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(54) INTERNAL COMBUSTION ENGINE OF THE TYPE HAVING A MAIN COMBUSTION CHAMBER AND A FUEL IGNITION CHAMBER CONNECTED THERETO

(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 present invention relates to an internal combustion engine of the type having a main combustion chamber and a separable fuel ignition chamber connected thereto. The use of a separate ignition chamber permits a better regulation of the wall temperature of the ignition chamber and consequently an improved ignition efficiency.

However, in known internal combustion engines of the above type, there is the disadvantage that the fuel/air mixture, especially when it is kept lean, ignites poorly in the ignition chamber, thus causing the internal combustion engine to generate an irregular torque. In addition, with a relatively cold internal combustion engine and/or rich mixture, there is the danger of carbonization. If the temperature level is increased in the ignition chamber, then these disadvantages may be considerably reduced in the partial load range of the internal combustion engine; but, there is then the danger that, at high speeds and loads, thermal corrosion occurs, and eventually, at very high temperatures self-ignition. To avoid the self-ignition of the fuel/air mixture in the ignition chamber it is known to limit the maximum temperature of the ignition chamber by way of the engine's cooling water. Such cooling, however, must be designed for the full-load operation of the engine at high speeds. Thermal corrosion and self-ignition are in fact thereby avoided, but, in the region of low engine power, e.g. during idling, the ignition chamber is thereby severely cooled down so that the tendency of the fuel/air mixture to become inflammable when ignition is needed is considerably reduced, apart from the fact that a cold place of ignition has the tendency to carbonize which may cause the ignition device to fail.

There is provided by the present invention an internal combustion engine having a main combustion chamber and an ignition chamber, which is connected to the main combustion chamber by a transfer channel, the temperature of the ignition chamber wall being controllable by controlling the heat flow from the ignition chamber wall to cooled parts of the internal combustion engine; wherein at least one zone is provided between the ignition chamber wall, which is to be controlled in respect of temperature, and the cooled parts of the internal combustion engine, and said zone is partially filled with a vaporizable heat transmitting medium such that at the temperature to which it is heated by the heat from the ignition chamber, it transmits heat by vaporization from the ignition chamber wall to said cooled parts of the engine.

The internal combustion engine according to the invention has the advantage that even extremely lean fuel/air mixtures are positively ignited especially in the range of low speeds and load. The place of ignition in the ignition chamber is also prevented from carbonizing in the range of low power and during the warm-running of the internal combustion engine, and from thermally corroding in the range of high speeds and loads. A further advantage can be seen in that, because of a rapid heating up of the ignition chamber, the ignition conditons during the warm-running of the internal combustion engine are quite generally improved, less firing voltage is required, and consequently there is a reduction in the tendency to produce a creepage current and in the emission of hydrocarbons.

When the ignition chamber is in the form of an auxiliary chamber having a tangentially entering transfer channel, it is particularly advantageous for the running limit of the engine to be extendable in the direction of very lean fuel/air ratios. The extension of the running limit signifies a reduction in the emission of harmful substances and especially a reduction in the fuel consumption. Because of the arrangement of the transfer channel relative to the ignition chamber and also to the main combustion chamber, the charge movement is systematic, so that even extremely lean mixtures can be ignited. The wall temperature of the ignition chamber is advantageously kept close to, although below, the self-igniting temperature of the fuel/air mixture. However, any pre- or swirl chamber may basically serve as the ignition chamber, for example, the prechamber of a layer charge engine wherein a quantity of fuel, which is independent of the main injected quantity and which produces a rich mixture in the ignition chamber, is injected into the prechamber, the rich mixture being relatively easily ignitable. In the case of the centrifugal chamber with a tangential overflow channel, too saturated a supply of fuel or mixture to the ignition chamber can be avoided, especially in conjuction with a regulation of the wall temperature, apart from the fact that fuel is also saved because of the lean ignitable fuel/air mixture.

An embodiment of the invention is shown in the accompanying drawings, in which:

Figs. 1 to 3 are explanatory diagrams.

Fig. 4 shows the embodiment in longitudinal section, and

Figure 5 is a transverse section on the line arranged in Figure 4.

Fig. 1 is a diagram in which the energy Q, needed for the ignition, is shown on the ordinate and the characteristic number λ for the fuel/air ratio is shown in the abscissa. The greater the number λ, the leaner the fuel/air mixture. In the case of numbers somewhat smaller than $\lambda=1$, a minimum of ignition energy Q is necessary.

Fig. 2 is a diagram in which the necessary ignition energy Q is again shown on the ordinate and the temperature T of the fuel/air mixture at the place of ignition is shown on the abscissa. The lines in the diagram arise for various air numbers λ. When $\lambda=1$, a relatively low ignition energy is necessary for the ignition, this energy reducing with the increasing temperature of the fuel/air mixture. When the curve $\lambda=1$ intersects the abscissa, this marks the self-igniting temperature T_s. With leaner or richer fuel/air mixtures, either a higher ignition energy Q or a higher ignition temperature T of the fuel/air mixture is necessary for the ignition, as the line $\lambda=1.0$ shows. The teaching given by the diagrams in Fig. 1 and Fig. 2 is that the closer the temperature of the fuel/air mixture is to the self-igniting temperature (variable depending upon the mixture), the lower is the energy Q necessary for the ignition. It follows from this inter alia that the leaner is the fuel/air mixture, the more important it is to adjust the temperature as closely as possible to the point of self-ignition. Since, due to the fact that the wall temperature of the ignition chamber is controlled to maintain a comparatively high level, the thermal discharge following ignition is less than conventional, and in addition, the charge itself has a higher temperature than is conventional, due to the heat transmitted from the wall to the gas, particularly favourable ignition conditions arise, whereby even very lean mixtures ($\lambda=1.5$ to 1.8) can be inflamed. By controlling the high wall temperatures, it is possible to elect to make the ignition chamber smaller than is usual so that the proportion of the volume of the ignition chamber relative to the compression volume of the main combustion chamber may amount to less than 5%, and even, as is preferred, between 1 and 4%. Because of the small volume of the ignition chamber and the small specific surface, that is, ratio of surface area to volume, resulting therefrom, the throttling effect of the transfer channel and the thermal losses are also relatively small, as are the emissions of hydrocarbons. The small dimensions enable the designer, moreover, to shape such an ignition chamber so that it can be disposed like a sparking plug in the head of the internal combustion engine.

In the diagram shown in Fig. 3, the distance A from the wall of the ignition chamber is shown on the ordinate, this chamber being assumed to be beneath the abscissa and shown by hatching. On the other hand, however, the speed *u* of the fuel/air mixture flowing along the chamber wall and its temperature T are plotted on the ordinate. The curve u shows the change in the fuel/air mixture speed with an increasing distance from the wall of the ignition chamber. Whilst the speed is zero immediately at the wall of the chamber, it initially increases to A1 (boundary layer thickness) in order to decrease again to the value "0" with increasing distance up to the centre of the vortex of the fuel/air flow in the ignition chamber. The dotted curve T_1 shows the temperature of the fuel/air mixture in an engine where the temperature of the ignition chamber wall is not regulated. To avoid self-ignition when the internal combustion engine is at maximum power, the chamber wall temperature in the partial-load range must be kept low, and this serves to produce a cooling down which disadvantageously affects the fuel/air mixture. The dash-dot curve T_2 shows the influence of the ignition chamber wall, regulated to a comparatively high temperature level, upon the heating up of the fuel/air mixture. In the vicinity of the ignition chamber wall, the fuel/air mixture is heated up to almost self-igniting temperature, whereas the fuel/air mixture quantities passing further away are heated up less intensely. Substantially at the distance A1, whereby the flow curve *u* has an optimum, the temperature of the fuel/air mixture has dropped to a lower value which remains practically constant in the remaining portion of the vortex. A favourable ignition can therefore be obtained especially in the space defined by A1, and thereby as close as possible to the ignition chamber wall. The ignition is best effected in the flow boundary layer in the direct vicinity of the ignition chamber wall because there the speed *u* is at a minimum and the temperature of the fuel/air mixture almost reaches self-igniting temperature. In order to obtain a particularly favourable ignition of the fuel/air mixture, a minimum of ignition energy Q is necessary. Besides the low flow speed and high temperature at the place of ignition, a further advantage arises by coating the ignition chamber wall with a catalytically active material (e.g. nickel), in that the preliminary reactions are largely effected in the mixture at the place of ignition immediately at the wall. This is also favourable for a positive ignition.

Fig. 4 shows an example of such a temperature control of the ignition chamber wall. The cylinder head of the engine comprises cavities 2′ with cooling water flowing therethrough; and the embodiment entails the use of a heat pipe 32 installed in a bore in the cylinder head between the housings of adjacent cavities. The ignition chamber 7′ is connected to a combustion chamber 8′ if the engine by a transfer channel 9′ which enters the lower end of the ignition chamber tangentially; and the upper end of the ignition chamber receives therein an ignition device 19′, comprising an ignition electrode 11′ to produce a spark in the wall boundary region of the ignition chamber. The ignition chamber housing 5′ is preferably made from copper, a metal which has a good heat conductance and in addition has a relatively high coefficient of thermal expansion.

The fuel/air mixture passes from the main combustion chamber 8′ exclusively by way of the transfer channel 9′ into the ignition chamber so as to experience a homogeneous blending of air and fuel there without additional injection, i.e.. without stratification, by swirling of the fuel/air mixture. Because the ignition chamber 7′ is separate from the main combustion chamber and because of the tangential entry into the ignition chamber by way of the channel 9′, a so-called solid vortex is initially formed in the ignition chamber, this vortex increasingly changing into a potential vortex, thus ensuring an optimum homogeneous blending of fuel and air. It is pointed out in this connection that a "solid vortex" is defined by the expression $v=k \cdot r$ and a "potential vortex" by the expression $v=k/r$, where v is the tangential speed of fuel/air flow, k is a constant and r is the radius of the vortex. As stated further above, the speed of the mixture is low in the region of the wall boundary layer and there are, in particular, small turbulent eddies, i.e. the longitudinal dimensions of the existent turbulence are small. The electrode 11′ protrudes only slightly into this wall boundary layer, so that there best conditions obtain for firing of even very lean fuel/air mixtures. In order to reduce to a minimum the necessary ignition energy, especially with such lean mixtures, the ignition chamber wall 10′ is controlled in respect of temperature, this being—as stated above—at a temperature immediately below the self-igniting temperature of the mixture. This is effected by the heat pipe; this pipe transporting heat from the ignition chamber housing 5′ to the water-cooled engine housing 1′. The ignition chamber housing 5′ is designed such that it accommodates the heat pipe arrangement 32 as well as the transfer channel 9′ and the ignition device 19′. The ignition chamber housing 5′ is sealed by a cover 33 which is welded or soldered onto the housing 5′ and seals 117 in the heat pipe member 32 tightly. If necessary, for additional cooling, an annular channel 34, through which cooling water flows, may be disposed in the cover 33. The heat pipe 32 has an evaporator member 36 which is disposed on the bottom of the ignition chamber housing 5′ and at the base of the ignition chamber 10′, and a condensation member 37 which is disposed to underlie the cover 33. The evaporator member 36 comprises, on the one hand, fine grooves 38 which are formed in the axial direction of the heat pipe over as much of the exterior surface of the ignition chamber as possible and, on the other hand, a ring of fine-mesh netting at the base 39 of the ignition chamber housing. The condensation of the vaporizable medium is effected beneath the cover 33 and the return transport is effected by way of laterally disposed capillaries 40.

The heat pipe may be of a completely different shape from that of the example shown. Thus, for example, the path of the capillaries may be disposed at right angles to the axis of the heat tube. In the example shown in Fig. 4, the ignition chamber wall 10′ may, as an additional possibility, be in the shape of a hook 41 providing a nose-like bulge in the region of the electrode 11′, this hook ensuring a desired direction for the ignition spark parallel with the flow of the fuel/air mixture and this also being advantageous for the commencement of combustion.

The vaporizable medium employed may be potassium or sodium, which may be stabilised with an inert gas such as helium or argon.

WHAT WE CLAIM IS:—

1. An internal combustion engine having a main combustion chamber and an ignition chamber, which is connected to the main combustion chamber by a transfer channel, the temperature of the ignition chamber wall being controllable by controlling the heat flow from the ignition chamber wall to cooled parts of the internal combustion engine; wherein at least one zone is provided between the ignition chamber wall, which is to be controlled in respect of temperature, and the cooled parts of the internal combustion engine, and said zone is partially filled with a vaporizable heat transmitting medium such that at the temperature to which it is heated by the heat from the ignition chamber, it transmits heat by vaporization from the ignition chamber wall to said cooled parts of the engine.

2. An internal combustion engine as claimed in claim 1, wherein the zone is in the form of a heat pipe having a structure which exerts capillary forces upon the condensed heat-transmitting medium for returning said medium to the evaporator part of the heat pipe.

3. An internal combustion engine as claimed in claim 2, wherein the capillary action is effected by capillary tubes, and the evaporation part of the heat pipe comprises as large a portion as possible of the ignition chamber wall.

4. An internal combustion engine as claimed in any of the preceding claims, wherein the transfer channel, by which fuel/air mixture to be ignited passes exclusively from the main combustion chamber, is one which leads tangentially into the ignition chamber so as to promote an homogeneous blending of the air and fuel therein without additional injection or stratification.

5. An internal combustion engine as claimed in claim 4, wherein the ratio of the volumes of the main combustion chamber at the end of compression to ignition chamber is more than 20.

6. An internal combustion engine as claimed in claim 5, wherein said ratio is between 25 and 100.

7. An internal combustion engine as claimed in any of claims 1 to 6, wherein potassium or sodium is used as the vaporizable medium.

8. An internal combustion engine as claimed in claim 7, wherein the potassium or sodium is stabilised with an inert gas.

9. An internal combustion engine as claimed in claim 8 wherein the inert gas is helium or argon.

10. An internal combustion engine as claimed in any of the preceding claims, wherein the electrodes are disposed so that an ignition spark is formed in the wall boundary layer parallel to the direction of flow.

11. An internal combustion engine as claimed in claim 10, wherein the wall of the ignition chamber serves as an earth electrode.

12. An internal combustion engine as claimed in claim 10 or 11, wherein the chamber wall comprises a nose-like bulge.

13. An internal combustion engine as claimed in any of the preceding claims, wherein the ignition chamber wall comprises a coating of catalytically active material.

14. An internal combustion engine according to claim 13, wherein the catalytically active material is nickel.

15. An internal combustion engine substantially as hereinbefore described with reference to Figures 4 and 5 of the accompanying drawings.

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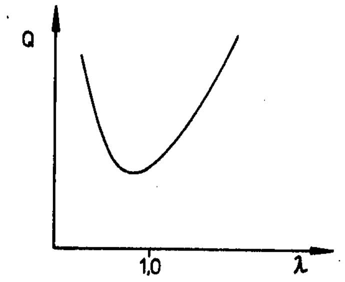

Fig. 1

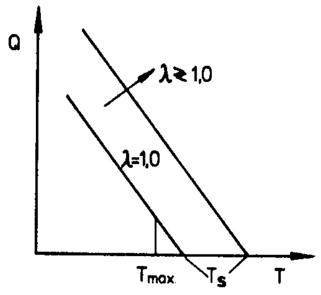

Fig. 2

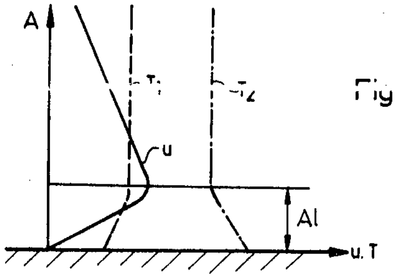

Fig. 3

Fig. 4

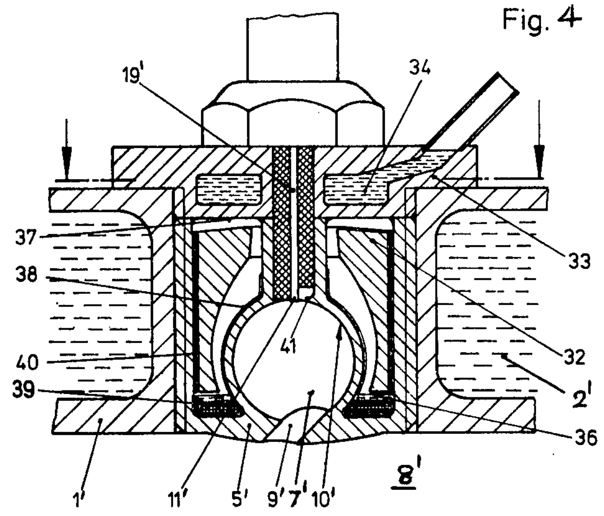

Fig. 5