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Bezeichnung der Erfindung: Fuel control system for an internal combustion
Title of invention: engine.
Titre de l'invention :

Klassifikation / Classification / Classement : F02D 5/00

ENTSCHEIDUNG / DECISION
vom / of / du 12 September 1990

Anmelder / Applicant / Demandeur :

Patentinhaber / Proprietor of the patent /
Titulaire du brevet : Lucas Industries PLC

Einsprechender / Opponent / Opposant : Robert Bosch GmbH

Stichwort / Headword / Référence :

EPÜ / EPC / CBE Art. 56

Schlagwort / Keyword / Mot clé : "Inventive step (yes)"

Leitsatz / Headnote / Sommaire

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Case Number : T 196/87 - 3.2.2

D E C I S I O N
of the Technical Board of Appeal
of 12 September 1990

Appellant : Robert Bosch GmbH
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Representative : Müller
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Respondent : Lucas Industries PLC
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Representative : Marks & Clerk
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Decision under appeal : Decision of Opposition Division of the European
Patent Office dated 18 March 1987 rejecting
the opposition filed against European patent
No. 0 017 328 pursuant to Article 102(2) EPC.

Composition of the Board :

Chairman : G. Szabo

Members : M. Noel

J.C. Saisset

Summary of Facts and Submissions

- I. European patent No. 0 017 328 comprising four claims was granted on 19 December 1984 in response to European patent application No. 80 300 535.4 filed on 25 February 1980.

Claims 1 and 2 (method and system) as granted read as follows:

"1. A method of controlling an internal combustion engine comprising measuring the roughness of the engine running so as to derive an electrical engine roughness signal dependent on the magnitude of fluctuations in the engine speed and controlling the rate of fuel flow to the engine in accordance with the time integral of a signal derived by comparing the engine roughness signal with a reference signal characterised in that the error between the engine roughness signal and a reference signal is integrated with respect to time to control the fuel flow, the rate of change of the integrated signal being dependent on the magnitude of the error, whereby the error is reduced to zero."

"2. An internal combustion engine fuel control system for carrying out the method claimed in Claim 1 and comprising a roughness measuring circuit (11,12,14) providing an electrical roughness signal determined by the magnitude of fluctuations in the speed of the engine, and a fuel flow control means (18,19) for controlling the fuel flow to engine in accordance the output signal from an electronic integrating circuit (15) the input to which is determined by the relationship of the roughness signal to a reference signal, characterised in that the input of the integrating circuit (15) is connected to the output of the roughness measuring circuit so as to integrate the error

between the roughness signal and the reference signal, whereby said error is reduced to zero."

II. The patent was opposed on the grounds of lack of novelty and of inventive step in the light of the prior art reflected essentially by the document

(1) DE-A-2 413 227.

III. By a decision dated 18 March 1987, the Opposition Division rejected the opposition since the subject-matter of the claims was deemed to be novel and based on an inventive step.

IV. The Appellant (Opponent) lodged an appeal against this decision on 16 May 1987 paying the appropriate fee simultaneously. The Statement of Grounds was received on 19 June 1987, in which the Appellant disputed the existence of any inventive step in view of the teaching of either document (1) or document

(2) GB-A-1 509 075,

combined with the teaching of document

(3) W. Leonhard, Einführung in die Regelungstechnik, pages 145-146, Vieweg 1972.

V. Oral proceedings took place on 12 September 1990. The Respondent, (Proprietor of the patent), although properly summoned, did not appear.

Basically the arguments advanced by the Appellant in his Statement of Grounds and in a further letter received on 3 August 1990, i.e. shortly before oral proceedings, were

maintained. In this letter a new document was introduced, namely

(4) US-A-4 098 242.

VI. The Appellant requested that the decision under appeal be set aside and that the patent be revoked.

The Respondent requested that the appeal be dismissed.

Reasons for the Decision

1. The appeal is admissible.
2. Formal aspects
 - 2.1 With the exception of the word "magnitude" in relation to error in Claim 1, all the features now contained in the characterising portions of Claims 1 and 2 can be clearly derived from the original description of the patent (cf. in particular page 5, second paragraph and from page 10, last paragraph to page 11, fourth paragraph).

As is clearly apparent from these passages, the engine roughness signal H at the output of the sample and hold circuit 14 (dependent on the instantaneous engine speed fluctuations) is connected to the inverting input (negative) of the integrator 150 (Fig. 3) and the speed reference signal Z at the output of a speed shaping circuit 17 is applied to the non-inverting input (positive) of the integrator. Since these two signals are separately applied to the respective inputs of the integrator the magnitude of their variable difference (error) is effectively integrated. The term "magnitude" can therefore be introduced in Claim 1 as it is directly

and unambiguously implied. It also distinguishes its subject-matter more concisely vis-à-vis the closest prior art. The claim further limits the extent of the protection conferred. Therefore it complies with Articles 123(2) and (3) EPC.

2.2 Document (4) has been refused to by the Board during oral proceedings because it was late-filed i.e. after the summons for oral proceedings (Article 114(2) EPC). In addition, it was not considered, on the Board's own accord, as more relevant than the other earlier cited documents.

3. Closest prior art

As acknowledged by the Appellant, the Board is also of the opinion that the document (1) discloses the precharacterising part of Claim 1 and appears to be the closest prior art.

Document (1) describes (cf. Fig. 1) an air-fuel ratio control system for an internal combustion engine 10 comprising means 68,70 for measuring the roughness of the engine running and deriving an electrical engine roughness signal dependent on the magnitude of fluctuation in the engine speed and means 60 for controlling the rate of fuel flow to the engine in accordance with the time integral of a signal 80 derived by comparing the engine roughness signal (output of 74) with a reference signal (output of 78).

Having regard more precisely to the description of Figures 1 and 4 of (1), the integrator 82 comprises an operational amplifier A4, the inverting input of which is connected via the conductor 80 to the output of a comparator 76 comprising an operational amplifier A3 as

well. The output of the comparator is produced by comparing a rectified roughness signal (output of rectifier 74) with a roughness threshold reference (output of potentiometer 78), both signals being applied simultaneously (junction between resistances R7 and R8) to the inverting input of comparator A3. In view of the basic nature of an analog comparator the signal at the output of comparator A3 (thus the input signal of integrator A4) can only have two possible values predetermined by the breakdown voltage of Zener diodes D4 and D3, positive or negative according to the roughness signal being higher or lower than the reference signal respectively (pages 18-19). Consequently it is not the error which is integrated but a fixed value derived from the error.

As to the Appellant's argument that despite the threshold voltages imposed by the diodes D3, D4 the magnitude of small errors are nevertheless integrated when occurring within a transient period for which the error is lower than the breakdown voltage, the Board cannot share this interpretation for the reason that the comparator A3 is an operational amplifier having a very high gain. Consequently its output changes abruptly from a positive value to a negative one. Furthermore, the following integrator A4 is designed in the control system to react only in response to a changing of polarity applied thereto, i.e. when the breakdown voltages of the diodes have been reached.

A further characteristic is that according to document (1) the rate of change of the integrator A4, 82 is fixed and determined by the magnitudes of resistor R11 and capacitor C4 so that the output of the integrator 82 increases or decreases at a positive or a negative fixed rate according to the polarity at the output of the comparator A3, 76 (page 20).

Summing up, it is clear that the integrator of document (1) does not directly integrate the error between the roughness signal and the reference signal and that the rate of change of the integrated signal is not made dependent on the magnitude of the error.

4. **Novelty**

The subject-matter of Claim 1 distinguishes over the closest prior art known from document (1) by its characterising portion. It is therefore new.

5. **Problem and solution**

The system according to document (1) provides an integrator output which is either increasing or decreasing at a fixed rate. A disadvantage of the system is that since the roughness error cannot be actually reduced to zero, hunting occurs even during steady running conditions.

The system according to document (1) is confined to the engine roughness being detected and the air/fuel ratio being modified so as to maintain engine roughness below a predetermined magnitude, i.e. to regulate the roughness to an acceptable level. In no case is the roughness error sought to be eliminated.

Since the integrator output can only ramp up and down at a fixed rate and since no one ramp rate can satisfy all engine operating conditions, the system according to document (1) appears to be inefficient and causes instability in some operating conditions.

The technical problem to be solved when starting from document (1) is therefore to provide an engine fuel control system of a different design, possibly simpler, which adapts itself automatically to different engine operating conditions and provides an accurate and stable roughness control response.

This problem is solved by the incorporation of features stated in the characterising portion of the method and system claims. With such an arrangement the ramp rate of the integrator is made dependent on the magnitude of the error and not just on its sign as in the prior art. For small errors the integrator output changes relatively slowly, but the rate of change increases with the magnitude of the error, thus ensuring automatic adaptation of the system till the error is reduced to zero whereby stable operation is obtained.

6. Inventive step

The control systems described in document (1) and in the patent operate according to totally different principles.

- 6.1 In the patent the output signal J of the integrator 15 controls the flow of the fuel in the main fuel control circuit 19 through a clock circuit 18, the frequency of which depends on the rate of change of the integrated signal J. Thus the response time of the injection depends on the rate of change of the integrated roughness error signal J (ramps, Fig. 5). Now, the ramp of signal J varies according to the magnitude of the error (H-Z) between the engine roughness signal H and the speed reference signal Z which in turn depends on the variable duration of the roughness pulse G (Fig. 5 and column 7, lines 3-14), this latter expressing the instantaneous speed variations of the engine. All things considered, the quantity of

injected fuel can be adapted to the instantaneous speed engine variations so that sudden changes in rotational speeds can be regulated out rapidly in the case of large roughness deviations and slowly in the case of small deviations.

- 6.2 In the document (1), on the other hand, the duration of the fuel injection period (in fuel delivery means 40) is not directly controlled by the output of the integrator 82, but rather by the output of the controller 60 which in turn generates pulses having a constant-sloped ramp with an amplitude, however, which is varied in accordance to the nature of the signal at the output of integrator 82. As already explained in point 4 above, the rate of change (or slope) of the integrated output signal J is increasing or decreasing at a fixed rate according to the polarity of the roughness signal at the output 80 of the comparator 76. It is precisely this slope inversion of the integrated signal that changes the amplitude of the ramp pulses produced by the controller 60, thus causing them to intercept sooner or later a predetermined reference level related to air flow so as to vary the injection period.

For example, by adjusting the roughness reference signal through the potentiometer 78 so as to cause the rectified roughness signal at the output of circuit 74 to be greater than the reference signal, the output 80 of the comparator 76 is positive and the integrator 82 produces a signal having a negative slope (rate of change determined by resistor R11 and capacitor C4). The decreasing signal at the output of the integrator 82 causes the amplitude of the ramp pulses produced in the controller 60 to be reduced, which in turn later intercept the predetermined reference level applied to the controller so as to increase the injection period. Thus, according to the setting of the potentiometer 78, the system oscillates

around a stable state (hunting effect) which the invention properly seeks to avoid.

6.3 It is specified in document (1) (cf. page 13, first paragraph) that causing the ramp of the controller generated pulse train to intercept the reference voltage later (for example) might be effected by decreasing the slope of the ramp portion of said pulse. The description of document (1), however, does not actually specify how such variation of slope can be achieved. Furthermore the ramp signal produced by the integrator 82 is not concerned at all, rather the ramp signal of the controller 60.

6.4 In view of the above, the rate of change of the integrator 82 is fixed in document (1) and its output can only have two values either increasing or decreasing according to the polarity (not the magnitude) of the roughness error signal at the output of the comparator 76 and also the integrator 82 must be followed by a complementary shaping circuit (inside the controller 60) to elaborate an operating injection control signal.

In contrast, according to the patent the integrator integrates directly (without need of a previous comparator) the magnitude of the error between the roughness signal and the reference signal and the regulated output of the integrator can be used directly to control the time duration of the injection, owing to the fact that by directly integrating the magnitude of the error, it can be reduced to zero.

6.5 The Appellant has argued that from the very principle of integral control as illustrated by document (3) (see Fig. 12.1, page 145) it follows that the integrator integrates the magnitude of the error (X3) which is applied to its input; consequently, the fact that the rate

of change of the integrated signal is dependent on the magnitude of the error whereby the error is reduced to zero, represents only the result of said integration, as stated by the Opposition Division in its decision (page 4, point 13).

The Board does not dispute this in any way. It must, however, first be recognised that in the patent it is actually the magnitude of the error which is applied directly to both inputs of the integrator. This is obviously not the case in either of document (1) or other citations, as further rightly observed in the impugned decision (page 7, point 20).

- 6.6 Starting from document (1) a person skilled in the art confronted to the problem as stated in Point 5 above could not be led to the claimed fuel control method or system which uses a completely different principle. To arrive at the claimed subject-matter the skilled person would essentially have to delete the comparator circuit 76, so that the engine roughness signal and the roughness reference signal be fed directly to both inputs of the operational amplifier A4 of the integrator 82 and also have to modify the controller 60 by deleting the shaping circuit. Having adapted those circuits, yet further substantive modifications would be required in other parts of the system to enable the arrangement to work with appropriate input and output signals. In the Board's view, such considerations already support the assumption of an inventive activity.

Document (2) is acknowledged in the introductory part of the patent as it was already considered during the examining procedure. However it does not come closer to the claimed subject-matter than document (1).

6.7 In addition, the skilled person could not find, either in document (2) or in any other document such as document (3), any indication to use the combination of characterising features as defined in Claims 1 or 2, since a comparator is connected beforehand to the integrator in all these documents. These disclosures are based on a different principle, and are therefore not suitable to lead a person skilled in the art readily to abandon the prevailing concept. Such situation can also be regarded as yet a further indication of an inventive step.

6.8 Furthermore, in the present case, simplification has been accompanied with an improvement of the overall performance. Since the error can be reduced to zero undesirable engine speed fluctuations can be rapidly eliminated without occurrence of hunting. Thus the integrating circuit ensures that stable operation is obtained. The achievement of simplicity with concomitant improved quality of performance is unexpected and must also be considered as pointing to non-obviousness.

6.9 For the foregoing reasons the Board considers that the subject-matter of the method Claim 1 implies an inventive step in the meaning of Article 56 EPC. The same considerations apply to the control system according to Claim 2 for carrying out the method of Claim 1, especially as it is even more clearly specified that the roughness signal is directly fed to an input of the integrator.

7. In column 2, line 57 of the published European patent specification a printer's error has resulted in the omission of some words. The text should be amended so as to read "... time interval between two transducer pulses exceeds the time interval between the preceding ..." which is fairly supported by the description as originally filed (page 4, second paragraph).

Order

For these reasons, it is decided that:

1. The appeal is dismissed.
2. The case is remitted to the first instance with the order to maintain the patent with the amendment as defined in above point 7.

The Registrar:

The Chairman:

S. Fabiani

S. Fabiani

G. Szabo

G. Szabo

M. Wolf

19.10.90

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53.10.1950

H. Müller