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D E C I S I O N
of 3 August 2000

Case Number: T 0651/97 - 3.2.4

Application Number: 92918680.7

Publication Number: 0610222

IPC: F02D 13/02

Language of the proceedings: EN

Title of invention:
Engine operation using fully flexible valve and injection events

Applicant:
CATERPILLAR INC.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - (yes) after amendment"

Decisions cited:
-

Catchword:
-

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Case Number: T 0651/97 - 3.2.4

D E C I S I O N
of the Technical Board of Appeal 3.2.4
of 3 August 2000

Appellant: CATERPILLAR INC.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 27 January 1997 refusing European patent application No. 92 918 680.7 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: C. A. J. Andries
Members: H. A. Berger
C. Holtz

Summary of Facts and Submissions

I. The appellant (applicant) has lodged an appeal against the examining division's decision of 27 January 1997 to refuse European patent application No. 92 918 680.7 (WO-A-92/14919) since there was no text agreed by the applicant to serve as a basis for the grant of a European patent (Article 113(2) EPC) and the application therefore did not meet the requirements of the Convention (Article 97(1) EPC). The appeal was received on 4 April 1997 and the appeal fee was paid simultaneously. The statement setting out the grounds of appeal was received on 6 June 1997.

II. During the examination proceedings the examining division at first held that the application did not meet the requirements of Articles 52(1) and 54 EPC, having regard to following prior art documents:

D1: GB-A-2 134 596

D2: EP-A- 376 714

An allowable claim was however worked out during oral proceedings before the examining division. However no approval was received from the applicant to the communication under Rule 51(4) EPC.

III. During the appeal proceedings the board drew the appellant's attention to several additional prior art documents, partly cited in the international search report, partly in the introductory part of the description of the application WO-A-92/14919 and partly firstly cited during the appeal proceedings in response to new filed requests. The following prior art

documents thereof are of interest:

D4: US-A-4 429 532

D5: FR-A-2 133 288

D10: US-A-4 466 390

Oral proceedings before the board were held on 3 August 2000 during which the appellant filed new claims 1 to 6.

IV. Claim 1 reads as follows:

"A system for controlling a plurality of operational modes of an engine (102) including intake valve and exhaust valve and fuel injection events, in which the engine (102) comprises a plurality of cylinders (104) having an intake valve (220) and an exhaust valve (222), an injector (224), a chamber and an intake and exhaust port, wherein the plurality of cylinders are connected by an intake and exhaust manifold, and the injector, intake valve and exhaust valve are controlled by a microprocessor (108), and the injector injects fuel directly into the cylinder, said system comprising said microprocessor (108) controlling an operational mode of each of the cylinders (104) individually and independently of each other cylinder,
said operational mode of each cylinder requiring at least one of an opening and closing event of the intake valve (220) and/or exhaust valve (222) during each engine cycle of said cylinder;
said microprocessor (108) including:
(a) valve control means for controlling the operation of the intake valves and exhaust valves (220, 222),

including controlling both of an opening and closing event of the intake valves and exhaust valves (220, 222) in accordance with the independently governed operational mode of each cylinder (104) and wherein the valve control means varies the control of the intake valve and exhaust valve independent of the operation of each other; and

(b) injector control means for controlling the operation of each of the injectors (224), including controlling fuel injection timing of each of the injectors (224), independently of the operation of the intake valves and exhaust valves (220,222);

wherein the valve and injection events result in an operational mode of the engine,

wherein the operational mode of at least one of said plurality of cylinders is different from the operational mode of another of said plurality of cylinders to achieve mixed modes of engine operation."

V. The appellant explained the system of claim 1 and pointed out that the flexibility in the control system is mainly based on two essential features. Firstly, the valve control means can vary the control of the intake valve and exhaust valve independently of the operation of each other (feature (a) of claim 1) and the injector control means controls the fuel injection timing of each of the injectors, independently of the operation of the intake valves and exhaust valves (feature (b) of claim 1), i.e. intra-cylinder independency, which is a significant element needed for achieving a plurality of operational modes of the engine. This independent variation must result in a particular operational mode of the engine. Secondly, the operational mode of at least one of the plurality of cylinders can be different from the operational mode of another of said

plurality of cylinders to achieve mixed modes of engine operation (last feature of claim 1), i.e. inter-cylinder independency. This control of the intake and exhaust valves and the injectors is carried out by a microprocessor controlling actuators which separately directly actuate the intake valves, exhaust valves and injectors, implying thereby that there is no engine driven camshaft between, since the camshaft would not allow the intended independent controlling. Furthermore, for the independent controlling it is also of importance that the injector directly injects the fuel into the combustion chamber and not upstream of the intake valve as disclosed, for instance, in document D1. According to claim 1 it is also necessary that in an operational mode of each cylinder at least an opening and closing event of the intake valve and/or exhaust valve must occur during each engine cycle of the cylinder, i.e. this excludes the operational modes during which both valves do not move, such as during closed motoring and exhaust breathing mode (see Figure 4).

With regard to inventive step, the appellant argued that none of the cited prior art documents could lead to the subject-matter of claim 1, neither alone nor in combination with one another.

VI. Requests

The appellant requested that the decision under appeal be set aside and that a patent be granted in the following version:

Claims: 1 to 6,

Description: Pages 1, 2, 3, 4, 4a, 4b and 5 to 18,

Drawings: Figures 1 to 8B

all as submitted in the oral proceedings on 3 August 2000.

Reasons for the Decision

1. The appeal is admissible.

2. *Allowability of the amendments (Article 123(2) EPC)*

2.1 Claim 1:

Claim 1 differs from claim 1 of the application WO-A-92/14919 by the features marked in bold letters:

A system for controlling a plurality of operational modes of an engine (102) including **intake** valve and **exhaust valve and fuel** injection events, in which the engine (102) comprises a plurality of cylinders (104) having an intake **valve** (220) and **an** exhaust valve (222), an injector (224), a chamber and an intake and exhaust port, wherein the plurality of cylinders are connected by an intake and exhaust manifold, **and the injector, intake valve and exhaust valve are controlled by a microprocessor (108), and the injector injects fuel directly into the cylinder,** said system comprising **said microprocessor (108) controlling an operational mode of each of the cylinders (104) individually and independently of each other cylinder,**

said operational mode of each cylinder requiring at least one of an opening and closing event of the intake valve (220) and/or exhaust valve (222) during each engine cycle of said cylinder;
said microprocessor (108) including:

(a) valve control means for controlling the operation of the intake valves and exhaust valves (220, 222), including controlling **both** of an opening and closing **event** of the intake **valves** and exhaust valves (220, 222) in accordance with the independently governed operational mode of each cylinder (104) **and wherein the valve control means varies the control of the intake valve and exhaust valve independent of the operation of each other**; and

(b) injector control means for controlling the operation of each of the injectors (224), including controlling fuel injection timing of each of the injectors (224), independently of the operation of the intake valves and exhaust valves (220,222);

wherein the valve and injection events result in an operational mode of the engine,

wherein the operational mode of at least one of said plurality of cylinders is different from the operational mode of another of said plurality of cylinders to achieve mixed modes of engine operation.

Beside simple clarifications of the wording of claim 1 the differing features are disclosed in the application

WO-A-92/14919 as follows:

The microprocessor is described on page 10, lines 3 to 15 in connection with Figure 2. The direct injection is disclosed throughout the application, for instance in Figures 2 and 3, and page 12, lines 3 to 6 in combination with Figure 4, according to which the injection occurs between the compression and expansion strokes (Figure 4: "High load", "Low load" and "Early closing" operation modes) during which the intake and the exhaust valves are closed. The individual and independent control of each cylinder by the microprocessor is disclosed on page 10, line 33 to page 11, line 10 in connection with Figure 2 and in claim 1, according to which cylinder control means (108) govern an operational mode of each of the cylinders (104) independently. The requirement of at least one of an opening and closing event of the intake and/or exhaust valve during each engine cycle is disclosed in Figure 4 and by the description with regard to the possible independent control of the elements (see page 11, lines 1 to 6). According to the amended description the closed motoring and exhaust breathing modes as shown in Figure 4 are excluded from the present invention (see amended page 5, line 25; page 11, line 24 and page 12, lines 10 and 33). That the microprocessor includes valve control means and injector control means is disclosed for instance in Figures 2 and 3 and the corresponding description. The control of both of an opening and closing event is disclosed in Figure 4. It is clear from the described operational modes that the valve and injection events result in an operational mode of the engine. The difference of the operational mode of at least one of said plurality of cylinders from the operational mode

of another of said plurality of cylinders to achieve mixed modes of engine operation is disclosed on page 6, lines 15 to 19.

The appellant's interpretation of claim 1 that the control means control actuators for directly actuating the inlet and exhaust valves and the injectors without a cam shaft can be accepted since it is implied by the intra-cylinder independency, and since separate actuators are disclosed on page 11, lines 3 to 5.

2.2 Claims 2 to 6 are based on claims 3 to 6 and 10 of the application WO-A-92/14919 with the change of the method claims to system claims which is acceptable with regard to the content of the description.

2.3 The description is adapted to the new claims and to the deletion of the originally filed Figures 8 and 9. Additional relevant prior art documents are cited.

2.4 Figures 8 and 9 of the application WO-A-92/14919 are deleted and Figures 10A and 10B are renumbered to Figures 8A and 8B.

2.5 The amendments made do not contravene Article 123(2) EPC.

3. *Novelty*

None of the cited prior art documents discloses a system with all the features of claim 1 at present on file. The subject-matter of claim 1 therefore is new in the meaning of Article 54 EPC.

4. *Closest prior art*

Document D5 is taken as the closest prior art in assessing inventive step. This document discloses a system for controlling a plurality of operational modes of an engine (see page 1, lines 7 to 25) including intake valve, exhaust valve and fuel injection events, in which the engine (1) comprises a plurality of cylinders (3,4) having an intake valve (16), an exhaust valve (17), an injector (18), a combustion chamber and an intake and exhaust port. The plurality of cylinders are connected by an intake and exhaust manifold (which is implicit in a multi cylinder engine). The injector, intake valve and exhaust valve are controlled by a microprocessor (11,11'; 9,24) which controls the operational mode of each of the cylinders, and the injector injects fuel directly into the cylinder (page 3, line 13: diesel engine), said operational mode of each cylinder requires at least one of an opening and closing event of the intake valve (16) and/or exhaust valve (17) during each engine cycle of said cylinder. Said microprocessor (11,11'; 9,24) includes:

(a) valve control means for controlling the operation of the intake valves and exhaust valves (16, 17), including controlling both of an opening and closing event of the intake valves and exhaust valves (16, 17) (page 4, lines 5 to 16);

(b) injector control means for controlling the operation of each of the injectors (18), including controlling fuel injection timing of each of the injectors (18), independently of the operation of the intake valves and exhaust valves (see page 2, lines 28 to 34; page 4, lines 5 to 14; page 5, lines 27 to 37 and Figures 1 and 3);

wherein the valve and injection events result in an operational mode of the engine.

The system of claim 1 differs therefrom by the following features:

- the microprocessor controls an operational mode of each of the cylinders individually and independently of each other cylinder (inter-cylinder independency);

- the valve control means for controlling the operation of the intake valves and exhaust valves, include controlling both of an opening and closing event of the intake valves and exhaust valves in accordance with the independently governed operational mode of each cylinder and wherein the valve control means varies the control of the intake valve and exhaust valve independent of the operation of each other;

- and the operational mode of at least one of said plurality of cylinders is different from the operational mode of another of said plurality of cylinders to achieve mixed modes of engine operation.

Document D1 which was taken into account during the examination proceedings is not relevant any more, since the control system described therein concerns the control of an engine with the injection upstream of the intake valve and not with a direct injection. Therefore the fuel inlet to the combustion chamber is dependent on the opening of the inlet valve. Furthermore, the operational mode of at least one of a plurality of

cylinders which is different from the operational mode of another as described in this document (see page 3, lines 115 to 121) concerns a mode during which the intake valves are kept closed and the outlet valves held open, whereas according to claim 1 of the application the operational mode of each cylinder requires at least one of an opening and closing event of the intake valve and/or exhaust valve during each engine cycle of the cylinder. Document D2 again describes a control system for an internal combustion engine in which fuel is injected upstream of the intake valve. Furthermore, although the intake valve control and the exhaust valve control might be independent from one another there is no operation mode of one of the cylinders described which might be different from another of the cylinders (inter-cylinder independency). The state of the art according to documents D1 and D2 therefore cannot lead to the system of claim 1 and is therefore not considered as an appropriate starting point or additional pertinent state of the art in assessing inventive step, due to the fact that a different engine type is concerned.

5. *Problem and solution*

5.1 Problem:

With regard to the system of document D5 the technical problem is to increase the flexibility of engine operation.

5.2 Solution:

By the microprocessor controlling an operational mode of each of the cylinders individually and independently

of each other (inter-cylinder independency) and by the valve control means and injector control means of the microprocessor allowing the control of the intake valve and exhaust valve to be varied independently of the operation of each other (intra-cylinder independency) and to control the operation of each of the injectors for direct injection also independently of the operation of the intake valve and exhaust valve (intra-cylinder independency), the possible operation modes of the engine are increased and the flexibility of engine operation is therefore improved.

6. *Inventive step*

6.1 The prior art documents at present on file reveal either the possibility of independent control of the intake valves, exhaust valves and direct injection without however control means for controlling an operational mode of at least one of a plurality of cylinders which is different from the operational mode of another of the plurality of cylinders to achieve mixed modes of engine operation (e.g. document D5), or control devices based on cam shaft control which are interconnected at least basically by the camshaft rotation (documents D4 and D10), or indirect fuel injection, i.e. injection upstream of the inlet valve with which fuel supply to the cylinder depends on inlet valve control (documents D1 and D2).

In this respect it is emphasised that the system of claim 1 functions without camshaft control. Such a camshaft control is not suggested in either the claims or the other parts of the application, and even has to be considered as contrary to the teaching of the present application (intra-cylinder independency).

6.2 Although according to the construction of the provided valve actuators (see Figures 2 and 3) the system of document D5 allows the control of the intake valve and exhaust valve independently of the operation of each other, and allows due to the direct injection into the cylinder (diesel engine) the control of the injection independently of the operation of the valves, means for this independent control of these elements in one of the cylinders are however not clearly and explicitly described in document D5 (intra-cylinder independency). Furthermore, it is not disclosed therein to operate at least one of the plurality of cylinders in a different mode from the operational mode of another of said plurality of cylinders (inter-cylinder independency).

6.3 The board considered documents D4 and D10 as further pertinent prior art documents. All the other documents cited in the international search report, in the introductory part of the description of the application WO-A-92/14919 and during the appeal proceedings in respect to several attempts by the appellant in formulating claim 1 do not come closer or are of less importance with regard to claim 1 at present on file.

6.4 It is true that document D4 discloses an apparatus in which only some of the cylinders of an engine of the compression ignition type can be braked to load the engine, thereby to increase the flow of fresh air into the turbocharger and in which means are provided for halting or reducing the flow of fuel to the braked cylinders (inter-cylinder independency), but the exhaust valves are normally opened by rocker arms (94) actuated by a cam shaft (see rocker arm 94) and when a brake-activating pushrod (100) is driven upwardly by

the engine camshaft they are opened during activation of a compression brake by a rod (88) moved by oil pressure (column 3, line 66 to column 4, line 2). Furthermore, since document D4 does not clearly describe the control of the intake valve during this braking mode, it is to be supposed with regard to the cam actuated exhaust valve that also the intake valve is controlled by the engine cam shaft. The interaction of valve movement caused by the camshaft control however cannot lead to a control system with which the inlet and outlet valves are controllable individually and independently from one another in the meaning of claim 1. Furthermore, although the teaching of document D5 had already been known for about 8 to 9 years before the system of document D4 was developed, the independent control of the intake valves and exhaust valves without a camshaft, i.e. with a direct actuator, was not taken into account in this diesel engine. Therefore, it cannot be reasoned that the teaching of document D4 leads to the subject-matter of claim 1.

6.5 Document D10 describes an electro-hydraulic valve control system in a multi cylinder internal combustion engine for controlling a plurality of operational modes of the engine. The system comprises a camshaft with a cam follower which is coupled through a mechanical-hydraulic link to the valve or the valve stem of one of the valves of the engine. The coupling includes a supply of pressurized hydraulic fluid which provides a plug or cushion of pressurized fluid between the cam follower and the valve element or valve stem. By draining the hydraulic fluid of the plug between the cam follower and the valve, control of the valve motion can be obtained independently of the position of the cam follower but only within the basic movement of the

cam follower. Therefore, the overall control time of operation of the valve is controlled by the camshaft but overriding control is obtainable. Although this control system allows the disconnection of some cylinders of the multi-cylinder engine (see column 4, lines 54 to 66) or only to fill them partly at light loading (inter-cylinder independency), and to optimize the interplay between variable valve controls and variable fuel injection with an electronic control unit (intra-cylinder independency), the independent variable control of the valves of respective cylinders of a multi-cylinder engine is only possible to a certain limit since the control of the basic movement of the valve is again carried out by the cam of a camshaft. Therefore, the individual and independent control in the meaning of the system of claim 1 cannot be obtained.

Document D10 mainly describes the intake valve control. According to the introductory part of the description (column 1, line 53 to column 2, line 7) electronic control of the timing of the open-time of the valve would be highly desirable, since electronic control can utilize sensed signals which can be processed in accordance with operating characteristics of the engine. It is however stated that it has not been possible to utilize the advantages of electronic control without excessive requirements of apparatus and the like which transfer the processed electrical signals to output elements, such as servo positioning elements operating on the valves directly. The suggestion of document D10 therefore results in providing a control system based on a camshaft. This document therefore leads away from a control system with direct actuation of the valves and the injector as

disclosed in document D5 and even indicates that there was a prejudice of using directly actuated valves for intra- and inter-cylinder independent control. Furthermore, fuel injection is only mentioned in general in this document D10 (see column 4, line 63 and column 5, lines 13 to 15) and it is not clearly disclosed if fuel is directly injected into the engine or is injected upstream of the intake valve, i.e. if the fuel admission to the cylinder is dependent on the opening of the intake valve. Therefore, the person skilled in the art would not be led by document D10 in connection with the teaching of document D5 to the system of claim 1.

6.6 The system of claim 1 therefore involves an inventive step (Article 56 EPC).

7. In view of the above claim 1 is patentable under Article 52(1) EPC. Claims 2 to 6, the description and the drawings also meet the requirements of the EPC.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the first instance with the order to grant a patent in the following version:

Claims: 1 to 6,

Description: Pages 1, 2, 3, 4, 4a, 4b, and 5 to 18,

Drawings: Figures 1 to 8B

all submitted in the oral proceedings on 3 August 2000.

The Registrar: The Chairman:

G. Magouliotis C. Andries