Abstract Title: Piston oil spray cooling system with two nozzles

An oil spray system for an internal combustion engine comprises a first nozzle (40) adapted to spray oil at the underside of a piston, for cooling, and a second nozzle (46) adapted to spray oil directly at the cylinder bore in which the piston reciprocates, for lubrication. Each nozzle share an oil feed and a solenoid valve is provided to disable one nozzle while the other is operative. Alternatively they may have a dedicated oil feed from the lubrication system of the engine, enabling the nozzles to be operated independently of each other.
Figure 8
Piston Cooling Nozzle

This invention relates to the cooling of the pistons of an internal combustion engine, and more particularly to the use of oil squirtsers or sprays to dispense cooling oil.

An established method of cooling pistons in an internal combustion engine is by the use of piston cooling nozzles. These are usually situated in the block directly beneath each piston and squirt a jet of oil up underneath the piston. Heat is then transferred into the oil and in so doing cools the piston.

In most engines so equipped, the piston cooling nozzles are permanently operated, cooling the piston under all speed and load conditions. At low engine speeds, piston cooling nozzles are not required for piston cooling. Some engines therefore, switch the nozzles off during these periods. This enables the engine manufacturer to minimise the oil pump size, without sacrificing oil pressure at idle speed, thus saving cost, weight and space. It is also important to note that switching off the cooling nozzles substantially reduces the oil flow requirement.

Disabling the nozzles at low engine speeds is often achieved by providing a spring-biased valve within the spray nozzle. The valve opens when the oil pressure provides sufficient force to overcome the spring. When engine speed drops, the corresponding drop in oil pressure causes the spring to close the valve and disable the spray nozzle. Disabling the nozzles in this way overcomes the disadvantages at low speed and load of high parasitic oil pump losses and more importantly, reduced combustion efficiency from over cooling.

While disabling the nozzles is effective in reducing the load on the engine, research has shown that reduced oil
flow from the cooling nozzles results in increased piston rubbing friction, counteracting the positive effects from improved combustion efficiency. There is therefore a need to cool the pistons only when required whilst still providing sufficient lubricating oil.

With a view to mitigating the foregoing disadvantage, the present invention provides an oil spray system for an internal combustion engine comprising a first nozzle adapted, when in use, to spray oil at the underside of a piston, and a second nozzle adapted, when in use, to spray oil directly at the cylinder bore in which the piston reciprocates, characterised in that a solenoid valve is provided to enable at least one nozzle to be disabled while the other is operative.

Preferably each nozzle has a dedicated oil feed from the lubrication system of the internal combustion engine to enable the nozzles to be operated independently of one another.

Alternatively both nozzles may share an oil feed from the lubrication system of the internal combustion engine and the solenoid valve allows one nozzle to be disabled while the other is operative.

Advantageously the nozzles are further operated in dependence upon the prevailing pressure of the oil feed.

Preferably the system includes a variable flow oil pump.

The oil pump may be controlled by a controller in response to engine operating parameters which may include any one or more of engine speed, engine load, exhaust gas temperature, turbo boost pressure, oil temperature and coolant temperature.
Preferably the piston contains a gallery with an entrance hole located on the underneath of the piston for receiving oil from the first nozzle, the nozzle being operate to spray oil only when the piston is accelerating towards bottom dead centre.

According to a second aspect of the present invention, there is further provided an oil spray system for an internal combustion engine comprising a piston having an integral oil gallery formed therein, an inlet hole located in the underside of the piston allowing ingress of oil to the gallery, and an oil spray nozzle in communication with the engine lubrication system, for spraying a jet of oil into the inlet hole and filling the piston gallery with oil, characterised in that the oil spray nozzle is operative to spray a jet of oil into the inlet hole only when the piston is accelerating towards bottom dead centre.

The invention will now be described further by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic representation of oil spray nozzles within an engine lubrication system,

Figure 2 shows an oil spray nozzle installed within an internal combustion engine,

Figure 3 shows a through an oil spray nozzle according to an embodiment of the present invention,

Figures 4a to 4d show the position of the shuttle valve of the nozzle of Figure 3 at different oil pressures,

Figure 5 shows a perspective view of an oil spray nozzle according to a further embodiment of the present invention,

Figure 6 shows a section along the line AA of Figure 5,

Figure 7 shows a section along the line BB of Figure 5, and
Figure 8 is a graph showing appropriate regions of engine power output and engine speed in which the different oil spray nozzles may be actuated.

Figure 1 shows a general lubrication system layout for the piston cooling nozzles of an internal combustion engine (ICE). The oil circuit comprises a sump 14, which contains the majority of oil in the system. From the sump 14, oil is drawn into and forced out of a pump 16. In this case, the oil pump is a variable flow rate oil pump 16. A variable flow lubricant pump can be achieved in a number of different ways from electric motor driven units with speed control to engine driven units with controllable flow output.

Oil exits the pump under pressure and passes through filter 18 before being cooled by cooler 20. This may be either an air/oil heat exchanger or a water/oil heat exchanger.

Oil then enters the engine block where it is passed through various chambers and galleries to feed the engine components that require oil for lubrication. At least one of these galleries (not shown in Figure 1) is in fluid communication with at least one oil spray nozzle 10. Usually, a separate oil spray nozzle 10 is provided for each piston and so the number and position of the oil spray nozzles will be dependent on the number of engine cylinders and their layout.

The oil pressure on the high pressure side of the oil pump 16 is monitored by an oil pressure sensor 22. The information from this sensor is fed into an engine control unit (ECU) 12. The ECU also electronically controls the variable flow rate oil pump.

Figure 2 shows a preferred embodiment of the present invention, in which a nozzle assembly 32 is installed within
an internal combustion engine. The nozzle assembly is bolted to the underside of the block, below water jacket 28, and is in fluid communication with an oil passageway from the main oil gallery (not shown).

Figure 2 also shows the direction of oil spray from the nozzle assembly 32. An oil spray or jet 30 is directed at the underside of piston 26. This is commonplace in the art and is intended to prolong the life of the piston by reducing its temperature. A second oil spray or jet 34 is sprayed from nozzle assembly 32 directly at the cylinder bore 38 into the area swept by the skirt of the piston 26.

As the piston reciprocates it wipes the oil around the bore 38 thus lubricating contact area between the piston and the cylinder bore.

It will be appreciated that in some circumstances there will be some indirect lubrication of the cylinder bore by virtue of splash from oil spray 30, especially as it impinges on moving parts such as the connecting rod 36 and the underside of the piston crown.

Figures 3 and 4 and 5 to 7 show different embodiments of a nozzle assembly of the present invention. Figures 3 and 4 (a to d) show a nozzle assembly 32 having two nozzles 40 and 46 selectively opened by means of a shuttle valve 48. The shuttle or spool 48 is essentially dumbbell shaped, having lower and upper cylindrical end sections 62, 64 joined by an axial section 66 of reduced diameter. The cylindrical end sections 62, 64 of the shuttle slide in sealing contact with the inner wall 68 of the nozzle assembly 32.

The shuttle 48 contains a central oil pathway between the oil feed side and the annular recess between the cylindrical end sections. Oil supply port 42 is fed with
pressurised oil from the main gallery. This oil flows around body of the nozzle assembly applying a force on the underside of the shuttle 48.

In Figure 4a, pre-loaded spring 44 applies an opposing force against the top surface of the shuttle valve urging it against pre-load stop 50. Here, the force on the shuttle 48 due to the oil pressure is lower than the opposing force of the spring 44, the shuttle valve remains closed, and no oil is released from the nozzle assembly 32.

In Figure 4b, as the oil pressure increases, the greater force on the underside of the shuttle 48 causes it to move upwards compressing the spring 48 (not shown) until the forces on both sides of the valve once again equalise. As the valve moves upwards, it exposes bore lubrication nozzles 46, which then communicate via annular recess and the central bore of the with the source of oil pressure. Thus oil at the pressure of the gallery is sprayed only from the bore lubrication nozzles 46.

In Figure 4c, as the oil pressure in the galleries increases further, the shuttle 48 is pushed further upwards within the nozzle assembly 32. Eventually, when the upper cylindrical end section 64 is pushed clear of the inner wall 68 of the nozzle assembly 32, the shuttle valve 48 allows oil to flow into the cooling nozzle 40 whilst still allowing oil to spray from the bore lubrication nozzle 46.

Figure 4d shows the result of increasing the pressure still further. Here, the lower cylindrical end section 62 blocks the flow of oil to the bore lubrication nozzle 46 while continuing to allow oil to spray from the piston cooling nozzle 40 towards the underside of the piston 26.

Figures 5 to 7 show an alternative nozzle assembly arrangement. Its function is similar to that of the
previously described embodiment except there are two separate spray nozzle feeds for piston cooling (Figure 6) and cylinder bore lubrication (Figure 7). Each of the nozzles includes a non-return valve formed of a ball 54, 58 biased by a spring 56, 60 towards a valve seat. The springs 56 and 60 are chosen such that the lubrication nozzle opens at a lower pressure than the oil cooling nozzle. Each could alternatively be designed to operate with a shuttle similar to the previous embodiment.

In both these embodiments, the control is based on oil pressure. It is possible for the operation of the valves to be controlled by a solenoid to respond to engine operating parameters other than the oil pressure alone. In such an arrangement, the solenoid would dictate when oil is fed to the nozzles. In this case, the nozzles associated with individual pistons may either be controlled independently or they may be connected to a common gallery to which the oil supply is regulated by a solenoid valve common to all the pistons.

The amount of lubricant required to lubricate the bore is substantially lower than that required to cool the piston. Therefore, at low engine speeds, one can continue to lubricate the bores without risking starving the bearings of oil. By using a variable displacement pump, it is possible to match the output of the pump to the prevailing oil demand.

On disabling the nozzles used for piston cooling, the oil pressure increases and by utilising a variable displacement pump, one can reduce the flow rate to supply only enough oil to meet the needs of the lubrication system for the operating conditions of the engine. This means that unnecessary pumping losses can be minimised or avoided.
A fixed displacement oil pump operates in two modes, the first with the pressure relief valve open and the second with the pressure relief valve closed. When the pressure relief valve is closed, the flow restriction of the engine lubrication circuit is low enough to avoid the oil pump outlet pressure reaching the pressure relief valve opening pressure. In this mode, when the jets are turned off by a solenoid valve the pump outlet pressure will rise and as the pump still pumps the roughly same mass of oil the oil pump power consumption increases. In the mode where the pressure relief valve is already open, the power consumption would not change substantially. This contrasts with a variable flow oil pump that would reduce its parasitic losses when the flow through the jets is reduced. When this is performed at the same time as the control of the jets, it provides a very useful combination.

ECU 12 determines when the pistons need to be cooled. This can be based on several inputs normally provided to the ECU. These may include accelerator pedal position, turbo boost pressure, exhaust gas temperature, coolant temperature and many others.

By controlling the pump 16, the system enables the engine to run at pre-defined oil pressure determined by the ECU 12. The oil pressure in the main oil gallery has to satisfy many engine components, including turbochargers, chain tensioners, valve train mechanisms, crankshaft bearings etc. as well as the piston cooling nozzles. As a result, the minimum and maximum pressures are limited, not only by the requirements of the piston cooling nozzles, but also the other components.

An additional benefit of using a variable displacement oil pump is that the oil pressure can be increased in line with the cooling requirement of the piston. This minimises the power consumption of the variable flow oil pump and
gives more refined cooling of the piston, balancing the cooling needs with combustion efficiency.

Figure 8 shows typical regions for the different modes of operation of the nozzles. The pressure at the outlet of the oil pump has a major input into the parasitic losses of the pump, be it a variable or a fixed displacement pump. In order to maximise pump efficiency, the pressure at which the bore is lubricated needs therefore to be set as low as possible, in order to reduce the pressure requirement of the pump as early possible.

The following table indicates typical pressures for three modes of piston nozzle operation:

<table>
<thead>
<tr>
<th>Main Gallery Gauge Pressure</th>
<th>Nozzle Operating mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1 bar</td>
<td>Both nozzles inactive</td>
</tr>
<tr>
<td>1 to 2.5 bar</td>
<td>bore lubrication nozzle active</td>
</tr>
<tr>
<td>2.5 bar to maximum pressure</td>
<td>piston cooling nozzle only active or both nozzles active</td>
</tr>
</tbody>
</table>

In an alternative embodiment, effective piston cooling is achieved by ensuring that the cooling oil sprayed at the underside of the piston remains in contact with the piston for as long as possible. The piston is therefore provided with an integral annular gallery which is cast in place during manufacture of the piston using a salt fillet. The gallery has an inlet hole that receives oil from a fine oil spray nozzle or jet. Oil may exit the gallery either through a similar hole or via the piston ring assembly in order to further lubricate the bore.

The valve control of the piston cooling nozzle is beneficial in that it allows the spray of oil into the piston to be synchronised with the angular position of the crank shaft. This means that it can spray a jet of oil only
when the piston is accelerating towards the bottom dead centre position, i.e. when the piston is slowing down on the upward stroke and speeding up on the downward stroke. The effect is that the inertia of the piston ensures that any oil contained within the gallery remains in place as the piston accelerates towards bottom dead centre, yet is forced out of the piston gallery as the piston accelerates towards top dead centre. The throughput of oil in the piston gallery is therefore more controllable and repeatable for more efficient cooling and piston longevity.
Claims

1. An oil spray system for an internal combustion engine comprising
   a first nozzle adapted, when in use, to spray oil at the underside of a piston, and
   a second nozzle adapted, when in use, to spray oil directly at the cylinder bore in which the piston reciprocates,
   characterised in that a solenoid valve is provided to enable at least one nozzle to be disabled while the other is operative.

2. An oil spray system as claimed in claim 1, wherein each nozzle has a dedicated oil feed from the lubrication system of the internal combustion engine to enable the nozzles to be operated independently of one another.

3. An oil spray system as claimed in claim 1, wherein both nozzles share an oil feed from the lubrication system of the internal combustion engine and the solenoid valve enables one nozzle to be disabled while the other is operative.

4. An oil spray system as claimed in claim 1 to 3, wherein the nozzles are further operated in dependence upon the prevailing pressure of the oil feed.

5. An oil spray system as claimed in any preceding claim, further including a variable flow oil pump.

6. An oil spray system as claimed in claim 5, wherein the oil pump is controlled by a controller in response to engine operating parameters.

7. An oil spray system as claimed in claim 6, wherein the parameters include any one or more of engine speed,
engine load, exhaust gas temperature, turbo boost pressure, oil temperature and coolant temperature.

8. An oil spray system as claimed in any preceding claim wherein the piston contains a gallery with an entrance hole located on the underneath of the piston for receiving oil from the first nozzle, the nozzle being operated to spray oil only when the piston is accelerating towards bottom dead centre.

9. An oil spray system for an internal combustion engine comprising a piston having an integral oil gallery formed therein, an inlet hole located in the underside of the piston allowing ingress of oil to the gallery, and an oil spray nozzle in communication with the engine lubrication system, for spraying a jet of oil into the inlet hole and filling the piston gallery with oil, characterised in that the oil spray nozzle is operative to spray a jet of oil into the inlet hole only when the piston is accelerating towards bottom dead centre.

10. An oil spray system substantially as herein described with reference to and as illustrated in the accompanying drawings.
**Application No:** GB0619258.7  
**Examiner:** Mike McKinney  
**Claims searched:** 1 to 8  
**Date of search:** 10 January 2007

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

<table>
<thead>
<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
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<tr>
<td>X</td>
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<td>JP 07243313 A (UNISIA JECS CORP) see figs and WPI Abstract Accession No. 1995-355821</td>
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<td>JP 07317519 A (ATSUGI UNISIA CORP) see figs and WPI Abstract Accession No. 1997-483727</td>
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<td>EP 0781901 A1 (YAMAHA MOTOR CO)</td>
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<td>US 4667630 A (SASAKI)</td>
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<tr>
<td>A</td>
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<td>JP 59120712 A (HINO MOTORS LTD)</td>
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