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(54) METHOD AND SYSTEM FOR DECREASING THE INJURIOUS CONSTITUENTS IN THE EXHAUST GASES OF INTERNAL COMBUSTION ENGINES

(71) We, ROBERT BOSCH GMBH, a German Company, of Postfach 50, 7 Stuttgart 1, Federal Repulic 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 performed, to be particularly described in and by the following statement:

The present invention relates to a method and system for decreasing injurious constituents in exhaust gases of internal combustion engines.

In one known method of decreasing the injurious constituents in the exhaust gases of internal combustion engines, the mass ratio of the operating mixture fed to the internal combustion engine, is regulated by means of an exhaust gas measuring probe detecting the composition of the exhaust gas, particularly but not exclusively an oxygen measuring probe whose output signal is fed by way of a threshold value switch to a variable-gain amplifier which controls a mixture adjusting device and which has an integrating behaviour, the switching state of which threshold value switch determines the direction of integration of the variable-gain amplifier.

A regulating method of this type, in which the quantity of fuel or the quantity of air fed proportionally to the mixture producer is increased or decreased in dependence upon the output signal of the exhaust gas measuring probe, has the disadvantage that accurate regulation of a desired mixture is influenced by the engine transit time during which the mixture produced passes through the internal combustion engine and arrives at the exhaust gas measuring probe. Mixture regulating devices operated in accordance with this method have an integrating characteristic, so that the mass ratio of fuel to air in the operating mixture of the internal combustion engine is corrected to an increasingly greater extent with an increasing period of time during which the value of the exhaust gas composition differs from the desired value. Consequently, with increasing engine transit time, or with a decreasing rate of throughput of the mixture, the composition of the exhaust gas increasingly differs from a desired value in one direction or the other until the correction signal arrives for triggering the integration in the opposite direction. Thus, continuously changing compositions of the exhaust gas are caused in dependence upon the engine speed and, particularly at low engine speeds corresponding to idling, produce troublesome periodic fluctuations in the engine speed ("sawing").

A method is known in which, in the intially mentioned regulating device, the variable-gain amplifier integrates in a speed-dependent rhythm only for a specific period of time. Thus, with increasing engine transit time, the time also increases during which the variable-gain amplifier does not integrate, thus resulting in an average time constant which is adapted to the engine transit time or to the engine speed and which is greater than the time constant set by the variable-gain amplifier. However, an expensive regulating device is required for a regulating characteristic of this type.

According to one feature of the present invention there is provided a method of decreasing contaminants in the exhaust gases of an internal combustion engine comprising monitoring a parameter of the exhaust gases and regulating in dependence upon the parameter value the mass ratio of the air to fuel mixture fed to the internal combustion engine engine by way of a threshold value switch and a variable-gain integrating amplifier whose direction of integration is determined by the switching state of the threshold value switch, wherein the effective time constant of the variable-gain amplifier varies in dependence upon the duration of the period of time between two successive change-over operations of the threshold value switch.

According to another feature of the present invention there is provided a system for decreasing contaminants in the exhaust gases of an internal combustion engine comprising a probe for monitoring a parameter of the exhaust gases and regulating the mass ratio of air to fuel mixture fed to the engine by way of a threshold value switch and a variable-gain integrating amplifier, the direction of integration of the amplifier being dependent upon the switching state of the threshold value switch, and an electrical charge store whose state of charge or discharge is dependent upon the time period between successive change-over operations of the threshold value switch and which serves to influence the effective time constant of the variable-gain amplifier in dependence thereon.

In one embodiment of the invention the output of the threshold value switch is connected to the input of the variable-gain amplifier by way of at least two resistors and a capacitor is connected in parallel with at least one of these resistors.

In another embodiment of the invention two capacitors are connected between the output and an input of the variable-gain amplifier and a resistor is connected in parallel with one of the capacitors.

In each of these embodiments simply by interposing a capacitor, the effective time constant of the variable gain amplifier, which is initially low after each change-over operation of the threshold value switch, is gradually increased in conformity with the charging of the capacitor which is rapid in the first instance; thus the time constant gradually increases as the charge across the capacitor increases and as the influence of the resistor connected in parallel therewith increases. By virtue of this very simple development, and with small components, one can obtain a decreasing slope in the voltage rise at the output of the variable-gain amplifier, or a corresponding increase in the time constant thereof, as the interval of time between two change-over operations of the threshold value switch increases.

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

Figure 1 shows, in the form a rough diagram, a characteristic of the output voltage of an oxygen measuring probe, acting as an exhaust gas measuring probe, plotted against time, compared with the voltage appearing at the output of a variable-gain amplifier for the purpose of controlling a device for adjusting the composition of the operating mixture and with a fixed time constant,

Figure 2 shows the voltage characteristic at the output of the variable-gain amplifier when the effective time constant is varied,

Figure 3 is a circuit diagram of one embodiment of the invention shown by way of example, and

Figure 3a is a circuit diagram of a second embodiment of the invention.

Referring to Figure 1, the top curve S shows, diagrammatically, a characteristic of the output signal Us of an exhaust gas probe plotted against time. This probe is an oxygen measuring probe of known construction which responds to differing partial pressures of the free oxygen in the exhaust gas compared with the oxygen in a reference medium and which has a step characteristic during a transition from an exhaust gas having a low oxygen content to an exhaust gas having a high oxygen content in the range of an air number of $\lambda = 1$. A high output voltage of the oxygen measuring probe signals a "rich" mixture having an air number of $\lambda<1$, and a low output voltage signals a "lean" mixture having an air number of $\lambda>1$. The bottom curve in Figure 1 shows a characteristic of the output voltage of an integrating variable-gain amplifier plotted against time when the inverting input of a variable-gain amplifier is controlled by the output of a threshold value switch responsive to the output signal of the oxygen probe. By way of example, the variable-gain amplifier can be arranged such that it integrates in a negative direction when the probe output voltage is high, and integrates in a positive direction when the probe output voltage is low. Thus, in conformity with the probe signal, there results at the output of the variable-gain amplifier a zig-zag curve whose centre line corresponds to a voltage which would be suitable for adjusting the mixture adjusting device so as to obtain precisely an air number $\lambda = 1$.

The period of time during which the integration is continued beyond the average value corresponding to $\lambda = 1$ until the direction of integration is reversed, corresponds to the transit time T_t of the regulating path. This period of time continues until the changed mixture has reached the oxygen measuring probe in the exhaust gas system of the internal combustion engine and, since the mixture has become too lean as a result of this overshoot operation, the output from the probe switches the variable-gain amplifier to integrate in the reverse direction. It will be seen from this that the transit time of the regulating path is reflected in the frequency of the changes in the output signal from the probe. This transit time increases as the rate of throughput of the mixture decreases, so that, particularly at low engine speeds, the amplitude of the deviation from the desired value becomes very great. The compositions of the mixture thus occurring lead to a periodic fluctuation in the engine speed, this being particularly troublesome during idling.

However, if the time constant or the slope of the voltage rise at the output of the variable gain amplifier were reduced, the rate of response of the regulation would be inadequate at higher engine speeds.

By virtue of the system illustrated in the circuit diagram of Figure 3, it is now possible, by simple means, to vary the time constant in dependence upon time. Figure 3 shows basically a known regulating circuit in which the output signal of an oxygen measuring probe 1 is fed to a threshold value switch 3 which, in turn, applies its output signal to the input of a variable-gain amplifier 4. The output of the variable-gain amplifier is connected to a mixture adjusting device 5 which varies the mass ratio of fuel to air in the operating mixture fed to the internal combustion engine (not further illustrated).

The threshold value switch 3 comprises an operational amplifier 7 to the inverting input of which is fed the output signal of the oxygen measuring probe 1 by way of a resistor 8. The other side of the oxygen measuring probe is connected to a common negative reference potential of a supply line 9. A final reference voltage is fed to the non-inverting input of the operational amplifier 7 by a voltage divider comprising series-connected resistors 11 and 12 connected between the common supply line 9 and a common supply line 14 carrying a positive potential. The output of the operational amplifier is connected to the supply line 14 by way of a resistor 15 and to the base of a p-n-p transistor 17 by way of a resistor 16. The emitter of the transistor 17 is connected to the positive potential of the supply line 14, while the collector is connected by way of a resistor 18 to the central tapping of a voltage divider comprising series-connected resistors 19 and 20 connected between the common supply lines 9 and 14. The inverting input of an operational amplifier 24 serving as the variable-gain amplifier 4, is fed by the latter voltage divider by way of a resistor 22. A capacitor 25 is connected between the output and the inverting input of the operational amplifier 24 to impart an integrating characteristic to the variable-gain amplifier. The non-inverting input of the operational amplifier 24 is fed by a voltage divider comprising the resistors 26 and 27 connected between the common supply lines 9 and 14. The output of the operational amplifier is connected to the positive potential of the supply line 14 by way of a resistor 28 and to the mixture adjusting device 5 (not further described).

As so far described the circuit corresponds to a conventional regulating device which is responsive to an oxygen probe. It will be appreciated that the voltage divider comprising the resistors 11 and 12 can also be supplied with a stabilized voltage in order to adjust the threshold value switch 3 with greater accuracy.

The system illustrated in Figure 3 operates in the following manner: the threshold value established at the non-inverting input of the operational amplifier 7 by means of the voltage divider 11, 12 is exceeded or passed in a negative direction according to the value of the output signal of the oxygen measuring probe 1. The correspondingly varying output signal is fed to the base of the transistor 17 which is thereby rendered either non-conducting or conducting. The transistor 17 remains non-conducting when the output voltage of the threshold value switch 3 is high corresponding to a low oxygen probe output signal, and is rendered conducting when the output voltage of the threshold value switch 3 is low corresponding to a high oxygen probe output signal. When the transistor 17 is conducting the resistor 18 is connected in parallel with the resistor 19 to the positive potential of the supply line 14, so that a higher voltage is established at the tapping of the voltage divider and is fed to the inverting input of the operational amplifier 24 by way of the resistor 22. On the other hand, when the transistor 17 is non-conducting, the voltage at the tapping of the voltage divider comprising the resistors 19 and 20 drops, so that a voltage below the desired value at the non-inverting input of the operational amplifier 24 is applied to the inverting input of the operational amplifier 24. Consequently, the variable-gain amplifier 4 changes its direction of integration. The mixture adjusting device is at the same time triggered in the opposite direction.

In accordance with one embodiment of the invention, a capacitor 30 is connected in series with the capacitor 25 in the feedback circuit between the output of the operational amplifier 24 and the inverting input and a resistor 31 is connected in parallel with the capacitor 25. In this arrangement, after a change-over operation of the threshold value switch, or upon a change in the input signal at the inverting input of the operational amplifier 24, the series combination comprising the capacitors 25 and 30 determines, in the first instance, the time constant or the slope of the rise in the absolute voltage at the output of the operational amplifier 24. With increasing transit time and an increasing period of time between two change-over operations of the threshold value switch, the resistor 31 becomes more effective owing to the increasingly effective resistance value of the capacitor 25, so that the time constant of the voltage rise at the output of the operational amplifier 24 is rendered increasingly effective by the series combination comprising the resistor 31 and the capacitor 30 in the feedback circuit. Figure 2 shows the influence exerted by the capacitor 30 on the time constant of the variable-gain amplifier. It will be seen in Figure 2 that, after a change in the direction of integration, the slope has, in the first instance, a high absolute value which, after a transition, assumes a lower value. In this manner, even in the case of a long transit time, the absolute value of the control variable at the output of the operational amplifier is prevented from assuming too high a value, thus limiting the adjustment of the mixture adjusting device 5, so that troublesome "sawing" is avoided in the case of long transit times and particularly during idling of the internal combustion engine.

A second embodiment of the invention is shown in Figure 3a. This embodiment difers from the embodiment of Figure 3 by virtue of the fact that a second resistor 21 is connected in series with the registor 22 and a capacitor 29 is connected in parallel with the resistor 21, while only a single integrating capacitor 25 is provided in the feedback circuit between the output of the operational amplifier 24 and its inverting input. The circuit is otherwise constructed in the same manner as the embodiment shown in Figure 3, so that reference is made to the preceding text with respect to the description and mode of operation.

In the embodiment of Figure 3a, the charge on the capacitor 29 is reversed at each change-over operation of the threshold value switch 3 or of the transistor 17, but the capacitor 29 effectively by-passes the resistor 21 during its charge-reversal time, so that, initially, the time constant of the variable-gain amplifier is determined only by the resistor 22 at the inverting input of the operational amplifier. The influence of the resistor 21 increases only as the charge on the capacitor 29 increases so that the time constant of the variable-gain amplifier increases as the charge on the capacitor 29 increases. The effect which the capacitor 29 has on the time constant of the variable-gain amplifier 4 is the same as that of the capacitor 30 in the first embodiment.

WHAT WE CLAIM IS

1. A method of decreasing contaminants in the exhaust gases of an internal combustion engine comprising monitoring a parameter of the exhaust gases and regulating in dependence upon the parameter value the mass ratio of the air to fuel mixture fed to the internal combustion engine by way of a threshold value switch and a variable-gain integrating amplifier whose direction of integration is determined by the switching state of the threshold value switch, wherein the effective time constant of the variable-gain amplifier varies in dependence upon the duration of the period of time between two successive change-over operations of the threshold value switch.

2. A system for decreasing contaminants in the exhaust gases of an internal combustion engine comprising a probe for monitoring a parameter of the exhaust gases and regulating the mass ratio of air to fuel mixture fed to the engine by way of a threshold value switch and a variable-gain integrating amplifier, the direction of integration of the amplifier being dependent upon the switching state of the threshold value switch, and an electrical charge store whose state of charge or discharge is dependent upon the time period between successive change-over operations of the threshold value switch and which serves to influence the effective time constant of the variable-gain amplifier in dependence thereon.

3. A system as claimed in Claim 2, wherein the output of the threshold value switch is connected to the input of the variable-gain amplifier by way of at least two series resistors, and the electrical charge store comprises a capacitor connected in parallel with at least one of these resistors.

4. A sytem as claimed in Claim 2, wherein the threshold value switch is connected by way of a resistor to the inverting input of the variable-gain amplifier which is formed by an operational amplifier, the electrical charge store comprises two capacitors connected in series in a feedback circuit between the output and the inverting input of the operational amplifier, and a resistor is connected in parallel with one of the said capacitors.

5. A method substantially as hereinbefore particularly described with reference to and as illustrated in Figures 1, 2 and 3 of the accompanying drawings.

6. A method substantially as hereinbefore particularly described with reference to and as illustrated in Figures 2 and 3a of the accompanying drawings.

7. A system constructed and arranged and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figures 2 and 3 of the accompanying drawings.

8. A system constructed and arranged and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figures 2 and 3a of the accompanying drawings.

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Fig.1

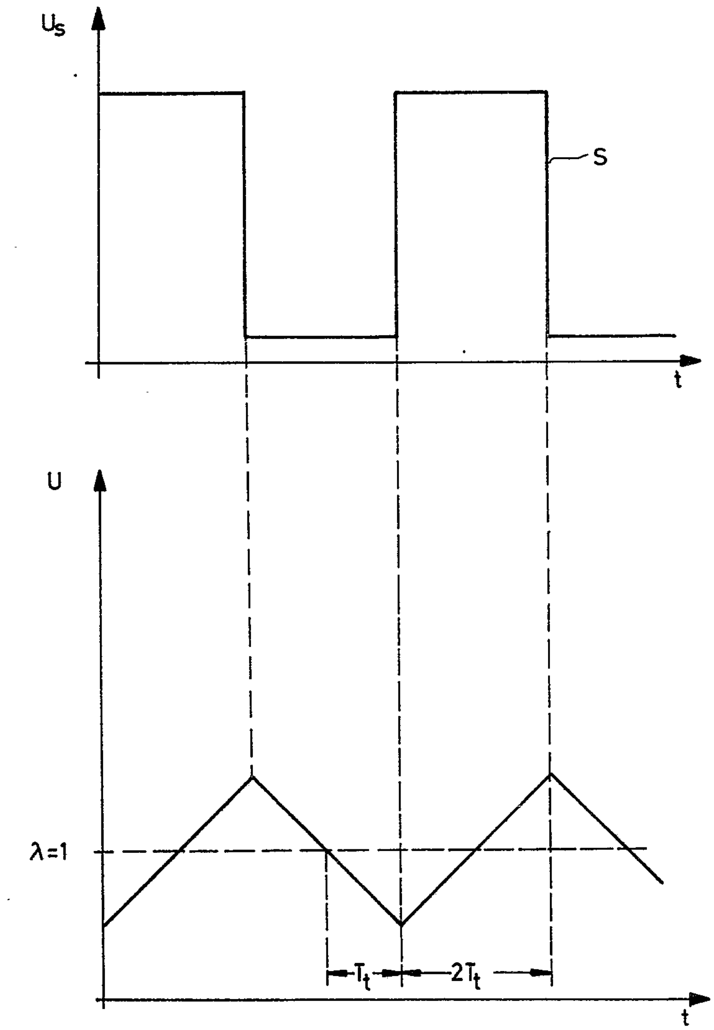

Fig. 2

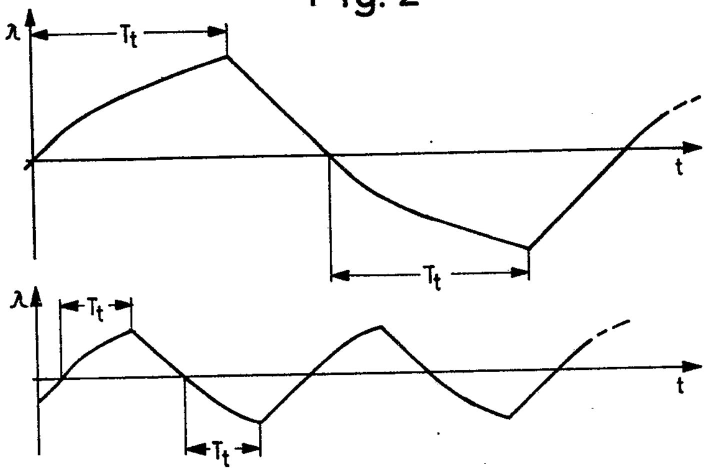
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Fig. 3a

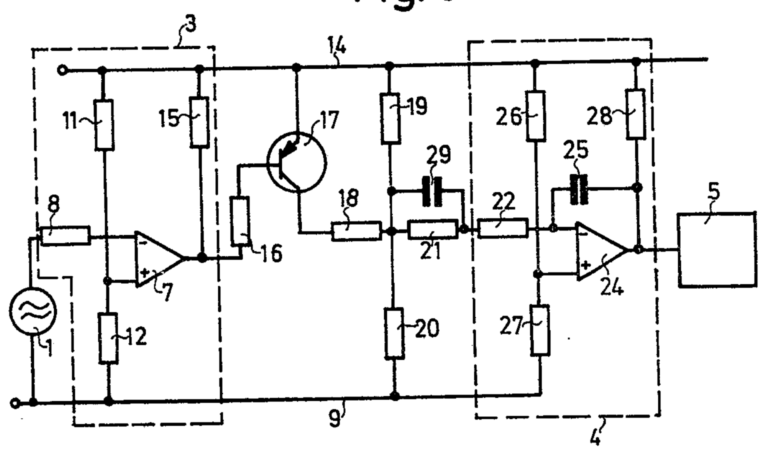
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Fig.3