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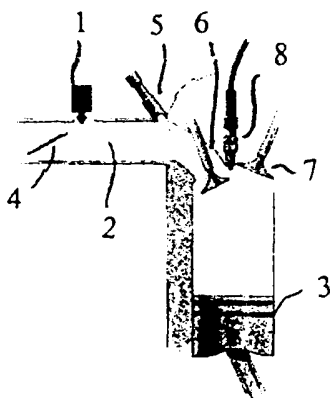
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(54) Title: METHOD FOR MEASURING THE AIRFLOW IN AN INTERNAL COMBUSTION ENGINE



(57) Abstract: The invention refers to a method for determining the airflow to an internal combustion engine such as for example a motorcycle engine. The airflow measurement is made via measurement of the pressure in the inlet manifold (2) with a pressure sensor (1) placed between the throttle (4) and the inlet valve (6). The measurement is made at predetermined crankshaft angles whereby at least one pressure measurement takes place near the piston's ((3) lower turning point. The pressure measurement values can be weighted according to the rotation rate of the engine and different measurements at different angles can be made and used to calculate the amount of air contained in the cylinder, the airflow past the throttle or the degree of opening of the throttle.

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METHOD FOR MEASURING THE AIRFLOW IN AN INTERNAL COMBUSTION.**5 DESCRIPTION****Technical field**

The present invention concerns a method of determining the flow of air to an internal
10 combustion engine that operates over a wide revolution rate range and that has high
requirements on fast reaction, as for instance a motorcycle engine.

State of the art

15 For internal combustion engines it is of the greatest importance that the right mixture
of air and fuel is provided at the right time to be able to achieve optimal output power and to
produce the least possible amount of emissions. Through fuel injection better control of the
air/fuel mixture can be obtained compared to an engine with a carburettor. In general fuel
injection takes place in the inlet manifold before the combustion chamber. For engines with
20 small volumes between the throttle and the cylinder large pressure changes take place, so-
called pulsations, which make it difficult to correlate the pressure in the inlet manifold with
the real airflow to the engine.

There are examples of the above for motorcycle engines. A throttle signal is used to
indicate how large an area the throttle has momentarily as a load signal. Because this method
25 has important drawbacks for small airflows this method can be combined with a pressure
sensor that measures the average pressure in the inlet manifold, which gives a relatively good
correlation for such small airflows.

US-A-5,590,632, US-B1-6,276,341, EP-A2-0 521 545, EP-A1-0 639 704, US-A-
5,027,278 and EP-A2-0 420 442 all show internal combustion engines with at least one piston
30 and including an outlet valve, an inlet valve and inlet manifolds with a port, a throttle and
injectors arranged in the inlet manifold. All the documents additionally show a pressure
sensor. However, none of the documents shows the problem and solution concerning
measurement of the airflow for an internal combustion engine with pulsations.

Summary of the invention

The present invention aims to provide a solution to the problem of determining the airflow in an internal combustion engine with a small volume between the throttle and the cylinder and/or where large rhythmic pressure changes, so-called pulsations, occur, which solution uses a pressure signal from the inlet manifold as a measure of the airflow to the engine thus fulfilling the high requirements on fast and exact fuel supply needed for engines with advanced dynamics without complicated measurement systems such as throttle position sensors or heated film air mass sensors.

Furthermore, the invention implies that with only a pressure signal it can be determined when the throttle angle is so large that a pressure value that can be related to the ambient pressure can be measured.

Furthermore, the proposed method of measuring the airflow past the throttle into the inlet manifold means that adjustments can be made to the fuel supply for different changes in the engine specifications, such as wear, the opening and closing times of the valves, throttle area, exhaust gas pressure and the like.

The present invention concerns a method of determining the airflow to an internal combustion engine that includes at least one piston working on a crankshaft, which engine includes at least one outlet valve, at least one inlet valve and an inlet manifold with at least one port, at least one throttle and injectors that are arranged in the said input manifold. The invention is characterised by the airflow measurement taking place via measurement of the pressure between the said throttle and the inlet valve at predetermined crankshaft angles whereby at least one pressure measurement takes place near the piston's lower turning point.

Other characteristics of the invention are evident from the following patent claims.

Short description of the drawings

The invention will now be described in more detail with reference to the embodiments shown in the drawings.

Figure 1 shows typical pulsations in the input manifold of a single cylinder engine.

Figure 2 shows a diagram of the pressure in the input manifold during the engine's cycles and the throttle position during those cycles.

Figure 3 shows a diagram of the pressure as a function of the crankshaft angle at 4000 rpm for different loads on the engine.

Figure 4 shows a diagram of the pressure in the input manifold where the pressure changes are measured during a time interval when the inlet valves are closed.

Figure 5 shows an embodiment of a pressure sensor assembly.

5

Description of preferred embodiments

Figure 1 shows the variations in the pressure (pulsations) in the inlet manifold for partial loads in a typical single cylinder engine as a function of the crankshaft angle. The pressure varies in the embodiment between 0.8 bar and 0.2 bar with maxima at the beginning
10 of the inlet stroke, that is the upper turning point, and minima at the end of the inlet stroke, that is at the lower turning point.

The pulsations occur because the piston sucks air with it on moving from the upper turning point to the lower turning point. This air is taken from the inlet manifold via the open inlet valve which results in the pressure falling during expansion in the cylinder and the part
15 of the inlet manifold that is between the throttle and the inlet valve because the throttle chokes the air more than the piston sucks air. The minimum pressure is obtained when the piston stops sucking air, which occurs around the lower turning point. Thereafter the pressure in the inlet manifold increases again because air flows continuously through the throttle. The pressure that obtains when the inlet valve closes is the same pressure as that in the cylinder for
20 static conditions, which pressure is therefore a measure of the amount of air that has been enclosed.

The diagram according to figure 2 shows how the inlet pressure varies during the engine's cycles as the throttle is open from the closed position (0.1 bar) to the wholly open position (1.0 bar). Curve number 1 shows the pulsations in the inlet during the engine's
25 cycles. Curve number 2 shows the pressure in the inlet manifold when the inlet valve closes, that is immediately after the lower turning point (about -140 degrees). Curve number 3 shows the average of curve number 1. Curve number 4 shows the throttle position expressed in degrees. From the diagram it is clear that the average of the inlet pressure (curve number 3) is significantly different to the pressure in the inlet manifold when the inlet valve closes (curve
30 number 2) while the latter pressure better corresponds to the airflow to the cylinder.

Figure 3 shows how the inlet pressure varies with the crankshaft angle at an engine speed of 4000 rpm. Curves number 5, 6, 7 and 8 show the conditions at 20%, 40%, 80% and 100% engine loading. In the diagram -540 to -360 degrees are the outlet stroke, -360 to -180 degrees the inlet stroke, -180 to 0 degrees the compression stroke and 0 to 180 degrees the

work stroke. From the diagram it is clear that the pressure curves 6, 7 and 8 do not correlate linearly with the load when the valve closes (-140 degrees). A better correlation is obtained at the lower turning point (-180 degrees) but with too low values for measures of the cylinder's degree of filling at low loads. The difference in pressure between -180 degrees and -140
5 degrees affects the cylinder's degree of filling. This is because the piston turns and can push back part of the sucked in air depending on the rotation rate.

One embodiment of the invention makes use of the relations that can be discerned from diagrams 2 and 3. According to the invention the pressure between the throttle and the inlet valve is measured at predetermined crankshaft angles whereby at least one pressure
10 measurement should be made near the lower turning point of the piston. Then the pressure is measured in such a way that it reflects the pressure variations in the inlet manifold during the suction stroke. The measured pressure can then be weighted depending on the engine's rotation rate to compensate for differences in the cylinder's degree of filling. Then the thus obtained value can be used to determine the airflow to the engine in order to control the
15 engine's air/fuel mixture. According to an additional embodiment of the invention a pressure measurement is achieved either during the inlet stroke or the compression stroke or alternatively the pressure measurement is carried out during both the inlet stroke and the compression stroke. According to a further embodiment at least one pressure measurement is made when the pressure curves have their minima or immediately thereafter.

20 According to a further embodiment of the invention at least one of the pressure measurements is made at the end of the inlet stroke.

According to another embodiment of the invention at least one of the pressure measurements is made within +/- 90 degrees of the crankshaft from the piston's lower turning point.

25 According to a further embodiment of the invention at least one of the pressure measurements is made within +/- 45 degrees of the crankshaft from the piston's lower turning point.

According to a further embodiment of the invention the value of a pressure measurement during the inlet stroke when airflows into the cylinder is used, preferably in the
30 range from about -300 degrees to about -200 degrees according to figure 3. The value is compared to the value of a pressure measurement before the inlet stroke begins, that is, when air does not flow into the cylinder, preferably before -360 degrees, in order to calculate the throttle opening according to what is shown in figures 2 and 3. This degree of opening can be

used for example to measure the ambient pressure when the valve is open so much that the pressure in the inlet manifold is a good average of the engine's ambient pressure.

Thus using only the pressure signal it is possible to determine when the valve angle is sufficiently open that the ambient pressure can be measured.

5 According to a further embodiment, see figure 4, at least two of the pressure measurements are made when the inlet valves are closed, that is, immediately after the inlet stroke and before the next inlet stroke, whereby the difference between these two measurement values constitutes a measure of the airflow into the inlet manifold. This value can be is utilized to be able to make adjustments of the fuel supply for different changes in the
10 engine's specifications such as wear, the opening and closing times of the valves, the valve area, the exhaust gas pressure and the like.

Figure 5 shows schematically an embodiment of the position of a pressure sensor 1 in the inlet manifold 2 of an internal combustion engine with at least one piston 3. In the inlet manifold 2 there is also a throttle 4, one or more injectors 5 and an inlet valve 6. A spark plug
15 8 and an outlet valve 7 are also shown in the figure. The pressure sensor is advantageously arranged in a vertical direction in the inlet manifold so that liquid cannot flow into the pressure sensor 1.

Using the pressure sensor, which is arranged on or near the inlet manifold after the throttle, the inlet stroke's lower turning point can be identified for the majority of the engine's
20 operating range because during the inlet stroke the pressure sensor goes from its maximum value to its minimum value. At the lower turning point the pressure is measured, the value of which, when weighted depending on the rate of rotation, gives a measure of the airflow to the internal combustion engine.

The function and construction are clear from the present description. Even if the
25 embodiments shown and described are preferred it is self evident that they can be modified within the frame of the scope that is defined in the following claims.

Patent Claims

1. A method for measuring the airflow in an internal combustion engine with at least one
5 piston (3) operating on a crankshaft, which engine includes at least one outlet valve (7), at
least one inlet valve (6) and an inlet manifold (2) with at least one port, at least one
throttle (4) and injectors (5) arranged in the said inlet manifold (2) whereby the internal
combustion engine is of the type that has at least one of a small volume between the
throttle (4) and the inlet valve (6) and large rhythmic pressure variations, called
10 pulsations, **c h a r a c t e r i s e d b y** the said airflow measurement being made through
measurement of the pressure between the said throttle (4) and the said inlet valve (6) at
predetermined crankshaft angles whereby one pressure measurement is made during at
least one of the inlet stroke or the compression stroke whereby at least one pressure
measurement is made near the piston's (3) lower turning point.
- 15 2. The method according to claim 1, **c h a r a c t e r i s e d b y** at least one of the pressure
measurements being made within +/- 90 degrees of the crankshaft from the piston's lower
turning point.
3. The method according to claim 1, **c h a r a c t e r i s e d b y** at least one of the pressure
measurements being made within +/- 45 degrees of the crankshaft from the piston's lower
20 turning point.
4. The method according to claim 1, **c h a r a c t e r i s e d b y** the said pressure measurement
values being weighted depending on the rotation rate of the engine.
5. The method according to any of claims 1-3, **c h a r a c t e r i s e d b y** at least one of the
pressure measurements being made at the end of the inlet stroke.
- 25 6. The method according to any of the previous claims, **c h a r a c t e r i s e d b y** the value
of the pressure measurement being used to calculate the amount of air enclosed in the
cylinder.
7. The method according to any of claims 1-6, **c h a r a c t e r i s e d b y** at least two
measurements of the pressure being made when the inlet valve is closed, that is, after the
30 inlet stroke and before the next inlet stroke, whereby the difference between these
measurements constitutes a measure of the airflow past the throttle into the inlet manifold.
8. The method according to any of claims 1-7, **c h a r a c t e r i s e d b y** at least two
measurements of the pressure being made of which at least one during the inlet stroke
when air flows into the cylinder and at least one before the inlet stroke when air has not

begun to flow into the cylinder whereby the difference between these measurements constitutes a measure of the degree of opening of the throttle.

Figure 1

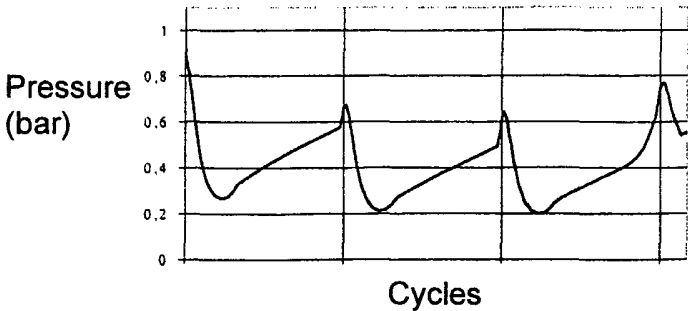


Figure 2

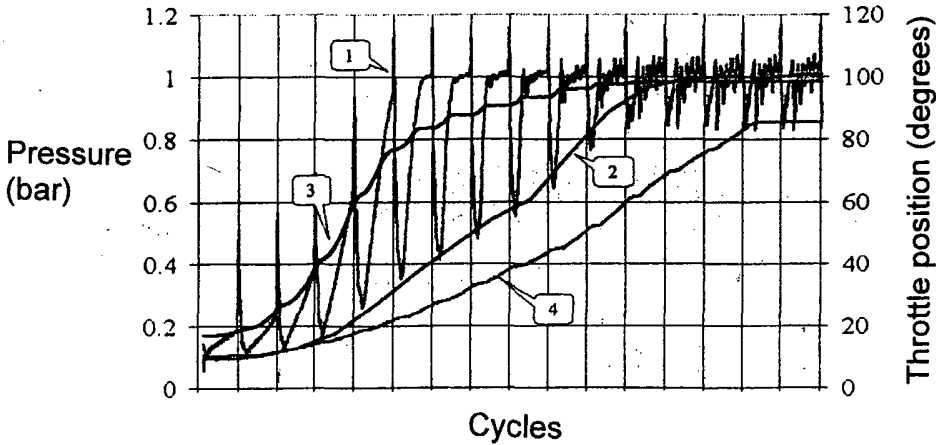
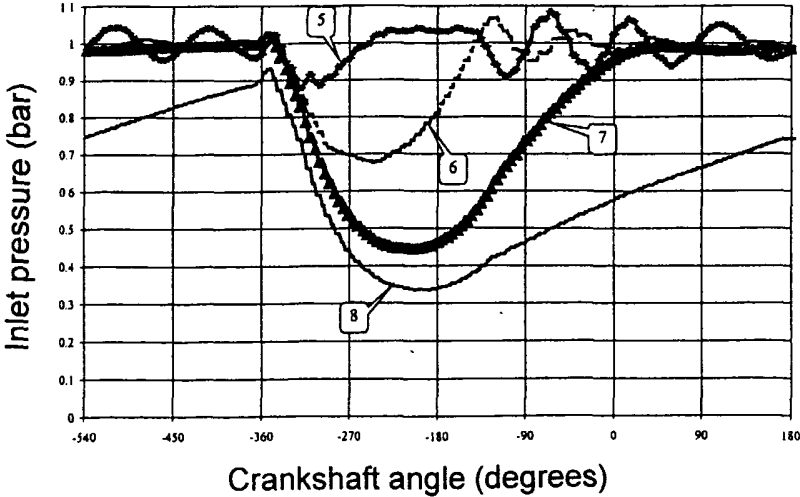


Figure 3



2/2

Figure 4

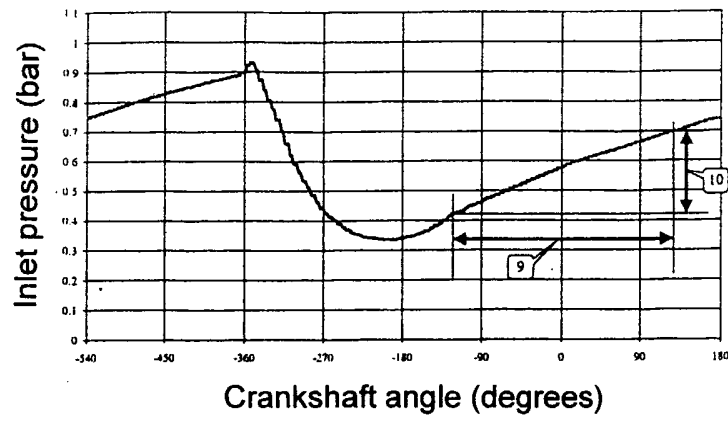


Figure 5

