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OXIDATION OF PROPANE-AIR MIXTURE ACTIVATED BY NON-EQUILIBRIUM HIGH-FREQUENCY CORONA DISCHARGE PLASMA *)

Filimonova E.A., Dobrovolskaya A.S.

Joint Institute for High Temperatures of Russian Academy of Sciences, Moscow, Russia
helfil@mail.ru

The problem of ignition of lean mixtures is an actual issue arising in the development of modern power-efficient engines. The difficulties of ignition and formation of a combustion wave in a lean mixture when using a conventional spark plug are overcome by application of high-frequency (2-5 MHz) corona discharges. However, the use of non-equilibrium plasma of such a discharge in an engine can lead to additional production of non-thermal nitrogen oxides, especially in the case of a lean fuel-air mixture containing an excess amount of oxygen. This unresolved thoroughly problem hinders the use of this type of discharge in the internal combustion engine. Therefore, it is important to answer the question under what conditions and what type of discharge is suitable for replacing the spark plug when using lean mixtures. It is also important to understand the effect of the discharge on other exhaust components: carbon oxides and unburned hydrocarbons.

In work [1], the measured composition of a lean propane-air mixture with an equivalence ratio in the range of 0.2-0.45 at an elevated pressure of up to 5 bar, activated by a high-frequency corona discharge, showed that in the absence of ignition, oxidation of the mixture nevertheless occurs. Chemically active particles produced by the discharge, when interacting with the fuel, reduce the concentration of propane and produce long-lived intermediate components and nitrogen oxides.

The aim of this work was to identify the processes that lead to a change in composition under the influence of a non-equilibrium plasma and to compare the simulation results with the data of work [1]. The premixed mixture at T=300 K passed continuously through a combustion chamber with a volume of 200 cm3, where it was treated with a discharge with a frequency of 2.54 MHz for 3 ms in the center of the chamber. During this time, the energy deposited in the discharge zone was ~ 3 J. The volume of the treated zone depended on the pressure: the higher the pressure, the smaller the zone activated by the discharge. To find the composition and heating of the mixture, the approach described in [2] was used. The heating of the mixture during the discharge did not exceed 260 degrees. Multi-pulse and multi-channel energy supply was taken into account during the modeling. Calculations showed that it is necessary to take into account the change in the composition of the mixture and the temperature in the streamer channel when each subsequent streamer passes through it. The key component for propane decomposition is the O atom produced by the discharge, and for NO formation it is necessary to take into account the production of N atoms in the excited and ground states. At the post-discharge stage, the propane concentration further decreases, this leads to an increase in the concentration of intermediate oxidation products such as C3H6, C2H4, CO. The activated region itself is almost not diffused within 100 ms.

Comparison of the concentration values of C3H8, NO, NO2 (in ppm units) immediately after the end of the discharge with the values measured in the experiment [1] showed good agreement. The concentrations of C3H6, C2H4, CO at the end of the discharge differed from the measured ones, they were lower, but continued to increase over time. Apparently, they were measured later than C3H8, NO, NO2.

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References

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