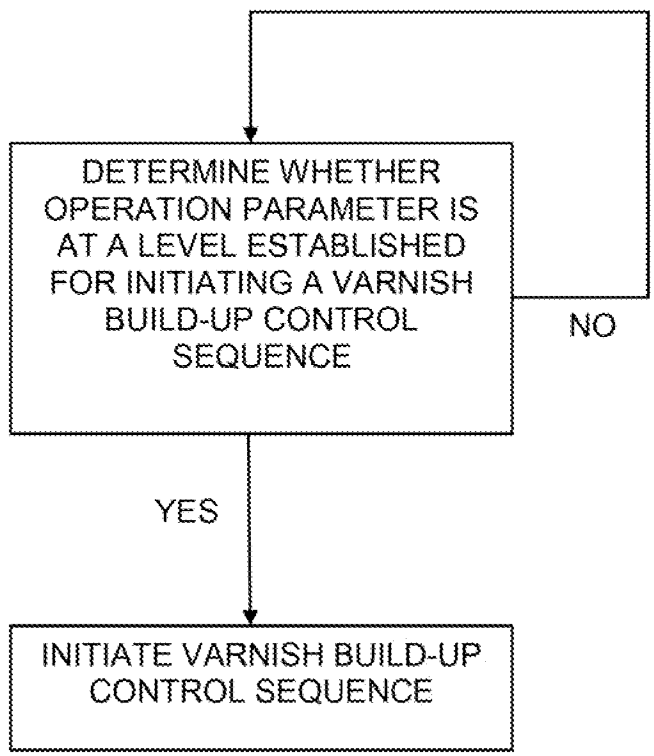
DETERMINE WHETHER OPERATION PARAMETER IS AT A LEVEL ESTABLISHED FOR INITIATING A VARNISH BUILD-UP CONTROL SEQUENCE
NO
YES
INITIATE VARNISH BUILD-UP CONTROL SEQUENCE

FIG. 2

DIESEL ENGINE ARRANGEMENT AND METHOD FOR VARNISH BUILD-UP CONTROL

BACKGROUND AND SUMMARY

[0001] The present invention relates to a method and diesel engine arrangement for varnish build-up control in a variable geometry turbine (VGT) of a diesel engine turbocharger.

[0002] Varnish is an unwanted, usually glossy film that primarily comprises unburnt hydrocarbons. In a turbocharged diesel engine, this condition often results from incomplete combustion in a relatively cold engine cylinder. The semi-burnt fuel hardens on the turbocharger nozzle, tending to cause it to stick, and usually requiring replacement of the turbocharger.

[0003] In conventional diesel engines, it is known to periodically cycle the VGT nozzle through an open and closed position to facilitate removal of built-up soot. It is also known to perform "heat mode" operations that are designed to increase exhaust gas temperatures to facilitate cleaning, regenerating, or heating up of exhaust aftertreatment system components such as diesel oxidation catalysts and diesel particulate filters. It has also been found that soot deposits tend to occur during extended operation at idle in low temperatures, and that it can be beneficial to periodically heat exhaust temperatures to facilitate soot removal. These operations do not, however, ordinarily prevent or remove varnish build-up.

[0004] It is therefore desirable to provide a method for controlling varnish build-up. It is also desirable to provide a diesel engine arrangement set up to facilitate control of varnish build-up.

[0005] According to an aspect of the present invention, a method is provided for controlling varnish build-up in a variable geometry turbine (VGT) of a diesel engine turbocharger. According to the method, it is determined whether an operation parameter is at a level established for initiating a varnish build-up control sequence. Upon determining that the operation parameter is at the established level, the varnish build-up control sequence is initiated. The sequence comprises increasing exhaust temperature upstream of the VGT to a first exhaust temperature, and changing an opening size of a VGT nozzle between a smaller and a larger opening size in association with increasing the exhaust temperature to the first exhaust temperature.

[0006] According to another aspect of the present invention, a diesel engine arrangement comprises a diesel engine, a turbocharger, the turbocharger comprising a variable geometry turbine (VGT) downstream of the engine, means for determining whether an operation parameter is at a level established for initiating a varnish build-up control sequence for controlling varnish build-up on the VGT, and a controller arranged to initiate the varnish build-up control sequence when the determining means determines that the operation parameter is at the established level. The varnish build-up control sequence comprises increasing exhaust temperature upstream of the VGT to a first exhaust temperature, and changing an opening size of a VGT nozzle between a smaller and a larger opening size in association with increasing the exhaust temperature to the first exhaust temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The features and advantages of the present invention are well understood by reading the following detailed description in conjunction with the drawings in which like numerals indicate similar elements and in which:

[0008] FIG. **1** is a schematic view of a diesel engine arrangement according to an aspect of the present invention; and

[0009] FIG. **2** is a flow chart illustrating steps in a method for varnish build-up control according to another aspect of the present invention.

DETAILED DESCRIPTION

[0010] FIG. **1** schematically shows a diesel engine arrangement **21** according to an aspect of the present invention. The arrangement **21** comprises a diesel engine **23** and a turbocharger **25**, the turbocharger comprising a variable geometry turbine (VGT) **27** downstream of the engine. Means is provided for determining whether an operation parameter is at a level established for initiating a varnish build-up control sequence for controlling varnish build-up on the VGT **27**. The particular means depends upon what the operation parameter is. The operation parameter may be a function of several distinct parameters, such as engine operation parameters or parameters based on modeling, and may involve several distinct sensors, estimates, or determinations. A controller **29** is arranged to initiate the varnish build-up control sequence when the determining means determines that the operation parameter is at the established level.

[0011] The varnish build-up control sequence comprises increasing exhaust temperature upstream of the VGT **27** to a first exhaust temperature, and changing a nozzle opening of a VGT nozzle **33** between a smaller and a larger opening size (shown schematically in FIG. **1** by dotted lines) in association with increasing the exhaust temperature to the first exhaust temperature, such as by moving vanes of the VGT between a maximum open (100%) and a maximum closed (0%) opening size, or between some positions between maximum open and maximum closed. By describing the change of the nozzle opening size to be "in association with" increasing the exhaust temperature, it is intended to convey that the nozzle opening size change may be performed at the same time as the temperature increase, or at a different time, such as after each or all temperature increase, but that there is a relationship between the changing of the nozzle opening size and the increase of exhaust temperature specifically relating to a varnish build-up control sequence.

[0012] Nozzle opening size change and exhaust temperature increase performed during a "vanish build-up control sequence" is also intended to contrast with changes in size of the nozzle opening and increases in exhaust temperature that occur randomly in relation to each other during engine operation or that are related to each other but that are unrelated to a specific sequence for varnish build-up control. For example, closing of a VGT nozzle opening may result in an increase in exhaust temperature upstream of the VGT, but these two steps will not be performed in association with each other as steps of a varnish build-up control sequence unless they are performed in response to determination that an operation parameter is at a level established for initiating the varnish build-up control sequence.

[0013] While not wishing to be bound by theory, changing the opening size, at least when performed in connection with VGTs of the type having movable vanes, usually has the effect of scraping surfaces of the VGT and dislodging varnish or soot deposits. Increasing temperature upstream of the VGT can, depending upon the temperature, facilitate further combustion of hydrocarbons in the exhaust stream, thus facilitating preventing the hydrocarbons from forming varnish deposits on components of the VGT, or turn varnish deposits into soot that can be more easily removed from components of the VGT by movement of VGT components such as vanes. The increase in temperature can be performed using the same equipment and same techniques that are conventionally used during a "heat mode" operation of the type conventionally used to heat, regenerate, or clean a diesel oxidation catalyst (DOC), a diesel particulate filter (DPF), or selective catalytic reduction device (SCR). Raising temperatures to at least about 175° C. upstream of the VGT has been found to be useful in assisting in preventing varnish deposits, and raising temperatures to at least about 350° C. has been found to be useful in assisting in turning varnish deposits into soot or otherwise removing existing varnish deposits.

[0014] The operation parameter in response to which the varnish build-up control sequence is performed ordinarily comprises one or more parameters indicative of varnish build-up or of potential for varnish build-up. Illustrative of the operation parameter are an estimated level of varnish build-up, an actual level of varnish build-up, force required to change nozzle opening size in the VGT, a period of engine operation, a period of engine operation at idle, an ambient temperature, and a engine coolant temperature, detection of faulty hardware, cylinder temperature, intake manifold temperature, injection pressure. Operation parameters such as force required to change nozzle opening size in the VGT may reflect the effect of varnish build-up and the means for determining whether the operation parameter is at the level established for initiating the varnish build-up control sequence may be, for example, electrical sensors **35** such as ammeters, voltmeters, or other sensors conventionally used to measure power drawn by a motor **37** while attempting to move vanes of the VGT. Operation parameters such as period of engine operation, period of engine operation at idle, ambient temperature, and engine coolant temperature may be parameters tending to function as causes or factors involved in varnish build-up and the means for determining whether the operation parameter is at the level established for initiating the varnish build-up control sequence may measure may be sensors, such as thermometers or temperature sensitive switches **39** and timers **41**. Operation parameters such as actual level of varnish build-up may be based on direct observation or measurement, and the means for determining whether the operation parameter is at the level established for initiating the varnish build-up control sequence may be devices that permit direct or indirect measurement or observation, such cameras **43**. Operation parameters such as the estimated level of varnish build-up may be based, for example, on models that calculate varnish build-up as a function of other parameters that might be actual, measured parameters, such as those parameters tending to cause or be involved in varnish build-up, and the means for determining whether the operation parameter is at the level established for initiating the varnish build-up control sequence may be any of the means used for determining the level of the actual parameters, e.g., electrical sensors, thermometers, temperature switches, timers, sensors that provide different signals when the sensors are covered with different amounts of varnish, and/or cameras. Operation parameters such as faulty hardware may include those tending to relate to "fuel slobber" such as faulty fuel injectors, and faulty sensors. Operation parameters such as cylinder temperature may include determination that the cylinder is relatively cold, which is a circumstance that can lead to or reflect varnish. Operation parameters such as cold intake manifold temperatures and low injection pressure are also parameters that can lead to or reflect varnish.

[0015] The controller **29** may be arranged to increase exhaust temperature to the first exhaust temperature by one or more techniques. The controller **29** may, for example, increase exhaust temperature by reducing VGT nozzle opening size, retarding fuel injection timing, e.g., by controlling operation of a fuel injection nozzle **45**, reducing fuel injection pressure, e.g., controlling operation of a fuel injection pump **47**, by increasing engine **23** speed, and dosing via a seventh injector **49**.

[0016] The varnish build-up control sequence may function with the objective of reducing or eliminating varnish build-up that has occurred, or with the objective of preventing varnish build-up, or both reducing or eliminating varnish build-up and preventing varnish build-up. The varnish build-up control sequence that might be performed to prevent varnish build-up may involve increasing exhaust temperature upstream of the VGT **27** to a different first exhaust temperature, and changing a nozzle opening of a VGT nozzle between a smaller and a larger opening size in association with increasing the exhaust temperature to the first exhaust temperature to a different extent, at a different rate, or for different numbers of cycles than the varnish build-up control sequence that might be performed to reduce or eliminate varnish build-up. Consequently, under some circumstances, varnish build-up may occur in spite of operation of a varnish build-up control sequence intended to prevent varnish build-up, in which case it may become necessary to initiate a varnish build-up control sequence that is intended to reduce or eliminate built-up varnish.

[0017] To illustrate, the determining means, such as an electrical sensor **35**, might constantly monitor the force required to change the opening size of the nozzle **33** in the VGT **27**. The controller **29** can be arranged to at least one of increase the exhaust temperature to the first exhaust temperature from a second, lower exhaust temperature through a sufficient number of temperature cycles, which may include maintaining the exhaust temperature at the first exhaust temperature for a predetermined length of time during each cycle, and change the size of the opening of the nozzle **33** of the VGT **27** between the smaller and larger opening size a sufficient number of times so that a force required to change the nozzle opening size in the VGT remains below a predetermined value. In the event that the force required to change the nozzle opening size in the VGT **27** nonetheless exceeds the predetermined value, which may be the result of varnish build-up, the varnish build-up control sequence can function in a build-up reduction or elimination mode. In the build-up reduction or elimination mode, the controller **29** can be arranged to at least one of cycle the exhaust temperature between the first exhaust temperature—which may be a higher first exhaust temperature than the first exhaust temperature to which the exhaust gas is raised to attempt to prevent varnish build-up—and a second, lower exhaust temperature through a sufficient number of temperature cycles and change the nozzle opening of the VGT between the smaller and larger opening size a sufficient number of times so that the force required to change the nozzle opening size in the VGT changes to a value below the predetermined value.

[0018] FIG. **2** is a flow chart illustrating fundamental steps in a method for controlling varnish build-up in the VGT **27** of a diesel engine turbocharger **25**. A first step **100** can comprise determining whether an operation parameter is at a level established for initiating a varnish build-up control sequence. If the operation parameter is not at the established level (i.e., "NO"), the operation parameter is continuously or periodically monitored to determine whether it has changed and is at the established level (i.e., "YES"). A second step **200** can comprise, upon determining that the operation parameter is at the established level, initiating the varnish build-up control sequence in response. The sequence can comprise increasing exhaust temperature upstream of the VGT **27** to a first exhaust temperature, and changing a nozzle opening of a VGT nozzle **33** between a smaller and a larger opening size in association with increasing the exhaust temperature to the first exhaust temperature.

[0019] The operation parameter in response to which the varnish build-up control sequence is performed ordinarily comprises one or more parameters indicative of varnish build-up or of potential for varnish build-up such as one or more of an estimated level of varnish build-up, an actual level of varnish build-up, force required to change nozzle opening size in the VGT, a period of engine operation, a period of engine operation at idle, an ambient temperature, and a engine coolant temperature.

[0020] The method ordinarily comprises cycling the exhaust temperature between the first exhaust temperature and a second, lower exhaust temperature through a plurality of temperature cycles. The first exhaust temperature will ordinarily be a temperature selected for the purpose of preventing varnish deposits, presently believed to be a temperature of at least around 175° C., or a temperature selected for the purposed of removing varnish deposits, such as by turning varnish deposits into soot flakes, presently believed to be a temperature of at least around 350° C. The second, lower exhaust temperature will ordinarily be the exhaust temperature that is being produced through the particular engine operation mode in question under the particular ambient conditions, e.g., engine operation under heavy engine loads or at idle, and/or at high or low ambient temperatures and pressures. The exhaust temperature can be raised by equipment conventionally used for performing "heat mode" operations that are used to heat, regenerate, or clean engine exhaust aftertreatment system components, or by other techniques known to raise exhaust temperatures.

[0021] The length of time that temperature is maintained at the first temperature, and the length of time at the lower second temperature between any successive cycles, will depend upon factors including the length of time necessary for effective varnish build-up control in a given engine operating in a particular operation mode under particular ambient conditions. The effect of any heating cycles on other exhaust equipment or engine operation will ordinarily also be considered in selecting a length of time that temperature is maintained at the first temperature or the second temperature.

[0022] The opening size of the nozzle **33** of the VGT **27** may be changed between the smaller and larger opening size after cycling the exhaust temperature through the plurality of temperature cycles, between temperature cycles, or during periods of increased temperature. The opening size of the nozzle **33** can be cycled between the smaller and larger opening size through a plurality of nozzle opening and closing cycles. The opening size of the nozzle **33** of the VGT **27** can be changed between a 0% and a 100% opening size (and back, if appropriate), although the opening size may be changed to some other opening sizes that are less than fidlly closed or fully open.

[0023] A varnish build-up control sequence that has been found to be particularly efficacious in preventing varnish build-up involves keeping the opening size of the nozzle **33** at a predetermined opening size when engine coolant temperature is above a predetermined engine coolant temperature. For example, in a particular type of engine, a VGT may be kept open when coolant temperatures are above 60° C. until coolant temperature reaches a higher temperature (such as 80° C.) to facilitate warm-up of the engine. However, particularly at cold ambient temperatures, with the VGT open, coolant temperatures may never or only slowly reach the higher temperature and exhaust temperatures may be relatively low, which can tend to result in the formation of varnish deposits. The inventors have found it to be useful to keep the opening size of the nozzle in such vehicles at an opening size of 3.6% of maximum opening size when coolant temperature is above 60° C. and below 80° C. to facilitate prevention of varnish build-up. Opening sizes and coolant temperatures most useful for preventing varnish build-up are expected to be different for different engine types, operation modes, and ambient operation conditions.

[0024] Another varnish build-up control sequence that has been found to be particularly efficacious in preventing varnish build-up involves an operation parameter comprising an ambient temperature at or below a predetermined ambient temperature and a period of operation at or exceeding a predetermined length of time. For example, operation of certain engine types at ambient temperatures of −15° C. for extended periods of time has been observed to result in varnish build-up. The inventors have discovered that it is useful to initiate a varnish build-up control sequence after operation at these low temperatures after a certain length of time, such as four hours, to prevent varnish build-up. The varnish build-up control sequence can comprise cycling the exhaust temperature between the first exhaust temperature and a second, lower exhaust temperature through a plurality of temperature cycles.

[0025] Another varnish build-up control sequence that has been found to be particularly efficacious in preventing varnish build-up involves an operation parameter comprising operation of the engine at extended idle for a predetermined length of time. For example, the inventors have found that, for certain engine types, initiating the varnish build-up control sequence upon determination that the engine has operated at extended idle for a half hour can be useful in preventing varnish build-up. By contrast, in this same type of engine, an algorithm automatically initiates VGT cycling (without increasing temperature) after one hour of extended idle as a soot build-up control strategy.

[0026] The ultimate objective of a varnish build-up control sequence for controlling varnish in a VGT is to ensure that proper operation of the VGT, particularly the ability of the vanes of the VGT to open and close the nozzle, is not affected by varnish build-up. In a given situation, the varnish build-up control sequence will typically involve one or more of cycling the exhaust temperature between the first exhaust temperature and a second, lower exhaust temperature through a sufficient number of temperature cycles and changing the nozzle opening of the VGT between the smaller and larger opening size a sufficient number of times so that a force required to change the nozzle opening size in the VGT is below a predetermined value. This may involve measuring the force required, such as by electrical sensors **35**, and initiating a varnish build-up control sequence when the force required rises above a normal level and repeating heating and/or opening size change cycles until the force required returns to the normal level as part of a varnish build-up prevention mode, or initiating a varnish build-up control sequence when the force required rises above an acceptable level and repeating heating and/or opening size change cycles until the force required returns to the acceptable level as part of a varnish build-up reduction or elimination mode.

[0027] In the present application, the use of terms such as "including" is open-ended and is intended to have the same meaning as terms such as "comprising" and not preclude the presence of other structure, material, or acts. Similarly, though the use of terms such as "can" or "may" is intended to be open-ended and to reflect that structure, material, or acts are not necessary, the failure to use such terms is not intended to reflect that structure, material, or acts are essential. To the extent that structure, material, or acts are presently considered to be essential, they are identified as such.

[0028] While this invention has been illustrated and described in accordance with a preferred embodiment, it is recognized that variations and changes may be made therein without departing from the invention as set forth in the claims.

1. A method for controlling varnish build-up in a variable geometry turbine (VGT) of a diesel engine turbocharger, comprising:

determining whether an operation parameter is at a level established for initiating a varnish build-up control sequence; and

upon determining that the operation parameter is at the established level, initiating the varnish build-up control sequence, the sequence comprising

increasing exhaust temperature upstream of the VGT to a first exhaust temperature, and

changing an opening size of a VGT nozzle between a smaller and a larger opening size while increasing the exhaust temperature to the first exhaust temperature.

2. The method for controlling varnish build-up as set forth in claim **1**, wherein the operation parameter comprises one or more of an estimated level of varnish build-up, an actual level of varnish build-up, force required to change nozzle opening size in the VGT, a period of engine operation, a period of engine operation at idle, an ambient temperature, a engine coolant temperature, detection of faulty hardware, cylinder temperature, intake manifold temperature, injection pressure.

3. The method for controlling varnish build-up as set forth in claim **1**, comprising cycling the exhaust temperature between the first exhaust temperature and a second, lower exhaust temperature through a plurality of temperature cycles.

4. The method for controlling varnish build-up as set forth in claim **1**, comprising changing the opening size of the VGT nozzle between the smaller and larger opening size after cycling the exhaust temperature through the plurality of temperature cycles.

5. The method for controlling varnish build-up as set forth in claim **1**, comprising changing the opening size of the VGT nozzle between the smaller and larger opening size by cycling the nozzle between the smaller and larger opening size through a plurality of nozzle opening and closing cycles.

6. The method for controlling varnish build-up as set forth in claim **1**, wherein the first exhaust temperature is a temperature sufficient to cause accumulated varnish accumulated on the VGT to turn into soot flakes.

7. The method for controlling varnish build-up as set forth in claim **1**, wherein the first exhaust temperature is approximately 175° C. or greater.

8. The method for controlling varnish build-up as set forth in claim **1**, wherein the first exhaust temperature is approximately 350° C. or greater.

9. The method for controlling varnish build-up as set forth in claim **1**, comprising maintaining the exhaust temperature at the first exhaust temperature for a predetermined length of time.

10. The method for controlling varnish build-up as set forth in claim **1**, comprising changing the opening size of the VGT nozzle between a 0% and a 100% opening size.

11. The method for controlling varnish build-up as set forth in claim **10**, comprising keeping the opening size of the VGT nozzle at a predetermined opening size when engine coolant temperature is above a predetermined engine coolant temperature.

12. The method for controlling varnish build-up as set forth in claim **1**, wherein the operation parameter comprises an ambient temperature at or below a predetermined ambient temperature and a period of operation at or exceeding a predetermined length of time, and wherein the varnish build-up control sequence comprises cycling the exhaust temperature between the first exhaust temperature and a second, lower exhaust temperature through a plurality of temperature cycles.

13. The method for controlling varnish build-up as set forth in claim **1**, the operation parameter comprises operation of the engine at extended idle, and wherein the varnish build-up control sequence is initiated upon determination that the engine has operated at extended idle for a predetermined length of time.

14. The method for controlling varnish build-up as set forth in claim **1**, comprising increasing exhaust temperature to the first exhaust temperature by one or more of reducing VGT nozzle opening size, retarding injection timing, reducing fuel injection pressure, increasing engine speed, and seventh injector dosing.

15. The method for controlling varnish build-up as set forth in claim **1**, comprising one or more of cycling the exhaust temperature between the first exhaust temperature and a second, lower exhaust temperature through a sufficient number of temperature cycles and changing the opening size of the VGT nozzle between the smaller and larger opening size a sufficient number of times so that a force required to change the opening size in the VGT is below a predetermined value.

16. A diesel engine arrangement, comprising:

a diesel engine;

a turbocharger, the turbocharger comprising a variable geometry turbine (VGT) downstream of the engine;

means for determining whether an operation parameter is at a level established for initiating a varnish build-up control sequence for controlling varnish build-up on the VGT; and

a controller arranged to initiate the varnish build-up control sequence when the determining means determines that the operation parameter is at the established level, the varnish build-up control sequence comprising

increasing exhaust temperature upstream of the VGT to a first exhaust temperature, and changing an opening size of a VGT nozzle between a smaller and a larger opening size while increasing the exhaust temperature to the first exhaust temperature.

17. The diesel engine arrangement as set forth in claim **16**, wherein the operation parameter comprises one or more of an estimated level of varnish build-up, an actual level of varnish build-up, force required to change opening size of the VGT nozzle, a period of engine operation, a period of engine operation at idle, an ambient temperature, and a engine coolant temperature.

18. The diesel engine arrangement as set forth in claim **16**, wherein the controller is arranged to increase exhaust temperature to the first exhaust temperature by one or more of reducing VGT nozzle opening size, retarding injection timing, reducing fuel injection pressure, increasing engine speed, and dosing via a seventh injector.

19. The diesel engine arrangement as set forth in claim **16**, wherein the determining means determines whether a force required to change the opening size of the VGT nozzle exceeds a predetermined value, and the controller is arranged to at least one of cycle the exhaust temperature between the first exhaust temperature and a second, lower exhaust temperature through a sufficient number of temperature cycles and change the opening size of the VGT nozzle between the smaller and larger opening size a sufficient number of times so that the force required to change the opening size of the VGT nozzle changes to a value below the predetermined value.

20. The diesel engine arrangement as set forth in claim **16**, wherein the controller is arranged to at least one of increase the exhaust temperature to the first exhaust temperature from a second, lower exhaust temperature through a sufficient number of temperature cycles and change the opening size of the VGT nozzle between the smaller and larger opening size a sufficient number of times so that a force required to change the opening size of the VGT nozzle remains below a predetermined value.

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