(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 828 394 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.06.2021 Bulletin 2021/22

(51) Int Cl.:
F01M 1/02 *(2006.01)* ***F01M 5/00*** *(2006.01)*

(21) Application number: **20209600.4**

(22) Date of filing: **24.11.2020**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
KH MA MD TN

(30) Priority: **26.11.2019 IT 201900022197**

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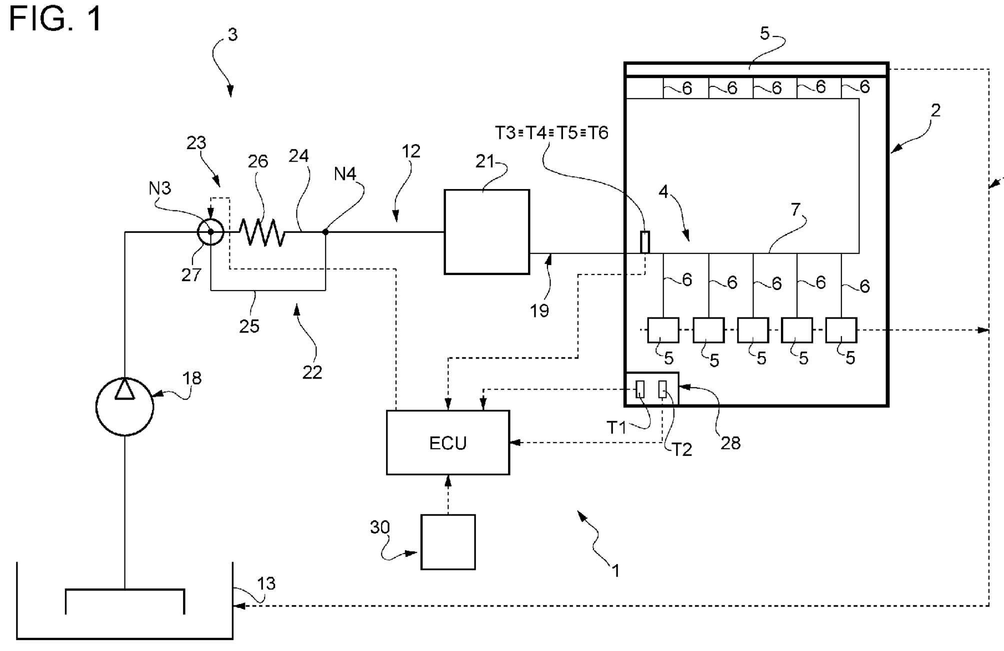
(54) AN ENGINE ASSEMBLY HAVING AN ENGINE AND A LUBRICATION SYSTEM FOR DELIVERING LUBRICATING OIL TO THE ENGINE

(57) An engine assembly (1) is provided with an engine (2) and with a lubrication system (3) for circulating oil from/to the engine (2) and including an oil circuit (12) and an oil conditioning apparatus (23, 21) for allowing temperature conditioning of the circulating oil, wherein the engine assembly further include a sensor assembly (28) for detecting values associated to operative parameters of the engine (2), as well as for generating a first signal associated to the detected values, and a control unit (ECU) that receives the first signal and extract a first amount of information therefrom relative to values of the operative parameters, wherein the oil conditioning apparatus (23) includes also an adjustment device (27) that is controllable to cause a temperature variation of a portion of the circulating oil, and wherein the control unit (ECU) controls the adjustment device (27) based on the extracted first amount of information.

FIG. 1



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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Patent Application claims priority from Italian Patent Application No. 102019000022197 filed on November 26, 2019.

TECHNICAL FIELD

[0002] The present invention concerns an engine assembly having an engine and a lubrication system for delivering lubricating oil to the engine.

BACKGROUND OF THE INVENTION

[0003] An operating engine is normally supplied with lubricating oil to reduce friction between the moving parts of the engine and to cool other parts.

[0004] The lubricating oil is delivered to the engine through a lubrication system including an oil circuit that carries out a continuous recirculation of the delivered lubricating oil.

[0005] In some cases, the oil circuit includes a heat-exchanging path, in which at least a partial quantity of the lubricating oil taken from the engine flows and transfers heat to a secondary cooling medium.

[0006] In those cases, the oil circuit includes also a bypass path that allows the remaining quantity of the recirculated lubricating oil to bypass the heat-exchanging path.

[0007] The amount of lubricating oil flowing through the heat-exchanging path is determined by a thermostat, which admits the passage of an oil flow based on the temperature of the lubricating oil taken from the engine.

[0008] More precisely, the thermostat starts admitting the oil flow to the heat-exchanging path when the temperature above overcomes a fixed threshold, which is peculiar of the thermostat. Once the threshold is overcome, the admitted oil flow increases with the temperature.

[0009] In this manner, during the startup phase of the engine, all the lubricating oil recirculated through the oil circuit bypasses the heat-exchanging path and heats up by getting heat from the operating engine.

[0010] After the end of the startup phase, the temperature of the lubricating oil delivered to the engine is maintained within a limited range thanks to the operation of the thermostat.

[0011] Indeed, the thermostat causes a portion of the recirculated lubricating oil to be cooled along the heat-exchanging path, wherein the portion increases with increasing temperature of the lubricating oil upstream of the thermostat.

[0012] The temperatures of the limited range, which essentially depend on the threshold of the thermostat, are chosen sufficiently high to minimize the friction within the engine.

[0013] For higher temperatures, drawbacks related to oil ageing and wear of the engine parts may occur, especially at heavy load conditions on the engine.

[0014] In the above framework, the need is felt to improve lubrication of known engines in order to reduce oil ageing and wear of the engine parts while maintaining at least comparable lubrication performances in terms of friction reduction.

[0015] An aim of the present invention is to satisfy the above-mentioned need.

SUMMARY OF THE INVENTION

[0016] The aforementioned aim is reached by an engine assembly and by an associated lubrication method as claimed in the appended set of claims. In particular, dependent claims set out specific embodiments of the invention.

BRIEF DESCRIPTION OF DRAWINGS

[0017] For a better understanding of the present invention, preferred embodiments are disclosed in the following, by way of non-limiting examples and with reference to the attached drawings wherein:

- Figure 1 is a scheme representing an engine assembly, according to the invention, with a lubrication system and an engine supplied with lubricating oil by means of the lubrication system;
- Figure 2 is a chart representing a mapping between a desired reference temperature for the supplied lubricating oil and the operating condition of the engine; and
- Figure 3 is a block diagram showing a possible operating logic of the lubrication system of Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

[0018] With reference to figure 1, reference numeral 1 indicates, as a whole, an engine assembly installed on a not shown vehicle and comprising an engine 2 and a lubrication system 3 for delivering lubricating oil to the engine 2 during the operation thereof.

[0019] More precisely, the lubrication system 3 is configured to allow the circulation of the lubricating oil from and to the engine, such that some of the lubricating oil delivered to the engine 2 could be heated by heat generated by the engine 2 itself during operation.

[0020] With greater detail, the engine 2 comprises an oil delivering apparatus 4 (schematically shown in Figure 1), coupled to the lubrication system 3 to receive lubricating oil therefrom and configured to deliver the received lubricating oil to a plurality of well-known and schematically shown members 5 of the engine 2, which are subject to friction during the operation thereof.

[0021] For instance, members 5 may include piston rings, cylinder liners, piston skirts, bearings, a cylinder head, cranktrain components, etcetera. Other not shown members, such as the pistons in particular, are in thermal contact with the lubricating oil in order to transfer heat thereto and, therefore, to be cooled by the same lubricating oil.

[0022] Preferably, the oil delivering apparatus 4 has the same construction and operation of other known apparatus installed on vehicles already present in the market.

[0023] Specifically, the oil delivering apparatus 4 comprises a plurality of known-kind delivering devices 6, e.g. tubes or nozzles, respectively arranged to deliver lubricating oil to members 5, as well as it comprises an oil gallery 7, i.e. a plurality of ducts obtained in the engine 2 and arranged to supply the lubricating oil to the delivering devices 6.

[0024] In order to collect the lubricating oil delivered to members 5, the engine assembly 1 comprises an oil collecting apparatus 8, which more precisely includes a known-kind oil reservoir or oil pan 13. The collecting apparatus 8 has preferably the same construction and operation of other known apparatus installed on vehicles. With details, the collecting apparatus 8 is configured such that the lubricating oil delivered to members 5 drips therefrom down to the oil reservoir 13. For example, the collecting apparatus 8 may include ducts that convey the lubricating oil dripped from members 5 toward the oil reservoir 13.

[0025] The lubrication system 3 comprises an oil circuit 12 coupled to the oil delivering apparatus 4 and the oil collecting apparatus 8 in order to circulate the lubricating oil from the oil collecting apparatus 8 to the oil delivering apparatus 4.

[0026] In other words, from the collecting apparatus 8, the oil circuit 12 receives lubricating oil heated by members 5 during the operation of the engine 2. Then, the oil circuit 12 supplies at least a portion of the received lubricating oil to the oil delivering apparatus 4.

[0027] The oil reservoir 13 makes part of the oil circuit 12 and has the function of storing a lubricating oil reserve and a remaining portion of the received lubricating oil that is not redirected to the engine 2.

[0028] The oil circuit 12 comprises a pumping apparatus 18 (schematically illustrated in Figure 1), which is connected to the oil reservoir 13 to draw oil therefrom and supply the drawn oil to the engine 2. For instance, the pumping apparatus 18 may comprise a variable geometry pump. As another example, the pumping apparatus 18 may comprise a fixed geometry pump and a relief valve to redirect some of the pumped lubricating oil to the oil reservoir 13, such that the output pressure and flowrate of the lubricating oil directed to the engine 2 may be controlled.

[0029] The oil circuit 12 has a delivering section 19, which is arranged between the pumping apparatus 18 and the oil gallery 7, and in which the lubricating oil pumped by the pumping apparatus 18 flows toward the engine 2, in particular toward the oil gallery 7.

[0030] Preferably, the delivering section 19 is provided with an oil filter 21 configured to remove contaminants from the oil flow supplied to the engine 2.

[0031] The delivering section 19 includes an oil conditioning subsection 22, in particular arranged upstream of the oil filter 21, according to the flowing direction of the lubricating oil toward the engine 2.

[0032] Hereinafter, expressions like "upstream of" and "downstream of" shall be intended with reference to the aforementioned flowing direction.

[0033] The oil conditioning subsection 22 is provided with an oil conditioning apparatus 23, which is configured to allow conditioning, namely for increasing or decreasing the temperature of the oil flow supplied to the engine 2.

[0034] With specific reference to figure 1, the oil conditioning subsection 22 includes two circuit branches 24, 25, which split from a first common circuit node N3 and rejoin at a second common circuit node N4, downstream of the first common circuit node N3.

[0035] Still with reference to figure 1, the oil conditioning apparatus 23 comprises a heat exchanger 26 arranged on the circuit branch 24. The heat exchanger 26 is adapted to cause a heat transfer between the lubricating oil flowing through the circuit branch 24 and a heat transfer medium, e.g. an engine coolant for extracting heat from the lubricating oil.

[0036] At the first common circuit node N3, the oil conditioning apparatus 23 comprises an adjustment device 27 that is controllable to variate the respective flowrates of the lubricating oil through the circuit branches 24, 25.

[0037] For instance, the adjustment device 27 may comprise a wax thermostatic element arranged to obstruct the circuit branch 24 in an adjustable manner, and an associated electrical resistance for providing heat to the same element. In such a case, the flow rate admitted through the circuit branch 24, and thus through the circuit branch 25 consequently, would depend on the amount of heat generated by the electrical resistance, which is adjustable by providing more or less electric current to the latter.

[0038] Alternatively or additionally, the adjustment device 27 may comprise a controllable electrical thermostat or a control valve arranged to obstruct the circuit branch 24 in an adjustable manner.

[0039] Possibly, the adjustment device 27 may even comprise a three-way control valve exactly arranged at the first common circuit node N3.

[0040] In order to control the conditioning apparatus 23, the engine assembly 1 comprises a control unit ECU connected to the conditioning apparatus 23 itself.

[0041] Advantageously, control unit ECU controls the conditioning apparatus 23 based on an actual operating condition of the engine 2.

[0042] More precisely, the actual operating condition of the engine 2 is defined by at least one operative parameter associated to the operation of the engine 2.

[0043] The at least one operative parameter is preferably intended as a parameter indicative of the operating load to which the engine 2 is subject to.

[0044] Specifically, the actual operating condition of the engine 2 is defined by a first and a second operative parameter that are, in particular, respectively indicative of an actual output torque, and an actual output speed of the engine 2. Evidently, the actual output torque is indicative of the operating load on engine 2.

[0045] Alternatively, the operating condition of the engine 2 may be defined by the first parameter and many other operative parameters, possibly indicative of the operating load on engine 2, and in addition to or in replacement of the second operative parameter. An example of a further operating parameter suitable for defining the operating condition of the engine 2 is a parameter indicative of the operative mean temperature of the engine 2.

[0046] Moreover, the engine assembly 1 comprises a sensor assembly 28 connected to the engine 2 and arranged to detect values of one or more quantities associated to the actual operating condition of the engine 2, i.e. to the operative parameters defining the latter.

[0047] As it will become explicit hereinafter, examples of such quantities may be the output torque of the engine 2, the output speed of the engine 2, the temperature of the lubricating oil, the viscosity of the lubricating oil, the flow rate of the lubricating oil, and the like.

[0048] The sensor assembly 28 is further connected to the control unit ECU for supplying the latter with signals respectively generated according to the detected values. The control unit ECU determines a first amount of information from the received signals and controls the conditioning apparatus 23 according to such first amount of information, i.e. according to the actual operating condition of the engine 2.

[0049] In particular, the sensor assembly 28 comprises a first transducer T1 coupled to the engine 2 and arranged to detect values of a first quantity associated to the first operative parameter, i.e. indicative of the load to which the engine 2 is subjected, e.g. indicative of the output torque of the engine 2. Additionally but not necessarily, the sensor assembly 28 further comprises a second transducer T2 coupled to the engine 2 and arranged to detect values of a second quantity associated to the second operative parameter, i.e. indicative of the output speed of the engine 2.

[0050] Transducers T1, T2, are coupled to the control unit ECU and configured to generate respective signals associated to the detected values of the first and the second quantity to be supplied to the control unit ECU.

[0051] Based on the determined first amount of information from the received signals, the control unit ECU determines a desired or reference temperature of the oil flow supplied to the engine 2, in particular at a checkpoint, more in particular belonging to the oil gallery 7.

[0052] Accordingly, the control unit ECU controls the conditioning apparatus 23 in order that the desired temperature is approximately reached by the oil flow at that checkpoint.

[0053] In such a manner, the actual temperature of the oil flow is advantageously linked to the actual operating condition of the engine 2.

[0054] Specifically, the control unit ECU implements a feedback control of the temperature of the oil flow supplied to the engine 2. In support to this, the engine assembly 1 comprises a transducer T3 for detecting values of a third quantity indicative of the temperature of the oil flow; the transducer T3 is coupled to the mentioned checkpoint, so as to monitor the third quantity at the same checkpoint.

[0055] The transducer T3 generates a signal associated to the detected values of the third quantity and supplies the signal to the control unit ECU, which determines a second amount of information corresponding to the actual temperature of the oil flow at the checkpoint.

[0056] Preferably, the engine assembly 1 further comprises another transducer T4 for detecting values of a fourth quantity indicative of the pressure of the oil flow; the transducer T4 is in particular coupled to the same checkpoint to which the transducer T3 is coupled, so that the fourth quantity is monitored at the checkpoint by transducer T4.

[0057] In addition, the engine assembly 1 optionally comprises also a transducer T5 for detecting values of a fifth quantity indicative of the viscosity of the lubricating oil; the transducer T5 is in particular coupled to the same checkpoint to which the transducer T3 is coupled.

[0058] Furthermore, the engine assembly 1 optionally comprises a flow rate sensor T6 for detecting values of a sixth quantity indicative of the flow rate associated to the oil flow; the sensor T6 is in particular coupled to the same checkpoint to which the transducer T3 is coupled.

[0059] Moreover, the engine assembly 1 optionally comprises a body computer (not shown) configured to acquire the chemical characteristics of the lubricating oil, for instance the multigrade designation or other information related to signs attributed to the lubricating oil. For instance, examples of body computers with the just disclosed function are disclosed in Italian patent application IT201800002757.

[0060] The control unit ECU compares the second amount of information with a third amount of information, which is associated to the determined desired temperature, and processes the result of the comparison as usual under the common feedback control theory, e.g. under a PID control law.

[0061] In particular, the control unit ECU controls the adjustment device 27, specifically as a function of the result of the comparison above mentioned.

[0062] For example, the adjustment device 27 is commanded by the control unit ECU such that the flow rate through the circuit branch 24 is related to the difference between the desired temperature and the corresponding temperature of the oil flow.

[0063] The greater is the flow rate the lower is the resulting temperature of oil flow supplied to the engine 2.

[0064] According to a first embodiment, the desired temperature is determined by means of a mapping stored in the control unit ECU, wherein the mapping defines a relationship between the operating condition of the engine 2 and the desired temperature.

[0065] An exemplary representation of such mapping is shown in figure 2, in which a plurality of curves 50 of the first quantity as a function of the second quantity is illustrated in a 2D chart. The curves in figure 2 define a plurality of areas 70 that are each associated to a predetermined temperature value. Therefore, an operating condition of the engine 2, which is represented by two values of the first and the second quantity respectively, maps into a temperature value.

[0066] With the mapping of figure 2, during the operation of the engine 2, the control unit ECU determines instant by instant the desired temperature as a value corresponding to values instantly detected by or inferred from transducers T1, T2.

[0067] Preferably, the mapping is obtained on experimental basis, e.g. by using a dynamometer during calibration of the engine 2.

[0068] Conveniently, the temperature values may be chosen to decrease with the decreasing of the load on the engine 2, at the same level of output speed.

[0069] In this manner, the higher the load on the engine 2 the lower is the temperature of the lubricating oil delivered to the engine 2. This is beneficial because at high loads and high temperatures on engine 2, the latter and the delivered lubricating oil respectively suffer wear and oil ageing or degradation, whereas friction decrease is not significant as when loads and temperatures on engine 2 are low. A good balance between friction decrease and engine wear/oil ageing is reached, therefore.

[0070] Similarly, at output speeds near to the minimum and the maximum speed (MIN and MAX in Figure 2), the friction variation is more sensitive whereby the temperature of the lubricating oil is increased.

[0071] According to an advantageous variant of the first embodiment, instead of determining instant by instant the desired temperature, the control unit ECU determines the desired temperature for each of a sequence of intervals of time, for example having respective fixed durations.

[0072] The fixed duration is chosen based on the ability of the lubricating oil to reach stationary temperature conditions. In other words, the fixed duration is chosen according to the assumed rapidity of the lubricating oil in absorbing heat or in being cooled down through the heat exchanger 26, such that the desired temperature is reachable well before the end of the same fixed duration. In particular, a feasible fixed duration of each interval may be defined between 10 seconds and 600 seconds, preferably about 60 seconds. The duration may depend on a predicted path of the vehicle or on a mission that the vehicle has to carry out. If the vehicle is expected to cruise on a flat road, then the duration can be reduced; else, it should be increased.

[0073] For instance, the control unit ECU may impose that an instantly determined desired temperature applies for an entire interval of time including the instant of determination of the desired temperature.

[0074] More conveniently, in view of instantaneous values detected by the sensor assembly 28, the control unit ECU may predict the operating conditions of the engine 2 for a whole interval of time including the instant of detection of the instantaneous values.

[0075] For the latter purpose, the engine assembly 1 further comprises a further sensor assembly 30 for acquiring data that allow path prediction of the vehicle in which the engine assembly 1 is installed. The sensor assembly 30 is connected to the control unit ECU to supply the acquired data thereto.

[0076] Known path prediction algorithms have been developed in the art and are made available for actual implementation in control units. Each of these known algorithms necessitates of a peculiar set of starting data for carrying out the prediction.

[0077] Just for the sake of clarity, without any loss of generality, an example of result of a path prediction algorithm is a predicted path expressed in terms of trajectory of one or more points of the vehicle, possibly plus one or more angles representative of the orientation of the vehicle. In turn, a trajectory of a point may be expressed in terms of accelerations, velocities, and displacements, both in a 3D or a 2D framework.

[0078] The control unit ECU implements at least one of these well-known algorithms; accordingly, the sensor assembly 30 includes sensors suitable for providing the control unit ECU with the necessary set of starting data for carrying out the path prediction through the implemented algorithm.

[0079] More precisely, such sensors are configured to detect values of a set of quantities, which are indicative, as a whole, of the position and orientation of the vehicle, as well as of the conditions of the roads traveled by the vehicle.

[0080] For the sake of clarity, the conditions of the roads may include their grade, curvature, surface state, traffic conditions, and etcetera.

[0081] In particular, the sensor assembly 30 includes one or more sensors in the group of global positioning sensors (GPS), sensors for odometry like a steering angle sensor or a wheel speed sensor, radar sensors, and vision sensors such as cameras, lidars, 3D scanners and the like.

[0082] Moreover, the control unit ECU stores or has access to one or more geographical maps of the areas in which the vehicle is assumed to operate. Information associated to the geographical maps and to the data acquired by the sensor assembly 30 are collected together by control unit ECU for the path prediction.

[0083] Control unit ECU preferably performs the path prediction at the starting of each interval of time, such that a plurality of connected paths of the vehicle is predicted in respective association to the whole durations of the corresponding intervals of time.

[0084] Furthermore, the control unit ECU is configured to estimate the operating conditions of the engine 2 associated to each interval of time. The estimation is preferably performed at the starting of each interval of time, based on the predicted path and the signals provided by the sensor assembly 28.

[0085] Again, estimation algorithms for this purpose have been developed in the art and are made available for actual implementation in control units; the control unit ECU implements at least one of these well-known algorithms.

[0086] The estimated operating conditions within an interval of time are used by the control unit ECU to determine a representative or mean operating condition of the interval of time, which actually enters into the mapping for the determination of the desired temperature.

[0087] Specifically, the mean operating condition is defined by a weighted mean of the estimated operating conditions within the interval of time, wherein the weights are preferably higher for earlier operating conditions within the interval.

[0088] In particular, thanks to the implemented estimation algorithm, the control unit ECU estimates a plurality of values of the first quantity and a plurality of values of the second quantity in association to a plurality of instants within the interval of time. Then, the control unit ECU applies a set of stored weights, specifically decreasing with time, to compute the weighted means of the estimated values of the first quantity and the second quantity, respectively.

[0089] The weighted means define representative values of the trends of the operative parameters within the interval of time. Then, the control unit ECU uses the weighted means as entries into the mapping, for instance the one shown in figure 2, to determine the desired temperature associated to the interval of time.

[0090] According to a second embodiment, the desired temperature is determined as a result of a model-based optimization process carried out by control unit ECU.

[0091] For this purpose, control unit ECU stores one or more mathematical models, which are singularly or globally indicative of friction losses within the engine 2 during the operation thereof and of at least one between an engine wear and a lubricating oil degradation during the same operation.

[0092] Each stored mathematical model includes one or more functions of a set of operative parameters of the engine assembly 1.

[0093] Such set of operative parameters includes at least an operating temperature of the lubricating oil and the above-mentioned first operating parameter, which contributes in defining the operating conditions of the engine 2.

[0094] Possibly, the operative parameters include also a parameter associated to the fourth quantity measured by transducer T4. Similarly, the operative parameters optionally include at least one parameter associated to the fifth quantity or the sixth quantity.

[0095] Preferably, the functions of the mathematical models are based on the chemical characteristics of the lubricating oil acquired by the aforementioned body computer.

[0096] Based on the mathematical models, the control unit ECU is configured to determine the desired temperature as the operating temperature of the lubricating oil leading to a desired operating state or condition of the engine 2, according to which a certain balance is reached between friction losses and preferably at least one between engine wear and lubricating oil degradation.

[0097] In fact, as previously outlined, while friction losses decrease with increasing operating temperatures of the lubricating oil, the engine wear and the lubricating oil degradation worsen. In particular, as the operating temperature rises, the friction losses decrease less and less, whereas engine wear and lubricating oil degradation grows significantly.

[0098] Therefore, a not improvable balance is obtained when a slight increase of the operating temperature of the lubricating oil would provoke a significant increase of the engine wear and a negligible decrease of the friction losses.

[0099] Preferably, the desired temperature is determined for each of a series of intervals of time having a fixed duration, for instance as disclosed for the first embodiment.

[0100] The actual operating conditions of the engine 2, which serve to the control unit ECU as inputs to search for the operating temperature leading to the desired state, are estimated by the control unit ECU itself by means of the estimation and path prediction algorithms described above in association to the first embodiment.

[0101] Given the mathematical models and the inputs, well-known algorithms can be retrieved in the literature for identifying the values of a parameter of the models, i.e. the operating temperature of the lubricating oil, such that a mathematical condition involving other parameters of the models, i.e. the reaching of the desired state of the engine 2, is satisfied. The control unit ECU implements at least one of these well-known algorithms.

[0102] Specifically, the mentioned other parameters are operative parameters of the engine 2 indicative of the friction losses and of at least one between the engine wear and the oil degradation.

[0103] The mathematical models, which link the operating temperature of the lubricating oil and the operating condition of the engine 2 to the friction losses, engine wear, and/or lubricating oil degradation, are preferably found experimentally, in particular through suitable test benches, in order to enable an adaptation according to the materials used on engine 2, e.g. for the coatings on the bearings and piston rings.

[0104] The significant influence of the operating temperature of the lubricating oil and of the operating conditions of the engine 2 on friction losses, as well as on engine wear and/or lubricating oil degradation, is well known in the art. For example, the publication entitled "Optimizing Base Oil Viscosity Temperature Dependence For Power Cylinder Friction Reduction" by M. J. Plumley et. al., published at SAE 2014 World Congress & Exhibition on 04/01/2014, provides a review of mathematical models linking the lubricating oil temperature to viscosity and thus to friction losses, engine wear and lubricating oil degradation.

[0105] With greater detail, in order to determine the desired temperature for a whole interval of time, the control unit ECU is configured to solve an optimal control problem based on the minimization of a cost function, which is associated to the same interval of time and based on the stored mathematical models.

[0106] The cost function may be stored in the control unit ECU and takes into account friction losses within the engine 2, as well as at least one of the engine wear and the lubricating oil deterioration, as a function of the operating temperature of the lubricating oil, which represents the optimization variable.

[0107] Therefore, the desired state of the engine 2 corresponds to the state caused by the optimized operating temperature of the lubricating oil, to which a global minimum of the cost function corresponds.

[0108] More precisely, the cost function comprises the weighted sum of a first term increasing with friction losses and of a second term increasing with one of the engine wear and the lubricating oil degradation. Conveniently, the cost function comprises the weighted sum of the first term, the second term, and a third term increasing with the other one of the engine wear and the lubricating oil degradation.

[0109] As a mere example, the first term may include the reciprocals of friction coefficients respectively associated to members 5 and/or the global energy loss due to friction, and/or the viscosity of the lubricating oil.

[0110] Similarly, the second and the third term may respectively include, for instance, wear peak factors respectively associated to members 5 and an amount of lubricating oil vaporization.

[0111] As an alternative to the weighted sum, the cost function could have comprised a nonlinear combination of the first term, the second term, and optionally the third term.

[0112] For the sake of intelligibility, Figure 3 summarizes the operation of the disclosed second embodiment.

[0113] During the route of the vehicle, at the starting instant of an interval of time, the control unit ECU (block 101) receives the data acquired by the sensor assembly 30 and accordingly proceeds with the path prediction for the whole interval of time.

[0114] Given the predicted path, the control unit ECU (block 102) also estimates the operative parameters that define the operating condition of the engine 2 for the whole interval of time.

[0115] The control unit ECU (blocks 103, 104, 105) computes the first, the second, and the third term as a function of the yet unknown desired temperature, using the estimated operative parameters as inputs.

[0116] The first, the second, and the third term (block 106), as a function of the unknown desired temperature, are weighted within the cost function.

[0117] Then, control unit ECU (block 107) determines the desired temperature that minimizes the cost function within the interval of time.

[0118] Hence, control unit ECU uses the determined desired temperature as a reference to control the adjusting device 27, in particular in a closed-loop fashion as already disclosed in detail earlier in the description.

[0119] In view of the foregoing, the advantages of the engine assembly 1 and of the associated lubrication method, according to the invention, are apparent.

[0120] Thanks to the relationship between the temperature of the lubricating oil delivered to engine 2 and the operating conditions thereof, a fuel consumption reduction during vehicle cruising (e.g. on a flat highway) can be gained through friction reduction due to a lubricating oil temperature increase. At the same time, penalties due to wear or oil ageing can be avoided through a lubricating oil temperature decrease when engine 2 operates at high load conditions (e.g. uphill).

[0121] This is not possible with known engine assemblies, because the regulation of the lubricating oil temperature is configured a-priori, without considering the actual operating conditions of the engine. In particular, with known engine assemblies, the lubricating oil temperature is maintained generally at a fixed target temperature, which is not appropriate to maximize a fuel consumption potential gain and to prevent unjustified wear and oil ageing phenomena that occur when the engine operates at high load conditions.

[0122] The adjusting device 27 enables on-road selection of the operating temperature of the lubricating oil delivered to the engine. This selection can occur with continuity and in a stable manner, thanks to the feedback control law implemented within the control unit ECU.

[0123] The model-based approach of the second embodiment allows an optimal and precise determination of the desired lubricating oil temperature, based on the operating conditions measured real-time. The cost function may be flexibly constructed, based on the actual special needs of the adopted vehicle or engine.

[0124] Finally, it is clear that modifications can be made to the described engine assembly 1, which do not extend beyond the scope of protection defined by the claims.

[0125] For example, the structure of the lubrication system 3 may be completely different from that actually disclosed and illustrated. In particular, the oil conditioning subsection 22 could just include the circuit branch 24 only.

[0126] The oil conditioning apparatus 23 may include only electrical heating or cooling devices, instead of the heat exchanger 26.

[0127] Moreover, the sensor assembly 28 may have various arrangements and even the transducer T3 may be differently arranged. For example, the transducer T3 may be coupled to the oil delivering section 19, such that the temperature of the lubricating oil may be controlled at a checkpoint of the oil delivering section 19.

[0128] Finally, the wording "a set of" is to be interpreted with the meaning of "at least one". Therefore, a set of operative parameters could include just one operative parameter or more.

Claims

1. An engine assembly (1) comprising an engine (2) and a lubrication system (3) configured for allowing circulation of lubricating oil from and to the engine (2), wherein the lubrication system (3) comprises an oil circuit (12) and oil conditioning means (23), which are coupled to the oil circuit (12) and configured to allow temperature conditioning of the lubricating oil; the engine assembly (1) further comprising:

   - a sensor assembly (28) configured to detect values associated to operative parameters of the engine (2), and to generate a first signal associated to the detected values; and
   - a control unit (ECU) coupled to the sensor assembly (28), for receiving the first signal and determining a first amount of information therefrom relative to first values of said operative parameters;

   characterized in that:

   - the oil conditioning means (23) comprise at least one adjustment device (27) being controllable to cause the occurrence of a temperature variation of at least a portion of the circulating lubricating oil; and
   - the control unit (ECU) is configured to control the adjustment device (27) based on the determined first amount of information.

2. The engine assembly (1) of claim 1, wherein the oil circuit (12) comprises an oil conditioning section (22) with a first branch (24) for allowing the passage of a first flow of the circulating lubricating oil and a second branch (25) for allowing a second flow of the circulating lubricating oil bypassing the first branch (24); wherein the oil conditioning means (23) further comprises a heat exchanger (26) coupled to the first branch (24) and configured to allow a heat transfer between the first flow and a heat transfer medium;
   the adjustment device (27) being coupled to the oil conditioning section (22) and being controllable to adjust the flow rate of the first flow, so as to define said portion of the circulating lubricating oil subject to said temperature variation.

3. The engine assembly (1) of claim 1 or 2, wherein the sensor assembly (28) comprises a first transducer (T1) configured to detect values associated to a first operative parameter of said operative parameters and indicative of an operating load acting on the engine (2).

4. The engine assembly (1) of claim 3, wherein the sensor assembly (28) further comprises a second transducer (T2) configured to detect values associated to a second operative parameter of said operative parameters and indicative of an output speed of the engine (2).

5. The engine assembly (1) of any one of the foregoing claims, wherein the control unit (ECU) is configured to:

   - determine a desired temperature of the circulating lubricating oil for at least one point of said oil circuit (12) or of said engine (2) and based on said first amount of information; and
   - control the adjustment device (27), such that the circulating lubricating oil reaches at said point a temperature approaching the determined desired temperature.

6. The engine assembly (1) of claim 5, further comprising a third transducer (T3) configured to detect values indicative of the temperature of the circulating lubricating oil, and to generate at least a third signal associated to the detected values by the third transducer;
   the control unit (ECU) being connected to the third transducer (T3), so as to receive the third signal and to determine a third amount of information therefrom relative to said temperature, and being configured to control the adjustment device (27) in closed loop with the determined desired temperature as a setpoint and the third amount of information as a feedback;
   wherein said point is placed downstream of said oil conditioning section (22), according to a flowing direction of the circulating lubricating oil toward the engine (2).

7. The engine assembly (1) of claim 5 or 6, wherein the control unit (ECU) stores a mapping function, which maps second values of said operative parameters to temperature values;

8. The engine assembly (1) of claim 7, wherein the control unit ECU is configured to determine the desired temperature through said mapping function as one of said temperature values corresponding to the first values of said operative parameters, based on said first amount of information.

9. The engine assembly (1) of claim 7, wherein the control unit ECU is configured to:

- predict, for an entire interval of time, the path of a vehicle provided with the same engine assembly (1);
- estimate trends of said operative parameters within said interval of time based on the predicted path and said first amount of information;
- compute third values of said operative parameters, which are representative of the estimated trends; and
- determine the desired temperature for said interval of time through said mapping as one of said temperature values corresponding to the third values of said operative parameters.

10. The engine assembly (1) of claim 5 or 6, wherein the control unit ECU is configured to determine the desired temperature as a further temperature value or as a function of time, which satisfies a predetermined mathematical condition, and in view of said first amount of information;
the mathematical condition being based on one or more mathematical models, which set at least a first model parameter and a second model parameter as respective functions of an operative temperature of the circulating lubricating oil at said point and of said operative parameters;
wherein the first model parameter is indicative of an energy loss due to friction, and wherein the second model parameter is indicative of a wear associated to the engine (2) and/or of a degradation of the lubricating oil.

11. The engine assembly (1) of claim 10, wherein the satisfaction of the mathematical condition corresponds to the minimization of a cost function of said operative temperature and said operative parameters; wherein the cost function:

- includes at least the first and the second model parameter as penalizing factors;
- is stored within the control unit (ECU); and
- is associated to an interval of time;

the control unit (ECU) being configured to:

- predict, for said interval of time, the path of a vehicle provided with the same engine assembly (1);
- estimate trends of said operative parameters within said interval of time based on the predicted path and said first amount of information; and
- determining the desired temperature as the function of time minimizing the cost function according to the estimated trends.

12. A lubrication method for lubricating an engine (2) by means of a lubrication system (3) configured to allow circulation of lubricating oil from and to the engine (2), wherein the lubrication system (3) comprises an oil circuit (12) for directing the circulating lubricating oil to the engine (2) and oil conditioning means (23), which are coupled to the oil circuit (12) and configured to allow temperature conditioning of the circulating lubricating oil;
and wherein the oil conditioning means (23) comprise at least one adjustment device (27) being controllable to cause the occurrence of a temperature variation of at least a portion of the circulating lubricating oil;
the method comprising:

- detecting values associated to operative parameters of the engine (2) by means of a sensor assembly (28);
- determining a first amount of information in association to the detected values, the information being relative to first values of said operative parameters; and
- controlling the adjustment device (27) based on the determined first amount of information.

13. The lubrication method of claim 12, further comprising:

- determining a desired temperature of the circulating lubricating oil for at least one point of said oil circuit (12) or of said engine (2) and based on said first amount of information;

wherein the adjustment device (27) is controlled such that the circulating lubricating oil reaches at said point a temperature approaching the determined desired temperature.

14. The lubrication method of claim 13, further comprising:

- providing a mapping function, which maps second values of said operative parameters to temperature values;

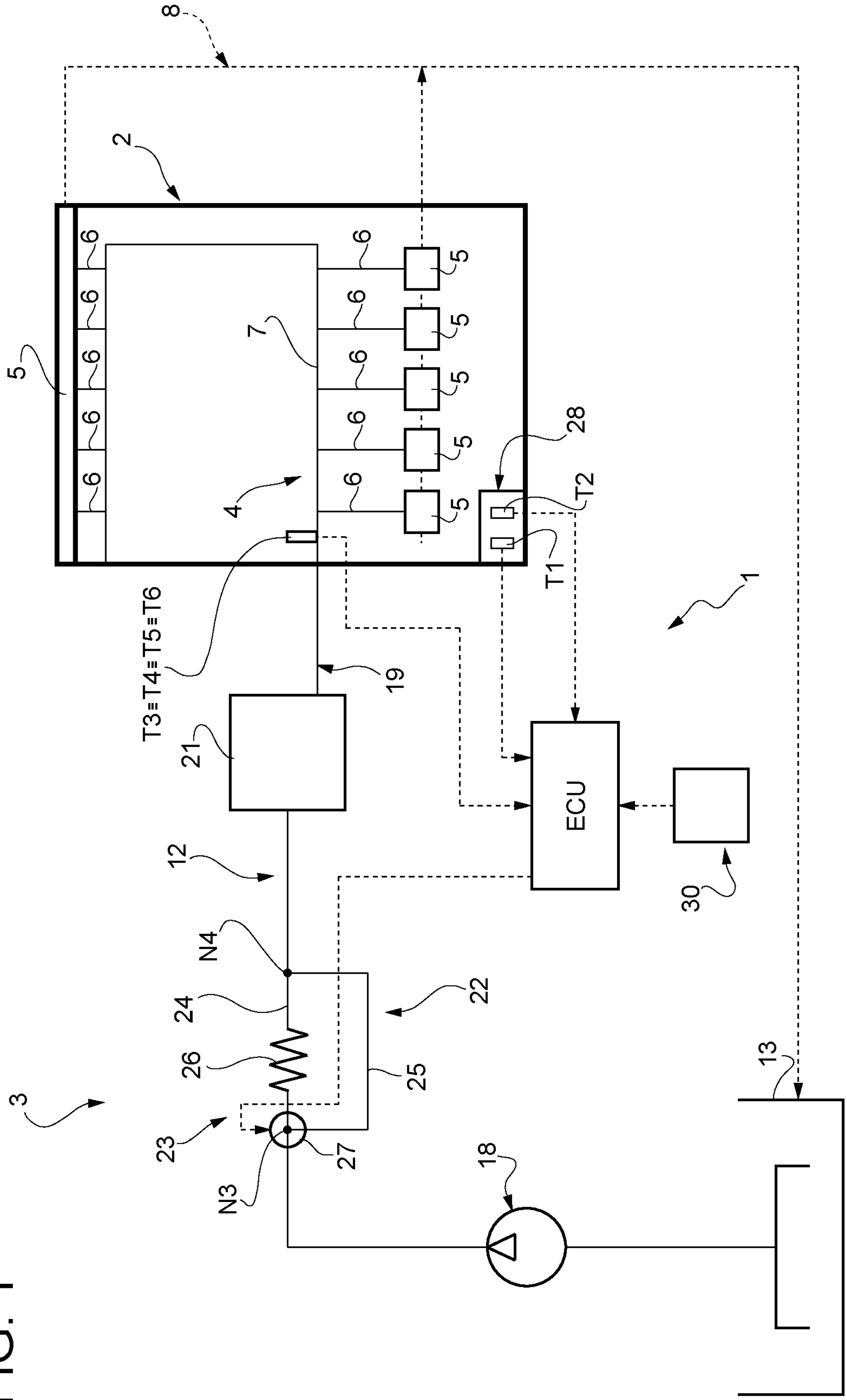
wherein the desired temperature is determined through said mapping function as one of said temperature values corresponding to the first values of said operative parameters, based on said first amount of information.

15. The lubrication method of claim 13, further comprising:

- providing a mathematical condition based on one or more mathematical models, which set at least a first model parameter and a second model parameter as respective functions of an operative temperature of the circulating lubricating oil at said point and of said operative parameters;

wherein the desired temperature is determined in view of said first amount of information as a further temperature value or as a function of time, which satisfies the mathematical condition; and
wherein the first model parameter is indicative of an energy loss due to friction, and wherein the second model parameter is indicative of a wear associated to the engine (2) or of a degradation of the lubricating oil.

FIG. 1


ECU
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N4
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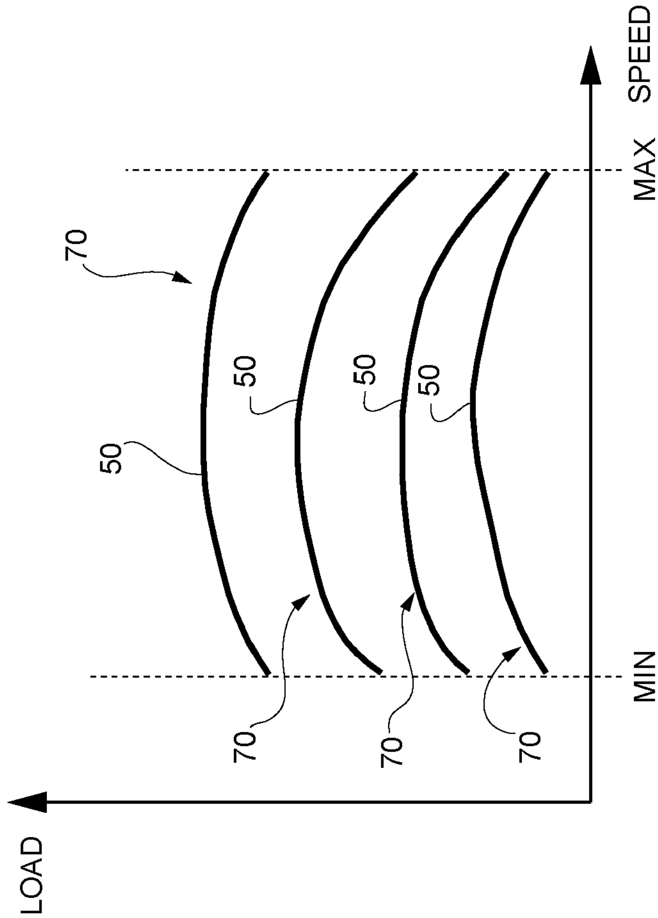
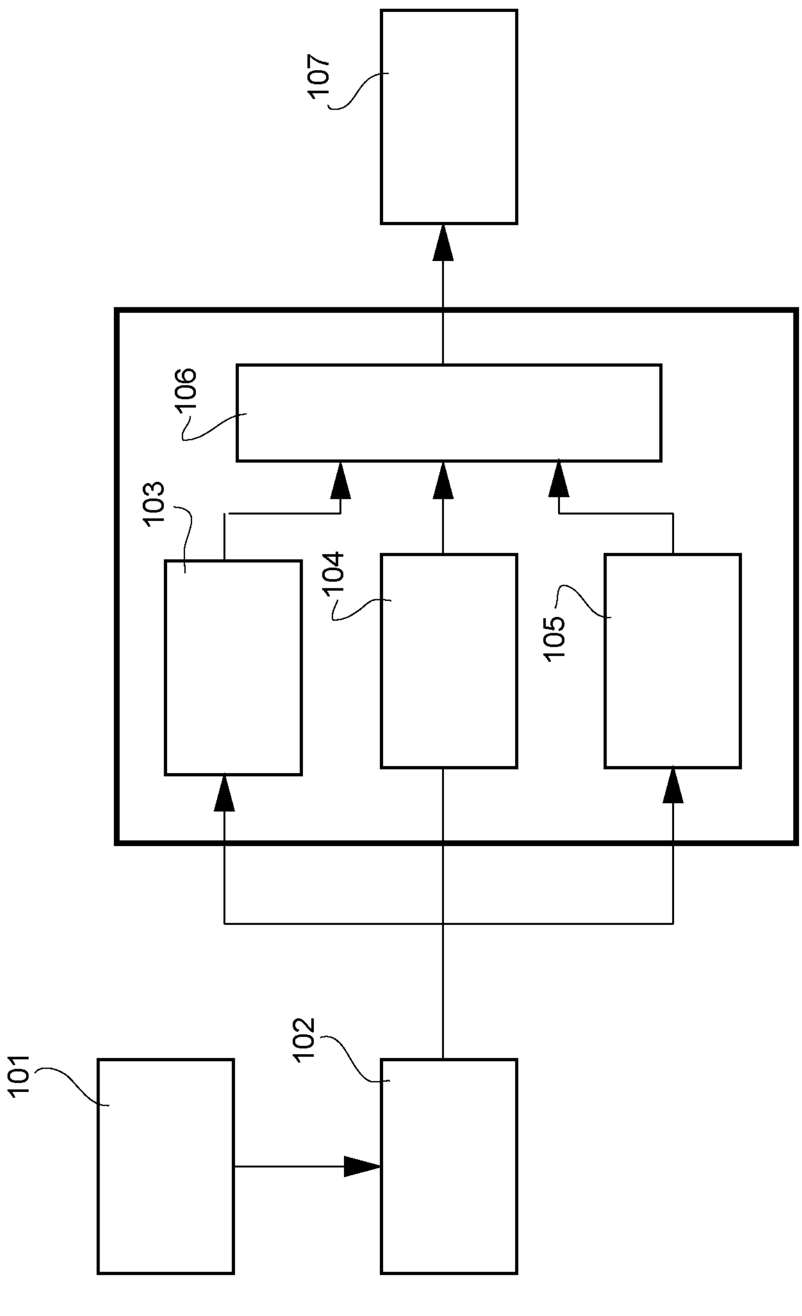


FIG. 2

FIG. 3



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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
The Hague	13 April 2021	Rini, Pietro

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