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(54) **Synchronisation device without a cam-position sensor for an internal combustion engine**

(57) A method for generating a synchronising signal over 720° for an internal combustion engine without the use of a cam sensor but with the use of alternative strategies, for example, by detecting the duration of the spark in a reference cylinder or the correlation of the engine acceleration with the throttle valve angle.

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Description

The present invention relates generally to synchronisation devices without cam-position sensors for combustion engines, particularly internal combustion engines for motor vehicles.

Most internal combustion engines for vehicles are currently supplied by a fuel-injection system controlled by an electronic engine management unit which almost always also controls the ignition. Many of the current systems have a precise angular reference over 360° of the engine crankshaft and not over 720° of the entire engine cycle (in the specific case of a four-cylinder, four-stroke engine, the most widely available model in current production).

However, in the case of engines which use individual ignition coils for each cylinder, of the so-called top-plug type, or for engines in which the cylinder phases are not symmetrical (for example, engines with five cylinders and V-engines with six cylinders of the so-called galloping type) it is essential to retain a precise reference at 720° .

In order to obtain this reference it is known to use sensors, for example, cam sensors, but these have the disadvantage of increasing the cost of the electronic engine management system.

The object of the present invention is to provide a synchronisation device which enables all the problems indicated above to be resolved satisfactorily.

According to the present invention this object is achieved by a synchronisation device having the characteristics indicated in the claims which follow the present description.

Further advantages and characteristics of the present invention will become apparent from the following detailed description provided as non-limitative example.

The essential idea on which the present invention is based is that of using an engine reference angle of 360° as the precise reference and of discriminating between odd and even 360° phases of a reference cylinder (which may be any one of the engine's cylinders) by using signals already available to the electronic engine management unit.

For this purpose a signal from circuits which supply information regarding the duration of the spark (or ionisation detection circuits) is used. These circuits, although known in the art, will become ever more necessary in the future to enable recent anti-pollution regulations to be complied with and to carry out diagnostic functions relating to the operation of the engine.

Ionisation detection circuits supply a signal proportional (in duration or amplitude) to the duration of the spark. However, the voltage for triggering and maintaining the combustion varies widely according to the pressure in the combustion chamber of the cylinder (approximately proportional to this) while the arc current of the spark is about constant. This means that, for a given energy supplied to the primary winding of the coil

(for a given coil efficiency) the duration of the spark varies considerably. In practice, the spark lasts for a normal period of time if the cylinder is in compression while it lasts much longer if the cylinder is in the exhaust stroke.

In order to synchronise the engine, it thus suffices to cause ignition in one cylinder, selected as the reference cylinder, when this is in compression (or in exhaust given that this information is not known a priori) and to repeat the ignition after 360° so as to enable the two data relating to the spark duration to be compared. The spark of shorter duration is obtained when the stroke is, effectively, a compression stroke. Typically this procedure may be carried out on starting, and hence with the internal combustion engine being rotated by the starter motor, in a very short space of time since two full revolutions of the engine suffice for it to be completed. Moreover, the procedure may be carried out before the commencement of fuel injection into the cylinders. It is thus possible to initiate fuel injection (also phased) and to initiate the subsequent ignitions to start the engine after the synchronising procedure has been completed.

The strategy explained above may be improved to increase the certainty of discrimination by using several different cylinders as successive references (still during the first revolution of the engine and possibly fractions of the next revolution). The additional information thus obtained may confirm the first result or indicate the need for further monitoring if the results do not agree.

This same strategy may also be repeated with the engine running should there be an inexplicable drop in the engine speed (throttle valve angle greater than α_0 and engine deceleration greater than X revolutions/sec for a given α_0 and X).

In the absence of an ionisation circuit, the strategy may be carried out by using other signals which may be available to the engine's electronic management unit.

One signal which is always available, or can be deduced, is typically the correlation of the engine acceleration (positive or negative) with the throttle valve angle. This information can well be used in symmetrical engines instead of the said signal indicative of ionisation. By way of example, a four- or six-cylinder engine with pairs of cylinders out of phase by 360° (or even by 370 - 380°) is considered. In this case the engine may be started with two half-injections of fuel into almost opposed cylinders and with almost simultaneous firing of their ignitions. Thus ignitions are lost in the cylinder on the exhaust stroke but these ignitions (with the valve timing overlap typical of engines in current production) are not harmful. In these conditions the engine starts effectively.

At this point, immediately the throttle valve angle exceeds a predetermined threshold (for example, throttle valve angle greater than β_0 , which corresponds, in practice, to a specific required torque, with the engine already started (rotational speed greater than Y revolutions/sec for given β_0 and Y), a search strategy may be undertaken to effect discrimination between even and odd 360° angles.

This strategy may comprise effecting ignition every 720° for all cylinders, with a random choice of association with the 720° reference, that is, a random choice between even 360° angles and odd 360° angles. If the engine decelerates beyond a predetermined limit, the opposite association is tested, that is the choice between even 360° angles and odd 360° angles is reversed. At the end of this test, the correct reference is thus identified. This strategy may cause a gap in the engine operation but this situation is not dangerous and is scarcely perceptible to the driver since the engine is being started.

Alternatively, a strategy for recognising the even 360° angles and odd 360° angles may be carried out independently of the position of the throttle valve when the engine is in the transitional stage between the disconnection of the starter motor and the attainment of idling conditions (about 400-600 revolutions per minute).

Once the 720° phase angles have been recognised by means of one of the said strategies, both the injection and the ignition are controlled with the use of all this information (thus injection may be phased). Even then, one of the above-mentioned strategies may possibly be repeated with the engine running should the engine speed drop inexplicably.

The strategies explained above may be used alone, in combination (for example to increase reliability should the ionisation detection circuit fail) or even in association with a cam-position sensor in order to considerably increase the general reliability of the engine control system.

Another source of information which can be used to determine the 720° phase reference is provided by pressure sensors in the cylinder, if these are present, since these enable direct determination of whether the reference cylinder is in compression or exhaust.

Naturally, the principle of the invention remaining the same, the constructional details and embodiments may be varied widely with respect to that described and illustrated without thereby departing from the scope of the present invention.

Claims

1. A method for synchronising an Otto-cycle internal combustion engine, the said engine having an ignition system and a fuel supply system controlled by at least one electronic engine management unit, and sensor means for providing the electronic unit with a first reference signal indicative of the angular position of the engine crankshaft over 360°, the method being adapted to generate a second reference signal indicative of the phase of at least one cylinder of the said engine so as to allow, in combination with the first reference signal, the angular position of the engine crankshaft to be determined over 720°, characterised in that it includes the steps of:

- detecting at least one physical quantity relating to the operation of the engine and indicative of the pressure in the said at least one cylinder in two predetermined angular positions of the crankshaft identified by means of the first reference signal and spaced by at least one revolution of the crankshaft,
- comparing the values of the physical quantity detected at the said two angular positions spaced by at least one revolution,
- generating the second reference signal on the basis of the result of the comparison of the said values.

2. A method according to Claim 1, characterised in that the two angular positions are spaced by substantially 360° and in that the physical quantity is the ionisation of the gases in the said at least one cylinder.

3. A method according to Claim 2, characterised in that the step of detecting the physical quantity indicative of the pressure in the said at least one cylinder in two predetermined angular positions of the crankshaft spaced by substantially 360° includes the step of causing two ignitions spaced by 360° in the said at least one cylinder close to the top dead centre point of the said at least one cylinder and detecting the duration of the sparks caused by the two ignitions.

4. A method according to Claim 3, characterised in that the step of generating the second reference signal includes the step of generating a signal indicative of a compression stroke in the said at least one cylinder corresponding to that spark caused by the two ignitions which is of shorter duration.

5. A method according to any one of Claims 1 to 4, characterised in that it includes the steps of detecting and comparing the said physical quantity for a plurality of cylinders of the engine.

6. A method according to Claim 1, characterised in that it includes the steps of:

- generating, a priori, the second reference signal indicative of the 720° phase angle,
- causing an ignition every 720° in each cylinder of the engine on the basis of the second reference signal generated a priori,
- detecting the correlation of the engine acceleration with the angle of opening of the engine throttle valve,
- in case of engine deceleration, in opposition to the angle of opening of the throttle, inverting the second reference signal indicative of the 720° phase angle.

7. A method according to Claim 6, characterised in that the second reference angle, generated a priori, is generated in a random manner.
8. A method according to Claim 1, characterised in that the step of detecting a physical quantity indicative of the pressure in the at least one cylinder includes the step of detecting the pressure in the chamber of the said at least one cylinder by means of a pressure sensor.
9. A method according to any of Claims 1 to 8, characterised in that it is carried out on starting up the engine.
10. A method according to any of Claims 1 to 9, characterised in that it is carried out after the engine has been started.
11. A method according to Claim 10 characterised in that it is carried out when the engine is decelerating in opposition to the throttle valve angle.

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