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(12) **Patent:**

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(54) METHOD OF PRODUCING SYNTHESIS GAS IN INTERNAL COMBUSTION ENGINES, MORE PARTICULARLY GAS ENGINES

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THIS INVENTION relates to a method of producing synthesis gas by the exothermic incomplete or partial combustion of hydrocarbons with oxygen in an internal combustion engine which simultaneously delivers mechanical power.

It is the object of the invention when producing synthesis gas in the working cylinders of an internal combustion engine, notwithstanding the formation of residues and more particularly of carbon during the chemical process, to assure the reliability and efficacy of the ignition and the avoidance of misses in ignition during operation.

When producing synthesis gas from hydrocarbons according to the method to which the present application refers it has been found that the maintenance of satisfactory operation requires a relatively high expenditure of O_2, as otherwise the reaction in the combustion chamber produces carbonaceous deposits which also coat the sparking plugs, cause the ignition to miss, and finally to fail altogether, with the concomitant total stoppage of the combustion engine. On the other hand, the high oxygen requirement is a grave disadvantage. In the first place, a high consumption of oxygen greatly impairs the efficiency of the reaction. In addition to this, it has been found that methane-oxygen mixtures with a high oxygen content lead to knooking phenomena in the combustion chambers as the reaction takes place, and very rough going of the gas engine is the result. The compression ratio as well as the load and consequently the efficiency of the engine and its performance must

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necessarily therefore be very low. Moreover, a high oxygen content is undesirable from the chemical angle alike because the hydrogen and carbon monoxide yields are thereby diminished, a greater proportion of the methane being burnt completely to water and carbon dioxide.

According to an essential feature of the present invention the above described drawbacks are overcome by replacing the conventional method of electrically igniting the gas mixture as used in the customary types of gas engine, as well as in the past more specifically in the present process by a form of ignition which operates by the injection of an igniting medium. Such forms of ignition are not new as such, but are already in use in so-called jet ignition engines. In these engines an igniting medium is injected under pressure into the highly compressed and therefore very hot reaction mixture inside the cylinders of the combustion engine. The igniting medium used may be an igniting oil, an oxygen carrier such as for instance hydrogen peroxide or other easily igniting media such as for instance acetaldehyde or methanol. Hitherto jet ignition had not been thought suitable for application to the process of producing synthesis gas in an engine, because the compression ratio required approaches that used in compression-ignition engines, and this appeared to be out of the question in view of the knocking tendency of the hydrocarbon-oxygen mixture needed for the production of the synthesis gas. Contrary to this preconceived notion and quite unexpectedly it has been found - and this is a

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further important feature of the present invention - that jet ignition can in fact be applied if at high compression ratios the oxygen content of the reactant mixture is kept lower than 39%. Although jet ignition does increase the formation of residues, especially of carbon, in the combustion chamber, this does not affect the operation of the engine because jet ignition, unlike electrical systems, is immune to carbonisation and continues to be effective without being effected by any deposits.

The application according to the invention of jet ignition, coupled with a material reduction in the oxygen content of the reactant mixture and an increase in the compression ratio of the gas engine to values equal to those used in Diesel engines permits trouble-free operation despite a noticeable increase in the formation of deposits inside the combustion chambers.

The result is a substantial improvement in the economy of the synthesis gas process because (a) oxygen consumption is less, (b) the efficiency of the thermal cycle in the engine is better owing to the higher compression, (c) power delivered by the machine is increased, and (d) the yield of synthesis gas per standard cub. metre of hydrocarbons is raised.

The applicability of the invention will be more particularly hereinafter described with reference to an illustrative example in which methane is broken down with oxygen in an internal combustion engine for the production of synthesis gas.

In the system of synthesis gas production to which the present invention relates a methane-oxygen mixture with a lower oxygen content than is required for

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complete oxidation is incompletely or partially burnt in an internal combustion engine which then simultaneously delivers power in the form of mechanical energy. The resultant exhaust gas contains principally hydrogen and carbon monoxide and then serves as a primary gas in chemical synthesis processes.

Practical experience has shown that the gas engine will only work smoothly without carbonisation and without missing on its cylinders if the methane-oxygen mixture that is brought to reaction has a relatively high oxygen content. The complete cracking of methane to form hydrogen and carbon monoxide which in practice is never attainable would require a volumetric ratio between the methane and oxygen of 1 in 0.5. In actual fact, in a synthesis gas engine equipped with a conventional ignition system ignition difficulties are experienced due to the formation of carbon even when the oxygen content of the mixture is substantially higher, and these difficulties are naturally augmented when attempts are made to lower the oxygen content.

When the oxygen content of the mixture is high enough for running the engine smoothly without missing on the ignition, the running of the engine at full load is nevertheless very harsh. High compression ratios of the engine such as would produce a good thermal efficiency of the cycle with respect to engine performance cannot be used owing to the supervention of knocking phenomena in the gas engine.

These major troubles in performing the method in a gas engine of normal construction can be eliminated by applying the principles which underlie the present

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invention. The compression ratio of the engine is raised to figures which approximate the conditions obtaining in a compression-ignition type engine. The oxygen content of the reacting methane-oxygen mixture is substantially lowered. As the herein proposed jet ignition system is entirely immune to the formation of carbon deposits the engine is capable of operation at very low oxygen contents without giving rise to operational trouble. Owing to the low oxygen content the engine will run smoothly and evenly despite its high compression ratio.

It will be readily understood that the steps proposed by the present invention materially increase the efficiency of synthesis gas production and therefore substantially improve the economy of the process, even if only the saving in the consumption of oxygen is taken into account.

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The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of producing synthesis gas, that is to say a mixture of carbon monoxide and hydrogen, by the partial combustion of at least one hydrocarbon gas, in which a reactant mixture containing said hydrocarbon gas and an oxygen-containing gas and having a low O_2 content is compressed in a confined space by reduction of the volume of said space, the compression ratio being at least equal to that customarily employed in compression-ignition engines, and an igniting medium is then injected under pressure into said compressed reactant mixture whereby said mixture is ignited and partially combusted and forms hydrogen and carbon monoxide and is permitted to expand and thereby to produce mechanical power.

2. A method as claimed in claim 1, in which the compression ratio exceeds that customarily employed in compression-ignition engines.

3. A method as claimed in Claim 1, in which the quantity of injected igniting medium is controllable.

4. A method as claimed in Claim 1 or 2, characterised in that the quantity of igniting medium used for ignition is controllable and can be varied in dependence upon the engine load and other operational factors.

5. A method as claimed in claim 1, 2 or 3, in which the igniting medium is an igniting oil.

6. A method as claimed in claim 1, in which the igniting medium is an oxygen carrier.

7. A method as claimed in claim 6, in which the oxygen carrier is hydrogen peroxide.

8. A method as claimed in claim 1, 2 or 3, in which the igniting medium is acetaldehyde.

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9. A method as claimed in claim 1, 2 or 3, in which the igniting medium is methanol.

10. A method as claimed in claim 1, in which an anti-knock substance is added to the hydrocarbon mixture that is to be reacted in the confined space.

11. A method as claimed in claim 10, in which the anti-knock substance is carbon dioxide.

12. A method as claimed in claim 10, in which the anti-knock substance is lead tetraethyl.

13. A method as claimed in claim 1, 2 or 3, in which electrical ignition is provided in addition to the injection of the igniting medium.

14. A method as claimed in claim 1, 2 or 3, in which both a jet ignition and electrical ignition are provided in such manner that both types of ignition can work simultaneously.