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(54) CONTROL SYSTEM FOR A FUEL INJECTION PUMP OF A DIESEL ENGINE

(71) We, ROBERT BOSCH GMBH, a German company of Postfach 50, 7 Stuttgart 1, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

The invention relates to a control system for the temperature dependent control or limitation of the injected fuel quantity in a diesel engine.

Control systems for temperature-dependent control of a servo control device for determining or limiting the position of the fuel-feed-rate adjusting member of a fuel injection pump of a diesel engine, are already known, in which the servo control device is controllable by means of an electronic control circuit in dependence upon operating parameters, such as air temperature. The known control systems process the air-temperature control signal in order to effect an additive correction of the position or limitation, adjusted by means of the control system, of the adjusting rod of the injection pump, that is, the position of the adjusting rod is corrected to an extent corresponding to the air temperature. Owing to stricter legislation relating to the reduction of noxious emission in diesel engines, such corrections are no longer adequate for the fuel metering requirements of diesel engines: in order to satisfy the new emission regulations, the volume of air and the volume of fuel must be precisely correlated in the diesel engine. There is, according, an urgent need for a method of air-temperature and fuel-temperature compensation.

According to the present invention there is provided a control system for temperature-dependently determining or limiting the quantity of fuel delivered by a fuel injection pump of a diesel engine, comprising a servo control device for determining the position of or limiting the travel of a fuel-feed-rate adjusting member of the injection pump and an electronic control circuit operative to control the servo control device, the electronic control circuit having an intake-air-temperature sensor and a fuel temperature sensor coupled therein in opposition, such that the diference between their output signals influences a control signal of the electronic control circuit so as to achieve precise determination of the fuel quantity fed to the engine or precise adjustment of the maximum permissible fuel feed quantity to which the injection pump can be adjusted in accordance with the volume of air supplied to the engine.

The control system according to the present invention advantageously enables the position of the servo control device, determined or limited by means of the control system, and thus also the controlled or maximum permissible fuel feed rate, to be corrected, in order to provide clean combustion in the diesel engine, even in the event of there being substantial differences between the intake-air temperature and the fuel temperature. Owing to the output signals of the two temperature sensors being coupled in opposition, the signals cancel each other out when air temperature and fuel temperature are equal, or else they may be adjusted to a predetermined value.

The temperature sensors may be coupled in a bridge circuit whose output is connected to a differential amplifier to provide a simple, inexpensive electronic control circuit arrangement by which a pressure signal from a pressure transducer in the engine inlet manifold is corrected. Such means for correcting the pressure signal are particularly advantageous in the case of supercharged diesel engines. There is no need to make any changes in the subsequent control circuit, which may possibly comprise a family of fuel-flow characteristics.

The invention will hereinafter be further described by way of example with reference to the accompanying drawings in which:

Fig. 1 is a simplified diagram of one embodiment of the present invention;

Fig. 2 is a simplified circuit diagram of the embodiment of Fig. 1; and

Figs. 3 and 4 each show a bridge circuit for combining the intake-air temperature and fuel-temperature signals.

The control system, a simplified arrangement of which is shown in Figure 1, comprises a fuel injection pump 2, provided with a mechanical rotational-speed governor 1, the operating rod 3 of which pump, serving as a fuel-feed adjusting member, being movable by means of the governor 1 in dependence upon the speed of rotation and the position of an operating lever 4, in order to vary the amount of fuel delivered by the injection pump 2. In the embodiment shown, the operating rod 3 is provided with a striker arm 5, which cooperates with a stop member 6 of a servo control device 7.

The servo control device 7 is operable by means of an electronic control circuit 8, and comprises substantially a hydraulic servo motor 10, having a pressure chamber 9 connected to a solenoid valve 11, which controls the supply and return flow of the fuel, serving as a control fluid and supplied by a fuel feed pump 12 for the injection pump 2. The solenoid valve 11, in the form of an electromagnetic slide valve, has an intermediate position, in which, as shown in the drawing, a line 13 to the pressure chamber 9 is blocked with respect to a supply line 14 and a return line 15. This form of construction of the solenoid valve 11 enables a saving of fuel to be effected, as compared with other pulse-operated valves frequently used. For bridging fluctuations in pressure, and in order to permit rapid controlling action, a hydraulic accumulator 16 is connected to the supply line 14, and is connected vie a portion 14*a* of the supply line 14, which portion incorporates a non-return valve 20, to a feed line 17, via which fuel, drawn by means of the fuel pump 12 from a tank 18, is delivered via a filter 19 to the injection pump 2. The non-return valve 20 prevents the hydraulic accumulator 16 from running empty. Excess fuel is returned via a pressure-retaining or pressure-regulating valve 21 and a return-flow line 22, to the tank 18.

In the simplified ararngement shown in Figure 1, the hydraulic servo motor 10, which, together with the solenoid valve 11, serves as a servo control device, has a diaphragm 23, which delimits the pressure chamber 9 and serves as a movable wall. The side of the diaphragm 23 adjacent to the pressure chamber 9 is subjected to the pressure of the fuel delivered via the line 13 and controlled by the valve 11, and a return spring 24, which abuts the housing of the servo motor 10 acts on the other side of the diaphragm. The diaphragm 23 is also rigidly connected to the stop member 6, whose position RW_x, determined by the solenoid valve 11 and the electronic control circuit 8, limits the position of the operating rod 3 of the injection pump 2 in a direction to increase the quantity of fuel for injection, namely, in dependence upon operating parameters, of which the engine speed *n*, the intake-air temperature T_L, and the fuel temperature T_K, and also the absolute air pressure P_L, prevailing in the inlet manifold of the engine and serving as a measured value of the air flow to the engine, are the most important for the limitation, performed by means of the embodiment under discussion, of the maximum permissible quantity Q_{max} of fuel for injection.

A signal proportional to the engine speed is supplied to the electronic circuit 8 by a rotational-speed transducer 27, which cooperates with a toothed wheel 25 on the cam shaft 26 of the injection pump 2. The absolute air pressure P_L, prevailing in the inlet manifold of the engine, is measured by means of an absolute-pressure transducer 28 and converted into a control signal for the electronic control circuit 8.

The absolute-pressure transducer 28 comprises substantially a pressure transducer 29, incorporating a module comprising a stack of evacuated capsules, and an electrical displacement transducer or sensor 31. An intake-air-temperature transducer or sensor 32 and a fuel-temperature transducer or sensor 33, a driving switch 36, which serves for starting the engine, and a transducer 37 for feeding back the position RW_x of the stop member 6 to the electronic control circuit 8, are also connected to the electronic control circuit 8.

The travel transducer 37 is necessary, since, without it, the servo control device 7 would not operate sufficiently accurately. Accordingly, the electronic control circuit 8 incorporates also an electronic variable-gain servo-amplifier, advantageously in the form of a PID controller, denoted by the reference numeral 38. The variable-gain electronic amplifier 38 produces a control signal S for the solenoid valve 11, as long as the actual value, measured by means of the travel transducer 37, differs from a desired value, provided by an electronic control means 39. The electronic control means 39 is part of the electronic control circuit 8, and is shown here, purely notionally, by a rectangle in the circuit 8. The stopping direction of the operating rod 3 is denoted by the arrow 42.

In the illustrated exemplary embodiment the control circuit 8 serves only to limit the regulating travel, the electronic control means 39, shown purely notionally in the control circuit 8, comprises a characteristic generator for a full-load regulating travel, which generates a desired-value signal S_I, for an instantaneous speed *n*, for the position RW_x of the stop member 9, namely, in dependence upon the signals of the rotational-speed transducer 27 and the absolute-pressure transducer 28, serving as an air flow transducer, corresponding to values of a family of characteristics of the fuel feed rate for full-load operation, which values are acquired from the engine, in order to establish a limit value for limiting engine performance (for example, a permissible smoke limit or an acceleration response), while allowing for the injection pump characteristic. Such a characteristic control system is described in British Patent Application No. 45316/77, (Serial No. 1590459).

Since the full-load feed rate to be controlled is dependent not only upon the pressure P_L, but also upon the intake-air temperature T_L, for precise measurement of the air flow, the absolute intake-air pressure P_L is coupled multiplicatively with the air temperature T_L in the electronic control means 39 shown notionally in Figure 1, since the respective fuel feed Q, or the respective regulating travel RW of the operating rod 3 of the injection pump 2 vary substantially in case of variations in temperature.

In addition to the intake-air temperature T_L, account is taken also of the fuel temperature T_K, which is opposingly coupled, in the electronic control means 39, with the intake-air temperature T_L. A particularly simple and advantageous circuit for this purpose is described hereinafter with reference to Figures 2 to 4.

Figure 2 is a circuit diagram showing the electronic control circuit 8, together with the variable-gain amplifier 38 and the electronic control means 39, together with the respective transducers, the servo control device 7, and the injection pump 2 together with the governer 1, for a second embodiment. In this case, the stop member 6 of the servo control device 7 is shown as acting directly upon the operating rod 3 of the injection pump 2; the method of operation within the governor 1 corresponds exactly to that shown in Figure 1, however.

For the sake of clarity, the circuit diagram is so constructed that the transducers and the electronic control means 39 are arranged towards the left-hand side, being connected, on the right-hand side, to an electronic control circuit 44 for the control element 7, together with a stop 6, the electronic circuit 44 comprising the variable-gain amplifier 38 and the travel transducer 37 serving to detect the position RW_x of the stop member. The rotational-speed transducer 27 is arranged in the governor 1, and its speed signal n is converted by means of an electronic control circuit in the control means 39, to a rotational-speed-dependent control signal, which is applied, for example, to a performance characteristic generator for full-load regulating travel, in the control means 39, as described with reference to Figure 1.

The electronic control means 39 provides a desired-value signal S_I, in dependence upon the speed n of the rotational-speed transducer 27, and a signal Sp of the absolute-pressure transducer 28. The signal Sp is generated directly by the electrical travel transducer 31, in proportion to the pressure signal P_L of the pressure transducer 29, and is corrected, in a coupling circuit 45, by the signals T_L and T_K of the intake-air-temperature transducer 32 and the fuel-temperature transducer 33. As stated above, the signals P_L and T_L of the pressure transducer 29 and the air-temperature transducer 32, are multiplicatively coupled. This is effected by correction of the supply voltage of the electrical displacement transducer 31, provided in the coupling circuit 45, by the air-temperature transducer 32, in dependence upon the intake-air temperature T_L. Additive coupling is possible only in cases where less accurate control is acceptable.

Since the volume of fuel delivered by the injection pump varies according to temperature, if the values of pressure and volume are constant, the supply voltage of the electrical travel transducer 31 is corrected additionally by means of the fuel-temperature transducer 33, whose control signal T_K is coupled in opposition to the control signal T_L of the air-temperature transducer 32, since, in general, given equal intake-air and fuel temperatures, no correction of the control signal S_p is necessary.

The multiplicative coupling of the two signals T_L and T_K with P_L may, advantageously, be effected by means of a bridge circuit 46, which is further described hereinafter with reference to Figures 3 and 4, and is shown by a dash-dot line in Figure 2. The output signal of the bridge circuit 46 is denoted by the reference S_T, and is fed into the coupling circuit 45, instead of the signals T_L and T_K, as a signal for correcting the supply voltage of the absolute-pressure transducer 28.

The multiplicative coupling shown in a simplified form in, and described with reference to, Figure 2, of the air temperature T_L, in the inlet manifold of the engine, with the fuel temperature T_K, is effected advantageously, as previously shown by a dash-dot line in Figure 2, by means of the bridge circuit 46 shown in Figure 3, in each arm of which there is provided a temperature transducer 32, 33, and which is connected to the input of a differential amplifier 47, in the form of a proportional variable-gain amplifier. The air-temperature transducer 32 and fuel-temperature transducer 33, associated with the respective arms of the bridge, are each connected to a respective tuning resistor 48, 49, for balancing the temperature-dependent control voltage, the two temperature transducers 32 and 33 being preferably in the form of NTC resistors. For balancing the two arms of the bridge, the latter may, alternatively, be connected to two different supply voltage sources U_1 and U_2, as shown in Figure 4. The output signal S_T of the differential amplifier 47 may, for correction of the control signal S of the variable-gain amplifier 38, be applied directly to the electronic control means 39. However, the most effective and most economical method is one in which, as shown in Figure 2, the output signal S_T of the differential amplifier 47 corrects the supply voltage of the travel transducer 31 incorporated in the absolute-pressure transducer 28, this being effected by means of the coupling circuit 45.

In measuring engine performance, it has been shown that air/fuel-temperature correction of the pressure signal P_L is not necessary, if the temperatures of both media are equal. Accordingly, the bridge circuit 46, shown in Figures 3 and 4, is so constructed that, when air and fuel temperatures are equal, the bridge voltage difference, fed into the differential amplifier 47, is zero. If slight correction is necessary, however, the bridge circuit 46 may be so adjusted that, when the temperatures are equal, the bridge voltage difference corresponds to a predetermined value.

Both embodiments show methods of intake-air-temperature and fuel-temperature compensation, or correction, in control systems, by means of which the travel of the fuel-feed-rate adjusting member 3 of the injection pump 2 in the direction to increase the amount of fuel for injection is limited. The same correction circuit may also be used, if, instead of the control system incorporating the electronic control circuit 8, there is provided an electronic governor circuit, which, in addition to, or without, a mechanical rotational-speed governor, determines the position of the fuel-feed-rate adjusting member in all operating modes of the engine. A particular advantage of the present invention is that, owing to the use of the bridge circuit, only one electronic amplifying circuit is required for both kinds of compensation, namely, intake-air-temperature and fuel-temperature compensation.

WHAT WE CLAIM IS:—

1. A control system for temperature-dependently determining or limiting the quantity of fuel delivered by a fuel injection pump of a diesel engine, comprising a servo control device for determining the position of or limiting the travel of a fuel-feed-rate adjusting member of the injection pump and an electronic control circuit operative to control the servo control device, the electronic control circuit having an intake-air-temperature sensor and a fuel temperature sensor coupled therein in opposition, such that the difference between their output signals influences a control signal of the electronic control circuit so as to achieve precise determination of the fuel quantity fed to the engine or precise adjustment of the maximum permissible fuel feed quantity to which the injection pump can be adjusted in accordance with the volume of air supplied to the engine.

2. A control system as claimed in claim 1, in which the intake-air-temperature sensor and the fuel-temperature sensor are coupled in a bridge circuit, whose output is connected to the input of a differential amplifier, an output signal of the differential amplifier being connected to the electronic control circuit controlling the servo control device.

3. A control system as claimed in claim 2, in which the temperature sensors are so connected that, when air temperature and fuel temperature are equal, the bridge-voltage difference applied to the differential amplifier is zero, or corresponds to a predetermined value.

4. A control system as claimed in claim 2 to 3, in which, for balancing the temperature-dependent control voltage of the two temperature sensors, a respective tuning resistor is connected to each temperature sensors, or the two branches of the bridge are connected to different supply-voltage sources.

5. A control system as claimed in any of claims 2 to 4, further comprising an air-pressure transducer for connecting the control signal in accordance with the air-pressure, the air-presure transducer acting as an air volume transducer, and comprising an absolute-pressure transducer, which measures the absolute air-pressure in the inlet manifold of the engine and converts it into a pressure signal.

6. A control system as claimed in claim 5 in which a coupling circuit is provided for multiplicatively coupling the output signal of the differential amplifier with the signal of the absolute-pressure transducer.

7. A control system as claimed in any preceding claim in which the differential amplifier is a proportional amplifier having variable amplification.

8. A control system as claimed in claim 7, when appendant to claim 5 or 6, in which the supply voltage of a travel transducer, incorporated in the absolute-pressure transducer, is correctable by means of the output signal of the differential amplifier.

9. A control system as claimed in any preceding claim in which the temperature sensors comprise NTC resistors.

10. A control system constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in the accompanying drawings.

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1590460 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

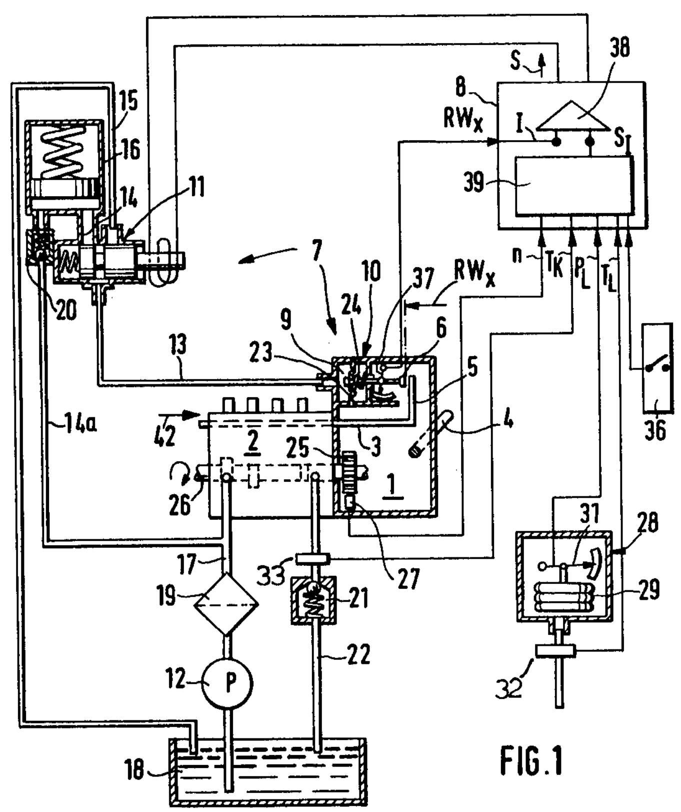

FIG.1

1590460 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

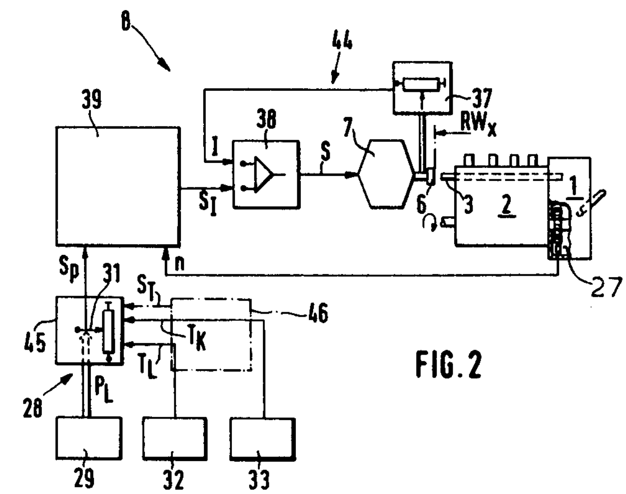

FIG. 2

FIG. 3

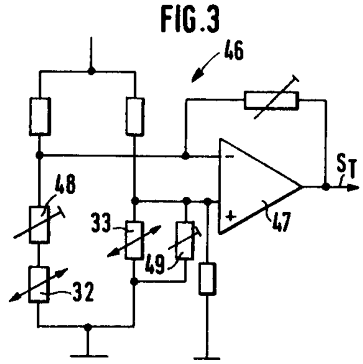

FIG. 4