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(54) **ENGINE TEMPERATURE MANAGEMENT**

TEMPERATURSTEUERUNG EINER BRENNKRAFTMASCHINE

GESTION DE LA TEMPERATURE D'UN MOTEUR

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## Description

The present invention relates to engine temperature management.

The conventional manner of regulating the temperature of an engine is to pass the coolant, usually water, through a thermostatic valve having a through flow cross section that increases with temperature. The thermostatic valve therefore acts, as its name implies, to maintain the same coolant temperature, regardless of the engine operating conditions.

In practice, this is not ideal because the cylinder walls have a finite thickness and thermal conductivity which results in the critical inner surface temperature being different from the coolant temperature. Under high load, when the temperature gradient is at a maximum, the inner surface temperature is significantly higher than the coolant temperature whereas under low load the temperature gradient is lower and the inner surface temperature is somewhat lower. It is essential to set the coolant temperature to allow for the highest temperature gradient and ensure that the inner surface never exceeds a safety limit. The result of this is that under low load conditions, the engine is cooler than necessary, leading to increased fuel consumption and hydrocarbon emissions.

To mitigate this problem, electronically controlled valves have been used proposed, for example in JP-57 0024181, replace the thermostatic valve to vary the coolant flow rate with engine speed and load. The aim of these earlier proposals, in common with the present invention, is to enable higher engine temperatures under low load operation. To estimate the heat rejection, the known systems have used various operating parameter such as fuel injection quantity, air mass flow and manifold vacuum but all these give only an imprecise and indirect estimate of the heat rejection that does not follow sufficiently rapidly the changing conditions in the combustion chamber.

The present invention therefore seeks to provide an engine in which the temperature management of the coolant is capable following the changes in heat rejection per operating cycle from the combustion chambers more rapidly and with greater precision.

In accordance with the present invention, there is provided a fluid cooled internal combustion engine comprising means for measuring the peak gas pressure in each combustion cycle and means for varying the coolant flow rate in dependence upon of the measured values of peak pressure.

The invention is predicated on the realisation that the peak pressure in a combustion cycle and the heat rejected to the combustion chamber walls during the same cycle are closely related to one another and that by measurement of the peak pressure one can determine the temperature gradient in the walls of the combustion chamber and thereby estimate the more critical temperature on the inner surface of the walls. In this

way, it is possible to maximise the temperature under all operating conditions and thereby reduce hydrocarbon emissions and fuel consumption.

The improvement in fuel consumption is believed to be caused by the increase in charge temperature and resultant decrease in charge density. This has the effect of reducing the volumetric efficiency of the engine during part load operation and therefore reducing the air pumping losses.

The improvement in hydrocarbon emissions results from the lower charge density in the crevice volumes of the combustion chamber and increased oil film temperature. The higher oil temperature reduces the effect of storage of hydrocarbons by absorption and subsequent desorption.

In the preferred embodiment of the invention, the coolant flow rate is varied as a predetermined function of the prevailing coolant temperature, the measured combustion peak pressure and the engine speed.

More particularly, the engine may comprise means for measuring the coolant temperature, means for estimating the average heat rejection per cycle through the combustion chamber walls from the measured peak pressure, means for estimating the temperature on the inner surface of the walls of the combustion chamber from the temperature of the coolant in contact with the outer surface of the walls of the combustion chamber and the estimated heat rejection during each combustion cycle, and means for varying the coolant flow rate in such a manner as to set the inner surface temperature of the walls at a value determined by the prevailing engine speed and load.

The most precise method of determining the mean heat rejection through the combustion chamber is to analyse the pressure diagram taken from the combustion cycle to determine the instantaneous heat transfer and then integrate over the cycle. This is however very tedious and time consuming and is not practical for use outside an engine test laboratory.

Another method attempted by the Applicants involved calculating the brake mean effective pressure (BMEP) from the measured pressure diagram and correlating the BMEP, which is a measure of engine load, empirically against the mean heat rejection rate. This type of correlation is similar to those in which the engine load is estimated from manifold vacuum, air mass flow or fuel flow. These correlations are not satisfactory because engine load is more closely related to the heat generation process of the combustion cycle than to the heat rejection process.

The invention is based on the fact that the heat rejection during the combustion cycle is predominately driven by the instantaneous temperature difference between the hot combustion gases and the walls of the combustion chamber. A major proportion of the heat rejection per cycle takes place during the short time interval within the cycle when the temperature of the combustion gases is at its maximum. It is therefore reason-

able to expect the mean heat rejection per cycle to be more closely related to the peak gas temperature or the peak combustion pressure.

Extensive experimental data of the heat rejection per cycle against the peak combustion pressure of each cycle has been taken for a wide selection of engine types, each covering the full range of speed and load operating conditions. All the data was found to correlate closely according to a linear function for each engine speed, which indicates that an empirical linear relationship exists between the heat rejection per cycle and the peak combustion pressure of each cycle at a fixed engine speed. Further correlation shows the heat rejection per cycle varies as a negative power of the engine speed. One can modify the empirical relationship still further to take into account the bore size and it has been possible in this way to arrive at a single empirical formula that may be applied accurately to all engines at all values of engine speed and load to calculate the heat rejection per cycle.

The discovery of such an empirical relationship, of which there is no teaching from the previously known methods, makes it practicable to implement the thermal management method of the invention. Using only empirical equations and a few calibration constants, one can arrive at a much more accurate estimation of the heat rejection per cycle than was previously possible.

Because the invention is interested only in the peak pressure per combustion cycle, it is possible to simplify the design of the pressure sensor. In particular, it is not necessary to sense the pressure continuously and process the electrical output to determine the peak pressure. One may instead mount the pressure sensor behind a one-way valve so that only the peak pressures are applied to a small volume chamber containing the pressure sensor.

It is furthermore possible to use a single sensor to sense the peak pressure in all cylinders. This may be achieved by connecting all the combustion chambers through respective one-way valves to a common chamber containing the pressure sensor and from which the pressure is slowly bled to atmosphere through a flow restrictor. Such an arrangement for sensing the peak pressures in the combustion chambers of an engine is described in our co-pending International Patent Application WO 96/01415.

The invention will now be described further, by way of example, with reference to the accompanying drawing which is a block diagram of an engine with a coolant management system.

An engine 10 is connected to a peak combustion pressure sensor 12, a speed sensor 14 and a coolant temperature sensor 16, all of which sensors supply input signals to a micro-computer 18 that may be the engine management computer. The signals from the sensors 12, 14 and 16 are processed in the micro-computer 18 and used to estimate the cylinder wall temperatures. Output from computer 18 is supplied to a coolant flow

control valve 20 which then sets the rate of coolant flow through the engine and radiator to optimise the engine cylinder wall temperature.

The pressure sensor 12 may be the same as that described in WO 96/01415 or it may be comprised of any other known system for measuring combustion pressure. The other blocks in the diagram may also be conventional and do not therefore call for detailed description.

The computer 18 processes the peak pressure information in conjunction with engine speed data and stored constants using a single empirical formula to arrive at the prevailing rate of heat rejection per cycle and from it an estimate of the wall temperature of the combustion chambers. The flow rate of the coolant through an electronically controlled valve 20 is then varied by the computer 18 to optimise the cylinder wall temperature for the prevailing operating conditions.

## Claims

1. A fluid cooled internal combustion engine comprising means (12) for measuring the peak gas pressure in each combustion cycle and means (20) for varying the coolant flow rate in dependence upon the measured values of peak pressure.
2. A fluid cooled internal combustion engine as claimed in claim 1, comprising means for measuring the coolant temperature (16), means (18) for estimating the average heat rejection per cycle through the combustion chamber walls from the measured peak pressure, means (18) for estimating the temperature on the inner surface of the walls of the combustion chamber from the temperature of the coolant in contact with the outer surface of the walls of the combustion chamber and the estimated heat rejection during each combustion cycle, and means for varying the coolant flow rate (20) in such a manner as to set the inner surface temperature of the walls at a value determined by the prevailing engine speed and load.
3. A fluid cooled internal combustion engine as claimed in claim 1 or claim 2, wherein the means for measuring the peak pressure (12) comprises a pressurised chamber connected to all the combustion chambers by respective one-way valves, a single pressure sensor within the pressurised chamber and a flow restrictor connected to bleed off the pressure from the pressurised chamber to the ambient atmosphere.

## Patentansprüche

1. Eine flüssig gekühlte Brennkraftmaschine beste-

hend aus einer Vorrichtung (12) zum Messen des Spitzengasdrucks in jedem Verbrennungszyklus und einer Vorrichtung (20) zum Verändern der Durchflussrate des Kühlmittels, in Abhängigkeit von den gemessenen Werten des Spitzendrucks.

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2. Eine flüssig gekühlte Brennkraftmaschine nach Anspruch 1, bestehend aus einer Vorrichtung zum Messen der Temperatur des Kühlmittels (16), einer Vorrichtung (18) zur Schätzung der mittleren Wärmeabgabe pro Zyklus durch die Wände der Brennkammer von dem gemessenen Spitzendruck, einer Vorrichtung (18) zur Schätzung der Temperatur auf der inneren Oberfläche der Wände der Brennkammer von der Temperatur des Kühlmittels im Kontakt mit der äusseren Oberfläche der Wände der Brennkammer und der geschätzten Wärmeabgabe während jedes Verbrennungszyklus und einer Vorrichtung zum Verändern der Durchflussrate des Kühlmittels (20) auf eine derartige Weise, dass die Temperatur der inneren Oberfläche der Wände auf einen Wert gesteuert wird, der durch die ausschlaggebende Drehzahl und Last der Brennkraftmaschine bestimmt wird.

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3. Eine flüssig gekühlte Brennkraftmaschine nach Anspruch 1 oder 2, in der die Vorrichtung zum Messen des Spitzendrucks (12) eine unter Druck gesetzte Kammer enthält, die an allen Brennkammern durch ein jeweiliges Rückschlagventil, einen einzigen Druckaufnehmer in der unter Druck gesetzten Kammer und einen Durchflussreduzierer angeschlossen ist, um den Druck von der unter Druck gesetzten Kammer in die Umgebungsatmosphäre auszustossen.

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## Revendications

1. Moteur à combustion interne refroidi par liquide, comprenant des moyens (12) destinés à mesurer la pression de gaz maximale dans chaque cycle de combustion et des moyens (20) destinés à modifier le débit d'écoulement du liquide de refroidissement en fonction des valeurs mesurées de pression maximale.
2. Moteur à combustion interne refroidi par liquide selon la revendication 1, comprenant des moyens (16) destinés à mesurer la température du liquide de refroidissement, des moyens (18) destinés à estimer le rejet de chaleur moyen par cycle à travers les parois de la chambre de combustion à partir de la pression maximale mesurée, des moyens (18) destinés à estimer la température sur la surface interne des parois de la chambre de combustion à partir de la température du liquide de refroidissement en contact avec la surface externe des parois de la

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chambre de combustion et le rejet de chaleur estimé durant chaque cycle de combustion, et des moyens (20) destinés à modifier le débit d'écoulement du liquide de refroidissement de manière à amener la température de la surface interne des parois à une valeur déterminée par la vitesse et la charge prévalantes du moteur.

3. Moteur à combustion interne refroidi par liquide selon la revendication 1 ou 2, dans lequel les moyens destinés à mesurer la pression maximale (12) comprennent une chambre sous pression connectée à toutes les chambres de combustion par des soupapes unidirectionnelles respectives, un seul détecteur ou capteur de pression à l'intérieur de la chambre sous pression et un dispositif d'étranglement du débit connecté pour évacuer la pression depuis la chambre sous pression vers l'atmosphère ambiante.

