OIL MONITORING SYSTEM AND METHOD FOR A MECHANICAL MACHINE

Cross Reference to Related Application(s)

The present disclosure claims the benefit of Singapore Patent Application No. 10202303519R filed on 14 December 2023, which is incorporated in its entirety by reference herein.

Technical Field

The present disclosure generally relates to an oil monitoring system and method for a mechanical machine such as a power transmission system. More particularly, the present disclosure describes various embodiments of an oil monitoring system and method for monitoring an oil in use within a mechanical machine such as a power transmission system like a gearbox or engine.

Background

Power transmission systems often have multiple moving parts working together to perform their intended functions. Lubricants are used in these systems to reduce friction between the moving parts and improve their performance and overall lifespan. Examples of power transmission systems include gearboxes and engines in vehicles that require gear oil and engine oil, respectively, for lubrication.

Gear oil is used to lubricate gears in a gearbox and to prevent metal-to-metal contact between teeth on the gears. This reduces friction between the moving gears and prevents overheating of the gearbox. The gears are designed to work in the gearbox in a specific arrangement to achieve the desired engagements between the gear teeth. Misalignment of the gears can result in the gear teeth not engaging in the way they were designed to, resulting in vibrations and excessive forces on some parts of the gear teeth. This would eventually lead to premature wear and failure of the gears. Abrasion such as radial scratch marks can appear in grooves or some other parts of the gears. This can happen from rough wear due to insufficient lubrication and

presence of foreign particles in the gear oil, such as metallic wear debris, rust, sand, or weld spatter. Presence of water or moisture in the gear oil can also damage the gear and bearing components and lead to corrosion.

In a vehicle engine, water may mix with the engine oil due to internal leakage and this can cause corrosion in the engine. Insufficient lubrication can cause wearing of internal parts of the engine which can result in undesirable transmission noise and overloading. Misalignment of the engine's crankshaft can result in overloading and create dents in the crankshaft, consequently leading to engine failure.

Thus, insufficient lubrication in the gearbox and engine of a vehicle can lead to mechanical issues that may delay the operation of the vehicle, reduce productivity, and increase maintenance costs.

Studies were conducted in a fleet of buses assigned to the same route for approximately 300,000 km over 30 months. The route chosen was the most severe for the fleet and included several long and steep grades on the road. The buses were inspected at the 50,000 km and 100,000 km milestones. At the 100,000 km inspection milestone, it was found that there was evidence of wear in some power transmission systems of the buses. Further, it was found that the quality of the oil used in the power transmission systems plays a major role in the failure of the power transmission systems such as the gearboxes and engines.

Monitoring of the oil quality can be part of the inspection protocol for the buses. However, this would require periodic extraction of oil samples of the buses at various distance milestones. This would be laborious and increase maintenance downtime of the buses, which would reduce operational efficiency of the bus fleet and is not economically feasible.

Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved an oil monitoring system and method for a mechanical machine such as a power transmission system.

Summary

According to a first aspect of the present disclosure, there is an oil monitoring system for monitoring an oil in use within a mechanical machine. The oil monitoring system comprises:

a fluidic device comprising:

a fluidic connector for coupling the fluidic device to an oil drain hole of the mechanical machine for extracting the oil from the mechanical machine;

an outlet for communicating the oil out from the fluidic device; and

an inlet for communicating the oil into the fluidic device;

a sensor assembly comprising a set of sensors configured for measuring a set of properties of the oil; and

a fluid flow device connectable to the fluidic device and the sensor assembly, the fluid flow device configured for:

communicating the oil from the outlet of the fluidic device to the sensor assembly for measuring the properties of the oil; and

returning the oil from the sensor assembly to the inlet of the fluidic device after measuring the properties of the oil,

wherein the fluid flow device and sensor assembly are configured to measure the properties of the oil in use within the mechanical machine while the mechanical machine is in use, the properties of the oil indicative of oil quality.

According to a second aspect of the present disclosure, there is a method for monitoring an oil in use within a mechanical machine. The method comprises:

extracting the oil from the mechanical machine using a fluidic device coupled to an oil drain hole of the mechanical machine;

communicating, using a fluid flow device, the oil from an outlet of the fluidic device to a sensor assembly comprising a set of sensors;

measuring, using the sensors, a set of properties of the oil in use within the mechanical machine while the mechanical machine is in use; and

returning the oil from the sensor assembly to an inlet of the fluidic device after measuring the properties of the oil, the properties of the oil indicative of oil quality.

An oil monitoring system and method for a mechanical machine according to the present disclosure are thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

FIG. 1 is an illustration of an oil monitoring system, according to embodiments of the present disclosure.

FIG. 2A to FIG. 2C are illustrations of the oil monitoring system in use in a power transmission system.

FIG. 3A and FIG. 3B are illustrations of a fluidic device of the oil monitoring system.

FIG. 4A and FIG. 4B are illustrations of the fluidic device in use in the power transmission system.

FIG. 5A and FIG. 5B are identification details of buses from which oil samples were collected for experiments.

FIG. 6A to FIG. 6E are illustrations of experimental results from tribological tests on the oil samples.

FIG. 7A and FIG. 7B are illustrations of experimental results for moisture content in the oil samples.

FIG. 8A and FIG. 8B are illustrations of experimental results for iron content in the oil samples.

FIG. 9A to FIG. 9D are illustrations of trends of oil quality of the oil used in the power transmission system over time.

FIG. 10 is an illustration of various oil conditions from different combinations of oil properties measured by the oil monitoring system.

FIG. 11A to FIG. 11D are illustrations of a trend analysis of oil quality of the oil used in a bus fleet over time.

FIG. 12 is a flowchart illustration of an oil monitoring method, according to embodiments of the present disclosure.

FIG. 13A and FIG. 13B are illustrations of a visual interface of a current health profile of the oil in use in the power transmission system.

Detailed Description

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to an oil monitoring system and method for a mechanical machine, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith.

References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment.

As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise indicated. The term “set” is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range. The terms “first”, “second”, etc. are used merely as labels or identifiers and are not intended to impose numerical requirements on their associated terms.

In representative or exemplary embodiments of the present disclosure, with reference to FIG. 1, there is an oil monitoring system 100 for monitoring an oil in use within a mechanical machine such as a power transmission system 200. For example, the power transmission system 200 includes a gearbox of an automotive vehicle such as a car, truck, or bus, wherein the oil includes a gear oil in use within the gearbox. For example, the power transmission system 200 includes an engine of the automotive vehicle, wherein the oil includes an engine oil in use within the engine.

As shown in FIG. 2A to FIG. 2C, the oil monitoring system 100 includes a fluidic device 110 connectable to an oil drain hole 210 of the power transmission system 200. Specifically, as shown in FIG. 3A and FIG. 3B, the fluidic device 110 includes a fluidic connector 112 for coupling the fluidic device 110 to the oil drain hole 210 for extracting the oil from the power transmission system 200. The fluidic device 110 includes an outlet 114 for communicating the oil out from the fluidic device 110. The fluidic device 110 includes an inlet 116 for communicating the oil into the fluidic device 110.

The power transmission system 200 includes the oil drain hole 210 that is normally plugged with a drain plug. The fluidic device 110 can replace the drain plug by coupling to the existing oil drain hole 210, whether it is the gear oil drain hole of the gearbox (as shown in FIG. 4A) or the engine oil drain hole of the engine (as shown in FIG. 4B). For example, the fluidic connector 112 includes threads that correspond to the threads of the oil drain hole 210 so that the fluidic device 110 can be threaded to the oil drain hole 210 to extract the oil from the power transmission system 200.

The oil drain hole 210 provides an accessible location for the fluidic device 110. For example in vehicles, locating the fluidic device 110 at the oil drain hole 210 minimizes interruption of the bus operation and maintenance, while still keeping the fluidic device 110 accessible so that it can be easily removed and replaced during scheduled maintenance of the vehicle. The oil drain holes 210 for gear oil and engine oil also have little exposure to water splash by rain or water wash during maintenance. Further, the oil drain hole 210 is an existing part of the vehicle so that the original structure of the vehicle does not need to be modified to accommodate the fluidic device 110. For example, there is no drilling of the vehicle chassis to install the fluidic device 110.

The oil monitoring system 100 includes a sensor assembly 120 comprising a set of sensors configured for measuring a set of properties of the oil. The oil monitoring system 100 includes a fluid flow device 130 connectable to the fluidic device 110 and the sensor assembly 120. The fluid flow device 130 is configured for communicating the oil from the outlet 114 of the fluidic device 110 to the sensor assembly 120 for measuring the properties of the oil, and returning the oil from the sensor assembly 120 to the inlet 116 of the fluidic device 110 after measuring the properties of the oil.

In one embodiment, the fluid flow device 130 includes a pump. Specifically, the pump converts electrical energy into hydraulic energy and uses mechanical action to move the oil with respect to the fluidic device 110. In another embodiment, the fluid flow device 130 relies on other fluid motion to move the oil. For example, the fluid flow device 130 may rely solely on or with the assistance of gravity to move the oil.

Further, the fluid flow device 130 and sensor assembly 120 are configured to measure the properties of the oil in use within the power transmission system 200 while the power transmission system 200 is in use, the properties of the oil indicative of oil quality. For example, when the vehicle is driven, the fluid flow device 130 moves a small amount of oil from the oil drain hole 210 into the fluidic device 110, and moves the oil from the fluidic device 110 to the sensor assembly 120 for measurements. After measurements by the sensor assembly 120, the fluid flow device 130 returns the oil back to the fluidic device 110. The oil monitoring system 100 is thus configured to continuously circulate and monitor the oil in a closed-loop manner, thus avoiding contamination of the oil. All the measurements can be done automatically by the sensor assembly 120 without human intervention, thus obviating the need to extract oil samples from the vehicle for external measurements which would be more laborious and increase the downtime of the vehicle.

The oil monitoring system 100 may further include tubes 140 that fluidically connect the fluidic device 110, sensor assembly 120, and fluid flow device 130 together for circulation of the oil. As the oil can reach temperatures of above 90 °C, the tubes 140 should be made of a suitable material that can withstand high temperatures. For

example, the tubes 140 are made of polyurethane. Further, the tubes 140 may be protected with a fire-resistant E-glass sleeve to insulate the tubes 140 from heat emitted from the power transmission system 200 especially the engine.

The fluidic device 110 is preferably made of mild steel or aluminium. In some embodiments, the oil monitoring system 100 includes an external cover to protect the fluidic device 110 and the areas around the oil drain hole 210 from accumulation of dust and debris when the vehicle is driven. For example, the external cover includes a sheet metal such as mild steel or aluminium.

The power transmission system 200 can fail from various causes including overheating, abrasive wear, and corrosion of internal components. In particular, these failure modes can result from degradation of the oil used in the power transmission system 200. This can be due to oxidation, increase in moisture level in the oil, change in acidity of the oil, increase in the wear debris due to abrasive wear in the moving parts resulting in particle contamination. For example, soot may form in the engine as a by-product of diesel combustion. The sensor assembly 120 includes one or more sensors configured for measuring one or more properties of the oil to evaluate the oil quality.

Various experiments were conducted on samples of gear oil and engine oil extracted from a fleet of buses at various distance milestones to determine suitable properties or parameters for evaluating the oil quality. 8 samples of used gear oil and 1 sample of fresh gear oil, as well as 12 samples of used engine oil and 1 sample of fresh engine oil, were collected from the buses to perform the experiments in a laboratory to evaluate the deterioration of oil quality. FIG. 5A shows identification details of the buses from which the gear oil samples were collected. FIG. 5B shows the identification details of the buses from which the engine oil samples were collected.

The oil samples were tribologically evaluated using the pin on disk test to determine the friction and wear characteristics based on the ASTM G99 standard. The tribological testing conditions for the gear oil samples are shown in FIG. 6A. FIG. 6B and FIG. 6C show the average wear volume of the gear oil samples and engine oil

samples, respectively. FIG. 6D and FIG. 6E show the friction characteristics of the gear oil samples and engine oil samples, respectively.

The wear volume shows how the power transmission system 200 can get damaged while using degraded oil. It was found that the used oil samples showed higher wear volume compared to the fresh oil samples. The wear volume of the fresh gear oil was 0.126 mm^3 and the wear volume of the used gear oil ranged from 0.138 mm^3 to 0.144 mm^3, i.e. an increase of about 12.5%. The wear volume of the fresh engine oil was 0.126 mm^3 and the wear volume of the used engine oil ranged from 0.117 mm^3 to 0.144 mm^3, i.e. an increase of about 18.75%.

One failure mode of the power transmission system 200 is degradation of oil quality due to increase in moisture level. Moisture is derived from ambient air humidity slowly interacting with the oil over time. For example, moisture in engine oil can cause serious engine issues including loss of power and oil sludging. In one experiment, moisture was artificially introduced into the oil samples to test the oil quality with different moisture content conditions. Specifically, moisture was added into samples of fresh oil at different weight percentage, such as 0.1% and 0.2% weight of the oil. FIG. 7A shows the oil quality results for gear oil samples with increasing moisture content. FIG. 7B shows the oil quality results for engine oil samples with increasing moisture content. It was found that the oil quality decreases with increasing moisture content. Thus, the sensor assembly 120 may include a moisture sensor for measuring moisture content in the oil.

One failure mode of the power transmission system 200 is degradation of oil quality due to contamination by iron or ferrous particles. In one experiment, ferrous microparticles were artificially introduced into the oil samples to test the oil quality with different iron content conditions. Specifically, ferrous microparticles were added into samples of fresh oil at different ppm concentrations, such as from 5 to 25 parts per million. FIG. 8A shows the oil quality results for gear oil samples with increasing iron content. FIG. 8B shows the oil quality results for engine oil samples with increasing iron content. It was found that the oil quality decreases with increasing iron content. It was also observed in a scanning electron microscope that there was higher wear

depth on the gear surfaces, which showed that the addition of iron particles increased the wear volume of the gear oil. Thus, the sensor assembly 120 may include a particle sensor for measuring ferrous content in the oil.

Temperature of the oil is another property that can be measured. When gear surfaces slide against each other under high load, high pressure and temperatures can develop at the load-carrying asperities, promoting severe wear. When gear operation generates higher-than-normal operating temperatures, mineral-based gear oil can break down and lose some of its lubricating capability. This deterioration can cause the gear oil to separate into its constituent organic parts, including carbon, hydrogen, and oxygen in various chemical combinations. Thus, the sensor assembly 120 may include a temperature sensor for measuring temperature of the oil, such as to monitor any abnormal increase in temperature.

The oil monitoring systems 100 were installed on the respective power transmission systems 200 of the buses, including the gearboxes and engines, and the sensors measure various properties of the oil to determine the oil quality while the buses were driven. An oil quality index can be determined based on the measured properties. For example, the oil quality index decreases with respect to increasing moisture and ferrous content in the oil, i.e. the oil has degraded.

Samples of the oil were extracted from the bus fleet at regular intervals and these oil samples were evaluated in the laboratory. It was found that the moisture sensor is 90% to 94% sensitive to change in moisture, the particle sensor is 77.8% to 92% sensitive to change in ferrous content in the engine and 80% to 85% sensitive to change in ferrous content in the gearbox, and the temperature sensor is 97% sensitive to change in temperature.

FIG. 9A shows the comparison between the gear oil deterioration and oil quality index evaluated in the laboratory and evaluated in real-time by the sensors. FIG. 9B shows the comparison between the engine oil deterioration and oil quality index measured in the laboratory and measured in real-time by the sensors. For the engine oil, the average oil quality index for fresh oil was 8.458 with a standard deviation of ±0.008,

and for used oil was 3.974 with a standard deviation of ±0.037. The laboratory results show a 20.5% deterioration while the sensor results show a 21% deterioration. These results show that the sensors of the oil monitoring system 100 can provide accurate results for repeatable measurements to evaluate the oil quality in real-time while the bus is driven. In particular, the evaluation accuracy of the sensors ranges from 85% to 94%.

Samples of the oil were also extracted from a bus at regular intervals over an operational period of 900 hours and these oil samples were evaluated in the laboratory. FIG. 9C shows the trend of the gear oil quality index over 900 hours. FIG. 9D shows the trend of the engine oil quality index over 900 hours. It can be seen that the oil quality index gradually decreases over time, which can happen because the oil gradually accumulates moisture and iron particles, and possibly soot in the engine oil, over time.

Based on the trend of the oil quality index, alarm limits can be set to trigger maintenance alerts when the oil quality index reaches certain levels. This would allow the maintenance team to perform preventive maintenance at appropriate times while the bus is still operational, instead of breakdown maintenance when the bus is no longer operational. As shown in FIG. 10, the alarm limits may depend in different combinations of oil properties such as moisture content, iron content, and temperature. The alarm limits may also depend on other factors such as distance travelled and environmental parameters, which may include vibrations and noises from the power transmission system 200. For example, iron content in the oil may indicate that the oil is foamy. For example, higher oil temperature may indicate that the oil viscosity has dropped. For example, iron content and long distance travelled may indicate wear. For example, moisture content in the oil and certain environment parameters may indicate oxidation.

The trend analysis was expanded to the bus fleet over 900 hours. The mean oil quality index and crest factor was calculated over this duration. FIG. 11A and FIG. 11B show the results for gear oil. FIG. 11C and FIG. 11D show the results for engine oil. Even

after 900 hours of bus operation, the gear oil quality index and engine oil quality index were lower but still above the alarm limits.

Gaussian distributions of the oil quality indices were determined based on the mean and standard deviation. It was found that the sensitivity of the oil monitoring system 100 to detect gearbox failure was about 81.9% and the false positive rate was about 18.1%. Similarly, it was found that the sensitivity of the oil monitoring system 100 to detect engine failure was about 99.9% and the false positive rate was about 0.1%.

Various embodiments of the present disclosure also describe a method 300 for monitoring an oil in use within a mechanical machine such as a power transmission system 200, as shown in FIG. 12. The method 300 includes a step 302 of extracting the oil from the power transmission system 200 using a fluidic device 110 coupled to an oil drain hole 210 of the power transmission system 200. The method 300 includes a step 304 of communicating, using a fluid flow device 130, the oil from an outlet 114 of the fluidic device 110 to a sensor assembly 120 comprising a set of sensors. The method 300 includes a step 306 of measuring, using the sensors, a set of properties of the oil in use within the power transmission system 200 while the power transmission system 200 is in use, the properties of the oil indicative of oil quality. The method 300 includes a step 308 of returning the oil from the sensor assembly 120 to an inlet 116 of the fluidic device 110 after measuring the properties of the oil. Accordingly, the properties and quality of the oil, such as the gear oil or engine oil, can be continuously monitored while the power transmission system 200 is in use, such as while a vehicle is driven, and the oil continues to be re-circulated within the power transmission system 200.

In some embodiments, the method 300 includes a step of communicating measurement data of the measured properties of the oil from the oil monitoring system 100 to a remote server. The method 300 may further include a step of processing, using a computer processor of the remote server, the measurement data to determine a current health profile of the oil. For example, the health profile includes an oil quality index calculated based on the measured properties of the oil.

The remote server is communicative with the oil monitoring system 100 across a communication network. The remote server may be based on a centralized model, decentralized model, or hybrid model. As used herein, a server is a physical or cloud data processing system on which a server program runs. The server may be implemented in hardware or software, or a combination thereof. Some non-limiting examples of the server include computers, laptops, mini-computers, mainframe computers, any non-transient and tangible machines that can execute a machine-readable code, cloud-based servers, distributed server networks, and a network of computers.

The communication network is a medium or environment through which content, notifications, and/or messages are communicated among various components. Some non-limiting examples of the communication network include a virtual private network (VPN), wireless fidelity (Wi-Fi) network, light fidelity (Li-Fi) network, local area network (LAN), wide area network (WAN), metropolitan area network (MAN), satellite network, Internet, fiber optic network, coaxial cable network, infrared (IR) network, radio frequency (RF) network, and any combination thereof. Various components in the communication network may connect to it in accordance with various wired and wireless communication protocols, such as Transmission Control Protocol / Internet Protocol (TCP/IP), User Datagram Protocol (UDP), 2nd to 5th Generation (2G to 5G) communication protocols, Long Term Evolution (LTE) communication protocols, and any combination thereof. Each component to the communication network includes a data communication or transceiver module to communicate and transmit / receive data over the communication network. Some non-limiting examples of a transceiver module include an antenna module, a radio frequency transceiver module, a wireless transceiver module, a Bluetooth transceiver module, an Ethernet port, a Universal Serial Bus (USB) port, or any other module / component / device configured for transmitting and receiving data.

The remote server may include a display device for presenting a visual interface of the current health profile of the oil. FIG. 13A and FIG. 13B show exemplary visual interfaces of the gear oil and engine oil, respectively. The current health profile may provide information such as current oil quality index relative to the alarm limits, the

degradation rate of the oil, and the remaining useful life of the oil before it needs to be changed, i.e. preventive maintenance. For example, the current health profile comprises an expected maintenance schedule for the power transmission system 200.

In some embodiments, the computer processor is configured to process the measurement data using a machine learning model, such as to extract patterns, make predictions, and gain insights from the measurement data as well as the oil quality trends. In one embodiment, a machine learning model is used for time series analysis of the measurement data of the oil properties measured over a time duration. For example, the machine learning model includes ARIMA, STL, RNN, LSTM, or GRU.

The machine learning model is trained using pre-obtained measurement data of the oil. The measurement data may be split into a training dataset and a validation dataset, wherein the machine learning model is trained using the training dataset and its hyperparameters are fine-tuned using the validation dataset. The trained machine learning model is used to make predictions and forecasts for future time points, such as when the vehicle is expected to fail due to oil degradation. Information derived from the machine learning model is presented on the visual interface to convey the information to stakeholders or decision makers. The machine learning model may be continuously monitored, updated, and re-trained with new measurement data, such as from a bus fleet over regular bus operations.

The oil monitoring system 100 and method 300 provides for real-time monitoring of oil used in power transmission systems 200, such as gear oil in gearboxes and engine oil in engines of automotive vehicles. For example in a bus fleet, all the buses can be monitored remotely by the remote server for their oil quality to provide a comprehensive overview of the bus fleet operational performance. Real-time monitoring allows for the early detection of potential issues within power transmission systems 200 like the gearbox or engine. For example, abnormal temperature increases or unusual vibration patterns can signal the onset of problems like bearing wear or lubrication issues. Through continuous monitoring and data analysis such as using machine learning, predictive maintenance models can predict when components of the power transmission systems 200 are likely to fail. This helps in scheduling

preventive maintenance proactively, reducing operational downtime, preventing costly breakdowns, and minimizing repair costs. Real-time monitoring also contributes to safety by reducing the chances of unexpected failures while the buses are in operation. This can help prevent accidents and injuries associated with transmission system failures.

Therefore, the oil monitoring system 100 and method 300 described herein can improve performance, reliability, and cost-effectiveness of power transmission systems 200, particularly for a bus operator with a large fleet of buses. Real-time monitoring of the oil quality ensures that the gearboxes and engines in the buses are working within reasonable operational and safety limits. Labour and maintenance costs would be reduced in the long run. There is also lower risk of vehicle downtime or unwanted stoppages, which would inconvenience passengers and affect the commercial revenue of the bus operator. Moreover, collective oil monitoring results of the bus fleet can provide valuable information and insights to the bus operator and relevant stakeholders, such as investors, to make business decisions such as on future improvements of the bus systems.

In the foregoing detailed description, embodiments of the present disclosure in relation to an oil monitoring system and method for a mechanical machine, particularly a power transmission system, are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. For example, although embodiments of the present disclosure describe the oil monitoring system and method for use in power transmission systems in automotive applications such as engines and gearboxes, the oil monitoring system and method can also be applied to other mechanical machines in other applications, such as marine gearboxes and wind turbine gearboxes. More generally, the oil monitoring system and method can be used in various mechanical machines that require lubrication of moving parts.

The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present

disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

Claims

1. An oil monitoring system for monitoring an oil in use within a mechanical machine, the oil monitoring system comprising:

a fluidic device comprising:

a fluidic connector for coupling the fluidic device to an oil drain hole of the mechanical machine for extracting the oil from the mechanical machine;

an outlet for communicating the oil out from the fluidic device; and

an inlet for communicating the oil into the fluidic device;

a sensor assembly comprising a set of sensors configured for measuring a set of properties of the oil; and

a fluid flow device connectable to the fluidic device and the sensor assembly, the fluid flow device configured for:

communicating the oil from the outlet of the fluidic device to the sensor assembly for measuring the properties of the oil; and

returning the oil from the sensor assembly to the inlet of the fluidic device after measuring the properties of the oil,

wherein the fluid flow device and sensor assembly are configured to measure the properties of the oil in use within the mechanical machine while the mechanical machine is in use, the properties of the oil indicative of oil quality.

2. The oil monitoring system according to claim 1, wherein the mechanical machine comprises a power transmission system including a gearbox of an automotive vehicle, and wherein the oil comprises a gear oil in use within the gearbox.

3. The oil monitoring system according to claim 1, wherein the mechanical machine comprises a power transmission system including an engine of an automotive vehicle, and wherein the oil comprises an engine oil in use within the engine.

4. The oil monitoring system according to any one of claims 1 to 3, wherein the sensors comprise a moisture sensor for measuring moisture content in the oil.

5. The oil monitoring system according to any one of claims 1 to 4, wherein the sensors comprise a particle sensor for measuring ferrous content in the oil.

6. The oil monitoring system according to any one of claims 1 to 5, wherein the sensors comprise a temperature sensor for measuring temperature of the oil.

7. The oil monitoring system according to any one of claims 1 to 6, wherein the fluid flow device comprises a pump.

8. A method for monitoring an oil in use within a mechanical machine, the method comprising:

extracting the oil from the mechanical machine using a fluidic device coupled to an oil drain hole of the mechanical machine;

communicating, using a fluid flow device, the oil from an outlet of the fluidic device to a sensor assembly comprising a set of sensors;

measuring, using the sensors, a set of properties of the oil in use within the mechanical machine while the mechanical machine is in use, the properties of the oil indicative of oil quality; and

returning the oil from the sensor assembly to an inlet of the fluidic device after measuring the properties of the oil.

9. The method according to claim 8, further comprising communicating measurement data of the measured properties of the oil to a remote server.

10. The method according to claim 9, further comprising processing, using a computer processor of the remote server, the measurement data to determine a current health profile of the oil.

11. The method according to claim 10, wherein the computer processor is configured to process the measurement data using a machine learning model.

12. The method according to claim 10 or 11, wherein the current health profile comprises an expected maintenance schedule for the mechanical machine.

13. The method according to any one of claims 10 to 12, further comprising presenting, by the remote server, a visual interface of the current health profile of the oil.

14. The method according to any one of claims 8 to 13, wherein the mechanical machine comprises a power transmission system including a gearbox of an automotive vehicle, and wherein the oil comprises a gear oil in use within the gearbox.

15. The method according to any one of claims 8 to 13, wherein the mechanical machine comprises a power transmission system including an engine of an automotive vehicle, and wherein the oil comprises an engine oil in use within the engine.

16. The method according to any one of claims 8 to 15, wherein measuring the properties of the oil comprises measuring moisture content in the oil.

17. The method according to any one of claims 8 to 16, wherein measuring the properties of the oil comprises measuring ferrous content in the oil.

18. The method according to any one of claims 8 to 17, wherein measuring the properties of the oil comprises measuring temperature of the oil.