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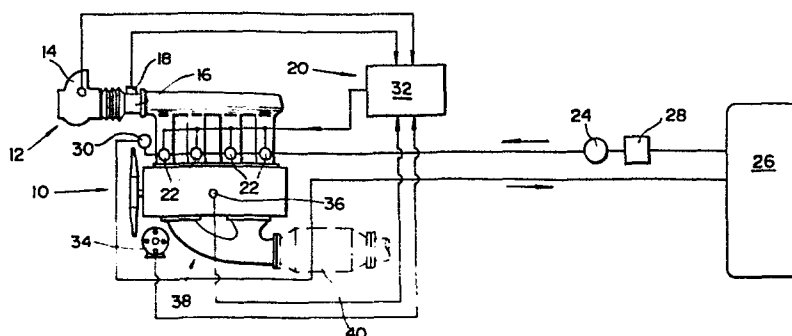
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54 Automotive air-fuel ratio control system.

57 A vibration sensor is mounted on the body of an engine so as to be directly exposed to the vibrations of same and produce a signal via which a closed loop air-fuel ratio control system can hold the air-fuel ratio of the mixture fed to the engine on the lean side of stoichiometric and in the near vicinity of the "best economy point" at which fuel consumption minimizes.

FIG.1



AUTOMOTIVE AIR-FUEL RATIO CONTROL SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to an automotive air-fuel ratio control system and more specifically to a system including an engine vibration sensor which provides real time information enabling the air-fuel ratio to be held on the lean side of stoichimetry in the near vicinity of a so called "best enconomy point".

Description of the Prior Art

To permit an internal combustion engine to be operated on fuels in which the ratio of gasoline to alcohol vary due to seasonal availabilty of alcohol (such as occurs in Brazil for example wherein the percentage of alcohol is apt to vary between 20 and 50%) or for other reasons such as an unexpected seperation of the fuel in the fuel tank per se into seperate alcohol and gasoline layers, it has been necessary to develop an air-fuel ratio control system which can compensate for the rather remarkable changes in the equivalence ratio resulting from varying percentages of alcohol in the fuel. For example, if the engine carburetor (for example) is calibrated to produce an air-fuel ratio of 15:1 when

operated on gasoline containing from 0 - 20% alcohol the equivalence ratio will vary from 0.98 (for pure gasoline) to 0.90 (when the fuel contains 20% alcohol). However, if the amount of alcohol increases to 50% the equivalence ratio falls to 0.78 which is too lean for stable engine operation and the carburetor must be recalibrated..

Hence, a so called Lean Limit Control (LLC) system has been developed wherein the angular acceleration/deceleration of the engine flywheel is detected and quality of combustion determined electronically. To achieve this detection a magnetic sensor has been mounted immediately adjacent the the engine flywheel and adapted to output signal indicative of the changes in the angular momentum of same. A full and detailed disclosure of this arrangement may be found in SAE (Society of Automotive Engineers Inc) Technical Paper No. 780039, the subject matter of which was made public at the Congress and Exposition Cobo Hall Detroit. February 27-March 3, 1979.

However, this arrangement has suffered from the drawback that the sensor disclosed in the above mentioned paper, is unable to provide the required indication of engine vibration. That is to say, in the case of an automotive internal combustion engine, the changes in angular momentum of the flywheel vary from between 0.025

and 0.04 of the total angular momentum whereby the circuitry associated with the sensor must be sufficiently sensitive so as to be able to distinguish the changes despite external influences such as background noise (electronic) which is inevitable in such an environment. Further, when the engine rolls on its suspension the sensor per se is apt rotate about the flywheel axis either in the same rotational direction as the flywheel or counter thereto and tend to induce erroneous momentum change indications. Moreover, changes in angular momentum are apt to not always indicate the notable engine vibrations which are apt to occur due to resonance frequencies of the engine and/or associated structures which are greatly aggravated if the engine is running on a lean mixture.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an air-fuel ratio control system which can (a) maintain the air-fuel ratio of an internal combustion engine on the lean side of stoichiometric and on or about a so called "best economy point", and (b) suppress annoying and/or damaging vibrations whereby smooth and economical engine operation can be simultaneously achieved.

The present invention accordingly features a sensor which senses the engine vibration directly and which

outputs a signal indicative thereof to circuitry which upon detecting vibration in excess of a predetermined level, issues a relatively rapid air-fuel mixture enrichment signal until the level of vibration falls below the predetermined level whereupon a relatively slow air-fuel leaning signal is produced. Continuous repetition of the enrichment-leaning signals causes the air-fuel ratio to hunt back and forth over the "best economy point".

More specifically, the present invention takes the form of an internal combustion engine equipped with an air-fuel ratio control system comprising, means for forming an air-fuel mixture, a vibration sensor mounted on the body of the engine for directly sensing the vibration of the engine and outputting a signal indicative of the magnitude thereof, and a control circuit associated with the air-fuel mixture forming means which circuit is responsive to the signal so that upon the magnitude of the vibration exceeding a predetermined level, the control circuit enriches the air-fuel mixture formed by the air-fuel mixture means and leans the air-fuel mixture when the magnitude is lower than the predetermined level.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the arrangement of

the present invention will become more clearly appreciated from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a schematic diagram of an embodiment of the present invention;

Fig. 2 is a block diagram showing the circuitry and wave forms produced therein by the control circuit shown in Fig. 1;

Fig 3 is a chart showing in terms of air-fuel ratio the corresponding variations in (a) engine vibration level, (b) engine stability, (c) fuel economy and (d) HC, CO and NO_x emissions; and

Fig. 4 is a graph showing in terms of engine torque and either engine or vehicle speed, the torque characteristics of the engine and the zones in which the present invention may find suitable application.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning to Fig. 1 an embodiment of the present invention is shown in which an internal combustion engine 10 is equipped with an induction system 12 including an air flow meter 14, a throttle chamber 16 and throttle valve position sensor 18. The induction system 12 further includes a fuel injection system 20 comprised of a plurality of injectors 22, a fuel pump 24 which inducts fuel from a fuel tank 26 via a filter 28, a pressure

regulator valve 30 and an injection control unit 32. As shown, the control unit 32 receives data inputs from the air flow meter 14, throttle position sensor 18, an engine distributor 34 and an engine vibration sensor 36 which is
5 attached to the engine proper so as to be directly exposed to the vibration thereof. The engine is also equipped with an exhaust system 38 including an oxidizing type catalytic converter 40.

Fig. 2 shows in block diagram form the injection
10 control unit 32 shown in Fig. 1. In this arrangement the input from the vibration sensor 36 (which may sense any one of engine acceleration, displacement or vibration frequency) outputs a signal "P" which is fed to a low pass filter 42. This circuit smooths the signal and
15 outputs a signal "Q" to a compensation/operation unit 44 which senses the peak value $Q_{\max}$ of signal "Q" and compares same with a predetermined value (viz., slice level S). Upon the value of $Q_{\max}$ exceeding the slice level the comparison/operation unit functions to
20 generate a first rapid fuel enrichment command signal R_1 (in this instance a pulse width increment command signal of +10% per 0.2 sec.) until the fuel being combusted in the engine becomes sufficiently rich to reduce the engine vibration to a level that the value of $Q_{\max}$ falls below
25 the slice level S, whereupon a relatively slow mixture

leaning signal R_2 is produced (in this instance a injection pulse width decrement signal of -10% per sec). The command signals R_1 and R_2 are fed to a injection pulse generating unit 46. This unit functions to
5 determine the basic pulse width of the energization pulses fed to the fuel injectors 22 in view of inputs indicative of engine rotation speed (RPM), air induction quantity, throttle valve position and engine coolant temperture (temperature sensor not shown), and modify
10 same under the influence of the command signals R_1 and R_2 .

In Fig. 3 the air-fuel ratio indicated by "A" is a critical one where engine vibration (see curve "a") will rise to a level which will induce physical discomfort and the limit of engine stablity be reached (see curve "b").
15 That is to say, the major vibration componets under this condition will have frequencies of 400Hz or lower. However, as shown by the fuel consumption curve "c", the "best economy point" "B" occurs at an air fuel-ratio
20 which is slightly less than that at which the critial point "A" occurs and at which the levels of HC, CO and NO_x are acceptably low while the amount of oxygen (O_2) contained in the exhaust gases is sufficient to promote secondary oxidization of the HC and CO in the catalytic
25 converter 40.

Hence, it will be appreciated that by holding the air-fuel ratio at point "B" through closed loop feedback control via sensing engine vibration, a total engine control system which enhances not only fuel economy and drivability but reduces noxious emissions, may be realized.

Under certain modes of engine operation, it is deemed advantageous (but not necessarily preferable) to override the command signals R_1 and R_2 . For example, during acceleration or heavy load operation when large amounts of power are temporarily required, in order to achieve the desired rich mixture, it is necessary to temporarily disable the closed loop control. Thus, the control unit may be adapted (via the incorporation of a micro computer or the like) to enable the closed loop control only when the engine is operating within the hatched zone shown in Fig. 4 and disable same when large amounts of power are required such as for hill climbing etc.; such as occur above and to the right of the hatched area.

It will also be appreciated that the present invention is not limited to the plurality of fuel injectors 22 shown and disclosed but may extend to electronically controlled carburetors, single point fuel injection arrangements and the like.

It will be further appreciated that the above disclosed arrangement may be operated on fuels containing relatively large percentages of alcohol without any need to modify the system in anyway. Viz., the system will automatically seek out and maintain "the best economy point" for the fuel the engine is being operated on.

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WHAT IS CLAIMED IS:

1. In an internal combustion engine, an air-fuel ratio control system comprising;

means for forming an air-fuel mixture;

a vibration sensor mounted on the body of said engine for directly sensing the vibration of said engine and outputting a signal indicative of the magnitude thereof; and

a control circuit associated with said air-fuel mixture forming means which control circuit is responsive to said signal so that upon the magnitude of said vibration exceeding a predetermined level, said control circuit enriches the air-fuel mixture formed by said air-fuel mixture means and leans said air-fuel mixture when said magnitude is lower than said predetermined level.

2. An air-fuel ratio control system as claimed in claim 1, wherein said predetermined level is selected to coincide with the vibration produced by said engine when said engine is operated on an air-fuel mixture which has an air-fuel ratio between the stoichiometric one and that of the leanest air-fuel mixture on which the engine can be stably operated.

3. An air-fuel ratio control system as claimed in

claim 1, wherein said predetermined level is selected to coincide with the vibration produced by said engine when said engine is consuming the minimum amount of fuel per unit time.

4. An air-fuel ratio control system as claimed in claim 1, wherein said control circuit enriches said air-fuel mixture at a first relatively high rate and leans said mixture at a second relatively slow rate.

5. An air-fuel ratio control system as claimed in claim 1, wherein said vibration sensor senses the acceleration of said engine per se.

6. An air-fuel ratio control system as claimed in claim 1, wherein said vibration sensor senses the amplitude of the engine vibration.

7. An air-fuel ratio control system as claimed in claim 1, wherein said vibration sensor senses the frequency of the engine vibration.

8. A method of operating an internal combustion engine comprising the steps of:

forming an air-fuel mixture using an air-fuel

mixture forming means;

directly sensing the magnitude of engine vibration using a vibration sensor mounted on the body of said engine and producing a signal indicative thereof;

enriching the air-fuel mixture produced by said air-fuel mixture forming means upon said sensor indicating a vibration having a magnitude greater than a predetermined level; and

leaning the air-fuel mixture formed by said air-fuel forming means upon said sensor indicating that said engine is vibrating with a magnitude less than said predetermined level.

9. A method as claimed in claim 7, further comprising the step of selecting said predetermined level to coincide with a vibration which is produced by said engine when operating on an air-fuel mixture having an air-fuel ratio which lies between the stoichiometric one and that which corresponds to the leanest mixture on which the engine can be stably operated.

10. A method as claimed in claim 8, further comprising the step of selecting said predetermined value to coincide with the vibration produced by said engine when said engine is consuming the minimum amount of fuel per unit time.

FIG. 1

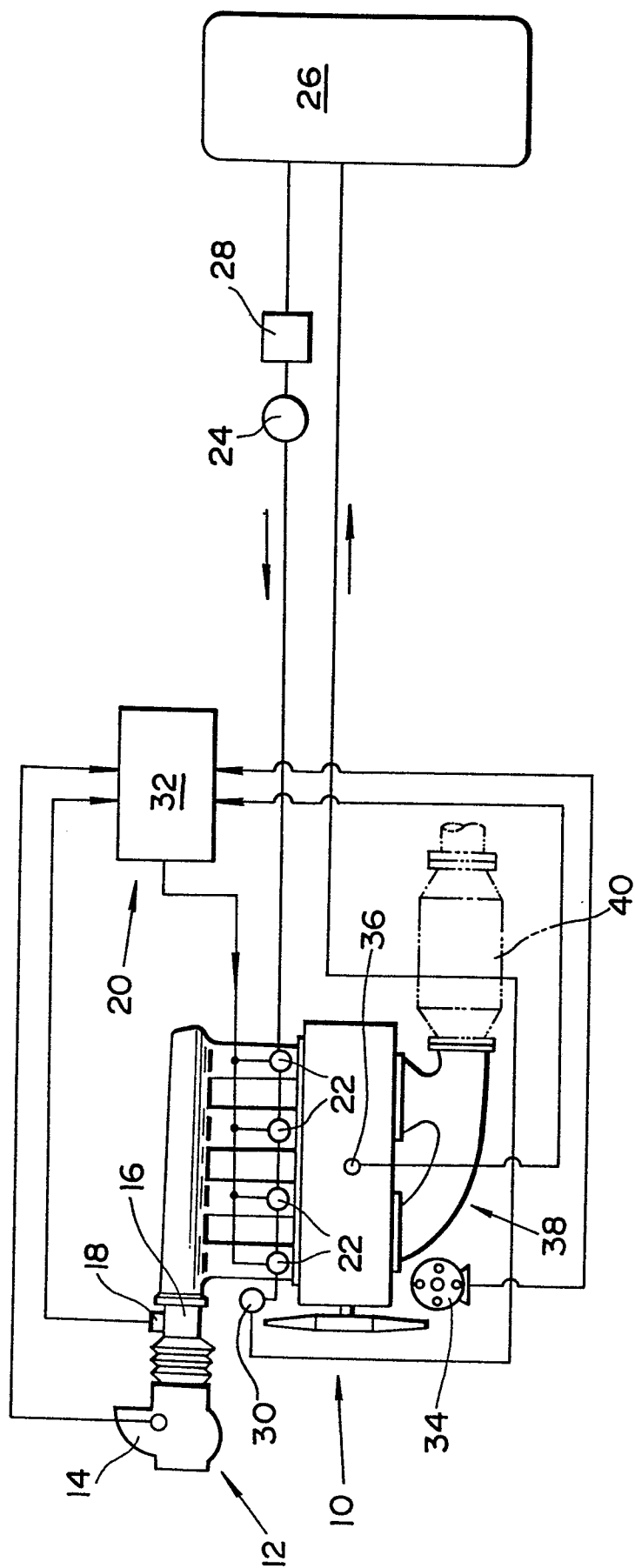


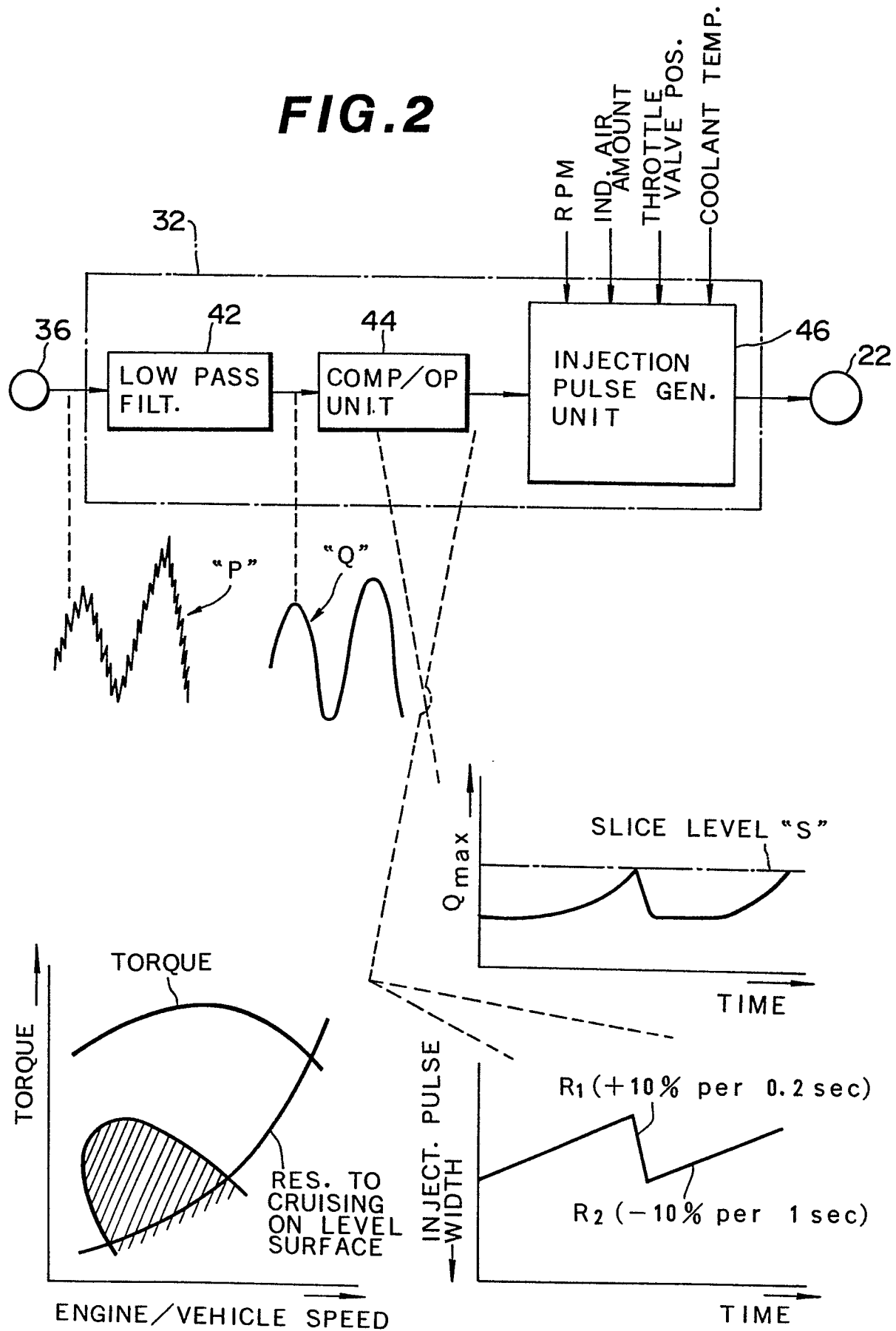
FIG. 2

FIG. 3