COMBUSTION REGIMES OF LOW STRETCHED PREMIXED METHANE-HYDROGEN-AIR MIXTURES NEAR FLAMMABILITY LIMITS*

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Understanding of the structure and combustion limits of premixed flames is one of the crucial fundamental problems of combustion science. Experimental investigations of counterflow premixed flames at low stretch rates [1-2] in the past required microgravity conditions due to the influence of natural convection resulting in additional heat losses. Nowadays, the method of flame stabilization in a narrow channel is used for the experimental study of combustion limit [3]. This work is aimed at experimental study of combustion regimes of low stretched premixed methane-hydrogen-air mixtures near flammability limits and methods of their obtaining in flat channels of different heights.

The experimental setup consists of two countercurrent slot-jet burners installed at a distance of 120 mm. Two quartz plates are installed between them, forming a flat channel. The channel on the fresh mixture side was filled with porous copper foam material to create a uniform flow. The channels with heights of 3 mm, 5 mm and 7 mm were investigated. The study area for all channels in the horizontal plane was 40x50 mm. Two K-type thermocouples connected to the computer were used. The first one recorded the temperature of the fresh mixture. Another K-type thermocouple was connected to the center of bottom quartz plate to measure the plate temperature and confirm the established of stationary combustion regime. The stretch rate is determined as a = V/L, where V is inlet gas velocity and the L is the half distance between burners.

The combustion limits were determined according to the following procedure. The gas flow rates were set on the BRONKHORST Series-F gas mass flow regulators and then the mixture was ignited. By indications of a thermocouples the stationary regime was determined. When the mixture was leaned, a new stationary regime was set, new data were registered and the mixture was leaned again until flame extinction.

In the study of methane-air flames in the range of stretch rate less than 45 s^{-1} in a channel 3 mm high, the combustion regime "distant flame" (DF) was observed [4]. This regime is typical for stretch rates of less than 30 s^{-1} and 25 s^{-1} in channels of 5 and 7 mm, respectively. In channels of increased height at higher stretch rate, the combustion regimes "near-stagnation flame" (NSF) or "flame tube" were also observed [4]. With increasing flow velocity, the NSF regime became more stable and appeared on richer mixtures. In the 7 mm channel by reducing the flow velocity, new combustion limits were found which was not found in previous study [3]. This data provided a broader knowledge of the combustion limits linked with new experimental conditions.

A methane-hydrogen-air flame with 30% hydrogen addition by volume was studied in a 7 mm high channel. The DF combustion regime was observed near the combustion limits. An unstable flame pulsation regime existed in other cases. The transition from DF to the NSF regime was abrupt. Moreover, the addition of hydrogen increases area of the flame existence.

REFERENCES

[1] Ishizuka S., Law C.K. An experimental study on extinction and stability of stretched premixed flames // Symposium (International) on Combustion. Elsevier, 1982. Vol. 19, № 1. P. 327–335.

[2] Maruta K., Yoshida M., Ju Y., Niioka T. Experimental study on methane-air premixed flame extinction at small stretch rates in microgravity // Symposium (International) on Combustion. Elsevier, 1996. Vol. 26, № 1. P. 1283–1289.

[3] Mokrin S.N., Odintsov E.S., Uriupin G.V., Tezuka T., Minaev S.S., Maruta K. Flammability limit of moderate- and low-stretched premixed flames stabilized in planar channel // Combustion and Flame. – 2017. – Vol. 185. – P. 261–264.

[4] Fursenko R., Mokrin S., Minaev S. Stationary combustion regimes and extinction limits of one-dimensional stretched premixed flames in a gap between two heat conducting plates // Proceedings of the Combustion Institute. – 2019 – Vol. 37, Issue 2 – P. 1655–1661.

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