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(54) **Detecting fuel injector opening**

(57) In order to determine the opening of a fuel injector of, for instance, a compression ignition engine, an electro-acoustic transducer such as a contact microphone monitors the acoustic waves produced by the injector. A monitoring circuit detects when the level of the output signals of the transducer increases, this increase being indicative of opening of the injector. By comparing the opening time of the injector with the position of the crankshaft, the timing of the engine can be checked without requiring dismantling.

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SPECIFICATION

**Improvements in or relating to methods of and apparatus for determining opening of injectors**

The present invention relates to methods of and apparatuses for determining opening of injectors. Such methods and apparatuses may be used for determining when an injector of a compression ignition engine opens. By comparing this opening time with the position of the engine crankshaft, it is possible to check the timing of the engine without having to dismantle the engine to inspect the drive to the injector arrangement.

According to one aspect of the invention, there is provided a method of determining opening of an injector, comprising applying an electro-acoustic transducer to the injector and monitoring the level of the output signal of the transducer to detect an increase therein indicative of opening of the injector.

According to another aspect of the invention, there is provided an apparatus for determining opening of an injector, comprising an electro-acoustic transducer arranged to be applied to the injector and a monitoring circuit arranged to monitor the level of the output signal of the transducer to detect an increase therein indicative of opening of the injector.

The transducer may comprise a contact transducer arranged to be in contact with the injector. The contact transducer may be a contact microphone, for instance of the piezo-electric type which is sufficiently rugged and reliable for this type of use. Alternatively the transducer may be a directional microphone not actually in contact with the injector.

In the case of a fuel injector of a compression ignition or diesel engine, the sudden flow of fuel through the injector when it opens to inject fuel into a cylinder of the engine produces acoustic waves which propagate in the metal body of the injector. The transducer receives these waves and converts them into an electrical signal whose level, at least at some frequencies, increases when the injector opens. Thus, the time or rise of the amplitude of this signal corresponds to the time when the injector opens.

The monitoring circuit monitors the output signal of the transducer, in particular the level thereof, and provides a signal indicative of the increase in amplitude corresponding to the opening of the injector. The monitoring circuit may include a filter allowing signals of frequencies corresponding to the sound produced by the injector when open to be preferentially amplified, thus increasing the signal-to-noise ratio or sensitivity of the monitoring circuit. Even when the engine is running normally and is thus producing a substantial amount of background noise, the monitoring circuit is still able to distinguish the acoustic waves produced by opening of the injector so as to produce a signal indicative of this opening. Thus the output signal from the transducer may be filtered so as to exclude noise or acoustic waves generated in other parts of the engine, thus permitting acoustic waves whose frequency is associated with the opening of the injector to be preferentially amplified.

It has been found that the acoustic waves associated with the opening of an injector have relatively high frequency. It is possible to use frequencies up to and in the region of 400 KHz. The use of frequencies in the region of 40 KHz has been found to be particularly advantageous. Accordingly, it is preferable for the output of the transducer to be filtered so as to pass signals having frequencies in such regions while suppressing or substantially reducing output signals whose frequencies lie outside these regions. Thus, a band-pass filter, preferably having a centre frequency of approximately 40 KHz, may be connected to the output of the transducer.

This permits more accurate detection of the opening of the injector in the presence of noise which is generated when the engine is being tested. In general, such noise has frequency components which lie outside these regions and thus may be removed or reduced sufficiently to allow a clear determination of opening of the injector to be made. Even when the noise has components, for instance, in the region of 40 KHz, it is still possible, for instance by arranging the transducer so as to be specifically sensitive to the acoustic waves produced by the injector while being much less sensitive to noise from other sources, to provide a signal with a sufficiently good signal-to-noise ratio to allow the opening of the injector to be reliably and accurately determined.

In a particularly simple embodiment of the invention, the transducer is attached to the injector by means of a spring clip. This has been found in practice to provide an adequate attachment of the transducer to the injector, and provides a quick, simple, cheap and convenient means of attachment, allowing the transducer to be readily detached when desired.

The method and apparatus may be used in conjunction with means for determining the position of a piston or crankshaft of an internal combustion engine so that the timing of the engine can be checked. In cases where there is no mark on a flywheel of the engine indicating top dead centre of one of the pistons, the top dead centre position can be determined by a method and apparatus as disclosed in our copending application No. (reference 230P41477X) entitled "Improvements in or relating to methods of and apparatuses for indicating a predetermined position of a piston or crankshaft of a piston engine", so that the engine timing can be checked without requiring any dismantling of the engine. The engine timing can thus be checked in a very quick and convenient manner.

CLAIMS

1. A method of determining opening of an injector, comprising applying an electro-acoustic transducer to the injector and monitoring the level of the output signal of the transducer to detect an

increase therein indicative of opening of the injector.

2. A method as claimed in claim 1, in which a contact transducer is placed in contact with the injector.

3. A method as claimed in claim 2, in which the contact transducer is a contact microphone.

4. A method as claimed in claim 3, in which the contact microphone is of piezo-electric type.

5. A method as claimed in claim 1, in which the transducer is a directional microphone which is directed at the injector.

6. A method as claimed in any one of the preceding claims, in which the components of the output signal of the transducer having frequencies corresponding to the acoustic waves produced by the injector when open are monitored and components having other frequencies are substantially ignored.

7. A method as claimed in claim 6, in which components having frequencies up to substantially 400 KHz are monitored.

8. A method as claimed in claim 7, in which components having frequencies in the region of 40 KHz are monitored.

9. A method of determining openings of an injector substantially as hereinbefore described.

10. An apparatus for determining opening of an injector, comprising an electro-acoustic transducer arranged to be applied to the injector and a monitoring circuit arranged to monitor the level of the output signal of the transducer to detect an increase therein indicative of openings of the injector.

11. An apparatus as claimed in claim 9, in which the electro-acoustic transducer is a contact transducer.

12. An apparatus as claimed in claim 10, in which the contact transducer is a contact microphone.

13. An apparatus as claimed in claim 12, in which the contact microphone is of piezo-electric type.

14. An apparatus as claimed in any one of claims 11 to 13, in which the contact transducer is provided with a spring clip for attachment to the injector.

15. An apparatus as claimed in claim 10, in which the electro-acoustic transducer is a directional microphone.

16. An apparatus as claimed in any one of claims 10 to 15, in which the monitoring circuit includes a filter arranged to pass components of the output signal of the transducer having frequencies corresponding to the acoustic waves produced by the injector when open.

17. An apparatus as claimed in claim 16, in which the filter is arranged to pass components having frequencies up to substantially 400 KHz.

18. An apparatus as claimed in claim 17, in which the filter is a bandpass filter having a centre frequency of substantially 40 KHz.

19. An apparatus for determining opening of an injector substantially as hereinbefore described.

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