(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 803 916 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.07.2007 Bulletin 2007/27

(51) Int Cl.:
F02D 41/34 *(2006.01)* ***F02D 41/14*** *(2006.01)*

(21) Application number: **05113097.9**

(22) Date of filing: **30.12.2005**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(71) Applicant: **Scania CV Aktiebolag (publ)**
151 87 Södertälje (SE)

(72) Inventor: **Pernestål, Anna**
SE-151 45 Södertälje (SE)

(74) Representative: **Olsson, Jan et al**
Bjerkéns Patentbyra KB
P.O.Box 1274
801 37 Gävle (SE)

(54) **A method and a system for synchronization**

(57) A method for synchronization or allocation of cylinders to the crankshaft position in a multi-cylinder internal combustion engine having a crankshaft (1) which rotates twice per working cycle comprises the steps of assuming the existing phase of the engine, injecting fuel into a cylinder being according to said assumed phase in the compression stroke, measuring a possible increase of the rotational speed of the crankshaft and repeating this procedure at least a further time. A phase assumption is considered to be correct if a said increase is obtained at least a predetermined number of times being at least two for this assumption. Otherwise the opposite phase is assumed as correct and the procedure is repeated for that new assumption.

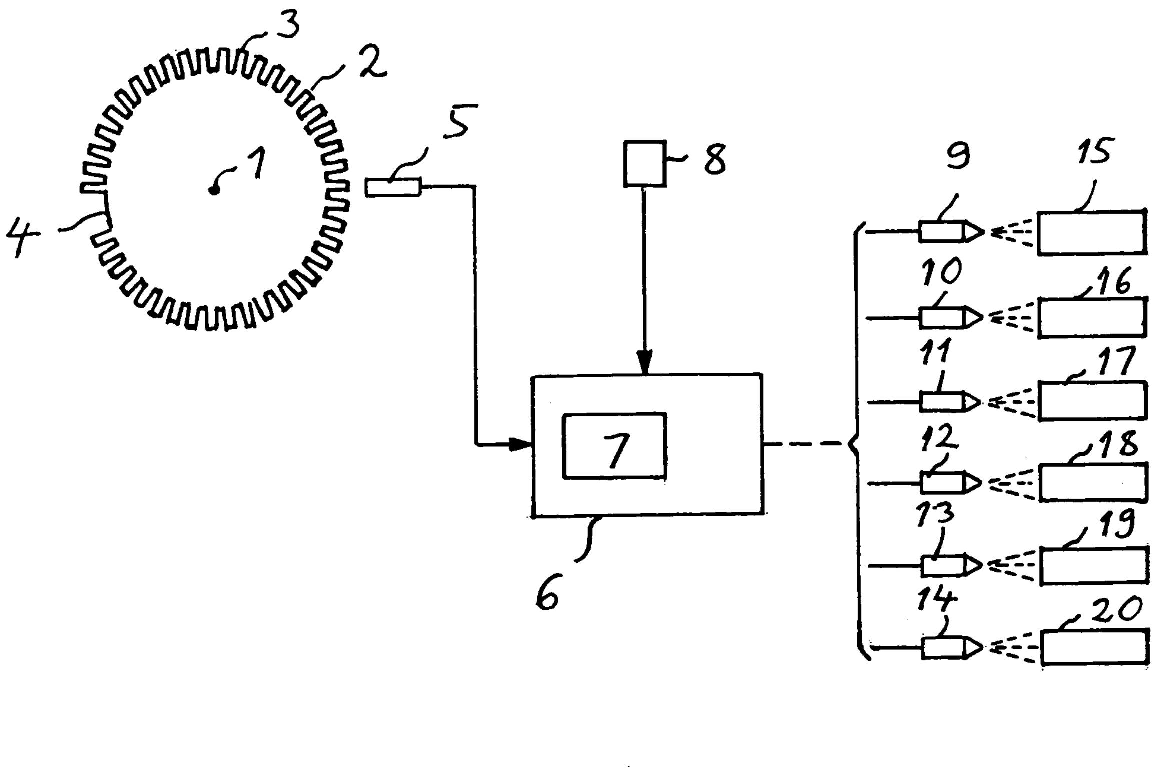

Fig 1

EP 1 803 916 A1

Description

Technical field of the invention and prior art

[0001] The present invention relates to a method for synchronization or allocation of cylinders to the crankshaft position in a multi-cylinder internal combustion engine having a crankshaft which rotates twice per working cycle as well as a system for such synchronization according to the preamble of the independent system claim.

[0002] The invention is applicable to any type of multicylinder internal combustion engines being of the so-called four stroke type. The engine may be arranged to drive a vehicle, but the invention is not restricted to that use.

[0003] The camshaft rotates in internal combustion engines of this type one revolution (a working cycle) when the crankshaft carries out two revolutions, so that the stroke in question would be unambiguously determined for each cylinder would the position of the camshaft be known. However, camshaft sensors are for cost reasons not always arranged in these engines and even if the engine has such a sensor it may fail.

[0004] These engines have more often two sensors sensing the position of the crankshaft. However, such sensors may only be used to determine the positions of the pistons of each cylinder from the detection of the position of the crankshaft, but it may not deliver information about which of the two possible rotations, the first or the second, of the working cycle is presently carried out by the crankshaft. However, it is necessary to know the phase of the cylinders (the engine) for deciding when fuel is to be injected into each cylinder. This is particularly important when the injection of fuel is controlled electrically and is independent of the camshaft which means that the camshaft does not prevent injection of fuel into a cylinder being in an incorrect phase therefor, but fuel may be injected into a cylinder at any time when ordered by an electronic control unit controlling the operation of the engine. This means that fuel may by mistake be injected into a cylinder being in the gas exchange phase. This would mean that the fuel would remain in the cylinder until the next compression stroke, and a homogeneous charged ignition like combustion may then take place, which may destroy the pistons and the cylinders. Injections into a cylinder being in the incorrect phase also creates high emission rates.

[0005] Thus, it is important to determine the phase of an internal combustion engine of this type, i.e. synchronize the engine, as quick as possible for avoiding wear or damage of components of the engine as well as unnecessary emissions of pollutions and black smoke.

[0006] The US patent application 2003/0089354 A1 describes a method for such synchronization, in which the fly wheel connected to the crankshaft is subjected to a disturbing oscillation used to determine which of the two crankshaft rotations is the correct one for a cylinder by comparison between phase positions of such oscillations and oscillations emanating from the ignition pulse.

[0007] The European patent 0 942 163 B1 describes a method, in which the position of the crankshaft of the engine is sensed and a command to inject fuel into one of the cylinders of the engine is ordered as the piston thereof is close to an upper dead centre position and this piston may be in the compression stroke, whereupon the rotational speed of the crankshaft is measured before said ordered injection and with a delay after said injection and a comparison of these two rotational speed values is carried out. If there is an increase in rotational speed it is determined that the phase assumed was correct and if not a new preliminary synchronization takes place by ordering an injection of fuel for the cylinder then assumed to be in the compression stroke when having the piston thereof in said upper dead centre position. This preliminary synchronization is verified if there is an increase in rotational speed. However, this method is only reliable for engines having an injection of fuel being dependent upon the camshaft position, so that injection of fuel may be commanded in the incorrect phase, but the injection will then not take place. This also means that as soon as an increase in rotational speed has been obtained it may be determined that fuel has in fact been injected and the phase of the engine is then as assumed.

Summary of the invention

[0008] The object of the present invention is to provide a method and a system of the type defined in the introduction, which makes it possible to quickly determine the phase of the engine upon start thereof also for multiple-cylinder internal combustion engines in which fuel may be injected at any time controlled by an electronic control unit independently of the position of the camshaft.

[0009] This object is according to the invention obtained by providing a method and system according to the appended independent method and system claims.

[0010] Accordingly, it is started by assuming the existing phase of the engine, and this assumption will mostly be correct, since an electronic control unit of the engine has mostly data stored about the state of the engine when stopped. However, the assumption may be incorrect if the engine has been moved around since the last stop, the turning off of the electronic control unit has been abnormal or it has been reprogrammed. Thus, although the risk of injecting fuel into a cylinder in the gas exchange phase is rather low it may not be neglected. However, fuel is injected into one of the cylinders assumed to be in the compression stroke and the rotational speed of the crankshaft is measured before said injection and with a delay after said injection and a comparison of these two rotational speed values is carried out. If the result of this comparison shows an increase of said rotational speed after said injection above a predetermined level, it is decided that there is an indication that the phase assumption was correct and otherwise that it was false. By introducing such a predetermined level it is avoided that an injection of fuel into a cylinder not being in the compression stroke will be detected as an indication that the phase assumption was correct, since there is a possibility that a type of combustion will then also take place and result in a slight increase of rotational speed. Furthermore, by repeating the injection of fuel and the rotational speed measurement and requiring that a predetermined number being at least two of indications that the phase assumption was correct has to be obtained for accepting the assumed phase as correct the risk of coming to a false conclusion with respect to the phase of the engine may be eliminated. There is namely a slight risk that an injection into a cylinder being in the gas exchange stroke may under certain circumstances result in an increase of the rotational speed of the crankshaft being above said predetermined level, but the probability that this may take place more than once, and especially more than twice or three times during a start procedure of a multi-cylinder internal combustion engine will be negligibly low. It is important that the step of fuel injection and rotational speed measurements and comparisons is repeated also if no increase of the rotational speed after said injection above a predetermined level is detected after the first injection of fuel into one of the cylinders, since this does not automatically mean that the phase assumption was false (it is in most cases correct), but there may have been some problem to initiate a combustion in the cylinder in question, for example as a consequence of the properties of a certain cylinder or that the engine temperature was low.

[0011] According to an embodiment of the invention a certain number of repetitions is carried out in step e) and if after that no indication that the phase assumption was correct has been obtained it is assumed that the phase assumption was incorrect and the steps b) - f) are repeated for the opposite phase, now assumed to be correct, but as soon as one indication that the phase assumption was correct is obtained said certain number of repetitions are carried out in step e) again. By introducing this certain number of repetitions, which may suitably be 2, 3 or 4, it is avoided that fuel is injected too many times into cylinders not being in the compression stroke and that additional attempts to obtain said predetermined number of indications that the phase assumption was correct is made as soon as a rotational speed increase above said predetermined level has been detected.

[0012] According to another embodiment of the invention if, after it has in step d) obtained an indication that the phase assumption was correct, a further such indication is not obtained after a fixed number of repetitions of steps b) - d) it is assumed that the phase assumption was incorrect and the steps b) - f) are repeated for the opposite phase, now assumed to be correct. According to a preferred embodiment this fixed number is 1, which means that it is not only necessary to obtain two indications that the phase assumption was correct for verifying the synchronization, but one such indication has to be directly followed by another such indication.

[0013] According to another embodiment of the invention said predetermined number is 2, 3 and 4, which are suitable figures for reliably determining the phase of the engine.

[0014] According to another embodiment of the invention the temperature of the engine or a parameter associated therewith is measured before the first fuel injection in step b) and the number of repetitions carried out in step e) is made dependent upon this temperature measurement, so that the number of repetitions is increased with decreasing engine temperature. When the engine temperature is very low there is a considerable risk that fuel is injected into one cylinder without obtaining any combustion, and it is therefore preferred to carry out more injections for the phase assumed to be correct under such conditions, since said phase assumption is, as said, mostly correct. Thus, without considering said temperature there is a risk of unnecessary changing the assumed phase to the false phase and injecting fuel into the cylinders in the false phase and procuring unnecessary wear or damage. It would also take longer time to start the motor.

[0015] According to another embodiment of the invention said predetermined level for the increase of the rotational speed of the crankshaft is set to be at least 5% of the rotational speed before the fuel injection in question. By such a predetermined level the risk will be low that an injection of fuel into a cylinder being in the gas exchange phase will result in a combustion indicating that the phase assumption was correct.

[0016] According to another embodiment of the invention said predetermined level for the increase of the rotational speed is lowered after an exceeding thereof has been detected for the first time in a step d). The first "real" combustion, i.e. the first combustion in a compression stroke of that cylinder, results in a greater increase of the rotational speed than combustions following thereupon, so that the predetermined level may initially be set higher for further reducing the risk of recording a combustion as a consequence of fuel injection into the cylinder being in the gas exchange stroke as a combustion in the compression stroke of the cylinder.

[0017] According to another embodiment of the invention, when step b) is carried out the second time for an assumed phase of the engine, fuel is injected into another cylinder than the preceding time. One advantage of this procedure is that if it is difficult to obtain combustion in one cylinder in spite of fuel injected into the cylinder in the compression stroke thereof a combustion detected as a "real" combustion may then be obtained in said other cylinder, so that the assumed phase will not be unnecessarily changed. One of the cylinders may also for any other reason behave differently than the other cylinders, and it is then appropriate to make a " test injection" of fuel into different cylinders. Furthermore, the delay between the two injections may be reduced if fuel is injected into another cylinder the second time than the first time, so that the entire synchronization procedure may be shortened.

[0018] According to another embodiment of the invention, when the step b) is carried out the second time for an assumed engine phase, fuel is injected into the next cylinder assumed to arrive at said compression stroke after the cylinder into which fuel has previously been injected. This means that the synchronization procedure may be shortened to an optimum, and it means for a six cylinder engine that fuel is injected into said other cylinder when the crankshaft has rotated 120° and for an eight cylinder 90° after the preceding injection.

[0019] According to another embodiment in which in step e) at least two repetitions are carried out fuel is in step b) each time injected into the cylinder being the next to arrive at the compression stroke according to the assumed phase of the engine after the cylinder into which fuel has previously been injected. This enables a duration of said synchronization procedure being as short as possible, so that the engine may be controlled according to normal control functions as soon as it has reached a normal number of revolutions.

[0020] According to another embodiment of the invention, when it is in step f) assumed that the phase assumption was incorrect and the steps b)-f) are repeated for the opposite phase, now assumed to be correct, fuel is in step b) first injected into the next cylinder arriving at the compression stroke according to the engine phase now assumed, which reduces the duration of the method.

[0021] According to another embodiment of the invention, when it is in step f) assumed that the phase assumption was incorrect and the steps b)-f) are repeated for the opposite phase, now assumed to be correct, fuel is in step b) first injected into another cylinder than the cylinder started with after step a). This is done for avoiding any false conclusions as a consequence of an inappropriate function of a cylinder of the engine.

[0022] According to another embodiment of the invention said repetitions are in step e) carried out during a predetermined period of time dependent upon the present rotational speed of the crankshaft. Thus, it is the number of repetitions that is essential, so that a period of time during which said repetitions are carried out is made dependent upon the number of revolutions of the crankshaft, since less time is needed for a certain number of repetitions and the entire method when the number of revolutions of the crankshaft is higher.

[0023] According to another embodiment of the invention the method is carried out on an engine of a vehicle, such a truck or a bus.

[0024] The object of the present invention with respect to the system is obtained by providing a system according to the appended independent system claim. The advantages and features thereof and of the embodiments of the system defined in the dependent system claims appear from the above discussion of the method according to the invention.

[0025] The method according to the invention is suitable to be carried out by means of a computer program, and the invention does for that sake also relate to a computer program loadable directly into the internal memory of a computer, which computer program comprises computer program code for causing the computer to carry out the steps according to the appended computer program claims.

[0026] Furthermore, the invention also relates to a computer program product comprising a data storage medium readable by an electronic control unit, a computer program according to the invention being stored on said data storage medium, as well as an electronic control unit comprising an execution means, a memory connected to the execution means and a data storage medium connected to the execution means, a computer program according to the invention being stored on said data storage medium.

[0027] Further advantages as well as advantageous features of the invention appear from the following description and the other dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] With reference to the appended drawings, below follows a specific description of embodiments of the invention cited as examples.

[0029] In the drawings:

[0030] Fig 1 is a very schematic view illustrating the general construction of an embodiment of a system according to the present invention,

[0031] Figs 2-5 are graphs illustrating the rotational speed of the crankshaft of a six cylinder internal combustion engine versus the angle of rotation of the crankshaft when a method for synchronization according to embodiments of the invention is carried out and how information about this speed is used for synchronization of the engine,

[0032] Fig 6 schematically illustrates an electronic control unit according to the present invention, and

[0033] Fig 7 is a flow chart illustrating the principles of a method according to the present invention.

[0034] DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0035] Fig 1 schematically illustrates a crankshaft 1 or a flywheel of a six cylinder internal combustion engine having a disc 2 rigidly connected thereto and provided with a plurality of angle marks 3 as well as a reference mark 4. The system comprises at least one sensor 5 adapted to continuously sense the position of the crankshaft rotating twice per working cycle of the engine. Information about the position of the crankshaft and thereby of the piston of each of the cylinders is sent to a control device 6 including an electronic control unit 7. Data concerning in which phase the engine was when previously stopped are stored in the control device. The control device is adapted to assume that the engine has not been moved since it stopped last time and will assume that the engine is in the same phase as when stopped.

[0036] The system also comprises means 8 adapted to measure a parameter associated with the temperature of the engine and deliver information about this parameter to the control device 6. The control device may by means of the electronic control unit control injecting means 9-14 to inject fuel into the cylinders 15-20 of the engine when the cylinder in question is determined by the sensor 5 to be close to the upper dead centre position and according to said assumed phase in the compression stroke.

[0037] The method for synchronization or allocation of cylinders to the crankshaft position in the six cylinder internal combustion engine schematically shown in Fig 1 is carried out when the engine is started by the start motor and the number of revolutions will be in the region of 200 revolutions per minute as follows: the existing phase of the engine, i.e. the existing number, first or second, of the rotation of the crankshaft in the existing working cycle is assumed by means of data stored in the memory of the control device 6. Fuel is then injected into one of the cylinders 15-20 as the piston thereof is close to an upper dead centre position and this piston according to said assumed phase is in the compression stroke. The rotational speed of the crank shaft is measured by means of information from said sensor 5 before said injection and with a delay after said injection, such as when the crankshaft has rotated 120° - then in the form of the average rotational speed between the 0°- and the 120°-position. These two rotational speed values are compared in said control device. If the result of said comparison shows an increase of said rotational speed after said injection above a predetermined level n_{diff}, it is decided that there is an indication that the phase assumption was correct and otherwise that it was false. Fuel is now injected into another or the same cylinder as the piston thereof is close to an upper dead centre position and this piston according to said assumed phase is in the compression stroke, whereupon the rotational speed of the crankshaft is measured again and compared with the rotational speed of the crankshaft before the last injection for revealing if the increase of the rotational speed is above a predetermined level. This procedure may be repeated for one or more further cylinders or it may be stopped after two cylinders. The number of said indications that the phase assumption was correct is after each such repetition compared with a predetermined number being at least two and if it is equal to this predetermined number said assumed phase is accepted as correct and the synchronization is verified and the procedure terminated, so that the electronic control unit may start to control the engine according to an algorithm of normal control functions as soon as the engine has reached a normal number of revolutions. It may then also be required that two or three such indications follow directly upon each other for verifying the synchronization. However, if after the last of the repetitions the number of indications that the phase assumption was correct is below said predetermined number it is assumed that the phase assumption was incorrect and fuel is injected into one of the cylinders as the piston thereof is close to an upper dead centre position and this piston according to said phase, now assumed to be correct, is in the compression stroke, whereupon the above procedure is repeated for this assumed phase. The assumed phase may in this way be changed a certain number of times.

[0038] A certain number of repetitions, i.e. injections of fuel into cylinders, is carried out, corresponding to a time lapsed from the first injection of t_{first}-thershold, and if after that no indication that the phase assumption was correct has been obtained it is assumed that the phase assumption was incorrect, but as soon as one indication that the phase assumption was correct is obtained said certain number of repetitions are carried out again.

[0039] The control device 6 may make said certain number or repetitions and said fixed number of further number of repetitions dependent upon the temperature of the engine reported by the sensor 8 and increase the number of repetitions with decreasing engine temperature, since the risk is higher when the engine temperature is low that a combustion will not take place in a cylinder in spite of injection of fuel thereinto in the compression stroke thereof.

[0040] Figs 2-5 schematically illustrate the development of the rotational speed of the crankshaft in the form of the number of revolutions per minute versus the angle of rotation of said crankshaft when applying a method according to different embodiments of the invention upon a six cylinder internal combustion engine. An angle of 120° corresponds to the position of the crankshaft when fuel is the first time in step b) injected into a cylinder after the assumption of the existing phase of the engine.

[0041] Fig 2 illustrates the case in which the assumption of phase 1 as existing phase was correct and the rotational speed does after said first injection show an increase above a predetermined level n_{diff}, such as above 5 percent of the rotational speed before that injection. This predetermined level may for some engines be set slightly higher, such as at 7 or 10 percent of the rotational speed before the injection. This means an indication that the phase assumption was correct. When the crankshaft has reached the position of 240° fuel is injected into the next cylinder assumed to be in the compression stroke, and it is shown that also this injection results in an increase of the rotational speed of the crankshaft above a predetermined level. The same applies for an injection at 360°. No more repetitions are carried out and the predetermined number mentioned above is here set to three and the synchronization is verified and the procedure terminated.

[0042] Fig 3 shows a case in which the initial engine phase 1 assumption is false and no increase of the rotational speed above a predetermined level is observed after injection of fuel in the first cylinder, whereupon fuel is also injected into the next two cylinders arriving at the compression stroke according to the assumed phase, but these injections do neither result in any increase of the rotational speed above said predetermined level.

Said certain number of repetitions is here by dimensioning t_{first}-threshold set to three, so that it is then assumed that the phase assumption was incorrect, and fuel is then at the position of 360° of the crankshaft injected into a cylinder assumed to be in the compression stroke in the phase 2 now assumed to be correct, such as the first cylinder instead of the fourth cylinder. This injection results in an increase of the rotational speed above said predetermined level n_{diff}, and this injection is followed by two further injections into the next cylinder with the same result, whereupon the synchronization is verified and the procedure terminated.

[0043] Fig 4 illustrates the case in which the first assumption with respect to the engine phase 1 is correct, but for any reason no combustion takes place in the first cylinder into which fuel is injected. However, it is then not assumed that the phase assumption was incorrect, but fuel is as in the procedure according to Fig 3 injected into the next cylinder arriving at the assumed compression stroke and an increase of the rotational speed above said predetermined level n_{diff} is observed. In the embodiment shown in Fig 4 said predetermined number is set to be three, and the synchronization is verified and the procedure terminated after having observed three said increases of the rotational speed above said predetermined level.

[0044] Fig 5 illustrates the case of an incorrect first assumption of the existing phase of the engine, which however for any reason results in an increase of the rotational speed of the crankshaft above said predetermined level n_{diff}. However, the next injection does not result in any rotational speed increase above n_{diff} (n_{diff} is in fact negative at 240°, but this has not been shown in Fig 5), so that $t_{between}$ two possible combustions is reaching $t_{between}$-treshold and it is then assumed that the phase assumption was incorrect and the procedure is repeated for the opposite phase 2, now assumed to be correct, resulting in an acceptance of that phase to be correct. Thus, in this case it would have been detrimental for the condition of the engine to verify the synchronization after obtaining the first increase of the rotational speed of the crankshaft above said predetermined level, since the phase assumption was in fact false.

[0045] Computer program code for implementing the method according to the invention is suitably included in a computer program, which is loadable directly into the internal memory of a computer, such as the internal memory of the electronic control unit 7 of a vehicle. Such a computer program is suitably provided with a computer program product comprising a data storage medium readable by an electronic control unit, which data storage medium has the computer program stored thereon. Said data storage medium is for instance an optical data storage medium in the form of a CD-ROM disc, a DVD disc etc., a magnetic data storage medium in the form of a hard disc, a diskette, a cassette tape etc., or a memory of the type ROM, PROM, EPROM or EEPROM of a Flash memory.

[0046] The computer program according to an embodiment of the invention comprises computer program code for causing a computer, e.g. in the form of a micro processor of an electronic unit such as an engine control unit: a) to assume or receive an assumption of the existing phase of a multi-cylinder internal combustion engine having a crankshaft which rotates twice per working cycle, i.e. the first or second rotation in a working cycle,

b) to control injection of fuel into one of said cylinders as the piston thereof close to an upper dead centre position and this piston according to said assumed phase is in the compression stroke,

c) to measure the rotational speed of the crankshaft before said injection and with a delay after said injection and to compare these two rotational speed values,

d) to decide that there is an indication that the phase assumption in a) was correct if the result of said comparison shows an increase of said rotational speed after said injection above a predetermined level and otherwise that it was false,

e) to control the steps b) - d) to be repeated one or more times,

f) to after each said repetition in step e) compare the number of said indications that the phase assumption was correct with a predetermined number being at least two and if it is equal to this predetermined number accept said assumed phase as correct and verify a synchronization of the cylinders of the engine and terminate the procedure and if after the last of said repetition(-s) the number of indications that the phase assumption was correct is below said predetermined number assume that the phase assumption was incorrect and repeat steps b) - f) for the opposite phase, now assumed to be correct,

and to change the assumed phase in this way maximally a certain number of times.

[0047] Fig 6 very schematically illustrates an electronic control unit 6 comprising an execution means 21, such a central processing unit (CPU), for executing computer software. The execution means 21 communicates with a memory 23, for instance of the type RAM, via a data bus 22. The control unit 6 also comprises data storage medium 24, for instance in the form of a memory of the type ROM, PROM, EPROM or EEPROM or a Flash memory. The execution means 21 communicates with the data storage medium 24 via the data bus 22. A computer program comprising computer program code for implementing a method according to the invention is stored on the data storage medium 24.

[0048] Finally, Fig 7 shows a flow chart of a method according to an embodiment of the present invention comprising the steps S1-S10.

[0049] The invention is of course not in any way restricted to the embodiments described above, but many possibilities of modifications thereof will be apparent to a person with ordinary skill in the art without departing from the basic idea of the invention as defined in the appended claims. It is obvious that said predetermined number, certain number and fixed number may be set to other integers than mentioned above for considering each particular circumstance such as type of engine and the environmental conditions, such as temperature, degree of moisture and so on.

Claims

1. A method for synchronization or allocation of cylinders (15-20) to the crankshaft position in a multi-cylinder internal combustion engine having a crankshaft (1) which rotates twice per working cycle, in which the position of the crankshaft is sensed continuously or when desired, the method being carried out when the engine is started and comprising the steps:

    a) the existing phase of the engine, i.e. the existing number, first or second, of the rotation of the crankshaft in the existing working cycle is assumed,
    b) fuel is injected into one of said cylinders as the piston thereof is close to an upper dead centre position and this piston according to said assumed phase is in the compression stroke,
    c) the rotational speed of the crankshaft is measured before said injection and with a delay after said injection and a comparison of these two rotational speed values is carried out,
    d) if the result of said comparison shows an increase of said rotational speed after said injection above a predetermined level, it is decided that there is an indication that the phase assumption in a) was correct and otherwise that it was false,
    e) one or more repetitions of steps b) - d) is carried out,
    f) after each said repetition the number of said indications that the phase assumption was correct is compared with a predetermined number being at least two and if it is equal to this predetermined number said assumed phase is accepted as correct and the synchronization is verified and the procedure terminated and if after the last of said repetition(-s) the number of indications that the phase assumption was correct is below said predetermined number it is assumed that the phase assumption was incorrect and the steps b) -f) are repeated for the opposite phase, now assumed to be correct, the assumed phase may in this way be changed a certain number of times.

2. A method according to claim 1, **characterized in that** in step e) a certain number of repetitions is carried out and if after that no indication that the phase assumption was correct has been obtained it is assumed that the phase assumption was incorrect and the steps b) - f) are repeated for the opposite phase, now assumed to be correct, but as soon as one indication that the phase assumption was correct is obtained said certain number of repetitions are carried out in step e) again.

3. A method according to claim 2, **characterized in that** said certain number is 2, 3 or 4.

4. A method according to any of claims 1-3, **characterized in that** if, after it has in step d) obtained an indication that the phase assumption was correct, a further such indication is not obtained after a fixed number of repetitions of steps b) - d) it is assumed that the phase assumption was incorrect and the steps b) - f) are repeated for the opposite phase, now assumed to be correct.

5. A method according to claim 4, **characterized in that** said fixed number is 1.

6. A method according to any of the preceding claims, **characterized in that** said predetermined number is 2, 3 or 4.

7. A method according to any of the preceding claims, **characterized in that** the temperature of the engine or a parameter associated therewith is measured before the first fuel injection in step b) and the number of repetitions carried out in step e) is made dependent upon this temperature measurement, so that the number of repetitions are increased with decreasing engine temperature.

8. A method according to any of the preceding claims, **characterized in that** said predetermined level for the increase of the rotational speed of the crankshaft is set to be at least 5% of the rotational speed before the fuel injection in question.

9. A method according to claim 8, **characterized in that** said predetermined level for the increase of the rotational speed is lowered after an exceeding thereof has been detected for the first time in a step d).

10. A method according to any of the preceding claims, **characterized in that** when step b) is carried out the second time for an assumed phase of the engine fuel is injected in another cylinder than the preceding time.

11. A method according to claim 10, **characterized in that**, when the step b) is carried out the second time for an assumed engine phase, fuel is injected into

the next cylinder assumed to arrive at said compression stroke after the cylinder into which fuel has previously been injected.

12. A method according to claim 11, **characterized in that** fuel is injected into said other cylinder when the crankshaft has rotated 120° for a six cylinder engine and 90° for an eight cylinder engine after the preceding injection.

13. A method according to any of the preceding claims, **characterized in that** in step e) at least two repetitions are carried out and that in step b) fuel is each time injected into the cylinder being the next to arrive at the compression stroke according to the assumed phase of the engine after the cylinder into which fuel has previously been injected.

14. A method according to any of the preceding claims, **characterized in that**, when it is in step f) assumed that the phase assumption was incorrect and the steps b) - f) are repeated for the opposite phase, now assumed to be correct, fuel is in step b) first injected into the next cylinder arriving at the compression stroke according to the engine phase now assumed.

15. A method according to any of claims 1-13, **characterized in that**, when it is in step f) assumed that the phase assumption was incorrect and the steps b) - f) are repeated for the opposite phase, now assumed to be correct, fuel is in step b) first injected into another cylinder than the cylinder started with after step a).

16. A method according to any of the preceding claims, **characterized in that** said repetitions are in step e) carried out during a predetermined period of time dependent upon the present rotational speed of the crankshaft.

17. A method according to any of the preceding claims, **characterized in that** it is carried out on an engine of a vehicle, such as a truck or a bus.

18. A system for synchronization or allocation of cylinders (15-20) to the crankshaft position in a multicylinder internal combustion engine having a crankshaft (1) which rotates twice per working cycle, the system comprising:

- means (5) adapted to sense the position of the crankshaft,
- means (S5) adapted to control injector means (9-14) to inject fuel into one of said cylinders as the piston thereof according to the sensing means is close to an upper dead centre position and this piston according to an assumption of the phase of the engine is in the compression stroke,
- means adapted to measure the rotational speed of the crankshaft before said injection and with a delay after said injection,
- first means adapted to compare said two rotational speed values and decide that there is an indication that the phase assumption was correct if the result of said comparison shows an increase of said rotational speed after said injection above a predetermined level and otherwise that it was false,

characterized in that it further comprises:

- a control device (6) adapted to control said control means, said rotational speed measuring means and said first comparison means to repeat said procedure of fuel injection, rotational speed measurement and comparison one or more times, and
- second means (S7) for comparing, after each repetition of said procedure, the number of said indications that the phase assumption was correct with a predetermined number being at least two,

and that said control device is adapted to terminate the procedure and consider the synchronization as verified if said number of indications that the phase assumption was correct is equal to said predetermined number and if after the last of said repetition(-s) said number of indications is below said
predetermined number to control said control means, rotational speed measuring means, and said first and second comparison means to carry out said procedure of fuel injection, rotational speed measurement and comparison two or more times for an assumption that the opposite phase to the previously as correct assumed phase is the correct phase.

19. A system according to claim 18, **characterized in that** it comprises means (8) adapted to measure the temperature of the engine before the first fuel injection, and that said control device (6) is adapted to make the number of repetitions of said procedure dependent upon the engine temperature by increasing the number of repetitions with decreasing engine temperature.

20. A system according to claim 18 or 19, **characterized in that** said first comparison means (S5) is adapted to decide that there is an indication that the phase assumption was correct if the increase of the rotational speed of the crankshaft is above a predetermined level set to at least 5% of the rotational speed before the fuel injection in question.

21. A computer program loadable directly into the internal memory of a computer, which computer program comprises computer program code for causing the computer:

a) to assume or receive an assumption of the existing phase of a multi-cylinder internal combustion engine having a crankshaft which rotates twice per working cycle, i.e. the first or second rotation in a working cycle,
b) to control injection of fuel into one of said cylinders as the piston thereof disclosed to an upper dead centre position and this piston according to said assumed phase is in the compression stroke,
c) to measure the rotational speed of the crankshaft before said injection and with a delay after said injection and to compare these two rotational speed values,
d) to decide that there is an indication that the phase assumption in a) was correct if the result of said comparison shows an increase of said rotational speed after said injection above a predetermined level and otherwise that it was false,
e) to control the steps b) - d) to be repeated one or more times,
f) to after each said repetition in step e) compare the number of said indications that the phase assumption was correct with a predetermined number being at least two and if it is equal to this predetermined number accept said assumed phase as correct and verify a synchronization of the cylinders of the engine and terminate the procedure and if after the last of said repetition(-s) the number of indications that the phase assumption was correct is below said predetermined number assume that the phase assumption was incorrect and repeat steps b) - f) for the opposite phase, now assumed to be correct,
and to change the assumed phase in this way maximally a certain number of times.

22. A computer program according to claim 21, **characterized in that** the computer program comprises computer program code for causing the computer:

- to in step e) carry out a certain number of repetitions and if no indication that the phase assumption was correct has been obtained to assume that the phase assumption was incorrect and to repeat the steps b) - f) for the opposite phase, now assumed to be correct, but as soon as one indication that the phase assumption was correct is obtained to again carry out said certain number of repetitions in step c).

23. A computer program according to claim 21 or 22, **characterized in that** the computer program comprises computer program code for causing the computer:

- to determine or receive a temperature value representing the prevailing engine temperature, and
- to make the number of repetitions carried out in step e) dependent upon said engine temperature value, so that the number of repetitions are increased with decreasing engine temperature.

24. A computer program product comprising a data storage medium readable by an electronic control unit, a computer program according to any of claims 21-23 being stored on said data storage medium.

25. An electronic control unit comprising an execution means, a memory connected to the execution means and a data storage medium connected to the execution means, a computer program according to any of claims 21-23 being stored on said data storage medium.

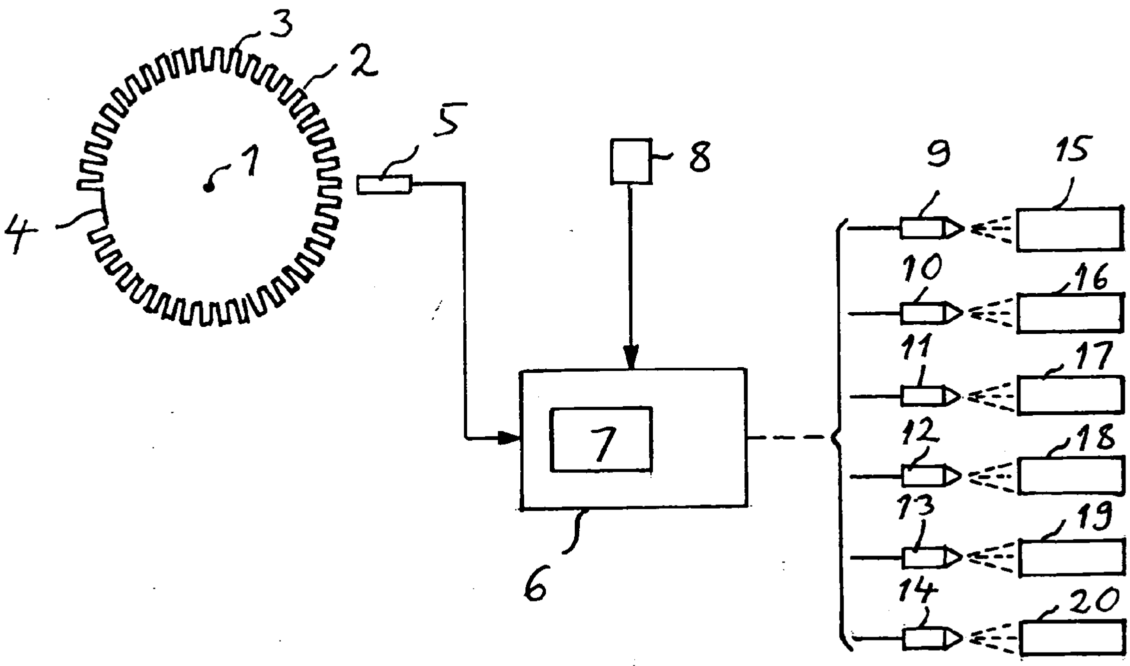

Fig 1

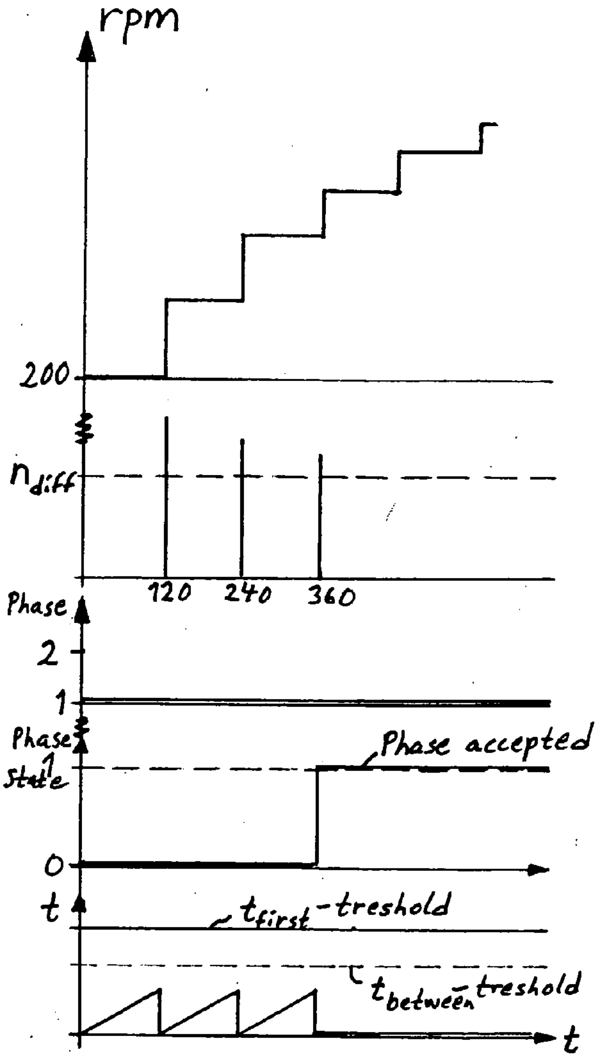
rpm
200
n_{diff}
120
240
360
Phase
2
1
Phase state
1
Phase accepted
0
t
t_{first}-treshold
$t_{between}$-treshold
t

Fig 2

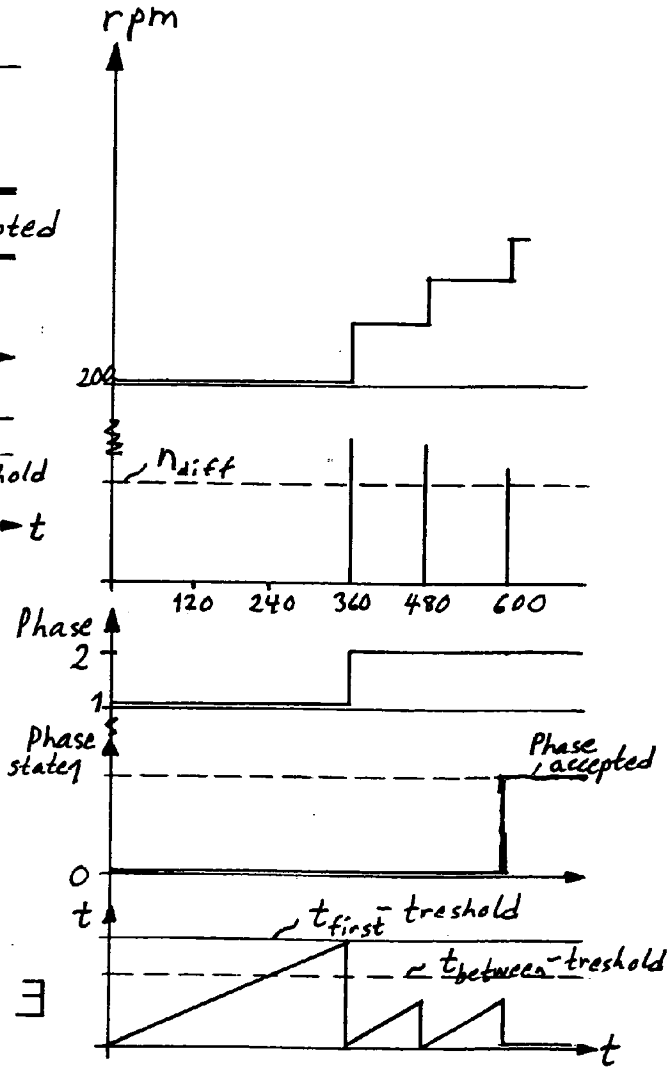
rpm
200
n_{diff}
120
240
360
480
600
Phase
2
1
Phase state
1
Phase accepted
0
t
t_{first}- treshold
$t_{between}$-treshold
t

Fig 3

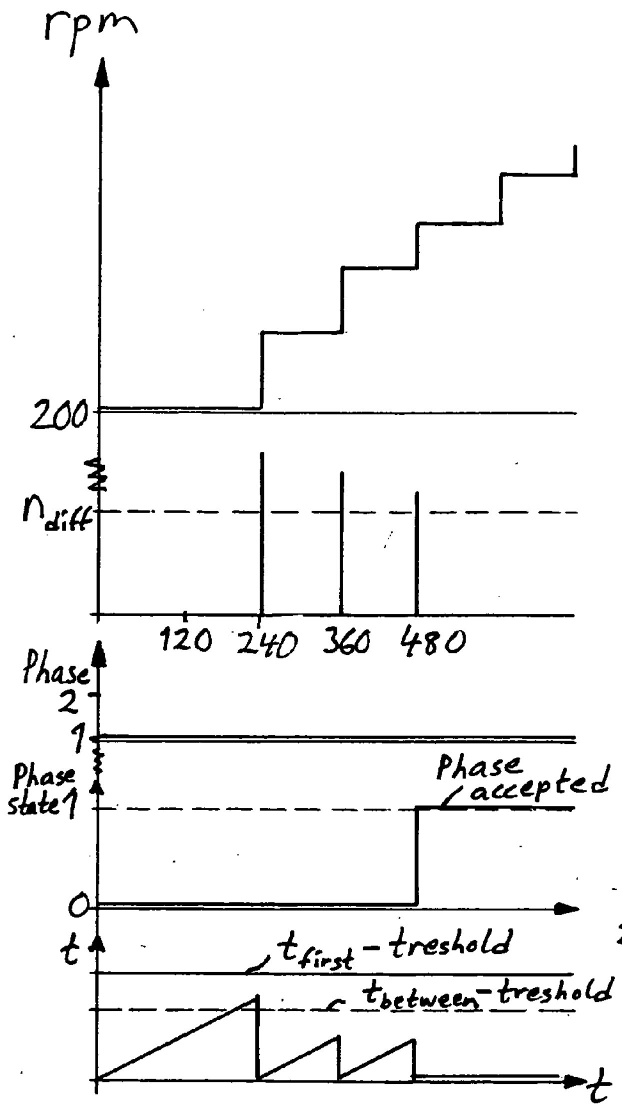
rpm
200
n_{diff}
120
240
360
480
Phase
2
1
Phase state
1
0
Phase accepted
t
t_{first} - treshold
$t_{between}$ - treshold
t

Fig 4

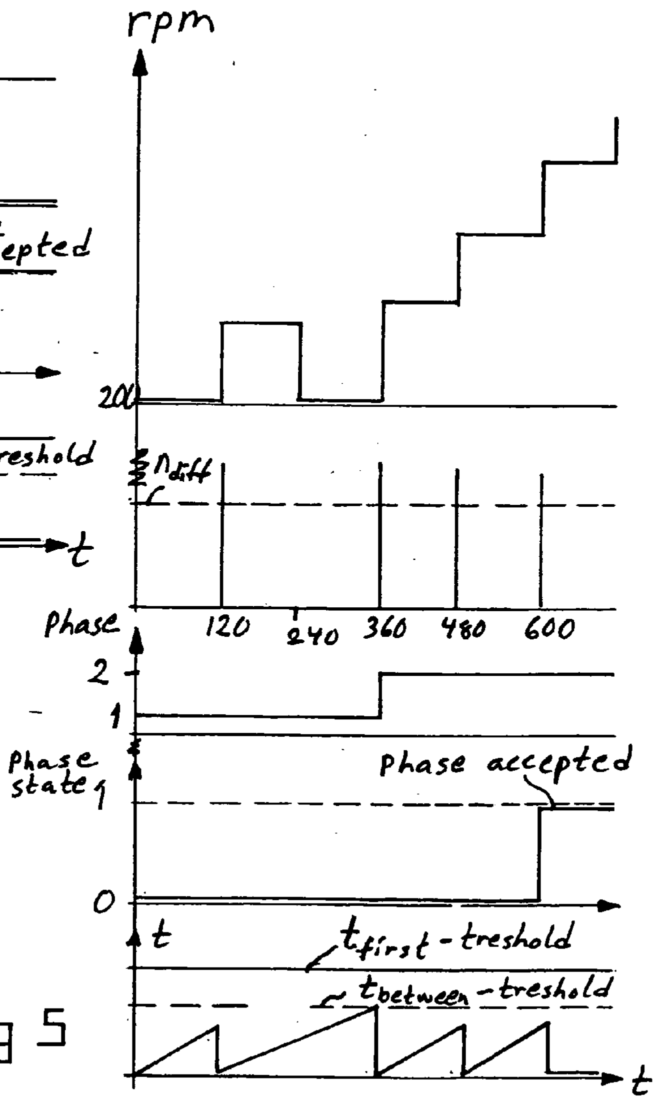
rpm
200
n_{diff}
Phase
120
240
360
480
600
2
1
Phase state
1
0
Phase accepted
t
t_{first} - treshold
$t_{between}$ - treshold
t

Fig 5

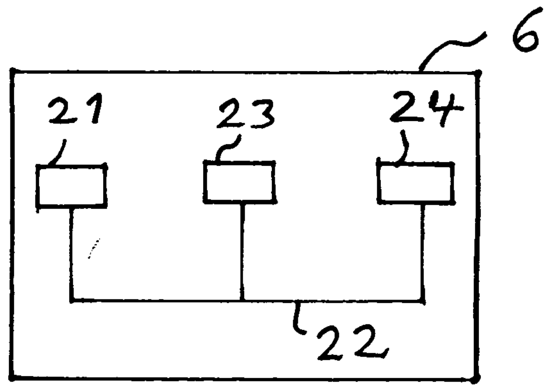

Fig 6

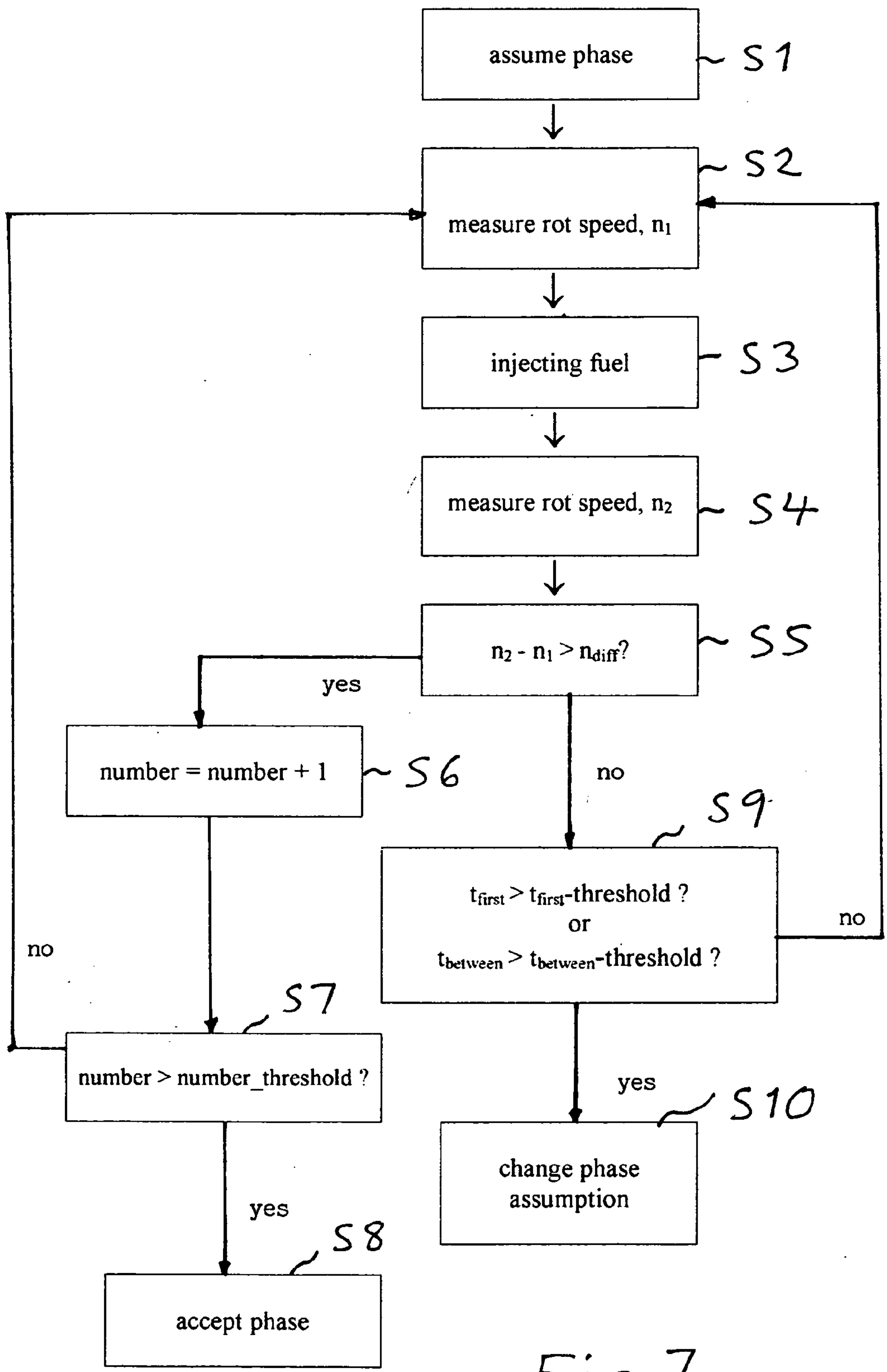
assume phase
S1
measure rot speed, n1
S2
injecting fuel
S3
measure rot speed, n2
S4
n2 - n1 > ndiff?
S5
yes
no
number = number + 1
S6
S9
tfirst > tfirst-threshold ?
or
tbetween > tbetween-threshold ?
no
no
S7
number > number_threshold ?
yes
S10
change phase
assumption
yes
S8
accept phase

Fig 7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 11 3097

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	FR 2 853 935 A (SIEMENS VDO AUTOMOTIVE) 22 October 2004 (2004-10-22) * page 1, line 30 - page 2, line 22; figures 1,2 * * page 4, line 16 - line 32; figures 1,2 *	1-6,8, 10-16, 18, 20-22, 24,25	INV. F02D41/34 F02D41/14
A	US 6 571 776 B1 (DUNSWORTH VINCE F) 3 June 2003 (2003-06-03) * paragraphs [0023], [0024]; figures 3a,3b *	1	
A	EP 1 050 676 A (DELPHI TECHNOLOGIES, INC) 8 November 2000 (2000-11-08) * paragraph [0025] *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 April 2006	Pileri, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

2

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 11 3097

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

07-04-2006

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
FR 2853935	A	22-10-2004	EP 1613850	A1	11-01-2006
			WO 2004092564	A1	28-10-2004
US 6571776	B1	03-06-2003	NONE		
EP 1050676	A	08-11-2000	NONE		

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20030089354 A1 **[0006]**
- EP 0942163 B1 **[0007]**