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Bezeichnung der Erfindung:
Title of invention:
Titre de l'invention : Direct injection internal combustion engine of the compression ignition type

Klassifikation / Classification / Classement : F02B 23/06

## ENTSCHEIDUNG / DECISION

**vom / of / du** 21 March 1990

Anmelder / Applicant / Demandeur : Kabushiki Kaisha Toyota Chuo Kenkyusho

Patentinhaber / Proprietor of the patent /
Titulaire du brevet :

Einsprechender / Opponent / Opposant :

Stichwort / Headword / Référence :

**EPÜ / EPC / CBE** Article 56

Schlagwort / Keyword / Mot clé : "Inventive Step - Yes"

**Leitsatz / Headnote / Sommaire**

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Case Number : T 244/88 - 3.2.2

# D E C I S I O N
## of the Technical Board of Appeal 3.2.2
## of 21 March 1990

Appellant : Kabushiki Kaisha Toyota Chuo Kenkyusho
41-1, Aza Yokomichi Oaza Nagakute
Nagakute-cho, Aichi-gun, Aichi-ken (JP)

Representative : E. Burger
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Decision under appeal : Decision of Examining Division 101 of the European Patent Office dated 29 December 1987 refusing European patent application No. 83 106 747.5 pursuant to Article 97(1) EPC

Composition of the Board :

Chairman : G. Szabo
Members : C. Andries
L. Mancini

## Summary of Facts and Submissions

I. European patent application No. 83 106 747.5 filed on 8 July 1983 (publication No. 0 098 619) was refused by a decision of the Examining Division 101 dated 29 December 1987.

II. The reason given for the refusal was that the subject-matter of Claim 1 did not involve an inventive step in view of the prior art disclosed in the following documents:

D1: CH-A-175 433;
D2: CH-A-305 821;
D3: DE-C-854 599;
D4: FR-A-870 277; and
D5: GB-A-448 758;

and in view of the normal capacities of a skilled engineer.

III. On 26 February 1988, the Appellant lodged an appeal against this decision, paying the appeal fee on the same date. A Statement of Grounds was filed on 26 April 1988.

IV. During the oral proceedings held on 21 March 1990 during which the Board also drew the attention of the Appellant to document GB-A-2 066 896 (D6), the Appellant filed new Claims 1 to 6, and correspondingly amended pages and drawings.

Claim 1, which is the only independent claim on file reads after correction of an obvious error (feature (ii): "cavity formed in the central portion of..." instead of "cavity formed in central the portion of...") as follows:

"A small-sized direct injection internal combustion engine of a compression ignition type, comprising:

(i) a piston (1) reciprocating within a cylinder,

(ii) a cavity (2) formed in the central portion of the top surface of said piston (1) so as to have its inlet opening (2h) throttled while allowing remaining portions to have a larger cross-sectional area,

(iii) intake means for supplying intake air into said cavity (2), said intake means being provided with swirling means for swirling said intake air,

(iv) a fuel injection nozzle (3,7) positioned in the cylinder head above a central region of said cavity and aligned with the axis of the cavity for injecting fuel into the cavity (2) in form of a hollow conical shell, the diameter of said region being less than 0.5 times the diameter (2h) of said inlet opening,

(v) the fuel injection nozzle (3,7) comprises swirling means (34,74) for injecting a fuel spray of low penetration from an injection port (32,73) towards the circumferential wall of said cavity (2) in a spray pattern of a hollow conical shell, having a predetermined spray angle ($\theta$) and a tangential velocity component,

(vi) the ratio of the area (A) of said inlet opening (2h) to the area ($A_0$) of the piston surface satisfies the relationship

$$0.07 \leqq A/A_0 \leqq 0.25,$$

(vii) the relation between the spray angle (θ) and the position of said injection port (32) of said fuel injection nozzle (3) is determined so that the fuel spray injected from the injection port (32) is directed toward the inner circumferential wall of said cavity (2) below a hollow conical shell defined by a straight line (t1) joining said injection port (32) with the inner wall of the throttled opening (2h) of said cavity (2), and above a hollow conical shell defined by a straight line (b1) joining said injection port (32) and such a portion of said cavity (2) as has a depth of 0.9 L from said opening (2h) when the depth of said cavity (2) is represented by L."

V. The Appellant requested that the decision under appeal be set aside and a patent be granted on the basis of the following documents:

Claims: 1 to 6 as submitted at the oral proceedings;
Description: pages 1 to 7, 7a, 7b and 8 to 20 as submitted at the oral proceedings;
Drawings: Figs. 1, 2, 3A, 3B, 4A, 4B and 5 to 7 as published;
Figs. 8 and 9 as submitted at the oral proceedings.

**Reasons for the Decision**

1. The appeal is admissible.

2. **Amendments**

The Board is satisfied that the present application documents do not contain subject-matter extending beyond

the content of the application documents as originally filed (Art. 123(2) EPC).

2.1 Present Claim 1 is supported by the originally filed Claims 1, 2, 3, and 4, and by the originally filed description (small-sized engines: page 7, lines 12 to 16; cavity in the central portion of the piston top surface: page 14, lines 27 to 30 and page 19, lines 33 to 36; nozzle positioned in the cylinder head and aligned with the cavity axis: page 12, lines 31 to 35; page 14, lines 20 and 21, and page 15, lines 1 to 5; spray of low penetration: page 18, lines 1, 2, 17 and 18 and page 19, lines 1 to 3).

Apart from the fact that an engine piston implies the possibility of reciprocation in a cylinder (feature (i)), the wording of the originally filed Claims 4 and 3 has also been clarified. Indeed, these claims are intended to define the region of location of the fuel nozzle in the cylinder head with respect to the opening of the cavity (page 12 of the originally filed description, lines 24 to 29) as well as the limits (below and above different hollow conical shells, each defined by a straight line) of the injected fuel spray (Figs. 4A and 4B). The clarifications are allowable.

2.2 Claims 2 to 6 correspond to Claims 9 to 11, 5 and 6 as originally filed.

2.3 The modifications of the description and the drawings only relate to their adaptation to the present claims, or to obvious errors, and are, therefore, also allowable.

3. **Interpretation**

To assess the subject-matter of Claim 1 properly, the expressions "small-sized engine", "hollow conical shell" and "fuel spray of low penetration" are interpreted, on the basis of the Appellant's submissions during the oral proceedings, as follows:

3.1 As it is also clearly indicated in the description (page 2, lines 20 to 22), the expression "small-sized engine" defines engines in which the piston has a diameter of not more than 100 mm.

3.2 The expression "injecting fuel in the form of a hollow conical shell" defines a fuel injection which is issued from the injection nozzle on all sides uniformly (umbrella-like). This definition is also supported by the description (page 8, lines 11 to 13: injection towards the whole inner circumferential wall; page 12, lines 34 and 35: injecting uniformly overall the whole circumference of the inner wall).

3.3 The expression "an injection nozzle for injecting a fuel spray of low penetration" implies the presence of a nozzle and other injection-influencing parameters and characteristics, which are capable of providing a spray having a low penetration. A person skilled in the art would know how to adapt the different co-operating characteristics to obtain such a spray.

4. Although it would be theoretically possible to have Claim 1 in the two-part form (Rule 29(1) EPC), the Board is of the opinion that in the present case the one-part form of the claim is appropriate, particularly since the combinational effect of the different features present in Claim 1, some of them only partly known from the basic

state of the art, contributes to the combustion, so that separation between these features is not appropriate. An improved combustion is the result of all features present.

5. **Novelty**

After examination of the cited documents, the Board is satisfied that none of them discloses an internal combustion engine having all the features as defined in Claim 1. Since this has never been disputed, there is no need for further detailed substantiation of this matter.

Therefore, the subject-matter as set forth in Claim 1 is to be considered novel within the meaning of Article 54 EPC.

6. **Closest prior art**

6.1 In the opinion of the Board the internal combustion engine according to document D1 reveals the closest prior art.

Document D1 clearly discloses for a person skilled in the art a direct injection internal combustion engine of a compression ignition type comprising features (i), (ii) and (iii) as defined in Claim 1 of the present application. Furthermore in the engine according to document D1 the fuel injection nozzle, which is positioned in the cylinder head at the central portion (page 2, lefthand column, lines 23 and 24) of said centrally located (page 1, right-hand column, lines 8 to 11: angenähert; page 2, left-hand column, lines 27 and 28: fällt mit der Zylinderachse zusammen) cavity for injecting fuel into said cavity in the form of four straight, radially, separate sprays (Figure 2), allows (by its predetermined spray angle) the fuel to be injected in the

cavity and up to the border of the inlet opening of that cavity (page 2: last four lines of the claim; drawings). The ratio of the area of said inlet opening to the area of the cylinder cross-section is between 1/3 (0,333) and 1/6 (0,166) (Claim).

6.2 Although document D6 discloses a diesel engine having an injection nozzle injecting fuel into a cavity in the form of a hollow conical shell, it does not come closer to the claimed engine as the engine disclosed in document D1, since it is clearly stated in document D6 that the shape of the cavity (combustion chamber) and its position in the piston are irrelevant (page 1, lines 115 to 117).

7. **Problem and solution**

7.1 As put forward by the Appellant, diesel engines of the type according to document D1 are frequently used as large-sized engines because they are advantageous over other types of diesel engines. Small-sized engines (as defined in above point 3.1) suffer more from problems in the formation of the air-fuel mixture than do the large-sized engines, particularly since due to the small cavity diameter in small-sized engines having pistons with a piston diameter smaller than 100 mm, the radially injected fuel spray impinges upon the inner wall surface of the cavity resulting in a reduced effective mixture for combustion, output power and mileage reduction and increased smoke generation.

A number of partially satisfying measures were known to prevent such a fuel impingement upon the cavity wall surface, allowing thereby the use of small-sized engines. According to the Appellant, it was also commonly accepted that injection nozzles having weak penetration cannot be used for small-sized engines.

The Board agrees with the Appellant when he states that the problems related to small-sized diesel engines can pose special problems not encountered in connection with larger engines.

7.2 The technical problem to be solved therefore consists in providing a diesel engine of small size in which the mixture preparation is improved to reduce fuel consumption. In other words the mixture preparation according to document D1 should be improved or adapted in such a manner that it can be used in small-sized engines.

7.3 Apart from a limitation to such size and the broadened ratio range, the solution of the problem according to Claim 1, characteristically differs from the most relevant art in document D1 in that

(a) the fuel can be injected into the cavity in the form of a hollow conical shell; and
(b) the fuel injection nozzle comprises swirling means for injecting into the cavity a fuel spray of low penetration having a particular spray angle and thereby a tangential velocity component.

Indeed, although it is true that document D1 does not disclose the ranges as defined in features (iv) (diameter of the region of location of the injection nozzle) and (vii) (location of the upper and the lower limits for fuel injection), a well as the whole range as defined in feature (vi) (ratio of the areas responsible for the squish flow), the engine according to document D1 nevertheless reveals an engine with features in these particular respects which are within the ranges and arrangements as claimed in the present application.

7.4 In view of the advantages (although not supported by specific measurements) revealed in the description (page 8, line 33 to page 9, line 34 and page 17, line 22 to page 18, line 13) and confirmed by the Appellant during the oral proceedings, the Board accepts that this problem is solved by the co-operation of the features specified in Claim 1, in particular since the fuel is sprayed by the nozzle toward the whole inner circumferential cavity wall with low penetration and since the fuel is mixed with the air and diffused in the depthwise direction by the intake air swirl, the squish flow resulting from the specific inlet means, and the specific claimed surface ratio.

8. Inventive step

8.1 A person skilled in the art, starting from a diesel engine according to document D1, who would try to obtain an engine allowing the solution of the above problem could not find, however an indication or an encouragement in the cited documents to use the combination of features as defined in Claim 1.

8.2 Document D1 does not disclose conditions limiting the described engine to any particular range of engine dimensions. The teaching of this document need not therefore be limited to large engines. However, express indications that specific features are of importance for small-sized engines are also missing.

Furthermore document D1 does not disclose or suggest the use of critical features (a) and (b) as defined in above point 7.3.

8.3 For a person skilled in the art it may be obvious, when trying to improve the combustion system according to D1, to use an injection nozzle, which distributes fuel in the

form of a hollow conical shell. Indeed a skilled person finds in document D5 the teaching that a better mixing is obtained if an injection nozzle issuing fuel in the form of a flat cone, which surrounds the injection nozzle uninterruptedly, is used instead of the nozzle issuing separate jets (cf. document D1). Document D5 does not, however, suggest swirling means in the nozzle itself so that a fuel spray of low penetration and having a tangential velocity component cannot be obtained. Therefore, its teaching cannot suggest to obtain a complete engine according to Claim 1.

8.4 Document D6, on the other hand, discloses the use of an injection nozzle spraying fuel in the form of a conical shell, which together with the squish flow obtains a nearly complete uniform mixing. However D6 discloses that the shape of the combustion chamber and its position in the piston are irrelevant, and that the air swirl generated by the swirl suction port may be reduced to a minimum or even dispensed with completely. More important is, however, that there is no indication or suggestion in document D6 either to use swirling means in the injection nozzle in the meaning of the present application or to the relevance of certain features for use in small-sized engines. A person skilled in the art can therefore not be guided by this teaching either to use swirling means in the injection nozzle. On the contrary, a clear teaching is given to use only the squish flow and a specific conical shell fuel spray.

8.5 Document D2 discloses a fuel injection nozzle which avoids clogging and manufacturing difficulties. It teaches to make use of means which create a rotational movement of the fuel in a chamber, which is in the form of a ring and which is located just upstream of the nozzle outlet opening. Although it is clear for a person skilled in the

art that the resulting injected fuel spray is in the form of a hollow conical shell having a tangential velocity component, there is no indication or suggestion to the problem to be solved in the present application (above point 7.2) or to the relevance of the teaching for small-sized engines. On page 2, lines 14 to 20 a person skilled in the art only finds a suggestion that this teaching can also be applied in an injection nozzle having different separate jets and that these separate jets are strongly dispersed and have a low penetration. However this teaching is linked to a problem (clogging; manufacturing difficulties), which is completely different from the present problem to be solved (point 7.2), so that a person skilled in the art would not be pushed in the direction of using such a kind of injection nozzle to obtain an improved small-sized engine (cf. T 39/82 "Light-reflecting slats/AUER-SOG", OJ EPO 1982, 420 - particularly Point 7.3).

Indeed, according to the jurisprudence of the Boards, the question to be answered when assessing inventive step is not whether the skilled person **could** have used features disclosed in document D2, but whether he **would** have done so in expectation of some improvement or advantage (cf. T 2/83 "Simethicone Tablet/RIDER", OJ EPO 1984, 265). Since the reason to use these features in the framework of document D2 is clearly revealed, a skilled person, without knowing the present application, would not be guided by it, to solve a completely different problem.

8.6 Document D3 only discloses a fuel injection nozzle which injects fuel in two stages, namely a centrally solid spray followed by a spray in the form of a hollow cone having a tangential velocity component. A person skilled in the art cannot be led by such a teaching, which defines a completely different nozzle, and which leads to a

completely different combustion process, to inject fuel in the form of only one hollow conical shell having a low penetration and a tangential velocity component, in an engine of any size.

8.7 Document D4 discloses a diesel engine wherein a rotational movement of the air is generated in a piston cavity (combustion chamber) mainly due to the lateral displacement of the cavity with respect to the cylinder axis (page 1, lines 47 to 56). No other teaching than this specific intensifying of the swirl flow has been given, so that a skilled person cannot find in document D4 the solution according to present Claim 1.

8.8 Any consideration with regard to the scope of the $A/A_0$ value range is irrelevant since the disclosure in document D1 already relies on a specific value following into the range of the present claim. That particular embodiment is the closest state of the art and there is no further contribution by the present invention in that respect although other embodiments of the present claim may benefit from the recognition of a broad range for $A/A_0$.

8.9 The Board has also considered the further documents cited in the Search Report and found them not prejudicial to the present Claim 1, either alone or in combination with the documents cited above.

8.10 The subject-matter of Claim 1 therefore involves an inventive step within the meaning of Art. 56 EPC.

9. The subject-matter of Claim 1 is therefore patentable within the meaning of Art. 52 EPC, so that based on this allowable Claim 1, and dependent Claims 2 to 6 which concern preferred embodiments of the small-sized engine according to Claim 1, and the modified description and drawings, a patent may be granted.

**Order**

**For these reasons, it is decided that:**

1. The decision of the first instance is set aside.

2. The case is remitted to the first instance with the order to grant a patent on the basis of the following documents:

   Claims 1 to 6, pages 1 to 7, 7a, 7b and 8 to 20 of the description, as well as Figures 8 and 9 as submitted at the oral proceedings.
   Figures 1, 2, 3A, 3B, 4A, 4B and 5 to 7 as published.

The Registrar: The Chairman:

S. Fabiani G. Szabo