Abstract Title: Cooling system comprising heat exchangers for motor vehicle cold start operation

A cooling system extracts heat from an exhaust gas heat exchanger 4 for the purpose of assisting heating of transmission and engine oils during cold start operation. This arrangement facilitates rapid warm up of lubricants which leads to better fuel economy. Under normal operating conditions, the exhaust gas heat exchanger is closed off under the control of a control module 21 which also controls an electric pump 1 and valve arrangement 15, 9, 11 in order to optimise performance of this system. The system also comprises a cabin heater matrix 5, a transmission oil heat exchanger 7, an engine oil heat exchanger 8 and temperature sensors 17-20.
Cooling Systems for Motor Vehicles

This invention relates to cooling systems for motor vehicles.

Vehicle Manufacturers are under pressure to improve the fuel consumption and emissions figures produced by standard drive cycle tests of their vehicles. Drive cycle tests, such as the new European drive cycle (NEDC) start with the engine and transmission cold. Most journeys start with a cold engine and fuel consumption and exhaust emissions are worse for a cold powertrain than when it is at normal operating temperatures. From a cold start, the engine metal, coolant, engine oil and transmission oil and exhaust treatment systems take a significant amount of time to warm up. These components are consequently not operating at their optimum temperatures for a significant portion of the drive cycle and this has a detrimental effect on fuel economy and emissions.

During cold start or early warm-up operation, the engine will not require any cooling and in order to reach maximum fuel efficiency in the shortest possible time, it would be advantageous to provide a means for heating lubricants such as the engine oil and transmission oil up to some optimum temperature.

During the later stages of warm-up operation, the engine metal will require some cooling whilst the lubricating oils may still require heating.

Under extreme operating conditions, such as trailer towing, for example, engine metal, engine oil and transmission oil will all require cooling.

It would be advantageous therefore to provide a means for providing heat input to selected powertrain components (for example the lubricating oils) at beneficial times during operation of the vehicle, whilst being able to provide adequate cooling when required.

It has been proposed that heat from the vehicle's exhaust gases be transferred to the engine coolant in order to warm up the passenger compartment of the vehicle. See SAE
technical paper 2001-01-1020 "Exhaust heat recovery system for modern cars" by P Diehl et al. This exhaust gas heat recovery system may be installed downstream of any catalytic converter which is fitted to the vehicle and before the first silencer (muffler).

The present invention aims to exploit the benefits of exhaust gas heat recovery by providing a cooling system capable of optimising the operating temperature of a vehicle powertrain so that fuel economy and exhaust emissions are improved.

Accordingly, the present invention comprises;

A cooling system for a motor vehicle having an engine, said cooling system including;

a plurality of heat exchangers,

a conduit for supplying coolant to said plurality of heat exchangers and to the engine,

a pump for enabling the coolant to circulate through said conduit, heat exchangers and engine,

temperature sensing means,

a valve arrangement,

and a control module for controlling the operation of the valve arrangement dependent upon an output from the temperature sensing means thereby to control the flow of coolant through the plurality of heat exchanges and the engine, and wherein the plurality of heat exchanges includes an exhaust gas heat exchanger and a lubricating oil heat exchanger arrangement.

By virtue of this arrangement, the rate at which the powertrain warms up is increased thereby reducing fuel consumption during the warm-up period. Further, the control module
permits active control of the operating temperatures of the engine metal and lubricating oils thereby optimising fuel economy over the full range of driving conditions.

During warm-up, heat is added to the coolant from the exhaust gas heat exchanger and used to warm the lubricant while the water in the engine is stagnated. When heat from the exhaust gas heat exchanger is no longer required, it can be effectively bypassed.

Preferably, the plurality of heat exchangers also includes a conventional radiator for transferring heat from the coolant to the air external to the vehicle.

A cabin heater matrix may also be provided for the purpose of warming up the passenger compartment.

The lubricating oil may be engine or transmission oil or preferably, a heat exchanger for each is provided and the valve arrangement may be configured to allow coolant to flow through one or the other or both during different engine operating conditions.

A header tank may be provided, as in most conventional cooling systems, for expelling air from the system and for setting the pressure at the pump inlet.

A radiator fan may be provided, as is conventional. This may be driven off the engine or may be electrically operated and controlled by the control module.

The pump may be run off the engine and its throughput or speed may be varied by suitable valves or electromagnetic couplings which may be controlled by the control module. Preferably, the pump is an electrically operated variable speed pump and is controlled by the control module. An electric pump is preferred because its speed range is independent of engine speed. In particular, it can be run even when the engine is switched off, if necessary.
The temperature sensing means may be conveniently located so as to monitor the temperature of the engine metal. Alternatively or in addition, the temperature of the coolant at an inlet to the pump may be monitored. Additionally, sensors may be provided to monitor the temperature of lubricating oil.

5 The valve arrangement may conveniently include a valve or thermostat for controlling coolant flow through a radiator.

The valve arrangement may include a diverter valve for inhibiting coolant flow through the engine during cold start and early warm-up conditions.

The valve arrangement may include a mechanism for controlling the supply of exhaust gas to the exhaust gas heat exchanger and shutting it off completely when heating of the coolant is not required.

In one embodiment, the control module is provided with at least one input signal which indicates a current condition under which the engine is working. Such a condition could be idling or fierce acceleration or hill-climbing, for example. The input signal could be provided by a throttle position sensor or engine intake airflow monitor, for example. In response to such an input, the control module predicts the heat flux from engine metal to coolant. For instance, under harsh acceleration, the engine metal temperature will tend to rise. The control module can predict this rise and in response, increase the pump speed and adjust the valve arrangement so that an appropriate throughput of coolant tends to maintain engine metal temperature at an optimum value. In addition, the coolant temperature at the pump inlet can be modified (by adjustment of fan speed and / or the valve arrangement).

Some embodiments of the invention will now be described by way of example only, with reference to the drawings of which;
Figure 1 is a schematic diagram of a cooling system in accordance a first embodiment and connected to an engine of a motor vehicle,

Figures 2, 3 and 4 are similar schematic diagrams illustrating operation of the cooling system of figure 1 under three different operating conditions.

With reference to Figure 1, an electrically operated pump 1 is installed in one arm of a conduit for pumping coolant through an engine 2 and back through a return arm of the conduit to a radiator 3. A heat exchanger branch of the conduit is located in parallel with the coolant flow path through the engine and downstream of the pump 1. The heat exchanger branch includes an exhaust gas heat exchanger (EGHE) 4, followed by a cabin heater matrix 5, followed by a splitter valve 6. Upstream of the splitter valve 6, the heat exchanger branch divides into two parallel paths, one containing a transmission oil heat exchanger 7 and the other, an engine oil heat exchanger 8. The two parallel paths join up with each other and with the return arm from the engine 2 at a diverter valve 9.

A header tank 10 is located between the pump inlet and the confluence of the heat exchanger branch and engine coolant path outlet.

A mixer valve 11 is positioned in the return arm of the conduit, downstream of the confluence of the heat exchanger branch and engine coolant path outlet, for dividing coolant flow between the radiator 3 and a radiator bypass link 12, thereby controlling the temperature of the coolant at the inlet to the pump.

The cabin heater matrix 5 is provided with a bypass 13. Coolant flow through the heater matrix 5 and its bypass 13 is controlled by conventional heating and ventilation controls (not shown).

The EGHE 4 is supplied with exhaust gas by means of a pipe 14. Supply of exhaust gas is controlled by a valve 15 located in the pipe 14.
The radiator 3 is provided with an electrically operated fan 16.

The arrangement of figure 1 also includes four temperature sensors. A first 17, is located for measuring temperature of the engine metal, a second 18, is located for measuring transmission oil temperature, a third 19 is located for measuring engine oil temperature and a fourth 20, is located for measuring the temperature of the coolant at the inlet to the pump 1.

The outputs of all four temperature sensors, 17, 18, 19, 20 are connected to a control module 21. The control module 21 has a first output connected to the pump 1 for controlling the operation thereof, a second output connected to the valve 15 for controlling the operation of the EGHE 4, a third output connected to the diverter valve 9 for controlling its operation, a fourth output connected to the splitter valve 6 for controlling its operation, and a fifth output connected to the mixer valve 11 for controlling its operation.

The control module 21 has a further input on line 22 from an engine control unit (not shown). This input indicates driving conditions, e.g. idle, full throttle.

Cold start and early warm up operation will now be described with reference to Figures 1 and 2. The temperature sensors 17, 20 for monitoring temperature of the engine metal and coolant at the pump inlet will indicate to the control module 21 that the system is cold. In response, the control module 21 switches on the pump 1 at some predetermined speed, opens the EGHE valve 15, sets the diverter valve 9 so that coolant flow through the engine 2 is stagnated, and sets the mixer valve 11 so that coolant flows down the radiator bypass link 12 and not through the radiator 3 itself. The control module 21 also sets the splitter valve 6 so that coolant flows appropriately through the transmission oil heat exchanger 7 and the engine oil heat exchanger 8 so that the oils are warmed quickly to their optimum, fuel-efficient, temperatures.
During this cold start and early warm up cycle, heat from exhaust gases is transferred to the coolant. This in turn warms the transmission and engine oils (as well as the cabin heater matrix if the occupants so desire). The coolant flow through the engine 2 is stagnated in order to reduce the coolant thermal inertia.

The late warm up stage will now be described with reference to Figures 1 and 3. When the engine metal temperature sensor 17 records a rise in temperature to a predetermined figure, the control module 21 sets the diverter valve 9 and partially opens the mixer valve 11 so that coolant is now allowed to circulate through the engine 2 and radiator 3. Subsequently, once the engine oil temperature has reached an optimum value, the control module 21 sets the splitter valve 6 so that coolant flows through the transmission oil heat exchanger 7 and not the engine oil heat exchanger 8.

Hence, in this late warm up stage, heat is transferred into the coolant by the engine 2 and the EGHE 4. Heat is still being removed however from the coolant by the transmission oil heat exchanger 7. Some heat is also dissipated by the radiator 3. Further, the pump speed can also be varied so that in conjunction with the diverter valve 9, coolant flow through the engine 2 and heat exchanger branch can be balanced in order to achieve cooling of engine metal and engine oil yet heating of the transmission oil.

Operation under fully warm, normal operating conditions of the engine will now be described with reference to Figures 1 and 4. When the engine metal has reached some predetermined temperature, the control module 21 adjusts the mixer valve 11 (i.e. the flow through the radiator 3) to maintain the temperature of the coolant at its inlet at some desired, predetermined value, typically 88°C. This can be varied by employing an electrically-adjusted thermostat. Lowering the temperature at which the thermostat (mixer valve 11) is fully open will reduce the load on the pump. Further, the effect of the EGHE 4 can be lessened by partially or completely closing off the valve 15 controlling the exhaust gases. The flow rate demand deduced from temperature sensor outputs of the engine,
transmission oil and engine oil is balanced by control of the pump speed and the action of the diverter valve 9 and the splitter valve 6.

In an alternative embodiment, the splitter valve is dispensed with and the engine oil heat exchanger and the transmission oil heat exchanger are connected in series with one another (rather than in parallel).

The actions of the pump, fan and valves are further influenced by the control module's response to the driving condition input on line 22. Therefore, whatever the driving conditions and whatever phase the engine is operating in, be it cold start, warm up, fully warm, the control module 21 can maintain optimum temperature of engine metal and lubricating oils.

In alternative embodiments, the mixer valve 11 and / or the diverter valve 9 are re-located to alternative positions. The alternative position for the mixer valve 11 is at the inlet to the pump 1, at the confluence of the radiator outlet and its bypass 12. The alternative position for the diverter valve 9 is at the outlet of the pump 1 where the heat exchanger branch and engine coolant path inlet diverge.
CLAIMS

1. A cooling system for a motor vehicle having an engine, said cooling system including;

   a plurality of heat exchangers,

   a conduit for supplying coolant to said plurality of heat exchangers and to the engine,

   a pump for enabling the coolant to circulate through said conduit, heat exchangers and engine,

   temperature sensing means,

   a valve arrangement,

   and a control module for controlling the operation of the valve arrangement dependent upon an output from the temperature sensing means thereby to control the flow of coolant through the plurality of heat exchangers and the engine, and wherein the plurality of heat exchangers includes an exhaust gas heat exchanger and a lubricating oil heat exchanger arrangement.

2. A cooling system as claimed in claim 1 in which said pump is an electrically operated pump and in which the control module is adapted to control the operation of said pump.

3. A cooling system as claimed in either preceding claim in which one of said plurality of heat exchangers is a radiator.

4. A cooling system as claimed in claim 3 in which the radiator is provided with a fan.
5. A cooling system as claimed in any preceding claim in which the control module is provided with an input signal indicative of an engine operating condition and is further adapted to adjust the coolant flow in response to said signal, in order to maintain the temperature of the engine at a pre-determined value.

6. A cooling system claimed in any preceding claim in which the lubricating oil heat exchanger arrangement includes a transmission oil heat exchanger.

7. A cooling system as claimed in any preceding claim in which the lubricating oil heat exchanger arrangement includes an engine oil heat exchanger.

8. A cooling system as claimed in any preceding claim and further including a heater matrix for warming the interior of the vehicle.

9. A cooling system substantially as hereinbefore described with reference to the drawings.
Amendments to the claims have been filed as follows

CLAIMS

1. A cooling system for a motor vehicle having an engine, said cooling system comprising;

   a plurality of heat exchangers including an exhaust gas heat exchanger and a lubricating oil heat exchanger arrangement,

   a conduit for supplying coolant to said plurality of heat exchangers and to the engine,

   an electrically-operated, variable speed pump for enabling the coolant to circulate through said conduit, heat exchangers and engine,

   temperature sensing means,

   a valve arrangement,

   and a control module for controlling the operation of the valve arrangement and of the pump dependent upon an output from the temperature sensing means thereby to control the flow of coolant through the plurality of heat exchangers and the engine.

2. A cooling system as claimed in claim 1 in which said plurality of heat exchangers further includes a radiator.

3. A cooling system as claimed in claim 2 in which the radiator is provided with a fan.

4. A cooling system as claimed in any preceding claim in which the control module is provided with an input signal indicative of an engine operating condition and is further adapted to adjust the coolant flow in response to said signal, in order to maintain the temperature of the engine at a pre-determined value.
5. A cooling system as claimed in claim 4 in which the input signal is indicative of a current condition under which the engine is working.

6. A cooling system as claimed in claim 5 in which the control module is adapted to predict an engine temperature rise depending on the input signal and to increase pump speed and adjust the valve arrangement in order to maintain engine temperature at an optimum value.

7. A cooling system claimed in any preceding claim in which the lubricating oil heat exchanger arrangement includes a transmission oil heat exchanger.

8. A cooling system as claimed in any preceding claim in which the lubricating oil heat exchanger arrangement includes an engine oil heat exchanger.

9. A cooling system as claimed in any preceding claim and further including a heater matrix for warming the interior of the vehicle.

10. A cooling system as claimed in any preceding claim in which the valve arrangement includes a mechanism for controlling the supply of exhaust gas to the exhaust gas heat exchanger.

11. A cooling system substantially as hereinbefore described with reference to the drawings.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<tr>
<th>Category</th>
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<tr>
<td>X,Y</td>
<td>X:1, 3-5, 7, Y:6,8</td>
<td>US5551384 A (HOLLIS) - see especially column 5, line 62 - column 6, line 2; column 6, lines 14-48; and figures 1, 6B and 8.</td>
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<tr>
<td>Y</td>
<td>6</td>
<td>JP2002340284 A (TOYOTA) and WPI Abstract Accession No. 2003-085886 [08] - see abstract and figure 1.</td>
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<tr>
<td>Y</td>
<td>8</td>
<td>US4391235 A (MAJKRZAK) - see column 3, lines 7-12; and figures 2 and 3.</td>
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Worldwide search of patent documents classified in the following areas of the IPC:
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