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(54) **Electronic system for identifying the strokes of an internal combustion engine.**

(57) Electronic system for identifying the strokes of a four-stroke internal combustion engine, having an output crankshaft coupled to an angular position sensor which generates a signal having an interval of 360° of the crankshaft. The signal has at least one zero reference corresponding to a zero reference of the crankshaft. The system can detect (100) the zero reference and arbitrarily assign (11) the strokes of the engine (2) with respect to the zero reference by determining at least one specified angular relation between the zero reference and the angular position in which the upper dead centre of a first cylinder is reached. The system can monitor (131, 133) the torques generated by two cylinders of the engine to detect a stroke relationship between these torques and to recognize a timing displacement of 360° in the arbitrarily assigned strokes. The system can also retime (137) the arbitrarily assigned strokes.

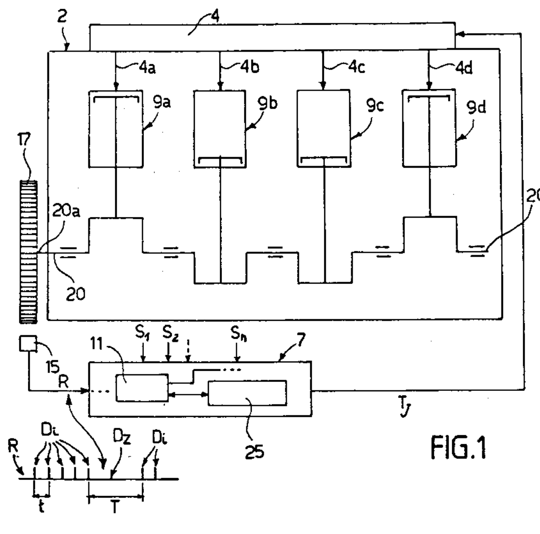

FIG.1

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The present invention relates to an electronic system for identifying the strokes of an internal combustion engine.

There are known electronic injection systems for internal combustion engines in which a microprocessor-based electronic controller receives at its input a plurality of data signals (for example, the number of engine revolutions, the throttle position, the intake air temperature, the cooling water temperature, etc.), and generates at its output the injection stroke and time for the different injectors.

Certain electronic injection systems, for example the systems known as "Multipoint" (one injector per cylinder) which are sequential (the fuel is injected into one cylinder at a time) and stroke-dependent (the fuel is injected in the suction stroke) also require angular reference systems permitting the recognition of the engine strokes (suction, compression, expansion, exhaust) present in the different cylinders of the engine.

The known angular reference systems use two angular position sensors: a first sensor which can supply a signal of the angular position of the crankshaft (with an interval of 360°) and a second sensor (with an interval of 720°) which can supply a signal of the angular position of the camshaft.

In particular, the first angular position sensor conveniently consists of a toothed pulley keyed to the crankshaft and a fixed sensor which can supply a pulse at the moment at which one tooth of the pulley passes in front of the fixed sensor. The toothed pulley also has a flattened portion, formed for example by the omission of two teeth, which is used as a zero reference for identifying the upper dead centres of the different cylinders of the engine. In particular, the upper dead centre of each cylinder of the engine is found, with an indeterminacy of 360°, in a specified angular position with respect to the zero reference. The upper dead centres of the different cylinders are then identified by counting specified numbers of pulses following the detection of the zero reference.

The second sensor consists of a toothed pulley keyed to the camshaft and a fixed sensor which can supply at its output a first signal level corresponding to a first zero reference detected by the first sensor and a second signal level corresponding to a subsequent detection of the zero reference. The second sensor is used to eliminate the 360° indeterminacy of the first sensor.

The known systems also have electronic controllers which receive the signals generated by the first and second sensors and process them to obtain the data on the engine strokes (suction, compression, expansion, exhaust) of the different cylinders.

The known angular reference systems entail a considerable complexity of construction and high costs.

The processing of the signals generated by the two sensors is also complex.

The object of the present invention is to provide an electronic system for identifying the strokes of an internal combustion engine which resolves the problems of the known systems. In particular, the object of the present invention is to provide an electronic system for identifying the strokes of an engine which uses only one angular position sensor.

The above object is achieved by the present invention in that it relates to an electronic system for identifying the strokes of a four-stroke internal combustion engine;

the said engine having an output crankshaft coupled to a sensor of the angular position of the said shaft;

the said sensor generating a signal having an interval of 360° of the crankshaft;

the said signal having at least one zero reference corresponding to a zero angular reference of the said crankshaft,

characterized in that it comprises:

- first electronic means capable of detecting the said zero reference;
- second electronic means capable of arbitrarily assigning the strokes of the cylinders of the said engine with respect to the said zero reference;

the said second electronic means determining at least one specified angular relation between the said zero reference and the angular position in which the upper dead centre of a first cylinder is reached;

- means of monitoring the torque generated by the said engine, capable of detecting an error of 360° of the crankshaft in the strokes assigned by the said second electronic means and capable of selecting retiming means capable of retiming the said strokes by 360°.

The invention will now be illustrated with particular reference to the attached figures, which represent a non-restrictive preferred embodiment, in which:

Figure 1 shows an internal combustion engine provided with an electronic system for identifying the strokes, made according to the principles of the present invention;

Figure 2 is a logical block diagram of the operations performed by the system according to the present invention; and

Figure 3 shows the variation with time of a monitored value of the system according to the present invention.

Figure 1 shows a four-stroke internal combustion engine 2 operating in an Otto cycle, provided with an injection device 4 controlled by an electronic controller 7 operating according to the electronic system of stroke identification according to the present invention.

In particular, the electronic controller 7 receives a plurality of signals S1, S2, ... Sn of input data collected in the engine 2 (for example, signals proportional to the engine coolant temperature, to the intake air temperature, to the throttle position, etc.) and generates at the output a plurality of injection times Tj supplied to the injection device 4.

The injection device 4 is provided with four injectors 4a, 4b, 4c, 4d operating with corresponding first, second, third and fourth cylinders 9a, 9b, 9c, 9d (shown schematically) of the engine 2 ("Multipoint" system) and can inject the fuel into one cylinder at a time (sequential system) and in the suction stroke (timed system).

The electronic controller 7 is provided with an engine stroke reference unit 11 permitting recognition of the engine stroke (suction, compression, expansion, exhaust) in each cylinder 9a, 9b, 9c, 9d of the engine 2.

The reference unit 11 receives at its input a signal from a sensor 15 coupled to a toothed pulley 17 mounted on one end of the crankshaft 20 of the engine 2. The sensor 15 can generate an electrical pulse when one tooth of the pulley 17 passes in front of the sensor 15. In particular, the toothed pulley 17 is keyed to one end 20a of the shaft 20 close to the cylinder 9a. The cylinder 9d is also close to one end 20b of the shaft 20 opposite the end 20a.

The toothed pulley 17 is provided with sixty teeth, with the omission of two, and therefore has a flattened portion formed by the absence of these two teeth, which is used as the zero reference. The zero reference is used to identify the upper dead centres of the different cylinders of the engine. In particular, the upper dead centre of each cylinder 4a, 4b, 4c, 4d is found, with an angular indeterminacy of 360°, in a specified angular position αa, αb, αc, αd with respect to the zero reference.

The signal R generated by the sensor 15 consists of a sequence of pulses Di equally spaced by an interval t. The signal R also has a flat portion Dz of width T (equal to approximately three times t) in which pulses cannot be detected; this flat portion Dz is produced during the passage of the flattened portion in front of the sensor 15.

The upper dead centre of each cylinder is identified with the said indeterminacy of 360° by counting a specified number of pulses Na, Nb, Nc, Nd after the detection of the zero reference.

In particular, when the zero reference is detected it is not possible to identify the timing of the different cylinders 9a, 9b, 9c, 9d in an unambiguous way, since the interval of the engine 2, operating in the Otto cycle, is 720° of the rotation of the crankshaft and the interval of the signal generated by the sensor 15 is 360° of the rotation of the crankshaft. Consequently it is not possible to know whether the 360° following the zero reference coincide with the first 360° of the cycle or with the final 360° of the engine cycle. It is therefore not possible to know whether the first specified angular position αa following the zero reference corresponds to the upper dead centre of the first cylinder 9a or to that of the fourth cylinder 9d of the engine 2.

The reference unit 11 also interacts with a device 25, for example the device described in French Patent FR-9111273 with the title "Process and device for measuring the torque of an internal combustion engine", capable of measuring the instantaneous torque developed individually by the different cylinders of the engine 2.

The unit 11 generates at its output a signal which describes the engine strokes (suction, compression, expansion, exhaust) of each cylinder 9a, 9b, 9c, 9d of the engine 2.

With particular reference to Figure 2, the operations performed by the unit 11 operating according to the system of the present invention will now be illustrated.

The first block encountered is the block 100 in which the system detects the signal R generated by the sensor 15.

In particular, in the block 100 the system is prepared to await the flat portion Dz of the signal R in order to identify the zero reference of the pulley 17.

Detection of the zero reference results in a passage from the block 100 to a block 110.

The block 110 arbitrarily assigns the strokes of the engine 2, assigning, for example, the upper dead centre of the first cylinder 9a to the first specified angular position following the zero reference; the assignation of the positions of the upper dead centres of the other cylinders is carried out in a way compatible with the first assignation.

In this way, the angular position αa of the upper dead centre of the first cylinder 9a is assigned after the detection of a specified number (for example, twenty) of pulses Na following the zero reference.

For the reasons stated above, the angular position found on the twentieth pulse following the zero reference may also correspond to the upper dead centre of the fourth cylinder 9d.

In case of error, the operation of the engine is not compromised, since the charge in the ignition coil (not illustrated) and the subsequent spark in the first cylinder 9a and in the fourth cylinder 9d are ensured; the performance of the engine 2 is, however, seriously degraded, since the injection and sparking are incorrectly advanced by 360°.

The block 110 is followed by a block 130 which detects an error in the assignation of the strokes (mistiming by 360°) and consequently retimes the injection.

In particular, the block 130 comprises a block 131 in which the instantaneous torque supplied by one cylinder of the engine, for example the cylinder recognized by the block 110 as the first cylinder 9a, is monitored by the device 25. This cylinder 9a is physically close to the pulley 17.

With particular reference to Figure 3, the letter A indicates a curve which represents the variation with time of the torque supplied by the cylinder recognized as the first cylinder 9a; the variation of this torque has an approximately sinusoidal form.

The block 131 is followed by a block 132 in which is stored the signal expressing the variation with time of the torque supplied by the cylinder recognized as the first cylinder 9a.

The block 132 is followed by a block 133 in which the instantaneous torque supplied by another cylinder of the engine, in particular the cylinder at the greatest distance along the shaft 20 from the first cylinder 9a, is monitored.

The block 133 may conveniently measure the instantaneous torque supplied by the cylinder recognized by the block 110 as the fourth cylinder 9d; the first cylinder 9a and the fourth cylinder 9d are coupled to opposite portions of the shaft 20. The torque supplied by the fourth cylinder 9d is also displaced by 360° of the crankshaft from the torque supplied by the first cylinder 9a.

With particular reference to Figure 3, the letter B indicates a curve representing the variation with time of the torque supplied by the cylinder recognized as 9d; the variation of this torque is approximately sinusoidal. In Figure 3 the displacement of 360° between the torques of cylinders 9a and 9d is also eliminated.

The block 133 is followed by a block 134 in which the torque measured in the block 131 is compared with the torque measured by the block 133; for this purpose, since the torque measured in the block 133 is displaced angularly and in time from the torque measured in the block 131, a time correction is made to the torque stored in the block 132. In particular, the stored torque (curve A) is displaced by 360° in such a way that the torques supplied by the first and fourth cylinders 9a, 9d can be compared, and these torques can be considered as if supplied simultaneously.

The torques supplied by the first and fourth cylinders 9a, 9d, given equal stoichiometric composition of the fuel mixture, spark advance and engine load, should have substantially equal variations in time, and the curves A and B should therefore coincide.

This does not happen in practice, owing to the torsional elasticity of the section of crankshaft between the cylinders 9a and 9d. For this reason, the torque supplied by the cylinder which is physically closest to the toothed pulley 17 is in advance of the torque supplied by the cylinder which is furthest from the toothed pulley 17. Therefore, if the assignations made by the block 110 are correct, the torque supplied by the cylinder 9a is in advance of the torque supplied by the cylinder 9d.

In order to determine the time relation between the torques of the cylinders 9a, 9d, the block 134 calculates the times t1 and t2 taken by the torques represented by the curves A and B to reach a specified threshold value $C_{threshold}$ (Figure 3).

The block 134 is followed by a block 135 in which the times t1 and t2 are compared with each other; in particular, if the time t1 is less than t2 (with the torque generated by the cylinder recognized as the first cylinder 9a in advance of the torque generated by the cylinder recognized as the fourth cylinder 9d) the block 135 is followed by a block 136; otherwise (if the time t1 is greater than t2 and therefore the torque generated by the cylinder recognized as the first cylinder 9a lags behind the torque generated by the cylinder recognized as 9d) the block 135 is followed by a block 137.

The block 137 retimes by 360° the timing set in the block 110; consequently, the upper dead centre of the fourth cylinder 9d (whose position is displaced by 360° with respect to that of the first cylinder) is assigned to the first angular position of the shaft 20 following the detection of a specified number of pulses (for example, twenty) from the zero reference.

The block 136 maintains the timing determined by the block 110.

The blocks 136 and 137 lead to the exit from the program.

The advantages of the present invention will be clear from the above, since the described system detects the engine strokes precisely although only one angular position sensor is used.

Finally, it will be clear that modifications and variations may be made to the described system without departure from the scope of protection of the present invention.

Claims

1. Electronic system for identifying the strokes of a four-stroke internal combustion engine;

   the said engine having an output crankshaft (20) coupled to a sensor (15, 17) of the angular position of the said shaft (20);

   the said sensor (15, 17) generating a signal (R) having an interval of 360° of the crankshaft;

the said signal (R) having at least one zero reference (Dz) corresponding to a zero angular reference of the said crankshaft (20),

characterized in that it comprises:

- first electronic means (100) capable of detecting the said zero reference;
- second electronic means (110) capable of arbitrarily assigning the strokes of the cylinders of the said engine (2) with respect to the said zero reference;

the said second electronic means determining at least one specified angular relation between the said zero reference and the angular position in which the upper dead centre of a first cylinder is reached;

- means (130) of monitoring the torque generated by the said engine (2), capable of detecting an error of 360° of the crankshaft in the strokes assigned by the said second electronic means (110) and capable of selecting retiming means (137) capable of retiming the said strokes by 360°.

2. System according to Claim 1, characterized in that the said torque monitoring means (130) comprise:

first monitoring means (131) capable of detecting the variation in time of the instantaneous torque supplied by a first cylinder (9a) of the engine, in particular a cylinder recognized as a cylinder physically close to the said angular position sensor;

second monitoring means (133) capable of detecting the variation in time of the instantaneous torque supplied by a second cylinder (9a) of the engine, in particular a cylinder at a maximum distance along the crankshaft (20) from the said first cylinder (9a);

compensation means (134), capable of eliminating the physical displacement between the variations in time of the torques supplied by the said first and by the said second cylinder, to permit the comparison between the torques supplied by the said first and the said second cylinder;

comparison means (135) selected after the said compensation means (134) and capable of comparing the torques supplied by the first and second cylinder (9a, 9d);

the said comparison means (135) being capable of selecting the said retiming means (137) on detection of a specified stroke relationship between the torques supplied by the first and second cylinder (9a, 9d).

3. System according to Claim 2, characterized in that the said comparison means (135) are capable of detecting the displacement between the torques supplied by the first and second cylinder (9a, 9d);

the said displacement being principally due to the torsional elasticity of the section of crankshaft lying between the said first and the said second cylinder (9a, 9d).

4. System according to Claim 3, characterized in that the said comparison means (135) are capable of selecting the said retiming means (137) when the torque generated by the said first cylinder (9a) lags behind the torque generated by the said second cylinder (9d).

5. System according to Claim 3 or 4, characterized in that the said comparison means (135) are capable of calculating first and second times (t1, t2) elapsing respectively between the instant of the start of a calculation and the instant in which the torques supplied by the said first and the said second cylinders reach a threshold value ($C_{threshold}$);

the said comparison means (135) being capable of comparing the said first and second times (t1, t2) with each other in order to determine the said specified time relation.

6. System according to Claim 5, characterized in that the said comparison means (135) are capable of selecting the said retiming means (137) when the said first time (t1) is greater than the said second time (t2).

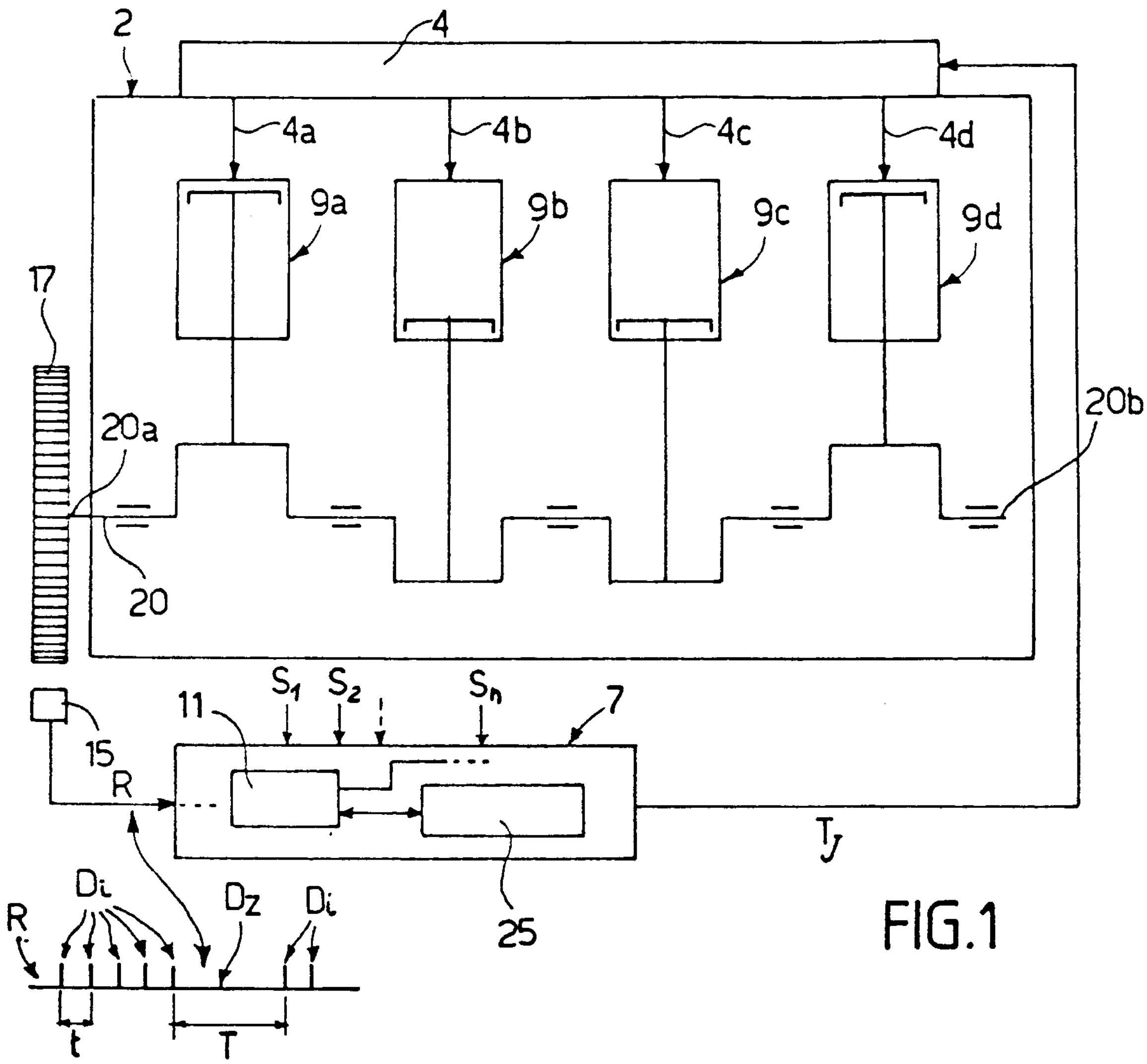

2
4
4a
4b
4c
4d
9a
9b
9c
9d
17
20a
20b
20
S_1 S_2 S_n
11
7
15
R
T_J
25
R
Di
Dz
Di
t
T

FIG.1

FIG. 3

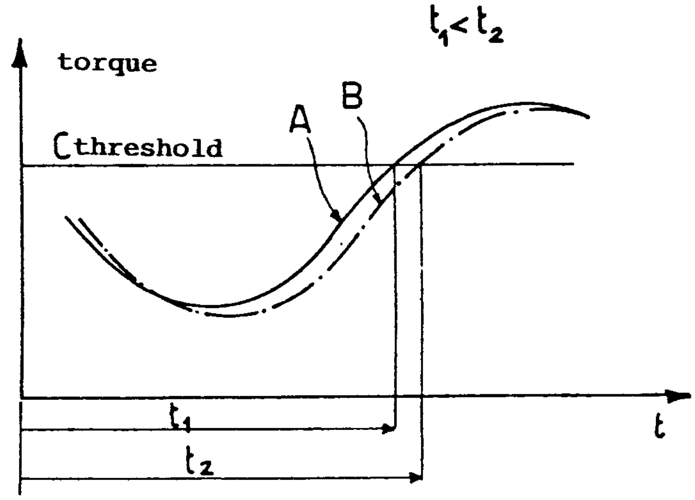
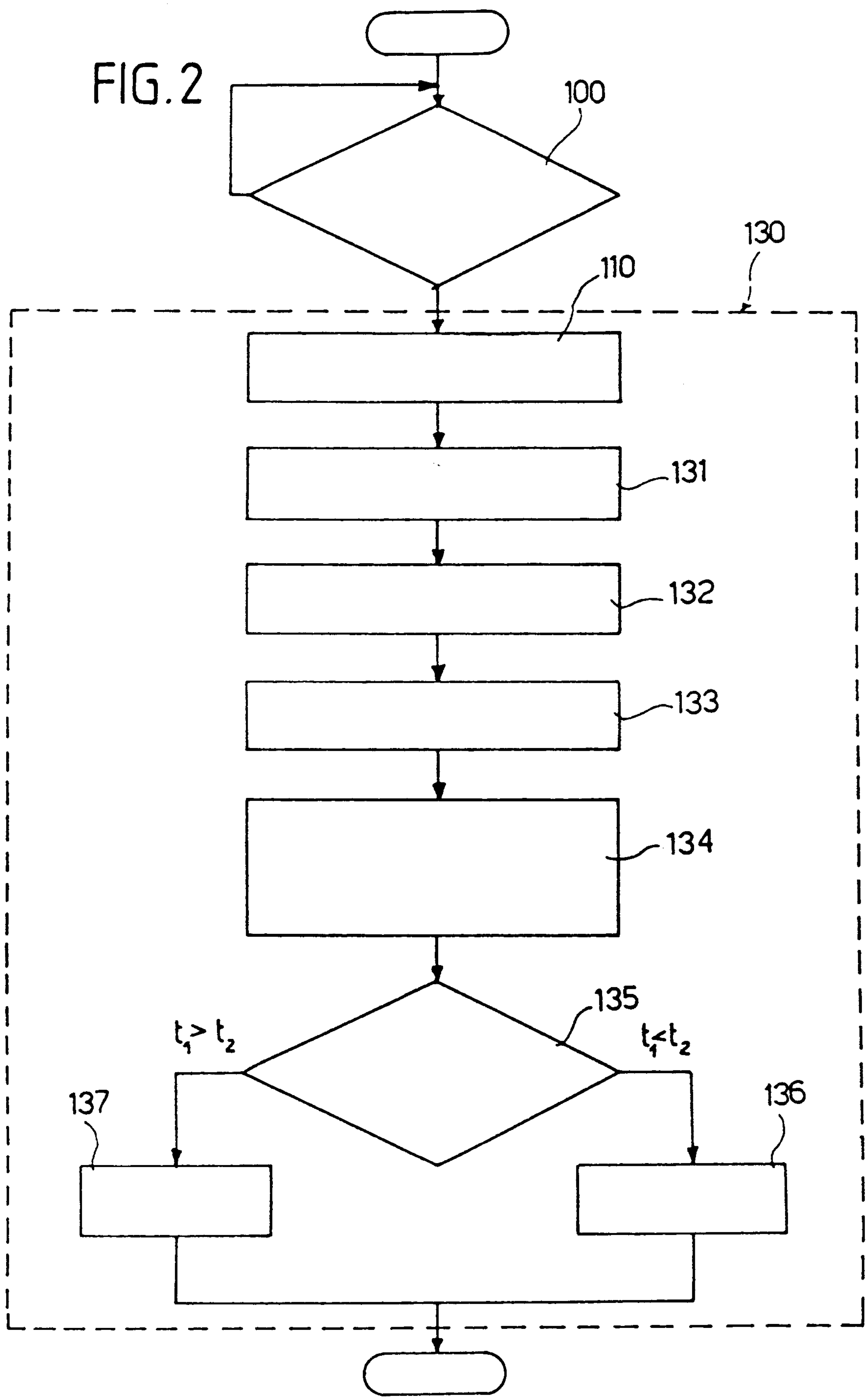

$t_1 < t_2$
torque
A
B
Cthreshold
t_1
t_2
t

FIG. 2



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EUROPEAN SEARCH REPORT

Application Number
EP 95 10 7844

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 576 334 (REGIE NATIONALE DES USINES RENAULT S.A.) 29 December 1993 * column 2, line 38 - line 57 * * column 3, line 33 - column 4, line 47 * * column 5, line 32 - column 11, line 16; figures * ---	1	F02D41/34 F02D41/06
A	FR-A-2 676 251 (ROBERT BOSCH GMBH) 13 November 1992 * the whole document * ---	1	
A	US-A-4 870 587 (KUMAGAI) 26 September 1989 * the whole document * ---	1	
D,A	EP-A-0 532 419 (REGIE NATIONALE DES USINES RENAULT S.A.) 17 March 1993 -----		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
F02D G01M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	8 September 1995	Moualed, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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