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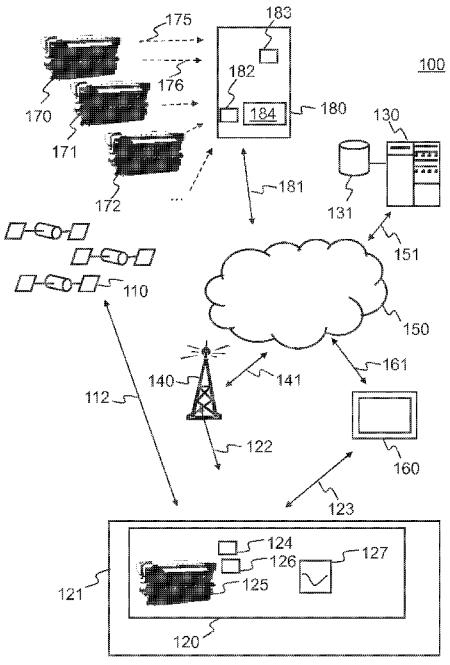


Fig. 1

(57) Abstract: A computer implemented method system and apparatus for determining condition of a liquid lubricant for an engine, the method comprising: receiving engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant; receiving engine operation data; combining the engine sensor data and the engine operation data to provide a dynamic operation model of the liquid lubricant; and determining condition information of the liquid lubricant based on the dynamic operation model.

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APPARATUS, DEVICE AND COMPUTER IMPLEMENTED METHOD FOR DETERMINING CONDITION OF LIQUID LUBRICANT

TECHNICAL FIELD

[0001] The present application generally relates to an apparatus, a device, a method and software code for determining condition information of a liquid lubricant for an engine.

BRIEF DESCRIPTION OF RELATED DEVELOPMENTS

[0002] This section illustrates useful background information without admission of any technique described herein representative of the state of the art.

[0003] Modern vehicles, such as marine vessels, face fuel efficiency requirements that are more and more stringent. New legislation in the United States and European Union within the past few years has set fuel economy and emissions targets not readily achievable with prior known vehicle and lubricant technology.

[0004] To address the increasing standards, engine equipment manufacturers are demanding better fuel economy as a lubricant-related performance characteristic, while maintaining deposit control and oxidative stability requirements.

[0005] Furthermore, requirements for engine performances constantly increase. Such engine performance parameters comprise, for example, Brake Mean Effective Pressure (BMEP) and maximum cylinder pressure. Therefore, there will be more stress on the lubricant affecting lubricant lifetime (and service life).

[0006] Lubrication of an internal combustion piston engine is typically arranged by feeding lubrication medium, typically oil, to parts of the engine requiring lubrication by pressurizing the lubricating oil and leading pressurized oil to the desired locations by means of lubrication channels arranged to the engine. While the engine is operated, the quality of the oil decreases due to e.g. contaminants originating from combustion process and also wearing of the components of the engine. Usually a closed circulation loop is used, for example in 4-stroke diesel engines, in which the same amount of lubricating oil is gathered to an oil sump of the engine after participating in lubrication and pumped again to the desired lubrication locations after proper treatment like filtering. Before the lubrication and possibly other properties of the oil are deteriorated too much the oil is changed.

[0007] There is also drive to reduce engine service demands that will also create the demand to maximise lubricant life time. The quality of lubricating oil has great impact on the service life and required maintenance intervals of the engine.

[0008] Mechanical moving parts working together, such as gears, are lubricated to eliminate or reduce metal-to-metal wear and thus ensuring machine operation time and operation predictability and prolonging machine life. Lubrication liquid may be supplied by a liquid lubrication system enabling evaluation and purification of the liquid and removing for example wear debris particles generated as the machine wears down over time.

[0009] In current solutions, it is possible to assess the lubricant, wherein various sensors may be placed to evaluate different aspects of its condition, such as large and small wear debris particles, water content and liquid degradation. The sensor data may then be statistically analysed to define triggers for warnings and system stops, when the system traverses specific historically determined thresholds.

[0010] However, since machines, such as engines, operate at different capacities and on different situations, the lubricant condition is affected differently even within the bounds of normal operation and therefore, service and operator personnel have difficulties when assessing, whether a change to lubricant sensor data is prompted by a change in operation intensity only, or whether the system is drifting. Thus, a noticeable change of data may be very difficult or impossible to notice until damage is already caused to the system.

[0011] Thus, an easy to set-up, accurate, and highly functional and reliable solution is needed to provide more accurate system for determining condition information of a liquid lubricant for an engine.

SUMMARY

[0012] According to a first example aspect of the disclosed embodiments there is provided a computer implemented method for determining condition of a liquid lubricant for an engine, the method comprising:

receiving engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant;

receiving engine operation data;

combining the engine sensor data and the engine operation data to provide a dynamic engine operation model for the liquid lubricant; and

determining condition information of the liquid lubricant based on the dynamic engine operation model.

[0013] In an embodiment, the engine sensor data is received from at least one sensor device and comprises information on electrochemical properties of the liquid lubricant at a molecular level.

[0014] In an embodiment, the electrochemical properties are configured to be measured by using a high frequency AC current to measure a ratio between conductance and capacitance of the liquid lubricant. The electrochemical properties comprise at least one of the following: loss factor data; and Tan delta (TD) number.

[0015] In an embodiment, the sensor device is operationally connected to the engine.

[0016] In an embodiment, the method further comprises correcting the engine sensor data before combination to the engine operation data.

[0017] In an embodiment, the method further comprises detecting an anomality based on at least one of the following: the engine sensor data; the engine operation data; the dynamic engine operation model; and the condition information.

[0018] In an embodiment, the method further comprises comparing condition information to reference maintenance threshold information; and generating automatic maintenance service order in response to the comparing step.

[0019] In an embodiment, the engine operation data is received from at least one sensor device or engine control system and comprises information on at least one of the following: liquid lubricant temperature; engine load; engine speed; engine on/off indicator; ambient conditions; fuel consumption; liquid lubricant reservoir level; liquid lubricant sump level; fuel properties; reference liquid lubricant properties; reference test results; on-site test results; and historical liquid lubricant management records on lubrication maintenance.

[0020] In an embodiment, combining the engine sensor data and the engine operation data comprises normalizing the engine sensor data with the engine operation data.

[0021] In an embodiment, the normalizing step comprises correcting the engine sensor data using liquid lubricant temperature.

[0022] In an embodiment, the correcting step comprises multiplying the liquid lubricant temperature with a pre-defined coefficient and subtracting the multiplied

result from a loss factor to refine the engine sensor data.

[0023] In an embodiment, combining step of the engine sensor data and the engine operation data comprises selecting a subset of the engine sensor data based on engine on/off indicator of the engine operation data.

[0024] In an embodiment, selecting step of the subset of the engine sensor data is triggered after the engine is determined to be on for a predefined time based on the engine on/off indicator.

[0025] In an embodiment, the condition information comprises at least one of the following: water contamination information, Base Number (BN) information, and viscosity information.

[0026] In an embodiment, the method further comprises: comparing condition information to threshold information; determining condition profile information comprising information on running hours when condition information being below threshold information; and transmitting the profile information from an engine apparatus comprising the engine for an edge cloud apparatus or a cloud apparatus.

[0027] In an embodiment, the combining step is configured to isolate quality of the liquid lubricant from other factors impacting fuel consumption.

[0028] In an embodiment, the other factors comprise at least one of the following: engine data; cooling water data; turbocharger data; maintenance data; and ambient conditions data.

[0029] In an embodiment, the liquid lubricant is automatically monitored using the condition information and service requests are automatically generated in order to maintain quality of the liquid lubricant in a pre-defined range for minimizing engine operating costs. The engine operating costs comprise at least fuel consumption.

[0030] In an embodiment, the method further comprises:

receiving reference engine sensor data, the reference engine sensor data corresponding to at least one parameter of a liquid lubricant of a reference engine;

receiving reference engine operation data;

combining the reference engine sensor data and the reference engine operation data to provide a reference engine operation model of the liquid lubricant; and

determining the dynamic engine operation model of the liquid lubricant using the reference engine operation model.

[0031] In an embodiment, the method further comprises transmitting the engine sensor data and the engine operation data from an engine apparatus comprising the engine to an edge cloud apparatus or a cloud apparatus for combining.

[0032] In an embodiment, the method further comprises pre-processing at least one of the engine sensor data and the engine operation data before transmission to the edge cloud apparatus or the cloud apparatus.

[0033] In an embodiment, the dynamic engine operation model implements a neural network.

[0034] In an embodiment, the method further comprises comparing the received engine sensor data and engine operation data to a specified data signature associated with the dynamic engine operation model of the liquid lubricant, and determining based on the comparison the condition information of the liquid lubricant.

[0035] In an embodiment, the specified data signature is programmed into a synapse of the neural network.

[0036] In an embodiment, the comparing step comprises inputting the engine sensor data and engine operation data into the neural network.

[0037] In an embodiment, the neural network is trained using a plurality of data signatures from the engine sensor data and the engine operation data.

[0038] In an embodiment, weights for different inputs are configured to be adjusted before feeding in to a hidden layer of the neural network comprised by the dynamic engine operation model.

[0039] In an embodiment, the method further comprises: receiving a plurality of reference engine operation models from a plurality of reference engines; determining a reference engine operation model of the plurality of reference engine operation models based on at least one of the engine sensor data or the engine operation data; and determining the dynamic engine operation model of the liquid lubricant using the determined reference engine operation model.

[0040] In an embodiment, the method further comprises: comparing engine sensor data with a plurality of reference engine sensor data associated with the plurality of reference engine operation models; determining the reference engine operation model of the plurality of reference engine operation models by selecting closest counterpart for engine sensor data; and determining the dynamic engine

operation model of the liquid lubricant using the determined reference engine operation model.

[0041] In an embodiment, the method further comprises: comparing engine operation data with a plurality of reference engine operation data associated with the plurality of reference engine operation models; determining the reference engine operation model of the plurality of reference engine operation models by selecting closest counterpart for engine operation data; and determining the dynamic engine operation model of the liquid lubricant using the determined reference engine operation model.

[0042] In an embodiment, the method further comprises determining at least one of the engine sensor data or the engine operation data based on the determined reference engine operation model.

[0043] According to a second example aspect of the disclosed embodiments there is provided an engine apparatus, comprising:

an engine;

a communication interface;

at least one processor; and

at least one memory including computer program code;

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to:

receive engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant;

receive engine operation data;

combine the engine sensor data and the engine operation data to provide a dynamic engine operation model of the liquid lubricant; and

determine condition information of the liquid lubricant based on the dynamic engine operation model.

[0044] According to a third example aspect of the disclosed embodiments there is provided a server apparatus comprising:

a communication interface;

at least one processor; and

at least one memory including computer program code;

the at least one memory and the computer program code configured to, with

the at least one processor, cause the apparatus to:

receive engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant;

receive engine operation data;

combine the engine sensor data and the engine operation data to provide a dynamic engine operation model of the liquid lubricant; and

determine condition information of the liquid lubricant based on the dynamic engine operation model.

[0045] According to a fourth example aspect of the disclosed embodiments there is provided a computer program embodied on a computer readable medium comprising computer executable program code, which code, when executed by at least one processor of an apparatus, causes the apparatus to: receive engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant; receive engine operation data; combine the engine sensor data and the engine operation data to provide a dynamic engine operation model of the liquid lubricant; and determine condition information of the liquid lubricant based on the dynamic engine operation model.

[0046] Different non-binding example aspects and embodiments of the disclosure have been illustrated in the foregoing. The above embodiments are used merely to explain selected aspects or steps that may be utilized in implementations of the present invention. Some embodiments may be presented only with reference to certain example aspects of the invention. It should be appreciated that corresponding embodiments may apply to other example aspects as well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047] The aspects of the disclosed embodiments will be described, by way of example only, with reference to the accompanying drawings, in which:

[0048] Fig. 1 shows a schematic picture of a system according to an aspect of the disclosed embodiments;

[0049] Fig. 2 presents an example block diagram of an engine apparatus (marine vessel or power plant) in which various embodiments of the invention may be applied;

[0050] Fig. 3 presents an example block diagram of a sensor device in accordance with an example embodiment;

[0051] Fig. 4 presents an example block diagram of a server apparatus in accordance with an example embodiment;

[0052] Fig. 5 presents an example block diagram of a remote computer apparatus;

[0053] Figs. 6a-c show diagrams illustrating oil conditioning data in accordance with an example embodiment of the invention;

[0054] Figs. 7a-b show diagrams illustrating determining condition information of the liquid lubricant for abnormal conditions in accordance with an example embodiment of the invention;

[0055] Fig. 8 shows diagram illustrating determining condition information of the liquid lubricant for quality management in accordance with an example embodiment of the invention;

[0056] Fig. 9 shows a schematic picture of a dynamic engine operation model 127 of the liquid lubricant and related information flows according to an example embodiment;

[0057] Fig. 10 shows a flow diagram showing operations in accordance with an example embodiment of the invention;

[0058] Fig. 11 shows a schematic diagram of an exemplary engine apparatus related items for determining condition of a liquid lubricant for an engine in accordance with an example embodiment; and

[0059] Fig. 12 shows a schematic diagram of a data item in accordance with an example embodiment.

DETAILED DESCRIPTION

[0060] In the following description, like numbers denote like elements.

[0061] Fig. 1 shows a schematic picture of a system 100 according to an example embodiment. A marine vessel 121 or a power plant 121 may comprise an engine apparatus 120, for example. Instead of a marine vessel or a power plant, the system 121 may comprise any setup utilizing an engine with a liquid lubricant used for engine operation.

[0062] As an example, a marine vessel 121 is discussed. The marine vessel 121 comprises an engine apparatus 120 comprising means for generating, processing and transceiving engine related data through a communication interface, for example. The apparatus 120 is capable of downloading and locally executing

software program code. The software program code may be a client application of a service whose possible server application is running on a server apparatus 130, 131 of the system 100. The apparatus 120 comprises an engine 125, a communication interface, a memory and a processor, and may further comprise at least one capturing device, such a sensor device, for providing engine operation data 124 and engine sensor data 126. The sensor device may comprise an accelerometer, a gyroscope, a temperature sensor, a pressure sensor, a measuring sensor or a camera, for example. The camera may also be used to provide video data and a microphone may be used for providing audio data, for example. The engine sensor data 126 may comprise information on at least one of the following: loss factor data, and Tan delta (TD) number.

[0063] In an embodiment, there is provided a computer implemented method, apparatus and system for determining condition of a liquid lubricant for an engine 125, the method comprises receiving engine sensor data 126, the engine sensor data 126 corresponding to at least one parameter of the liquid lubricant, receiving engine operation data 124, combining the engine sensor data 126 and the engine operation data 124 to provide a dynamic engine operation model 127 of the liquid lubricant, and determining condition information of the liquid lubricant based on the dynamic engine operation model 127.

[0064] In an embodiment, at least one reference engine 170-172 may be arranged and configured to generate reference engine profile data 182 by determining reference engine parameters 175 of the reference engine 170-172. At least one reference engine 170-172 is configured to generate reference engine liquid lubricant data 183 by mechanical or chemical testing of an oil sample 176 from the reference engine 170-172. Reference engine 170-172 related measurements, data collection and transceiving may be carried out by a reference engine data apparatus 180. A reference model 184 is generated by associating the reference engine profile data 182 with the reference engine liquid lubricant data 183.

[0065] The reference model 184 may be transmitted to a server apparatus 130, 131 for storing and processing over connection 181,150. The reference engine profile data 182 and/or the reference engine liquid lubricant data 183 may also be transmitted to a server apparatus 130, 131 for storing and processing. The reference model 184 may also be generated at the server apparatus 130, 131.

[0066] In an embodiment, the server apparatus 130 is configured to receive engine sensor data 126 and the engine operation data 124 and combining the engine sensor data 126 and the engine operation data 124 to provide a dynamic engine operation model 127 of the liquid lubricant. Furthermore, the server apparatus 130 is configured to determine condition information of the liquid lubricant based on the dynamic engine operation model 127. For clarity reasons, engine operation data 124, engine sensor data 126 and the dynamic engine operation model 127 are only shown at engine apparatus 120 but they can be also received and processed at the server apparatus 130 as disclosed.

[0067] In an embodiment, the engine apparatus 120 is configured to determine condition information of the liquid lubricant based on the dynamic engine operation model 127 locally.

[0068] In an embodiment, the reference model 184 is configured to be received at an engine apparatus 120 that may comprise on-site engine 125 or engine 125 operated in the marine vessel 121, for example. At the engine apparatus 120, engine parameters 124 and sensor data 126 are measured relating to operation conditions of an engine 125 of the engine apparatus 120, and condition information of the liquid lubricant may be determined using the reference model 184, engine operation data 124, and engine sensor data 126. The reference model 184 may replace dynamic engine operation model 127 or the dynamic engine operation model 127 may be determined using the reference model 184.

[0069] In the present description, by vessel are meant any kinds of waterborne vessels, typically marine vessels. Most typically the vessel is a cargo ship or large cruise vessel, but the present disclosure is also applicable for yachts, for example. In the present description, by power plant are meant any kinds of power generating systems, typically power plants with a power producing combustion engine 125, such as a gas engine or a diesel engine or a dual fuel engine. Most typically the power plant is a multi-source plant implementing also solar, wind or battery management system, but the present disclosure is also applicable for any system comprising an engine with a liquid lubricant.

[0070] The engine apparatus 120 is configured to be connectable, at least occasionally, to a network 150, such as Internet, directly via local connection or via a wireless communication network 140 over a wireless connection 122. The wireless

connection 122 may comprise a mobile cellular network, a satellite network or a wireless local area network (WLAN), for example. The wireless communication network 140 may be connected to a public data communication network 150, for example the Internet, over a data connection 141. The engine apparatus 120 may be configured to be connectable to the data communication network 150, for example the Internet, directly over a data connection that may comprise a fixed or wireless mobile broadband access. The wireless communication network 140 may be connected to a server apparatus 130 of the system 100, over a data connection. The network 150 may be private or public network.

[0071] In an embodiment, an engine apparatus 120 may set up local connections within the marine vessel 121 (or power plant, for example) with at least one capturing device, such as a sensor, and a computer device. The capturing device, such as a sensor, may be integrated to the engine apparatus 120 or the marine vessel 121, attached to the hull of the marine vessel 121 and connected to the vessel control system or arranged as separate sensor device and connectable to the network 150 over separate connection.

[0072] The engine apparatus 120 and its client application may allow the engine apparatus 120 to log into a vessel or engine data service run on a server 130.

[0073] Real-time interaction may be provided between the engine apparatus 120 and the server 130 to collaborate for marine vessel (or power plant) data over a network 150. Real-time interaction may also be provided between the engine apparatus 120 and the remote user device 160 to collaborate for marine vessel (or power plant) or engine data over a network 150, 161.

[0074] A sensor data item, such as engine operation data 124 and/or sensor data 126, is generated by a sensor device or engine apparatus 120 and transmitted to the server 130. Sensor data items may be pre-processed at engine apparatus 120 before transmitting or they may be sent without processing to the server 130.

[0075] Engine operation data 124 and/or sensor data 126 may also be stored within the engine apparatus 120 before transmission over the network 150. Then again, transmitted engine operation data 124 and/or sensor data 126 may be stored/and or processed at the server apparats 130 or at the remote user device 160. Engine operation data 124 and/or sensor data 126 may be maintained within an engine control system, such as the engine apparatus 120.

[0076] The dynamic engine operation model 127 may be generated at the engine apparatus 120 or at server apparatus 130, or at both. Latest version of the dynamic engine operation model 127 may be updated over the network connection 150 between the engine apparatus 120 and the server apparatus 130.

[0077] A capturing device (e.g. a sensor device) may capture and send sensor data as a real-time content or non-real time data to the server apparatus 130 or to the remote user device 160 over a peer-to-peer connection formed over network.

[0078] The engine apparatus 120 may be connected to a plurality of different capturing devices and instruments and the engine apparatus 120 may be configured to select which sensor device(s) is actively collaborated with.

[0079] A user of the engine apparatus 120 or the remote user device 160 may need to log in with user credentials to a chosen service of the network server 130.

[0080] In an embodiment, the system 100 comprises a sensor device configured to be comprised by or connectable to the engine apparatus 120 over a local connection. The local connection may comprise a wired connection or a wireless connection. The wired connection may comprise Universal Serial Bus (USB), High-Definition Multimedia Interface (HDMI), or RCA interface, for example. The wireless connection may comprise acoustic connection, Bluetooth™, Radio Frequency Identification (RF-ID) or wireless local area network (WLAN), for example. Near field communication (NFC) may be used for sensor device identification between the sensor device and the engine apparatus 120, for example.

[0081] A sensor device may also be connected directly to the public network 150, such as Internet, via direct local connection or via a wireless cellular network connection 140, 141.

[0082] In an embodiment, the system 100 may comprise a server apparatus 130, which comprises a storage device 131 for storing service data, service metrics and subscriber information, over data connection 151. The service data may comprise configuration data; account creation data; engine sensor data; engine operation data, sensor ID's; reference data items, user input data; real-time collaboration data; reference engine profile data, reference engine parameters, reference engine oil lubrication data, predefined settings; or attribute data.

[0083] In an embodiment, a proprietary application in the engine apparatus 120 may be a client application of a service whose server application is running on the

server apparatus 130 of the system 100. The proprietary application may comprise a dynamic engine operation model 127 of the liquid lubricant.

[0084] The proprietary application of the engine apparatus 120 may receive engine sensor input data and engine operation input data, then combine the engine sensor data and the engine operation data to provide a dynamic engine operation model of the liquid lubricant, and determine condition information of the liquid lubricant based on the dynamic engine operation model as the output data. The input data may comprise data captured by the capturing device such as a sensor device or a camera, or by the engine apparatus 120.

[0085] In an embodiment, configuration information or application download information for any apparatus may be automatically downloaded and configured by the server 130. Thus, the user of the devices may not need to do any initialization or configuration for the service. The system server 130 may also take care of account creation process for the service, sensor devices, apparatuses and users.

[0086] In an embodiment, the association of the devices can be one-time or stored persistently on any of the devices or the server 130.

[0087] In an embodiment, authentication of a sensor device or engine apparatus 120 on a system server 130 may utilize hardware or SIM credentials, such as International Mobile Equipment Identity (IMEI) or International Mobile Subscriber Identity (IMSI). The sensor device or engine apparatus 120 may transmit authentication information comprising IMEI and/or IMSI, for example, to the system server 130. The system server 130 authenticates the device or engine apparatus 120 by comparing the received authentication information to authentication information of registered users/devices/vessels/apparatuses stored at the system server database 131, for example. Such authentication information may be used for pairing the devices and/or apparatuses to generate association between them for a vessel or power plant data connection.

[0088] In an embodiment, a service web application may be used for configuration of a system. The service web application may be run on any user device, admin device, or a remote control device 160, such as a personal computer connected to a public data network, such as Internet 150, for example. The control apparatus 160 may also be connected locally to the engine apparatus 120 over a local connection 123 and may utilize the network connections of the apparatus 120

for configuration purposes. The service web application of the control apparatus 160 may provide searching/adding instruments, determining attributes, device setup and configuration, for example. The service web application of the control apparatus 160 may be a general configuration tool for tasks being too complex to be performed on the user interface of the engine apparatus 120, for example.

[0089] In an embodiment, a remote control apparatus 160 may be authenticated and configuration data sent from the control apparatus 160 to the system server 130, 131, wherein configuration settings may be modified based on the received data. In an embodiment, the modified settings may then be sent to the engine apparatus 120 over the network 150 and the local connection or the wireless operator. The modified settings may also be sent to external devices correspondingly, through the engine apparatus 120 or directly over the network 150.

[0090] In an embodiment, the sensor device may be wireless or wired.

[0091] The system 100 may also comprise a plurality of satellites 110 in orbit about the Earth. The orbit of each satellite 110 is not necessarily synchronous with the orbits of other satellites and, in fact, is likely asynchronous. A global positioning system receiver apparatus such as the ones described in connection with preferred embodiments of the present invention is shown receiving spread spectrum global positioning system (GPS) satellite signals 112 from the various satellites 110. The plurality of satellites 110 may be used for location purposes, input for determining traveled distance (since oil change, for example), or input for accurate time (since oil change, for example).

[0092] The remote control apparatus 160 may be configured to be operated by a remote operator of the vessel or the power plant 121. The remote control apparatus 160 may be arranged on a ground station, on the vessel or power plant 121 or on another vessel, for example.

[0093] Fig. 2 presents an example block diagram of an engine apparatus 120 (within a marine vessel or a power plant, for example) in which various embodiments of the invention may be applied. The engine apparatus 120 may comprise a user equipment (UE), user device or apparatus, such as a vessel computer system, in addition to the engine.

[0094] The general structure of the engine apparatus 120 comprises a control unit 200 and an engine unit 201.

[0095] The general structure of the control unit 200 may comprise a user interface 240, a communication interface 250, a satellite positioning device (GPS) 270, a capturing/sensor device 260 for capturing engine operation data, current activity data and/or current environmental data relating to the vessel or the power plant, a processor 210, and a memory 220 coupled to the processor 210. The control unit 200 further comprises software 230 stored in the memory 220 and operable to be loaded into and executed in the processor 210. The software 230 may comprise one or more software modules and can be in the form of a computer program product. The control unit 200 may further comprise a user interface controller 280.

[0096] The processor 210 may be, e.g., a central processing unit (CPU), a microprocessor, a digital signal processor (DSP), a graphics processing unit, or the like. Fig. 2 shows one processor 210, but the apparatus 120 may comprise a plurality of processors.

[0097] The memory 220 may be for example a non-volatile or a volatile memory, such as a read-only memory (ROM), a programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), a random-access memory (RAM), a flash memory, a data disk, an optical storage, a magnetic storage, a smart card, or the like. The apparatus 120 may comprise a plurality of memories. The memory 220 may be constructed as a part of the apparatus 120 or it may be inserted into a slot, port, or the like of the apparatus 120 by a user. The memory 220 may serve the sole purpose of storing data, or it may be constructed as a part of an apparatus serving other purposes, such as processing data. A proprietary application (client application) 231 comprising the dynamic engine operation model and determining condition information of the liquid lubricant based on the may be stored at the memory 220. Engine data, sensor data and environmental data may also be stored to the memory 220.

[0098] The user interface controller 280 may comprise circuitry for receiving input from a user of the apparatus 120, e.g., via a keyboard, graphical user interface shown on the display of the user interfaces 240 of the engine apparatus 120, speech recognition circuitry, or an accessory device, such as a headset, and for providing output to the user via, e.g., a graphical user interface or a loudspeaker.

[0099] The satellite positioning device 270 is configured to provide location information or time information, for example. Such information may comprise, for

example, position coordinates, speed, direction of movement, GPS time; and altitude information.

[00100] The communication interface module 250 implements at least part of data transmission. The communication interface module 250 may comprise, e.g., a wireless or a wired interface module. The wireless interface may comprise such as a WLAN, Bluetooth, infrared (IR), radio frequency identification (RF ID), GSM/GPRS, CDMA, WCDMA, LTE (Long Term Evolution), or 5G radio module. The wired interface may comprise such as universal serial bus (USB) or National Marine Electronics Association (NMEA) 0183/2000 standard for example. The communication interface module 250 may be integrated into the apparatus 120, or into an adapter, card or the like that may be inserted into a suitable slot or port of the apparatus 120. The communication interface module 250 may support one radio interface technology or a plurality of technologies. The apparatus 120 may comprise a plurality of communication interface modules 250.

[00101] A skilled person appreciates that in addition to the elements shown in Fig. 2, the apparatus 120 may comprise other elements, such as microphones, extra displays, as well as additional circuitry such as input/output (I/O) circuitry, memory chips, application-specific integrated circuits (ASIC), processing circuitry for specific purposes such as source coding/decoding circuitry, channel coding/decoding circuitry, ciphering/deciphering circuitry, and the like. Additionally, the apparatus 120 may comprise a disposable or rechargeable battery (not shown) for powering when external power if external power supply is not available.

[00102] In an embodiment, the apparatus 120 comprises speech recognition means. Using these means, a pre-defined phrase may be recognized from the speech and translated into control information for the apparatus 120, for example.

[00103] The satellite positioning device 270 and the sensor device 260 may be configured to be comprised by the apparatus 120 or connected as separate devices to the apparatus 120. In case the satellite positioning device 270 and the capturing device 260 are comprised in the apparatus 120 they may be connected to the apparatus 120 using an internal bus of the apparatus 120. In case the satellite positioning device 270 and the sensor device 260 are external devices connected to the apparatus 120 they may be connected to the apparatus 120 using communication interface 250 of the apparatus 120 or using the internal bus.

[00104] The general structure of the engine unit 201 may comprise an engine 291, engine sensor device 290 and a communication interface 293. The engine sensor device 290 may be not necessarily connected to the internal bus and to the main processor 210 and memory 220. Such sensor device 290 may be connected or operationally connected to the engine 291 and the communication interface 293 of the engine unit 201. Furthermore, sensor data items with sensor data provided by the sensor device 290 may be transmitted over the communication interface 293. Alternatively, sensor data items with sensor data provided by the sensor device 290 may be provided for and transmitted by the communication interface 250.

[00105] In an embodiment, a second sensor device 260 may be configured to be integrated to a marine vessel's 121 information system 200, and the first sensor device 290 is configured not to be integrated to the marine vessel's 121 information system 200 but operationally to the engine 291 only.

[00106] In an embodiment, the first sensor device 290 is configured to be integrated to the engine 291 of the engine apparatus 120.

[00107] No matter a single sensor 290 is shown, the sensor 290 may comprise a plurality of sensors 290. The sensor devices 290 may be configured to, for example, measure engine performance, liquid lubricant characteristics or operational data.

[00108] In an embodiment, a communication interface (see e.g., Fig. 3) of the sensor device 290 itself or the communication interface 293 of the engine unit 201 comprises an automatic identification system (AIS) receiver for receiving a wireless transmission comprising automatic identification system data from the marine vessel 121. The AIS receiver may include an antenna configured to receive the automatic identification system data or the sensor device 290 may include an antenna configured to receive the automatic identification system data. In another example, AIS receiver is configured to receive the automatic identification system data from an antenna external to the sensor device 290.

[00109] In an embodiment, the engine 291 and at least one sensor device 290 are configured to generate sensor data items based on the received automatic identification system data and sensor data. The sensor data item may thus comprise sensor data generated by the sensor device 290 and an identifier information. The identifier information may comprise at least one of the following: sensor-ID (S-ID);

engine-ID (E-ID), and vessel-ID (V-ID) (see also Fig. 12) that comprises at least part of the received automatic identification system data.

[00110] The sensor data item may also comprise information identifying the marine vessel (for example, International Maritime Organization (IMO) ship identification number or Maritime Mobile Service Identity (MMSI)). This identifying information may be taken from the automatic identification system (AIS) signal or it may be stored within the engine apparatus 120 when installed.

[00111] The sensor data relating to the engine 291 performance, liquid lubricant, or operation measured by the at least one sensor device 260, 290 or GPS 270 may comprise measured data values as they were measured and/or data after processing at least some of the measured data values first.

[00112] In an embodiment, universal clock information of the control unit 200 is determined based on a vessel receiver device, comprising at least one of the Global Positioning System (GPS) receiver 270 and a communication interface 250 of the marine vessel. The universal clock information may comprise at least one of the following: a Global Positioning System (GPS) time and a Coordinated Universal Time (UTC).

[00113] In an embodiment, a proprietary condition application (client application) comprising the dynamic engine operation model 231 may be received at an engine apparatus control unit 200 from the server apparatus, for example. Engine sensor data and engine operation data relating to the engine 291 of the engine apparatus 120 are measured using at least one sensor 260, 290. Condition information of liquid lubricant in the engine 291 of the engine apparatus 120 is then determined using the dynamic engine operation model 231.

[00114] In an embodiment, at least one of the propeller revolutions per minute, torque at propeller, propulsion power, thrust, and engine fuel consumption is a measurement value resulting from a corresponding indirect measurement based on vessel vibrations, and can be used as further input for the dynamic engine operation model 231.

[00115] For at least one first sensor 290, instead of a direct measurement of for example the propeller revolutions, it is possible to obtain this measurement value or data from an indirect measurement based on vessel vibrations detected by the sensor 290 attached to the vessel hull or engine, for example.

[00116] No matter a plurality of elements is shown, all elements are not essential for all embodiments. Some elements are optional, such as GPS 270, sensor device 260, user interface 240 and user interface controller 280.

[00117] Fig. 3 presents an example block diagram of a sensor device 260, 290 in which various embodiments of the invention may be applied. The sensor device 260, 290 may comprise various means for activity data detection, operational data detection and environmental data detection, for example. The sensor device 260, 290 may be used for both engine related data, such as engine sensor data or engine operation data, and environmental data capturing. The sensor device 260 may correspond to the sensor device 290 elements illustrated in Fig. 3.

[00118] In an embodiment, the sensor device 290 may comprise a liquid lubricant sensor for measuring quality of the lubricant in engine, gearbox or hydraulic system, for example. Loss factor data or tan delta number could be measured, for example.

[00119] In an embodiment, the sensor device 260, 290 and the processing of the sensor data may provide a plurality of parameters relating to an engine, for example one or more of the following: time, position (latitude & longitude), SOG (speed over ground), COG (course over ground), vibrations in three dimensions, propeller/engine RPM the operation conditions of the engine comprises at least one of the following: number of engine starts; operating hours since last oil change; load cycles of the engine; miles traveled with the engine; amount of fuel used by the engine; and integral sensor data of the engine.

[00120] The sensor device 290 may also comprise several capturing devices, combinations of any above-mentioned devices, and the like. The environmental temperature may comprise air temperature, water temperature or ground surface temperature, for example.

[00121] The sensor device 290 may comprise also a communication interface capable of connecting with at least one of the communication interfaces 250, 293. The generated sensor data may be transmitted to the communication interface 293. The sensor device 290 may also transmit its sensor data via its internal communication interface to the communication interface 250 of the control unit 200.

[00122] In an embodiment, the communication interface within the sensor device 290 or the communication interface 293 is, for example, a wireless transmitter or a wireless transceiver (for example, Wireless Local Area Network (WLAN) transceiver

or any mobile or cellular communication network transceiver (for example, Wideband Code Division Multiple Access (WCDMA), Long Term Evolution (LTE) etc.) or a local data port (e.g. Ethernet, Universal Serial Bus (USB) etc.).

[00123] In an embodiment, the sensor device 260, 290 may also store information identifying the engine, the marine vessel or the power plant. This may have been preconfigured to the sensor device 260, 290. Since the automatic identification system data identifies e.g. the marine vessel to which the received data relates to, the sensor device 260, 290 is thus able to make sure that the received automatic identification system data relates to the marine vessel to which the sensor device 260, 290 is affixed. One possibility for identifying the correct marine vessel is to use, for example, wireless signal strength of the AIS signal. The strongest AIS signal relates to the marine vessel to which the sensor device 260, 290 is attached. Yet another possibility is to compare the acceleration signal from the acceleration sensor to the data indicating vessel movements in the AIS signals and to determine the correct AIS signal based on the comparison.

[00124] A second sensor device 260 of the marine vessel main information system 200 may comprise corresponding elements as disclosed for the first sensor device 290.

[00125] In an embodiment, a sensor device 290 is configured to measure the marine vessel performance related data when the sensor device 290 is affixed to the hull structure of the marine vessel 121. For example, bolting, gluing or any other way for affixing or attaching the sensor device 290 to the hull structure or engine body may be used. In other words, since the sensor device 290 is firmly attached to the hull structure or engine body, there is no relative motion between the sensor device 290 and the hull structure or engine body respectively, and thus the sensor or sensors 290 sense the motions and vibrations of marine vessel or the engine via the hull structure or the engine body.

[00126] The AIS receiver (comprised by the communication interface 293 or the communication interface within the sensor device 290) may receive a wireless transmission comprising an AIS signal from the same marine vessel 121 to which the sensor device 290 is affixed. The sensor device 290 may beforehand store information identifying the marine vessel 121 (for example, International Maritime Organization (IMO) ship identification number or Maritime Mobile Service Identity

(MMSI)) so that it is able to determine that the AIS signal relates to the marine vessel 121 to which it is affixed. The AIS signal includes several pieces of information relating to the marine vessel, for example, the vessel's identity, engine(s) identifier(s) and type, position, course, speed, navigational status and other related information. The sensor device 290 may utilize the AIS signal as it was received (in other words, every piece of information contained in the AIS signal). In another example, the sensor device 290 may select a subset of information included in the AIS signal to be included in the sensor data. In one example, the subset includes at least position and/or time information of the marine vessel 121.

[00127] Normally the AIS signal is intended to assist a vessel's watch standing officers to track and monitor movements of other vessels and also allow maritime authorities to track and monitor movements of vessels. It also identifies and locates vessels by electronically exchanging data with other nearby ships.

[00128] In an embodiment, the AIS signal is received by a sensor device 290 installed in a vessel that is sending the AIS signal. This makes it possible for the sensor device to link the AIS signal with sensor data measured by the sensor or sensors 290. Since the sensor device 290 has the information included in the AIS signal and measurements from one or more sensors 290, there is no need to make the traditional integration tasks to the marine vessel's information systems. The AIS signal sent by the marine vessel to the sensor device 290 is a strong signal. Therefore, it may not be necessary to install a separate antenna in order to be able to receive the AIS signal. This makes the installation of the sensor device 290 simpler and quicker. For example, it is possible to install the sensor device 290 including only an internal antenna inside a marine vessel because the AIS signal leaks to the interior of the marine vessel via various existing cables, for example.

[00129] In an embodiment, a video camera is configured to provide video signal. Based on the video signal the apparatus may determine at least part of the environmental or operational data. The determination may be done by video image processing, pattern recognition, filtering or other such means, for example.

[00130] The sensor device 260, 290 may comprise communication interface module implementing at least part of data transmission. The communication interface module may comprise, e.g., a wireless or a wired interface module. The wireless interface may comprise such as a WLAN, Bluetooth, infrared (IR), radio

frequency identification (RF ID), GSM/GPRS, CDMA, WCDMA, LTE (Long Term Evolution), or 5G radio module. The wired interface may comprise such as universal serial bus (USB) or National Marine Electronics Association (NMEA) 0183/2000 standard for example. The communication interface module may be integrated to the sensor device 260, 290 or to an adapter, card or the like that may be inserted into a suitable slot or port of the sensor device 260, 290. The communication interface module may support one radio interface technology or a plurality of technologies. The sensor device 260, 290 may comprise a plurality of communication interface modules.

[00131] The sensor device 290 disclosed in Figs. 2-3 may include at least one accelerometer or three-dimensional accelerometer. Since the sensor device 290 may be affixed to the hull of the marine vessel or the engine body, the accelerometer is able to sense vibrations in the hull of the body. From the vibrations sensed by the accelerometer, it is possible to determine, for example, speed of rotation of a propeller of the marine vessel or of the main engine. In most vessels, the speed of rotation of the propeller is identical with the speed of rotation of an engine of a marine vessel. Thus, it is possible to determine, based on an analysis of the measurements of the accelerometer, the speed of rotation of a propeller and an engine of a marine vessel.

[00132] In an embodiment, in order to determine the speed of rotation of the propeller, the sensor device 290 or the associated computer device may analyze the signals measured by the accelerometer to identify the fundamental frequency in the signals. The fundamental frequency is the RPM (Revolutions Per Minute) of the engine or its multiple. One possible method for pitch detection (i.e. find the fundamental frequency) is the Harmonic Product Spectrum (HPS) method. In the method, a spectrum is compressed a number of times (down sampling), and it is compared with the original spectrum. It can then be seen that the strongest harmonic peaks line up. The first peak in the original spectrum coincides with the second peak in the spectrum compressed by a factor of two, which coincides with the third peak in the spectrum compressed by a factor of three. Hence, when the various spectrums are multiplied together, the result will form a clear peak at the fundamental frequency. It is obvious that the HPS is only one possible method for finding the fundamental frequency and also other methods may be used. The speed

of rotation of the propeller may also be stored in the memory of the sensor device 290 to be transmitted to or accessed by an external entity.

[00133] On the new engine designs, with multiple tunings and emission control strategy, it is increasingly complex to adjust a cylinder lubrication in an optimal way. Keeping this in view, the possibility of having an efficient and automated system to monitor the residual BN of the cylinder oil on real time basis, to provide adequate corrosion protection and manage cylinder liner wear, is even better solution.

[00134] Until now the available monitoring tools, mainly shaker kits provided by the oil suppliers, only allowed manual collection of the scrape down oil from the piston underside. The oil collection was conducted at predefined intervals taking samples from individual cylinders and analyzing for residual BN. This procedure does not take into account the effects of engine load variation, amount of injected fuel and ambient conditions continuously, and corrosion could start in a short span of time due to low base number (BN), which defines the oil's ability to neutralize acids, or oil feed rate not being continuously adjusted.

[00135] In an embodiment, a real-time cylinder oil monitoring system is intended to avoid cylinder corrosion by continuously analyzing the scrape down oil from the piston underside and therefore providing an indication of the corrosive environment inside the cylinder according to the specific ambient conditions and engine power. In this way the cylinder oil feed rate can be continuously adjusted to control the corrosive wear. The system includes an oil collection tray installed under each cylinder liner. The collected oil is guided through a manifold and is analyzed by means of a sensor device 290 detecting oil quality and residual base number (BN). According to the sensors' feedback (one per cylinder), the lubrication oil feed rate can be adjusted accordingly. In addition, the oil base number (BN) can be adjusted if there are multiple BN cylinder oils or a blending on board system.

[00136] In such system, oil passes through a dielectric gap of the sensor device 290, where it is energized by a high frequency oscillator. Taking advantage of the characteristic of oils to show decreasing conductivity for increasing contamination, the sensor "understands" the oil condition and determines its base number (BN).

[00137] Moreover, an additional sensor 290 is installed in the oil feed line to the engine 291 (oil still to be injected) and detects its characteristics as reference to compare the status of the collected one. In this way it is be possible to determine,

for each cylinder the oil deterioration. In an open loop system, the residual BN can be shown on an independent display unit or on the alarm and monitoring system. Manual adjustments to the feed rate or BN can be made for adequate corrosion protection based on retrieved information from individual cylinders. Sensors' 290 feedback can also be sent to cylinder lubrication control system 200, 201 as input, in order to adjust the oil feed rate to each cylinder in closed loop control (optional). This would result in an optimized oil feed rate for the specific ambient and engine operating conditions, determining an oil consumption reduction and minimizing the risk to corrosive wear.

[00138] Furthermore, device or apparatus analyzing the sensor data, such as a server apparatus 130, the sensor device itself, the control unit 200 or the remote apparatus 160 may perform frequency analysis of the signals measured by at least one acceleration sensor of the sensor device 290. In case the sensor device or some other device or apparatus performs the frequency analysis, the amount of sensor data to be transmitted outside the sensor device/computer device is reduced. The frequency analysis may comprise, for example, frequency-time analysis, such as Short-Time Fourier Transform (STFT) or Discrete Wavelet Transform (WFT). With the frequency analysis, an understanding of frequency components over a short time is received. The frequency analysis is performed, for example, so that motions of a marine vessel 121 can be understood better and also analyzed.

[00139] Further, the frequency analysis may comprise applying a dimensionality reduction method, for example, Principal Component Analysis (PCA) in order to identify the most significant components in the frequency domain.

[00140] An accelerometer and an inclinometer can be used to measure the same parameters since both of them measure acceleration. One of the main differences is that the accelerometer provides acceleration components separately, but they are more inaccurate. However, acceleration components are usually provided within a larger dynamic range. The inclinometer measures inclination more accurately but within a narrower range. Therefore, it is possible to perform RPM measurements also with the inclinometer if its bandwidth is high enough. Further, it may be possible to perform a frequency analysis for the data provided by the inclinometer and get the same or almost the same results than based on accelerometer data. One difference, however, is that the inclinometer does not measure vertical acceleration.

[00141] Based on the analysis of the sensor data, it may be possible to determine the operation efficiency of the marine vessel 121 (or the power plant, for example) and its engine 120 and to automatically trigger service requests such as oil change for the engine 120, for example.

[00142] Marine vessel data and engine data may be generated based on received sensor data from at least one sensor. Based on the engine data and the dynamic model 127, 231 it is possible to determine performance optimization. Sensor detected engine sensor data and engine operation data may also be transmitted to the server apparatus 130, 131 and utilize the data and the dynamic model 127, 231 there for determining condition information of the liquid lubricant, for example.

[00143] Fig. 4 presents an example block diagram of a server apparatus 130 in which various embodiments of the invention may be applied.

[00144] The general structure of the server apparatus 130 comprises a processor 410, and a memory 420 coupled to the processor 410. The server apparatus 130 further comprises software 430 stored in the memory 420 and operable to be loaded into and executed in the processor 410. The software 430 may comprise one or more software modules, such as service application 431 and can be in the form of a computer program product. The service application 431 may be configured to combine the engine sensor data and the engine operation data to provide a dynamic engine operation model of the liquid lubricant and determine condition information of the liquid lubricant based on the dynamic engine operation model.

[00145] The processor 410 may be, e.g., a central processing unit (CPU), a microprocessor, a digital signal processor (DSP), a graphics processing unit, or the like. Fig. 4 shows one processor 410, but the server apparatus 130 may comprise a plurality of processors.

[00146] The memory 420 may be for example a non-volatile or a volatile memory, such as a read-only memory (ROM), a programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), a random-access memory (RAM), a flash memory, a data disk, an optical storage, a magnetic storage, a smart card, or the like. The server apparatus 130 may comprise a plurality of memories. The memory 420 may be constructed as a part of the server apparatus 130 or it may be inserted into a slot, port, or the like of the server apparatus 130 by a user. The

memory 420 may serve the sole purpose of storing data, or it may be constructed as a part of an apparatus serving other purposes, such as processing data.

[00147] The communication interface module 450 implements at least part of radio transmission. The communication interface module 450 may comprise, e.g., a wireless or a wired interface module. The wireless interface may comprise such as a WLAN, Bluetooth, infrared (IR), radio frequency identification (RF ID), GSM/GPRS, CDMA, WCDMA, LTE (Long Term Evolution), or 5G radio module. The wired interface may comprise such as universal serial bus (USB) or National Marine Electronics Association (NMEA) 0183/2000 standard for example. The communication interface module 450 may be integrated into the server apparatus 130, or into an adapter, card or the like that may be inserted into a suitable slot or port of the server apparatus 130. The communication interface module 450 may support one radio interface technology or a plurality of technologies. Captured activity data associated with environmental data of the engine apparatus 120 (e.g. from marine vessel or from power plant), as well as measured engine parameters relating to operation conditions of the engine of the engine apparatus may be received by the server apparatus 130 using the communication interface 450.

[00148] The e-mail server process 460, which receives e-mail messages sent from engine apparatuses 120, such as marine vessel or power plant apparatuses, and remote computer apparatuses 160 via the network 150. The server 460 may comprise a content analyzer module 461, which checks if the content of the received message meets the criteria that are set for new activity data item of the service. The content analyzer module 461 may for example check whether the e-mail message contains a valid activity data item to be used as reference data item. The valid reference data item received by the e-mail server is then sent to an application server 440, which provides application services e.g. relating to the user accounts stored in a user database 470 and content of the content management service. Content provided by the service system 100 is stored in a content database 480.

[00149] A skilled person appreciates that in addition to the elements shown in Fig. 4, the server apparatus 130 may comprise other elements, such as microphones, displays, as well as additional circuitry such as input/output (I/O) circuitry, memory chips, application-specific integrated circuits (ASIC), processing circuitry for specific purposes such as source coding/decoding circuitry, channel coding/decoding

circuitry, ciphering/deciphering circuitry, and the like. Not all elements disclosed in Fig. 4 are mandatory for all embodiments.

[00150] In an embodiment, engine sensor data corresponding to at least one parameter of the liquid lubricant, and engine operation data are received at the server apparatus 130. The engine sensor data and the engine operation data are combined to provide a dynamic engine operation model of the liquid lubricant, and condition information of the liquid lubricant is determined based on the dynamic engine operation model.

[00151] According to an embodiment, reference engine profile data and reference engine oil lubrication data may be received at the server apparatus 130, wherein the reference engine profile data is generated by determining reference engine parameters of a reference engine, and the reference engine oil lubrication data is determined based on mechanical testing of an oil sample from the reference engine. A reference model may be generated at the server apparatus 130 by associating the reference engine profile data with the reference engine oil lubrication data.

[00152] The reference model or an engine-specific modified version of it may be used to determine the dynamic engine operation model of the liquid lubricant.

[00153] The reference model or an engine-specific modified version of it may be transmitted to the engine apparatus 120 for utilizing it for determining condition information of the liquid lubricant locally.

[00154] According to an embodiment, the server apparatus 130 may receive selection information for a plurality of reference engines and generate the reference engine profile data by determining reference engine parameters of the plurality of reference engines based on the selection information. The reference engine parameters may be generated based on sensor data received from at least one reference engine. The reference engine parameters may relate to different operation conditions of the reference engine.

[00155] In an embodiment, a reference engine data apparatus 180 (see Fig. 1) may be configured to determine the reference engine liquid lubricant data based on mechanical or chemical testing of lubricant samples from the plurality of reference engines based on the selection information. The mechanical or chemical testing of the sample, carried out by the reference engine data apparatus 180, may comprise

e.g. tribological lubricity test of the sample. The tribological lubricity test may be configured to be evaluated based on friction test rig results.

[00156] In an embodiment, reference engine sensor data and reference engine operation data may be determined and combined to generate reference engine operation model.

[00157] In an embodiment, the reference engine oil lubrication data is based on the tribological lubricity test of the oil sample, wherein the reference engine oil lubrication data comprises Stribeck type of friction data.

[00158] The reference model data of the reference model may be maintained at a server apparatus 130, and dynamically updating the reference model data in response to receiving reference engine profile data or reference engine oil lubrication data.

[00159] In an embodiment, the server apparatus 130 receives engine apparatus identification information and generates the reference model by associating reference engine profile data with reference engine oil lubrication data based on the engine apparatus identification information. The generated reference model may be transmitted to the engine apparatus 120 for determining engine current and future performance, as well as estimating engine oil lifetime.

[00160] Fig. 5 presents an example block diagram of a remote computer apparatus 160 in which various embodiments of the invention may be applied. The computer apparatus 160 may be a user equipment (UE), user device or apparatus, such as a mobile terminal, a smart phone, a laptop computer, a desktop computer or other communication device. The remote control apparatus 160 may be configured to be operated by a remote operator of the vessel 121 or the power plant 121 (Fig. 1). The remote control apparatus 160 may be arranged on a ground station, on the vessel 121 (Fig. 1) or on another vessel, for example.

[00161] The general structure of the computer apparatus 160 comprises a user interface 540, a communication interface 550, a processor 510, and a memory 520 coupled to the processor 510. The computer apparatus 160 further comprises software 530 stored in the memory 520 and operable to be loaded into and executed in the processor 510. The software 530 may comprise one or more software modules, such as remote client software application 531, and can be in the form of

a computer program product. The computer apparatus 160 may further comprise a user interface controller 560.

[00162] The processor 510 may be, e.g., a central processing unit (CPU), a microprocessor, a digital signal processor (DSP), a graphics processing unit, or the like. Fig. 5 shows one processor 510, but the computer apparatus 160 may comprise a plurality of processors.

[00163] The memory 520 may correspond to features disclosed for the memory 420 of the apparatus 120.

[00164] The user interface controller 560 may comprise circuitry for receiving input from a user of the computer apparatus 160, e.g., via a keyboard, graphical UI shown on a display of the user interfaces 240 of the computer apparatus 160, speech recognition circuitry, or an accessory device, such as a headset, and for providing output to the user via, e.g., a graphical UI or a loudspeaker.

[00165] The communication interface module 550 implements at least part of radio transmission and may comprise corresponding elements as module 250 of apparatus 120. The computer apparatus 160 may comprise a plurality of communication interface modules 550. Sensor data items from engines 125, 170-172, 291 and/or liquid lubricant data may be downloaded from the server apparatus 130 and stored to the remote computer apparatus 160.

[00166] A skilled person appreciates that in addition to the elements shown in Fig. 5, the computer apparatus 160 may comprise other elements, such as microphones, extra displays, as well as additional circuitry such as input/output (I/O) circuitry, memory chips, application-specific integrated circuits (ASIC), processing circuitry for specific purposes such as source coding/decoding circuitry, channel coding/decoding circuitry, ciphering/deciphering circuitry, and the like. Additionally, the computer apparatus 160 may comprise a disposable or rechargeable battery (not shown) for powering if external power supply is not available.

[00167] Figs. 6a-c show diagrams illustrating determining condition information of the liquid lubricant in accordance with an example embodiment of the invention.

[00168] Fig. 6a illustrates oil conditioning data (engine sensor data, loss factor) received from the sensor device and enriched with operating data of the asset, such as an engine, to produce signal corrected version of the (sensor) data as shown in Fig. 6b. The corrected (sensor) data may be further processed by analytics

algorithm (dynamic engine operation model) to produce real-time oil condition data, as shown in Fig. 6c.

[00169] In an embodiment, a method comprises receiving engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant, receiving engine operation data, combining the engine sensor data and the engine operation data to provide a dynamic engine operation model of the liquid lubricant, and determining condition information of the liquid lubricant based on the dynamic engine operation model.

[00170] The condition information of the liquid lubricant may comprise information on oil condition, failure prevention, oil quality management, equipment maintenance management or fuel consumption optimization, for example.

[00171] Oil condition information may comprise information on at least one of the following: Oil condition monitoring, BN (Base Number) monitoring, and viscosity monitoring.

[00172] Failure prevention information may comprise information on water contamination, for example.

[00173] Oil quality management information may comprise information on at least one of the following: Prediction of end of oil life in hours, monitoring remaining useful oil lifetime, smart top-up and sweetening (adding fresh oil and removing used oil), and oil consumption.

[00174] Equipment maintenance management information may comprise information on monitoring and flagging oil condition impacts on the equipment.

[00175] In an embodiment, the engine sensor data may be enriched with the engine operation data by combining the two data and then analyzing engine operating data impact on the sensor signal and creating necessary correction factors to corrected version of the raw signal data to provide a dynamic engine operation model of the liquid lubricant.

[00176] In an embodiment, the engine sensor data and the engine operation data may be combined by dropping off the sensor signal when the engine is off and maybe some pre-defined amount of time (e.g. hours) after the engine is turned on to ensure the potential condensates (like water) is removed from lubricating oil and that it will not affect to the signal anymore.

[00177] In an embodiment, the engine sensor data and the engine operation data may be combined by correcting the loss factor according to the liquid lubricant temperature when the engine is running. The correction coefficient is determined based on the correlation between the lube oil temperature and the loss factor in a short timescale, so that the impact of the oil degradation on the loss factor is negligible. The correction coefficient is estimated using the data collected while the engine is on and not containing any lube oil maintenance events (e.g. sweetening and top-up).

[00178] In an embodiment, the engine sensor data and the engine operation data may be combined by determining the loss factor against the engine running hours in order to better visualize the oil degradation rate and trend.

[00179] In an embodiment, the engine sensor data and the engine operation data may be combined by collecting physical lubricating oil samples and doing laboratory tests to find actual BN (Base Number) and viscosity values and in response to that it is possible to make correlation and conversion equations to change sensor loss factor into BN (Base Number) and viscosity reading. To reduce the lube oil quality estimation error, the bias of the conversion equations changing the loss factor to the lube oil quality characteristics can be updated using the results of the latest lab tests. In addition, loss factor readings can be used to determine the inadequate lab test results that should be discarded, and for triggering repeated lab tests.

[00180] The engine sensor data and the engine operation data may be transmitted to the server apparatus for combining to provide a dynamic engine operation model of the liquid lubricant or the combination and providing the dynamic engine operation model may be done locally on-site at the engine apparatus.

[00181] Figs. 7a-b show diagrams illustrating determining condition information of the liquid lubricant for abnormal conditions in accordance with an example embodiment of the invention.

[00182] In Fig. 7a, dark bars 710 illustrate the time periods when the engine is on. Time periods when engine is off, is shown on areas outside the bars 710. Engine on/off status information may be used as discussed in relation to Figs. 6a-c and other embodiments, for example.

[00183] Fig. 7a illustrates liquid lubricant measurement data received from the sensor that may be enriched with operating data of the asset, such as an engine, to

produce signal corrected version of the measured data, such as the dynamic engine operation model. Based on the dynamic engine operation model, unusual oil property change is detected as shown in Fig. 7b. The dynamic engine operation model including the unusual oil property change data may be further processed by analytics algorithm to produce real-time oil anomality indication. Such indication may be for example water detection in the oil and trigger automatic alerts for service operators of the asset, for example.

[00184] In an embodiment, engine sensor data may comprise at least one of the following: Loss factor data; and Tan delta number.

[00185] In an embodiment, engine operation data may comprise information on at least one of the following: lubricating oil temperature; engine load; engine speed; engine on/off indicator; and ambient conditions.

[00186] In an embodiment, the engine sensor data and the engine operation data may be combined to provide a dynamic engine operation model of the liquid lubricant by up-trending of the loss factor while the engine is turned off and down-trending of the loss factor for a pre-defined time after the engine is turned on, as shown in Fig. 7a.

[00187] In an embodiment, the engine sensor data and the engine operation data may be combined to provide a dynamic engine operation model of the liquid lubricant by detecting oscillations in the loss factor signal while the engine is running, as illustrated in Fig. 7b. Oscillations can be determined based on the dynamic engine operation model, for example, to indicate that there is probably water in liquid lubricant.

[00188] In an embodiment, the engine sensor data and the engine operation data may be combined to provide a dynamic engine operation model of the liquid lubricant by combing the loss factor reading from the sensor with the average lube oil lifetime in the engine, calculated using the lube oil maintenance history, the engine running periods and the engine load, in order to determine abnormal lube oil degradation trends not agreeing with the average lube oil lifetime in the engine.

[00189] In an embodiment, the engine sensor data and the engine operation data may be combined to provide a dynamic engine operation model of the liquid lubricant for detecting oscillations that may identify water in oil, for example. Oscillations may be detected in the loss factor signal while the engine is running.

Detection may be configured to be done, for example, by applying FFT (Fast Fourier Transform) to a part of the loss factor signal and detecting a spike in the signal spectrum in a certain frequency range. Water may be detected from the above by monitoring the signal deviations (too fast/high up-trending/down-trending vs the reference limit values). Reference data may be maintained from reference engines as disclosed, and mechanical or chemical testing done for initial reference data. However, as more reference data is gathered lab test will become unnecessary.

[00190] Fig. 8 shows diagram illustrating determining condition information of the liquid lubricant for quality management in accordance with an example embodiment of the invention.

[00191] In Fig. 8 engine sensor data, such as oil measurement data, received from a sensor device, which data may be enriched with operating data of the asset, such as an engine, to produce signal corrected version of the measured engine sensor data. From the combined data, a usual oil property change is detected as shown in Fig. 8. The combined data including the usual oil property change data may be further processed by analytics algorithm to produce real-time oil quality information. Such information may be for example a record of oil top-up sweetening and estimate of oil quality improvement, for example. Feedback from multiple reference engines to improve the detection, alerts and recommendations may be used.

[00192] In an embodiment, engine sensor data may comprise at least one of the following: Loss factor data; and Tan delta number.

[00193] In an embodiment, engine operation data may comprise information on at least one of the following: lubricating oil temperature; engine load; engine speed; engine on/off indicator; and ambient conditions. Furthermore, other sources of data that can be used for enriching (as operation data) sensor data may comprise at least one of the following: cleaned sensor signal data, pre-defined operational limits for the loss factor, current loss factor signal, engine running profile data, engine load profile data and historical lube oil management data on lubrication maintenance and lab records.

[00194] In an embodiment, the engine sensor data and the engine operation data may be combined to provide a dynamic engine operation model of the liquid

lubricant for determining real-time data for estimating quality improvement, for example. For oil quality management, a variety of steps may be done.

[00195] In an embodiment, end of oil lifetime in hours may be predicted and remaining useful oil lifetime may be monitored by carrying out at least some of the following steps. First, the loss factor may be limited to limit value. Second, current state of the loss factor may be used for enriching. Third, the difference of the limit value and the current state may be calculated and divided by the slope of the loss factor (loss factor degradation rate). Fourth, more precise calculations of the remaining oil may be determined based on engine running profile (expected running hours and load) and further using the fuel characteristics.

[00196] In an embodiment, smart top-up and sweetening may be managed to enable fine control of oil quality monitored by carrying out at least some of the following steps. First, upper and lower limits of the loss factor signal can be calculated for a specific site based on the correlation of the loss factor to the lube oil quality characteristics (like BN (Base Number) and viscosity), as well as lube oil and fuel specifications. The algorithm (dynamic engine operation model) may be configured to calculate when to sweeten and how much that can utilize the correlation between the sweetening volume and the effect of sweetening on the loss factor. Second, the algorithm can be integrated into automation system so that this can happen automatically, for example under control by the engine apparatus arranged at marine vessel or power plant, for example. Third, the algorithm may be arranged to calculate cost savings and lube oil savings achieved by optimizing the operations and lube oil maintenance, based on the previous history of lube oil maintenance, for example. Fourth, the algorithm may be configured to calculate how many engine running hours with the off-spec lube oil conditions have been avoided by the oil quality management.

[00197] Fig. 9 shows a schematic picture of a dynamic engine operation model 127 of the liquid lubricant and related information flows according to an example embodiment. The dynamic engine operation model (DEOM) 127 can be configured to operate as a stand-alone solution or as an integrated part of the control system of the marine vessel or power plant, for example. The dynamic engine operation model (DEOM) 127 enables automation of the liquid lubricant monitoring, prediction and maintenance management, and further enables a higher degree of autonomous

operation. For equipment maintenance management, monitoring and flagging oil condition impacts on the equipment may be provided.

[00198] In an embodiment, the dynamic engine operation model (DEOM) 127 is interfaced with engine sensor data 920 and engine operation data 930. Furthermore, in some optional features, the dynamic engine operation model (DEOM) 127 may be interfaced also to other sub-systems or information sources, such as user input 980, reference model related information 960 or maintenance information 940, as shown in Fig. 9, for example. The dynamic engine operation model (DEOM) 127 may further be configured to receive and manage information about the health status of sub-systems directly or through the power management and automation systems 950. The dynamic engine operation model (DEOM) 127 can determine condition information of the liquid lubricant based on the dynamic engine operation model and generate tasks and/or instructions for the asset management, automation and power management systems based on the dynamic engine operation model 127 and combining the engine sensor data and the engine operation data.

[00199] In an embodiment, equipment maintenance management may be provided. The dynamic engine operation model 127 is arranged to receive engine sensor data 920, wherein the engine sensor data corresponds to at least one parameter of the liquid lubricant. The engine sensor data 920 may comprise, for example, at least one of the following: loss factor from the sensor, Tan delta number from the sensor and lubricating oil temperature. The dynamic engine operation model 127 is arranged to receive engine operation data 930. The engine operation data 930 may comprise, for example, at least one of the following: Engine load information, engine speed information, engine on/off indicator, ambient condition information, route plan information including information like weather forecasts, navigation information for the dedicated route, waypoint information for the dedicated route, emission restricted areas, environmental restrictions and other relevant information. The route plan information may be received from the navigation system of the marine vessel system or the route plan information may be generated by the control apparatus. The route plan information may comprise at least one of the following: navigation information; and environmental information. The navigation information may comprise at least one of the following: destination

information of the dedicated route; remaining travel time of the dedicated route; remaining distance of the dedicated route; navigation information for the dedicated route; waypoint information for the dedicated route; emission restricted area information of the dedicated route; and environmental restriction information of the dedicated route.

[00200] In an embodiment, reference model related information 960 (see also Fig. 1 and items 180-184) associated to at least one reference engine with a liquid lubricant may be used as an input. The reference model related information 960 may comprise at least one of the following information: Engine overhaul statistics from a plurality of reference engines, engine performance and maintenance data from a plurality of reference engines, sensor data from a plurality of reference engines, and lube oil data from a plurality of reference engines.

[00201] In an embodiment, the maintenance information 940 may comprise at least one of the following: Historical failure information, historical liquid lubricant management records, historical maintenance and lab records, failure report information and lubricating oil running hour information (how long the liquid lubricant has been in the engine, gearbox, hydraulic system etc.).

[00202] At least the engine sensor data 920 and the engine operation data 930 is combined to provide a dynamic engine operation model 127 of the liquid lubricant, and condition information of the liquid lubricant is determined based on the dynamic engine operation model 127. Also, in combining, further information may be used.

[00203] In an embodiment, combining may also comprise collecting representative statistics on the failure frequency in connection to lube oil quality from reference data 960. Such data may be generated from existing installations whose data is maintained as reference data 960.

[00204] In an embodiment, combining may also comprise collecting representative statistics on the work and costs required in overhauls in connection to lube oil quality using maintenance history from reference data 960 or maintenance information 940.

[00205] In an embodiment, combining may also comprise collecting the site specific data from operation data 930 and/or user interface 980 and determining condition information based on the engine operation model 127 and the site specific

data against multiple reference engines information 960 in other reference installations.

[00206] The dynamic engine operation model 127 algorithm may be configured to compare reference data 960 from multiple reference engines against lube oil quality and lube oil quality history (e.g. from maintenance information 940) of the installation, in order to evaluate the expected effect of the overall lube oil quality on the engine availability and running costs, including the unplanned maintenance due to failures and additional overhaul costs.

[00207] In an embodiment, algorithms of the dynamic engine operation model 127 and lube oil limits are dynamically improved by continuously collecting the data from multiple reference engines in multiple reference installations. The dynamic engine operation model 127 may be configured to provide intelligent recommendations regarding the lube oil quality limits, based on the collected statistics, plant specific conditions (engine age, fuel and lube oil specifications, load profile, etc.) and goals (availability, costs, etc.), for example.

[00208] In an embodiment, fuel consumption optimization may be provided. The dynamic engine operation model 127 is arranged to receive engine sensor data 920, wherein the engine sensor data corresponds to at least one parameter of the liquid lubricant. The engine sensor data 920 may comprise, for example, at least one of the following: loss factor from the sensor, Tan delta number from the sensor and lubricating oil temperature. The dynamic engine operation model 127 is arranged to receive engine operation data 930. The engine operation data 930 may comprise, for example, at least one of the following: Engine load information, engine speed information, engine on/off indicator, ambient condition information, cooling water parameters, historical running profile and fuel consumption data, turbocharger operational data, route plan information including information like weather forecasts, navigation information for the dedicated route, waypoint information for the dedicated route, emission restricted areas, environmental restrictions and other relevant information. The engine operation data 930 may further comprise fuel property information and fuel consumption information.

[00209] In an embodiment, engine sensor data 920 is combined with engine operational data 930 comprising cooling water parameters, ambient condition

information and turbocharger operational data, and further with maintenance data 940 to isolate oil quality from other factors impacting fuel consumption.

[00210] The dynamic engine operation model 127 algorithm may be configured to control liquid lubricant quality management to keep the liquid lubricant in the optimum level with narrow changes in oil quality. Thus, impact of oil quality into fuel consumption may be calculated by using the dynamic engine operation model 127.

[00211] In an embodiment, the dynamic engine operation model 127 is configured to operate as a neural network. A computer implemented method for determining condition of a liquid lubricant for an engine, comprises receiving engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant; receiving engine operation data; combining the engine sensor data and the engine operation data to provide a dynamic engine operation model of the liquid lubricant; and determining condition information of the liquid lubricant based on the dynamic engine operation model.

[00212] In an embodiment, the combining step further comprises comparing the received engine sensor data and engine operation data to a specified data signature associated with the dynamic engine operation model of the liquid lubricant, and determining based on the comparison the condition information of the liquid lubricant.

[00213] The specified data signature is programmed into a synapse of a neural network, and the comparing step comprises inputting the engine sensor data and engine operation data into the neural network.

[00214] The neural network that may be trained using a plurality of data signatures from engine sensor data and engine operation data. Weights for different inputs 320-340, 380 may be adjusted before feeding in to hidden layer of the neural network comprised by the dynamic engine operation model 127.

[00215] The dynamic engine operation model (DEOM) 127 may be further arranged to receive operational characteristic information 930 representing at least one operating characteristic of a marine vessel. The operating characteristic information 930 of the marine vessel may comprise at least one of the following: information on currently active propulsion system; status information of energy generation sub-system; and status information of energy storage sub-system.

[00216] The dynamic engine operation model (DEOM) 127 may further be arranged to receive operational characteristic information 930 or user input information 980 representing at least one current environmental characteristic of the marine vessel, such as weather information; wind information; air pressure information; ice information; wave height, frequency or direction information; tidal data; current information; water temperature information; water saline level information; and roll or pitch information.

[00217] In an embodiment, if there has not been identified any violations of possible constraints, the dynamic engine operation model (DEOM) 127 may generate at least one task for controlling an automation element of the automation system 950 for liquid lubricant related monitoring, control or management.

[00218] In an embodiment, condition information generated based on the dynamic engine operation model (DEOM) 127 may be transmitted to a cloud server apparatus for vessel, fleet or power plant maintenance related monitoring and optimization. For example, maintenance actions and breaks may be automatically requested based on the received condition information of the liquid lubricant.

[00219] In an embodiment, the automation element of the marine vessel automation system 950 is configured to control at least one of the following: power management system of the marine vessel and navigation system of the marine vessel. The automation element may be configured to control, for example, power management system of the marine vessel for at least one of the following: schedule for changing propulsion power source; schedule for changing used fuel; schedule for activating scrubber; and schedule for operating HVAC (Heating, Ventilation and Air Conditioning).

[00220] In an embodiment, if there has not been identified any violations of possible constraints, the dynamic engine operation model (DEOM) 127 may generate liquid lubricant plan (LLP) 970 and utilize the liquid lubricant plan (LLP) 970 for determining control, monitoring or maintenance related tasks relating to engine control, maintenance activity, energy production, energy consumption or energy storage within the marine vessel automatically.

[00221] While cruising and performing transit during the voyage, the dynamic engine operation model (DEOM) 127 maintains a dynamic and up-to-date situational awareness in relation to the executed route (navigation) and liquid lubricant plan

(LLP) 970 and the continued health status from all energy/power producers. If the situation changes and a system changes health status, the dynamic engine operation model (DEOM) 127 may be configured to update the liquid lubricant plan (LLP) 970 including tasks and automatically notifying the operator system and/or navigation system. Based on notification, maintenance or service requests may be generated or the navigation system is allowed to modify the route plan information automatically.

[00222] Because the dynamic engine operation model (DEOM) 127 has access to information about optimal operation conditions of the sub-systems with liquid lubricant, the model can help to avoid stressing engines, preventing failures, as the safety limit parameters are known to the dynamic engine operation model (DEOM) 127. An operating mode may be used wherein only confirmed request from the operator is needed, and the dynamic engine operation model (DEOM) 127 may allow controlling and monitoring sub-systems within or outside the optimal operation conditions.

[00223] The liquid lubricant plan (LLP) 970 information can be provided in a first mode as a schedule made available to the engineers to follow. The engineers may perform the scheduled tasks based on the liquid lubricant plan (LLP) 970. In a second mode, the liquid lubricant plan (LLP) 970 may be embedded in the main display of the engine control room and the power management system, for example. The automation system may be further configured to provide an integrated guidance tool to prompt the operator when a task should take place and by acknowledgement from the operator enable and perform the task and end the task when performed. A third mode allows a fully automated solution, where the operator may only be informed about the liquid lubricant plan (LLP) 970 or the tasks determined by the dynamic engine operation model (DEOM) 127. Optionally, current status of the model and next steps may be informed to the operator but the dynamic engine operation model (DEOM) 127 is configured to control automation elements and/or maintenance tasks automatically. In such embodiment the liquid lubricant plan (LLP) 970 may be optional.

[00224] In an embodiment, the dynamic engine operation model (DEOM) 127 may be configured to control engine sub-systems and fuel selection via the automation and power management systems and the dynamic engine operation

model (DEOM) 127 can e.g. automatically negotiate the used main or aux engine within the vessel or power plant, loads for different engines, operating speeds for different engines, planned route with the navigation system based on the availability of energy producers with liquid lubricant and their health status (able to operate 0-100%) and the planned energy consumption in relation to ship operation, maintenance time and ship position, for example.

[00225] In an embodiment, the dynamic engine operation model (DEOM) 127 is configured to receive input from an operator (USR) 980 either at the vessel or power plant or remote at other vessel or remote control station, for example. In certain pre-defined operating modes or tasks, it may be required that operator acknowledgement is received from the operator (USR) 980 for the determined task by the dynamic engine operation model (DEOM) 127 before controlling an automation element.

[00226] In an embodiment, the dynamic engine operation model (DEOM) 127 may be updated in real-time.

[00227] Fig. 10 shows a flow diagram showing operations in accordance with an example embodiment of the invention. In step 1000, the method for determining condition of a liquid lubricant for an engine, is started, In step 1010, engine sensor data is received, wherein the engine sensor data corresponding to at least one parameter of the liquid lubricant. In step 1020, engine operation data is received. In step 1030, the engine sensor data and the engine operation data are combined. In step 1040, a dynamic engine operation model of the liquid lubricant is generated based on the combination. In step 1050, condition information of the liquid lubricant is determined based on the dynamic engine operation model. The method is ended in step 1060.

[00228] Fig. 11 shows a schematic diagram of an exemplary engine apparatus related items for determining condition of a liquid lubricant for an engine in accordance with an example embodiment.

[00229] First, from a plurality of candidate reference engines 170-172 at least one reference engine 170 and related engine and oil data is selected.

[00230] In an embodiment, selection information may be received for a plurality of reference engines from an operator of the system or defined automatically based on engine type identifiers, for example. The reference engine profile data may be

generated by determining reference engine parameters of the plurality of reference engines based on the selection information.

[00231] At least one reference engine 170-172 is configured to generate the reference engine profile data 182 by determining reference engine parameters 175 of the reference engine 170-172. The reference engine parameters 175 may be detected using at least one sensor either integrated to the engine 170 or external to the engine 170. The reference engine profile data 182 may be generated based on the reference engine parameters (sensor data) 175 from at least one engine 170. The reference engine parameters may relate to different operation conditions of the reference engine.

[00232] At least one reference engine 170-172 is configured to generate reference engine sensor (liquid lubricant) data 183 by e.g. mechanical or chemical testing of an oil sample 176 from the reference engine 170-172. The testing of the oil sample 176 may be done by a friction test rig 710 or any test device 710 configured to perform mechanical tribological lubricity test or chemical test of the oil sample 176. The test device 710 may be a separate test device and not integrated to the same device as other elements of apparatus 180.

[00233] Reference engine 170-172 related measurements, data collection and transceiving may be carried out by a reference engine data apparatus 180. A reference engine operation model 184 is generated by associating the reference engine operation data 182 with the reference engine sensor data 183. The reference engine sensor data 183 is thus resulting from liquid lubricant related data (Stribeck type friction data, tan delta, loss factor, for example).

[00234] Collected data 182,183 may be processed based on, combining engine operation data 182 to lubricity data 183 of liquid lubricant 176 into an independent mathematical function, for example. This function will not require look-up tables or polynomial fitting of sample or sensor data.

[00235] In an embodiment, the collected data of reference engine operational data 182 and the reference engine sensor (lubrication) data 183 may be processed at reference engine data apparatus 180 or transmitted to the server apparatus 130 over network 150 for processing.

[00236] In an embodiment, the reference model 184 may be transmitted to a server apparatus 130, 131 for storing and processing over connection 181. The

reference engine operation data 182 and/or the reference engine sensor data 183 may also be transmitted over network 150 to a server apparatus 130, 131 for storing and processing. The reference model 184 may also be generated at the server apparatus 130, 131.

[00237] In an embodiment, reference model data of the reference model may be maintained at a server apparatus, and dynamically updating the reference model data over network 150 in response to receiving reference engine operation data 182 or reference engine sensor data 183.

[00238] In an embodiment, the reference engine parameters 175 and oil samples 176 may be received and processed at engine manufacturer when testing the engines in test lab and before sending the engine(s) 170-172 to customers. The reference engines(s) 170-172 may also be test engines (not sent to customers) that are run at test lab with various operating profiles and various environmental effects to gather reference data for reference model calculation. The reference engines(s) 170-172 may also be engines in use by any remote site or installation.

[00239] Fig. 12 shows a schematic diagram of a data item in accordance with an example embodiment. The data item 1200 as disclosed may comprise engine sensor data 124 or engine operation data 126 or both. Correspondingly, the data item 1200 as disclosed may comprise reference engine sensor data 175 or lubricant data 176 or both. The data item 1200 comprises at least one identifier.

[00240] In an embodiment, the engine 291 and at least one sensor device 290 (see e.g. Fig. 2) are configured to generate sensor data items based on the received identification system data and sensor data. The sensor data item may thus comprise sensor data generated by the sensor device 290 and an identifier information. The identifier information may comprise at least one of the following: sensor-ID (S-ID); engine-ID (E-ID), and vessel-ID (V-ID) that may comprise at least part of the received automatic identification system data, for example.

[00241] A sensor data item, such as engine parameters 124, is generated by a sensor device of the marine vessel 121 or power plant and transmitted to the server apparatus 130. Sensor data items may be processed at the engine apparatus 120 before transmitting or they may be sent without further processing to the server 130.

[00242] Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein is an improved system for an engine apparatus.

[00243] A technical effect of one or more of the example embodiments disclosed herein is that accuracy and real-time monitoring of liquid lubricant condition is improved.

[00244] A technical effect of one or more of the example embodiments disclosed herein is that fuel efficiency of an engine is improved. A further technical effect of one or more of the example embodiments disclosed herein is that operational efficiency of an engine apparatus, is improved.

[00245] Still further technical effect of one or more of the example embodiments disclosed herein is that it enables early fault detection and failure prevention by detecting anomalities as early as possible. Furthermore, it enables real-time liquid lubricant quality management, real-time BN (Base Number) & Viscosity monitoring, and accurate and fast control of oil quality.

[00246] Still further technical effect of one or more of the example embodiments disclosed herein is that it optimizes liquid lubricant consumption and usage, reduces component failures, helps to optimize maintenance actions, generates an operator a view on their engines and how they are performing versus other engines.

[00247] Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

[00248] It is also noted herein that while the foregoing describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications that may be made without departing from the scope of the present invention as defined in the appended claims.

Claims:

1. A computer implemented method for determining condition of a liquid lubricant for an engine, the method comprising:

receiving engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant;

receiving engine operation data;

combining the engine sensor data and the engine operation data to provide a dynamic engine operation model for the liquid lubricant; and

determining condition information of the liquid lubricant based on the dynamic engine operation model.

2. The method of claim 1, wherein the engine sensor data is received from at least one sensor device and comprises information on electrochemical properties of the liquid lubricant at a molecular level.

3. The method of claim 2, wherein the electrochemical properties are configured to be measured by using a high frequency AC current to measure a ratio between conductance and capacitance of the liquid lubricant.

4. The method of claim 2 or 3, wherein the electrochemical properties comprise at least one of the following: loss factor data; and Tan delta (TD) number.

5. The method of any claim 1 to 4, wherein the sensor device is operationally connected to the engine.

6. The method of any claim 1 to 5, wherein the method further comprises correcting the engine sensor data before combination to the engine operation data.

7. The method of any claim 1 to 6, further comprising detecting an anomality based on at least one of the following: the engine sensor data; the engine operation data; the dynamic engine operation model; and the condition information.

8. The method of any claim 1 to 7, further comprising comparing condition information to reference maintenance threshold information; and generating automatic maintenance service order in response to the comparing step.

9. The method of any claim 1 to 8, wherein the engine operation data is received from at least one sensor device or engine control system and comprises information on at least one of the following: liquid lubricant temperature; engine load; engine speed; engine on/off indicator; ambient conditions; fuel consumption; liquid lubricant reservoir level; liquid lubricant sump level; fuel properties; reference liquid lubricant properties; reference test results; on-site test results; and historical liquid lubricant management records on lubrication maintenance.

10. The method of any claim 1 to 9, wherein combining the engine sensor data and the engine operation data comprises normalizing the engine sensor data with the engine operation data.

11. The method of claim 10, wherein the normalizing step comprises correcting the engine sensor data using liquid lubricant temperature.

12. The method of claim 11, wherein the correcting step comprises multiplying the liquid lubricant temperature with a pre-defined coefficient and subtracting the multiplied result from a loss factor to refine the engine sensor data.

13. The method of any claim 1 to 12, wherein combining the engine sensor data and the engine operation data comprises selecting a subset of the engine sensor data based on engine on/off indicator of the engine operation data.

14. The method of claim 13, wherein selecting the subset of the engine sensor data is triggered after the engine is determined to be on for a predefined time based on the engine on/off indicator.

15. The method of any claim 1 to 14, wherein the condition information comprises water contamination information.

16. The method of any claim 1 to 14, wherein the condition information comprises Base Number (BN) information.

17. The method of any claim 1 to 14, wherein the condition information comprises viscosity information.

18. The method of any claim 1 to 14, further comprising:

comparing condition information to threshold information;

determining condition profile information comprising information on running hours when condition information being below threshold information; and

transmitting the profile information from an engine apparatus comprising the engine for an edge cloud apparatus or a cloud apparatus.

19. The method of any claim 1 to 18, wherein the combining step is configured to isolate quality of the liquid lubricant from other factors impacting fuel consumption.

20. The method of claim 19, wherein the other factors comprise at least one of the following: engine data; cooling water data; turbocharger data; maintenance data; and ambient conditions data.

21. The method of any claim 1 to 20, wherein the liquid lubricant is automatically monitored using the condition information and service requests are generated in order to maintain quality of the liquid lubricant in a pre-defined range for minimizing engine operating costs.

22. The method of any claim 1 to 21, further comprising:

receiving reference engine sensor data, the reference engine sensor data corresponding to at least one parameter of a liquid lubricant of a reference engine;

receiving reference engine operation data;

combining the reference engine sensor data and the reference engine operation data to provide a reference engine operation model of the liquid lubricant; and

determining the dynamic engine operation model of the liquid lubricant using

the reference engine operation model.

23. The method of any claim 1 to 22, further comprising:

transmitting the engine sensor data and the engine operation data from an engine apparatus comprising the engine to an edge cloud apparatus or a cloud apparatus for combining.

24. The method of claim 23, further comprising:

pre-processing at least one of the engine sensor data and the engine operation data before transmission to the edge cloud apparatus or the cloud apparatus.

25. The method of any claim 1 to 24, wherein the dynamic engine operation model implements a neural network.

26. The method of claim 25, further comprising comparing the received engine sensor data and engine operation data to a specified data signature associated with the dynamic engine operation model of the liquid lubricant, and determining based on the comparison the condition information of the liquid lubricant.

27. The method of any claim 25 or 26, wherein the specified data signature is programmed into a synapse of the neural network.

28. The method of any claim 26 or 27, wherein the comparing step comprises inputting the engine sensor data and engine operation data into the neural network.

29. The method of any claim 26 to 28, wherein the neural network is trained using a plurality of data signatures from the engine sensor data and the engine operation data.

30. The method of any claim 25 to 29, wherein weights for different inputs are configured to be adjusted before feeding in to a hidden layer of the neural network comprised by the dynamic engine operation model.

31. The method of claim 22, further comprising:

receiving a plurality of reference engine operation models from a plurality of reference engines;

determining a reference engine operation model of the plurality of reference engine operation models based on at least one of the engine sensor data or the engine operation data; and

determining the dynamic engine operation model of the liquid lubricant using the determined reference engine operation model.

32. The method of claim 31, further comprising:

comparing engine sensor data with a plurality of reference engine sensor data associated with the plurality of reference operation models;

determining the reference operation model of the plurality of reference operation models by selecting closest counterpart for engine sensor data; and

determining the dynamic operation model of the liquid lubricant using the determined reference operation model.

33. The method of claim 31, further comprising:

comparing engine operation data with a plurality of reference engine operation data associated with the plurality of reference operation models;

determining the reference operation model of the plurality of reference operation models by selecting closest counterpart for engine operation data; and

determining the dynamic operation model of the liquid lubricant using the determined reference operation model.

34. The method of any claim 31 to 33, further comprising determining at least one of the engine sensor data or the engine operation data based on the determined reference operation model.

35. An engine apparatus, comprising:

an engine;

a communication interface;

at least one processor; and

at least one memory including computer program code;

the at least one memory and the computer program code configured to, with

the at least one processor, cause the apparatus to:

receive engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant;

receive engine operation data;

combine the engine sensor data and the engine operation data to provide a dynamic operation model of the liquid lubricant; and

determine condition information of the liquid lubricant based on the dynamic operation model.

36. A server apparatus comprising:

a communication interface;

at least one processor; and

at least one memory including computer program code;

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to:

receive engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant;

receive engine operation data;

combine the engine sensor data and the engine operation data to provide a dynamic operation model of the liquid lubricant; and

determine condition information of the liquid lubricant based on the dynamic operation model.

37. A computer program embodied on a computer readable medium comprising computer executable program code, which code, when executed by at least one processor of an apparatus, causes the apparatus to:

receive engine sensor data, the engine sensor data corresponding to at least one parameter of the liquid lubricant;

receive engine operation data;

combine the engine sensor data and the engine operation data to provide a dynamic operation model of the liquid lubricant; and

determine condition information of the liquid lubricant based on the dynamic operation model.

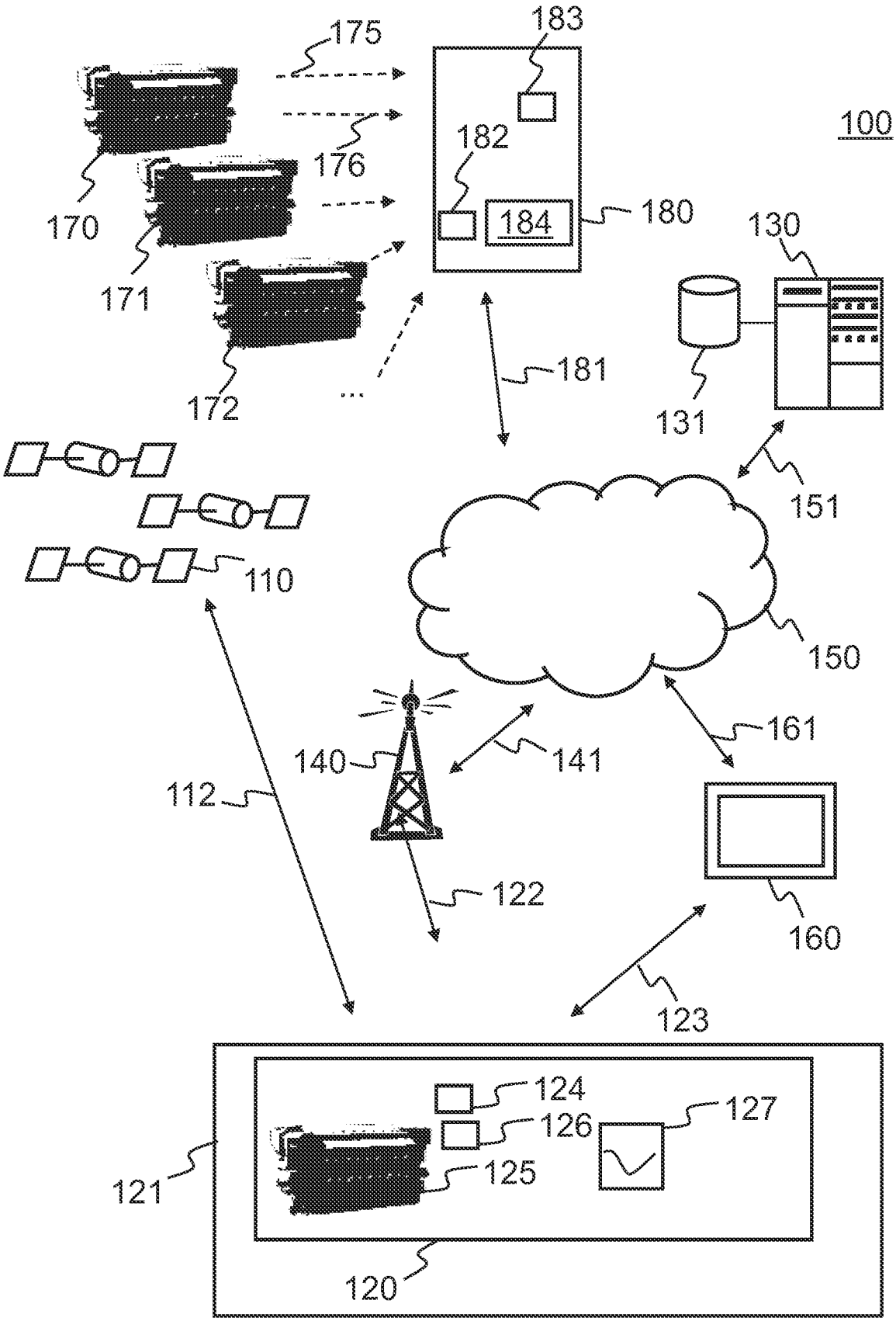

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Fig. 1

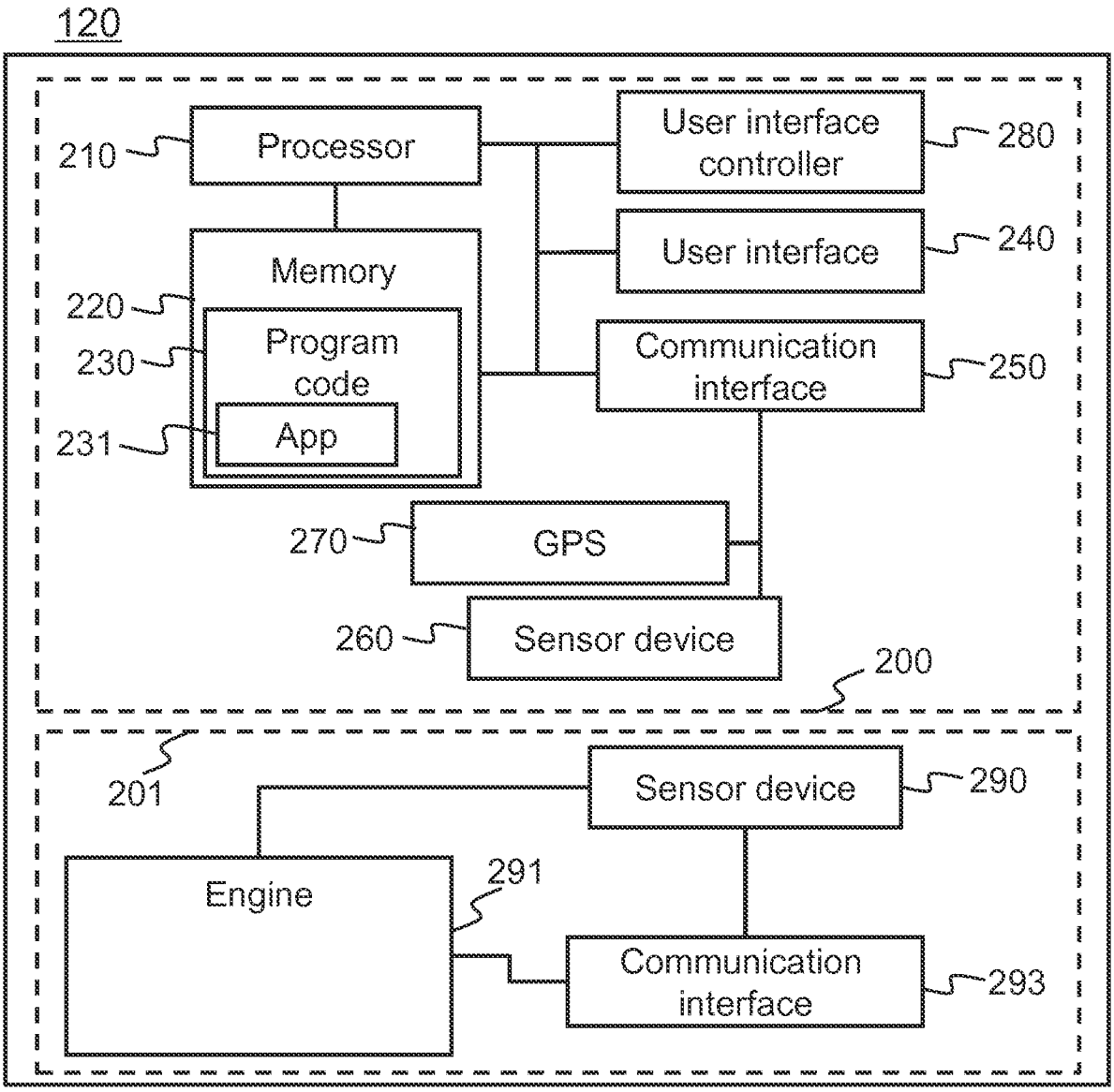

120
210
Processor
User interface controller
280
Memory
User interface
240
220
Program code
230
Communication interface
250
231
App
270
GPS
260
Sensor device
200
201
Sensor device
290
Engine
291
Communication interface
293

Fig. 2

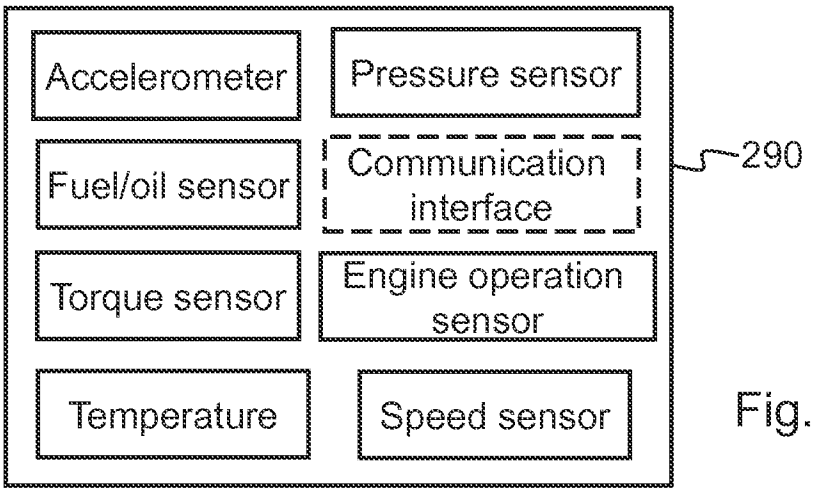

Accelerometer
Pressure sensor
Fuel/oil sensor
Communication interface
290
Torque sensor
Engine operation sensor
Temperature
Speed sensor

Fig. 3

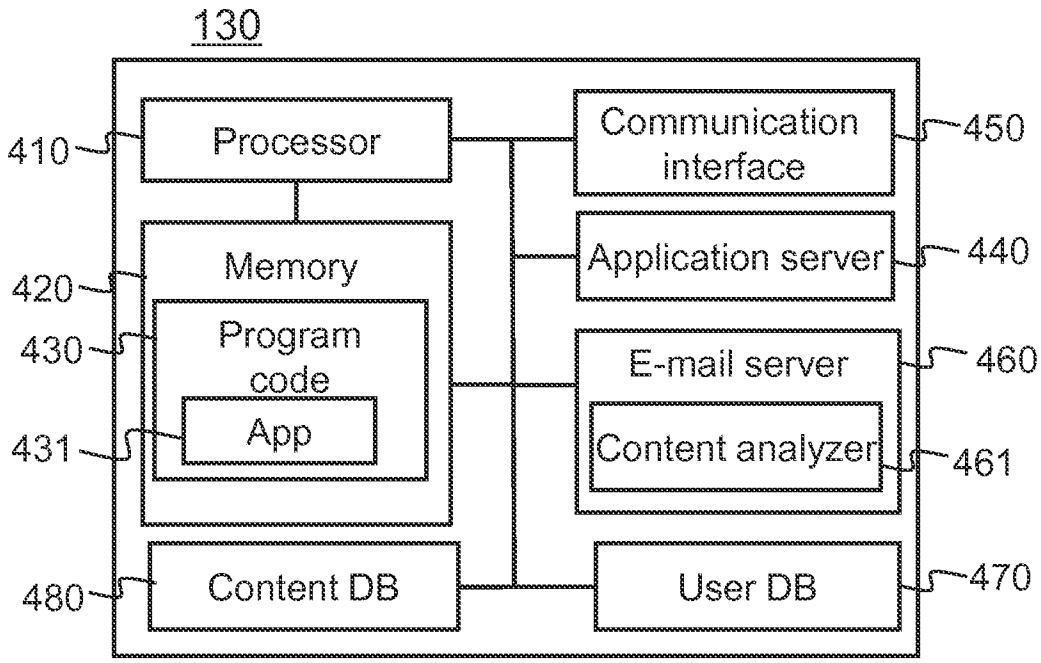

130
410
Processor
Communication interface
450
Memory
Application server
440
420
Program code
430
E-mail server
460
App
431
Content analyzer
461
480
Content DB
User DB
470

Fig. 4

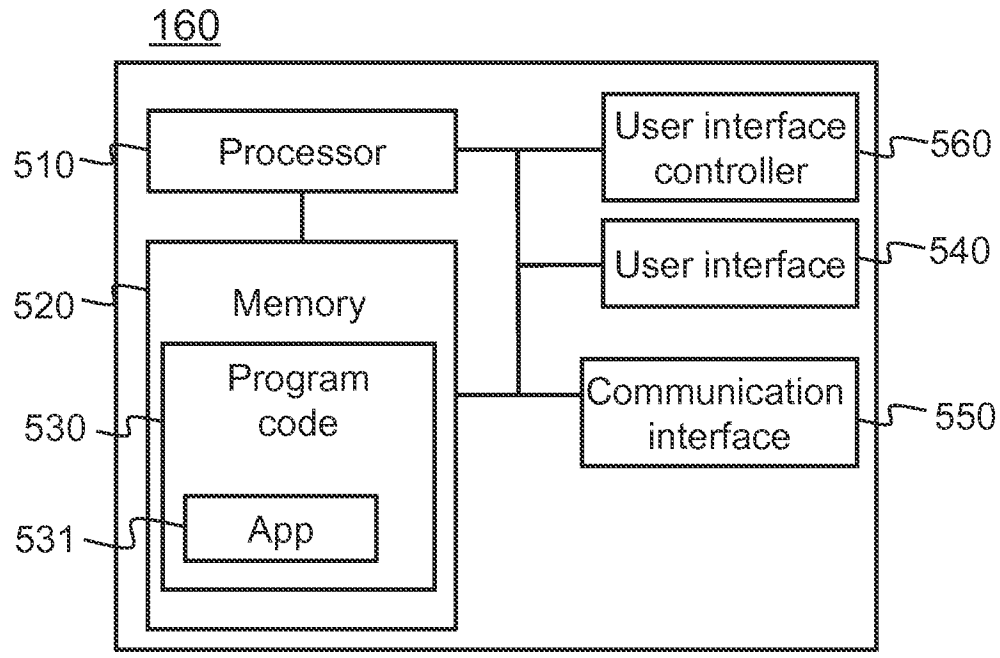

160
510
Processor
User interface controller
560
User interface
540
520
Memory
Program code
530
Communication interface
550
App
531

Fig. 5

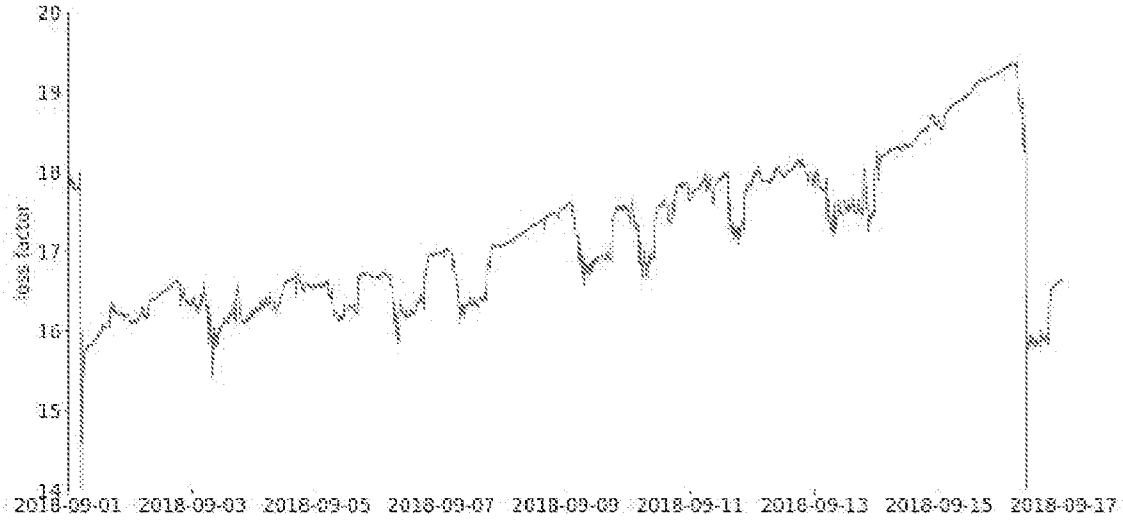


Fig. 6a

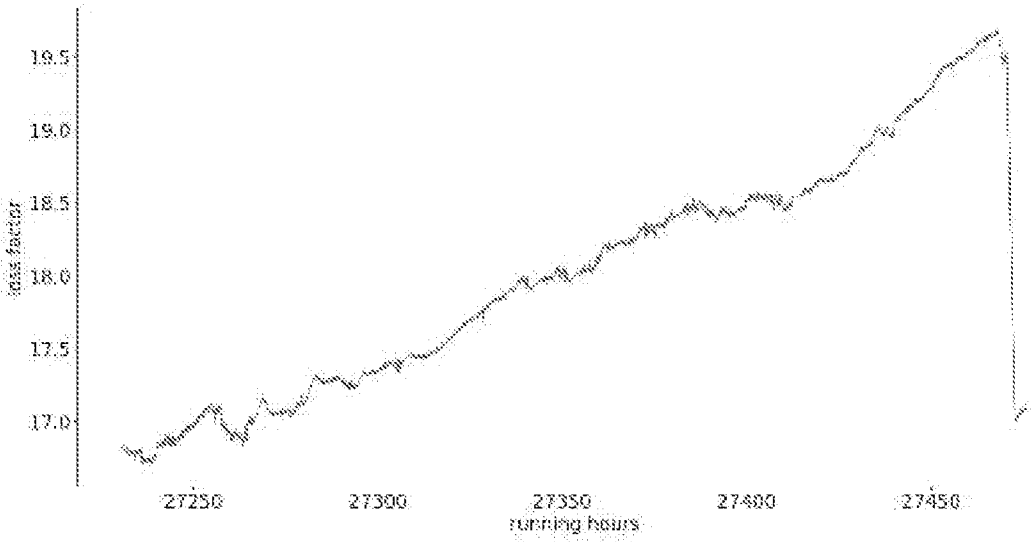


Fig. 6b

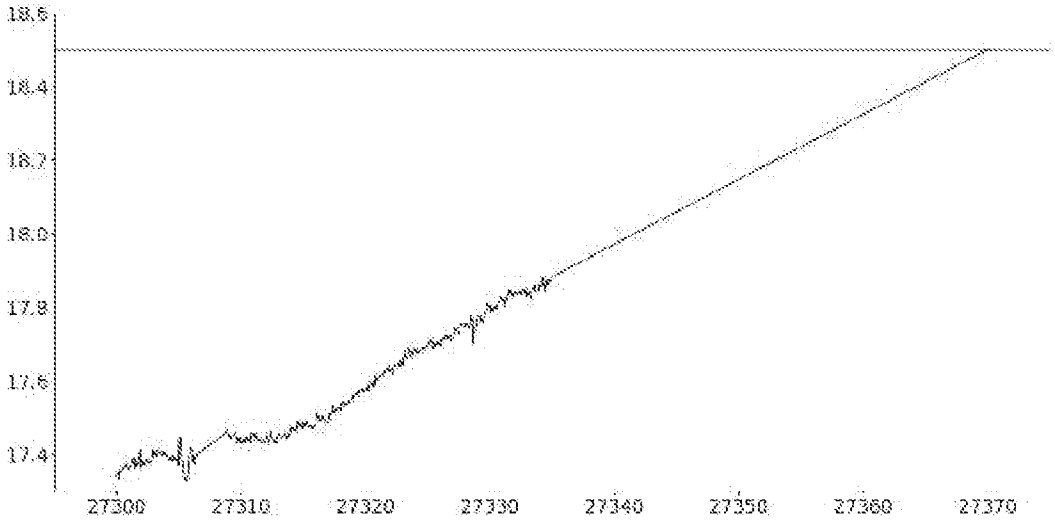


Fig. 6c

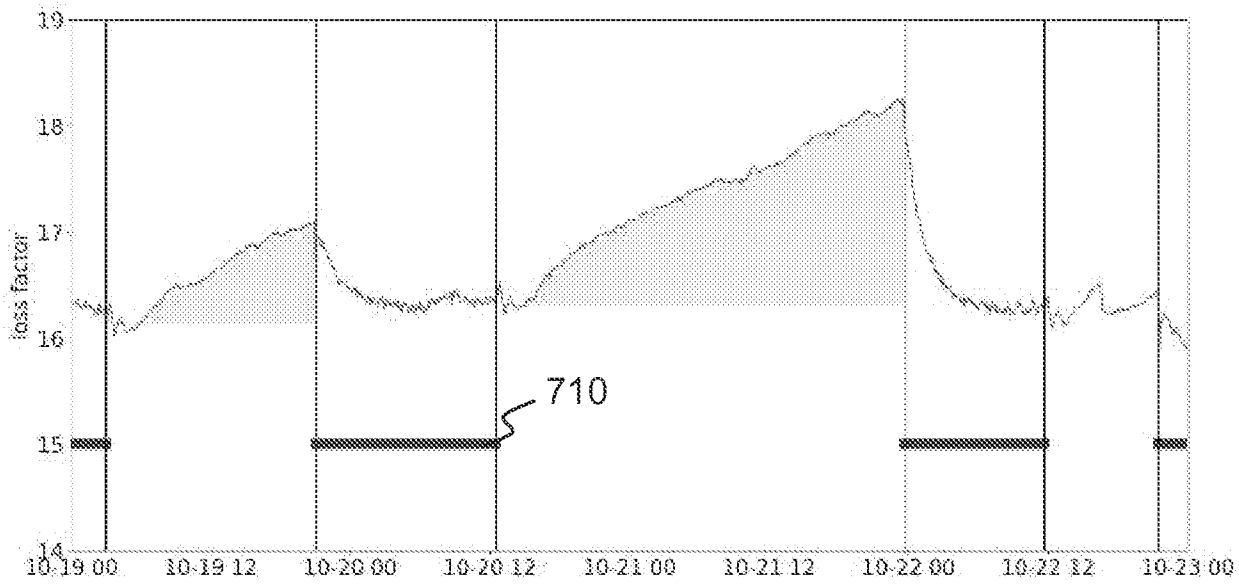

19
18
17
16
15
14
loss factor
710
10-19 00
10-19 12
10-20 00
10-20 12
10-21 00
10-21 12
10-22 00
10-22 12
10-23 00

Fig. 7a

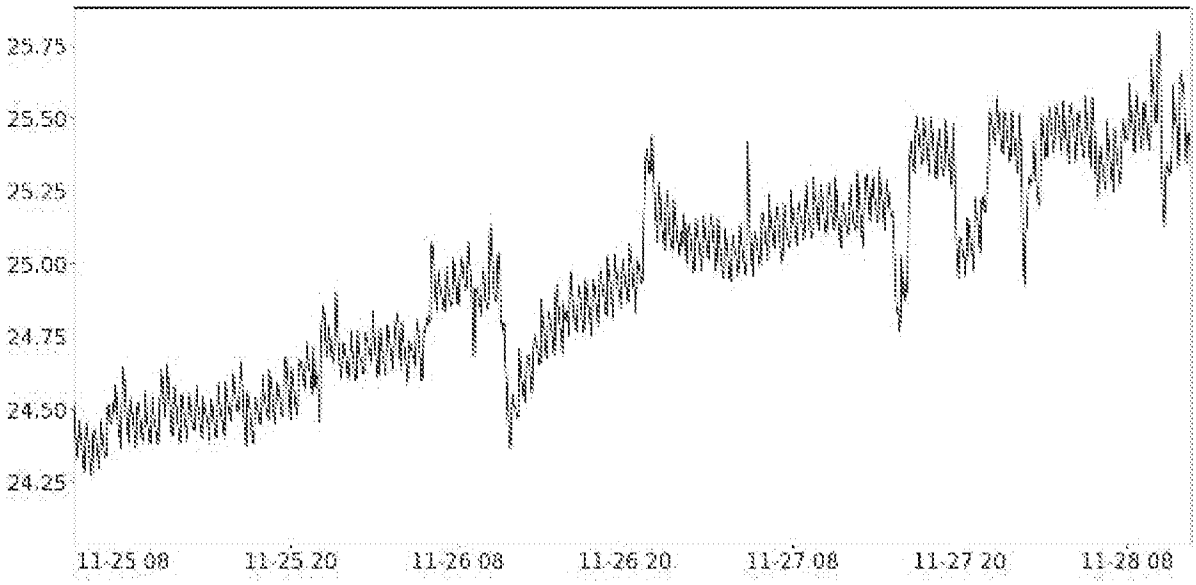

25.75
25.50
25.25
25.00
24.75
24.50
24.25
11-25 08
11-25 20
11-26 08
11-26 20
11-27 08
11-27 20
11-28 08

Fig. 7b

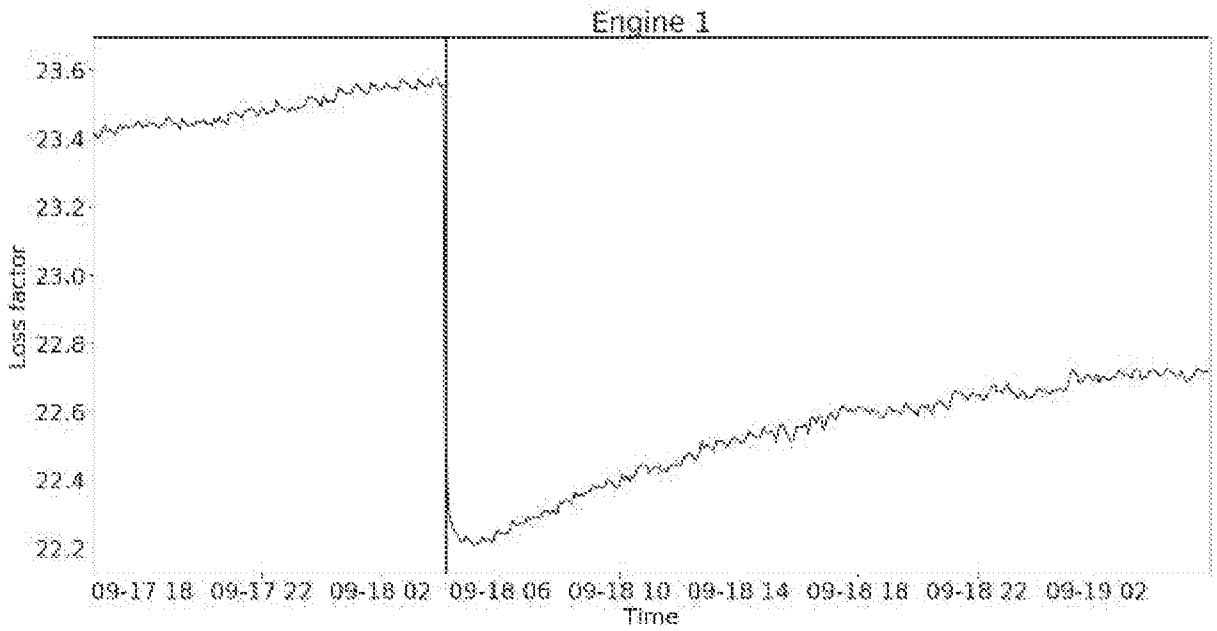

Engine 1
23.6
23.4
23.2
23.0
22.8
22.6
22.4
22.2
Loss factor
09-17 18
09-17 22
09-18 02
09-18 06
09-18 10
09-18 14
09-18 18
09-18 22
09-19 02
Time

Fig. 8

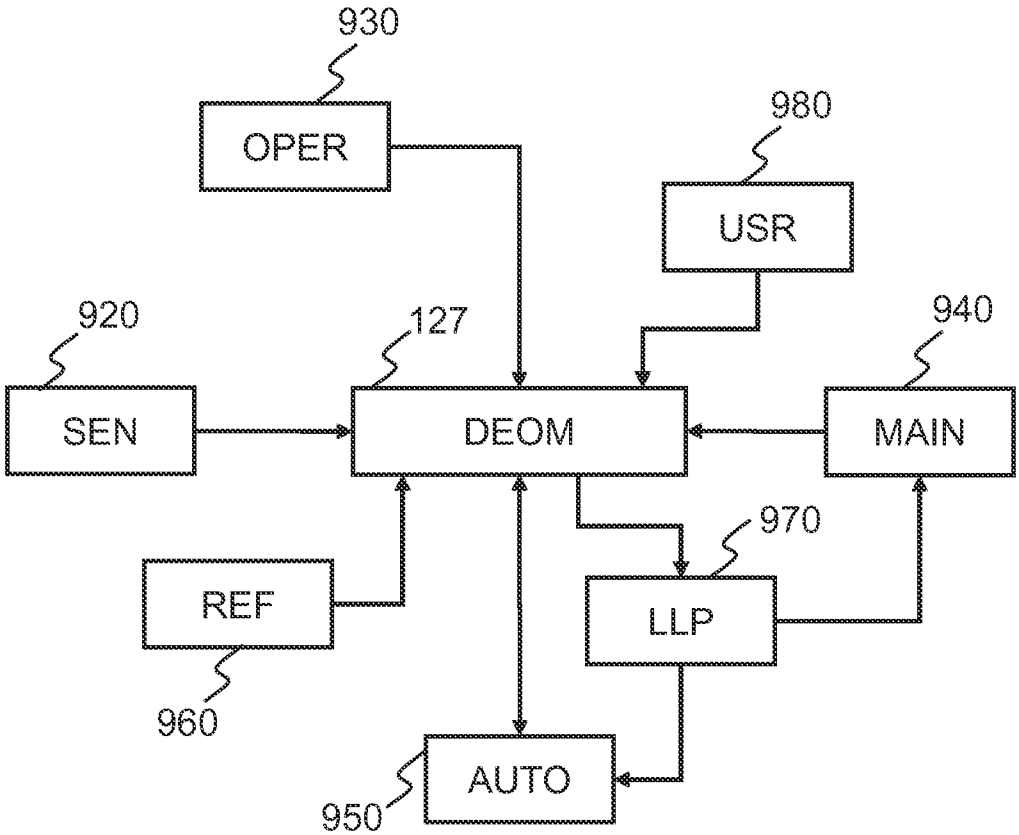

930
OPER
980
USR
920
127
940
SEN
DEOM
MAIN
970
REF
LLP
960
AUTO
950

Fig. 9

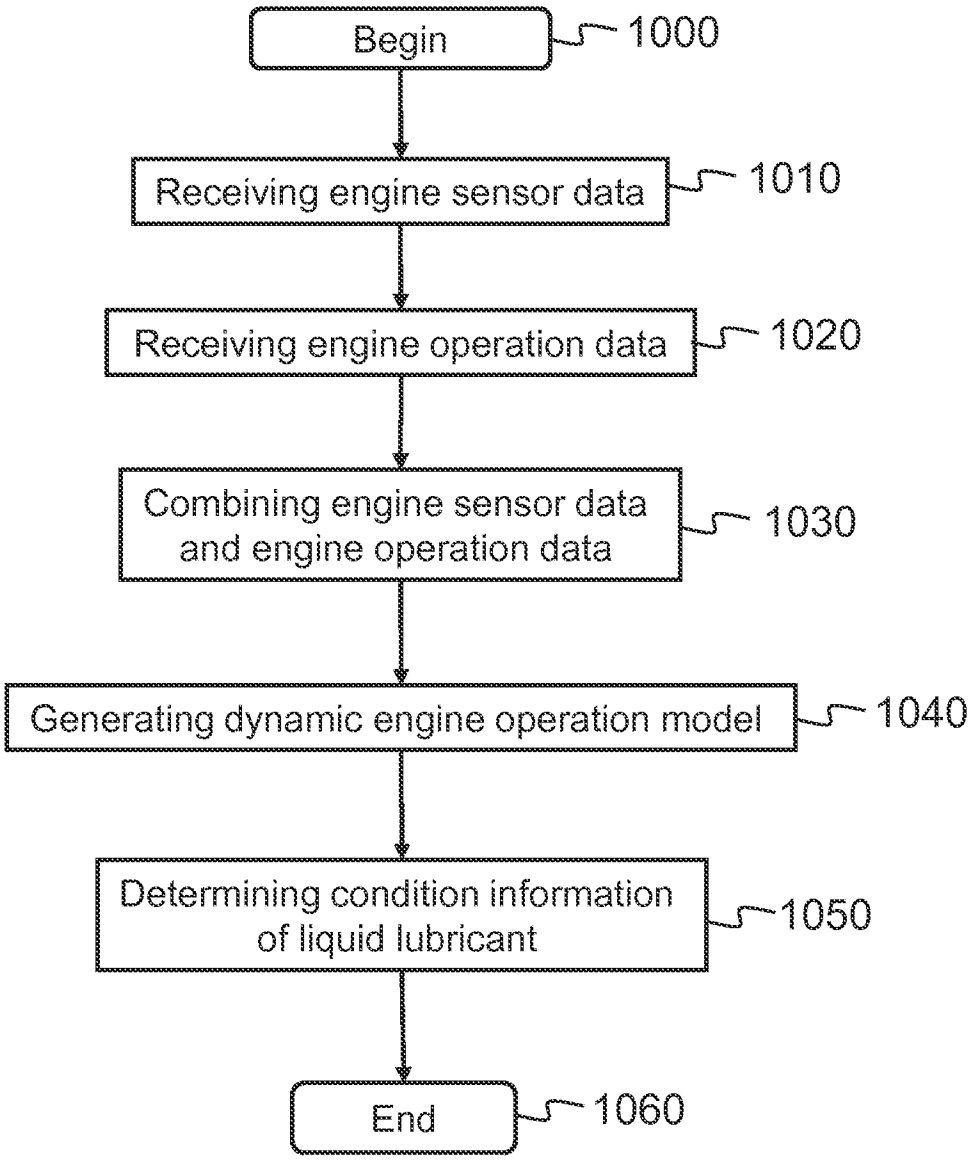

Begin
1000
Receiving engine sensor data
1010
Receiving engine operation data
1020
Combining engine sensor data and engine operation data
1030
Generating dynamic engine operation model
1040
Determining condition information of liquid lubricant
1050
End
1060

Fig. 10

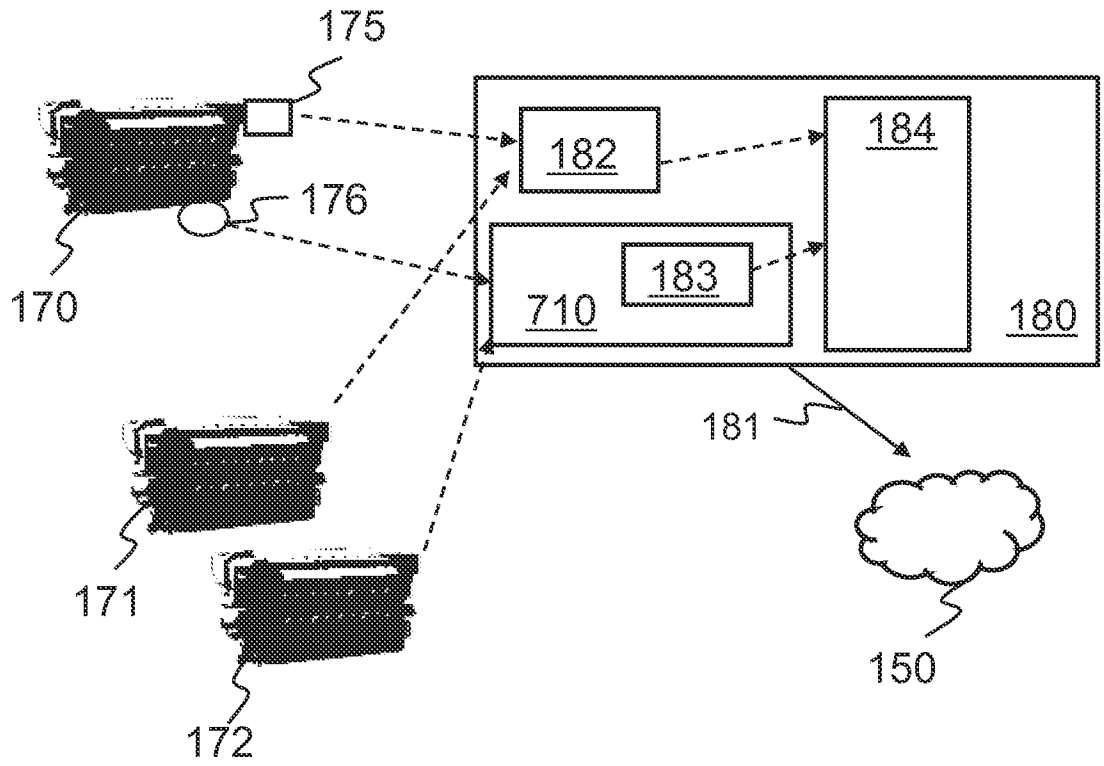

175
182
184
176
183
710
180
170
181
171
150
172

Fig. 11

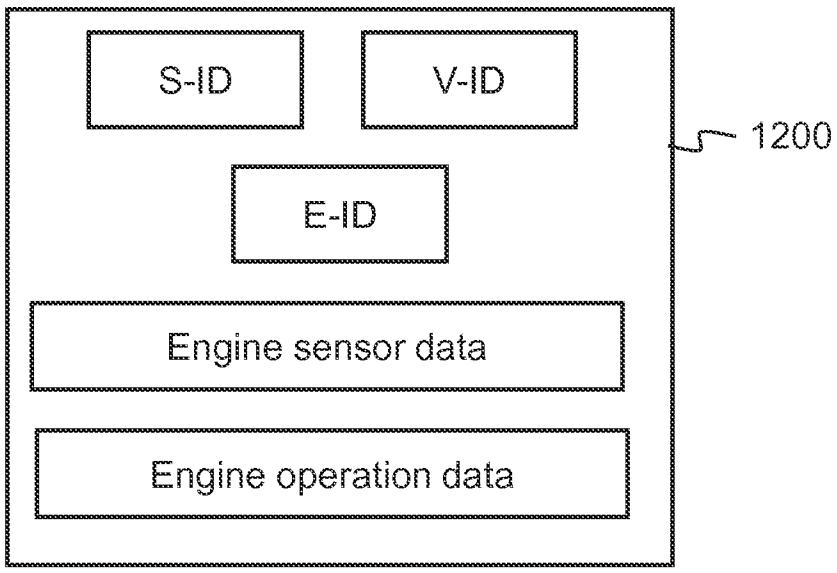

S-ID
V-ID
1200
E-ID
Engine sensor data
Engine operation data

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2019/050139

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01M11/10 F16N29/02 F16N29/04 G01N33/30 G07C5/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01M F16N G01N G07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2018/231518 A1 (VAIDYA ABHIJEET [US] ET AL) 16 August 2018 (2018-08-16) paragraphs [0019], [0022], [0030], [0038] - [0040]; figures 1-4 -----	1-12, 16-21, 35-37

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2019	06/11/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ducloyer, Stéphane

1

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INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2019/050139

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2010/250156 A1 (HALALAY ION C [US] ET AL) 30 September 2010 (2010-09-30) paragraphs [0006], [0017] - [0019], [0024], [0034] - [0035]; figures 1, 2	1-12, 15-17, 20,21, 35-37
X	US 2002/112529 A1 (BONDAROWICZ FRANK [US] ET AL) 22 August 2002 (2002-08-22) paragraphs [0012], [0023], [0026] - [0030], [0036], [0039], [0052], [0057], [0060]; figures 2-8	1-12, 15-17, 20,21, 35-37
A	US 2018/299375 A1 (YOUNG DUSTIN [US] ET AL) 18 October 2018 (2018-10-18) paragraphs [0103] - [0104], [0115] - [0116], [0175], [0179], [0201] - [0205]	18,23-34

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