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# Abstract

The interactions between Nanosecond Repetitively Pulsed (NRP) plasma discharges and laminar reactive flows are investigated. The NRP discharges used in this study have durations of 10 ns, voltage amplitudes up to 15 kV and are pulsed at a repetition frequency up to 30 kHz, thus yielding pulse energies of less than one millijoule.

In a first chapter, the effect of laminar air flows on the regimes of NRP discharges is investigated. First, the effect of steady air flows on the NRP discharges is assessed. It is shown that the modification of inter-electrode voltage amplitude, Pulse Repetition Frequency (PRF) and axial air velocity allow to cause NRP corona-to-spark or spark-to-corona regime transitions, while the azimuthal air velocity between the electrodes does not influence the regime of NRP discharges. Then, an acoustic oscillation is applied to the air flow and it is shown that, under certain conditions of relative velocity amplitude and of frequency of the forcing, similar corona-to-spark and spark-to-corona transitions could be observed. The results from these two experiments are interpreted in terms of dimensionless numbers and display the significance of two parameters in the observed NRP regime: the number of high-voltage pulses applied to a particle of air during its transit in the inter-electrode area and the power of each of these high-voltage discharges. A model is established and allows to reproduce qualitatively the trends obtained in the experiments.

The second chapter of the study focuses on displaying the influence of laminar premixed flames on NRP corona discharges. Two experimental setups implementing complementary configurations are used. In the first one, the NRP corona discharges are generated in a parallel direction to a laminar premixed lean methane-air flame, stabilised in a conical quartz tube with an acoustic forcing. In this configuration, the shape of the NRP discharges is significantly modified when the distance between the flame and the electrodes is less than 7 mm. This effect is also visible in the second configuration, where the NRP corona discharges are pulsed across the reaction front of an aerodynamically stabilised laminar premixed methane-air flame. The length of the discharges increases when the flame is stabilised between the electrodes, compared to the case without flame. This effect of the flame's presence is attributed to a local increase in the reduced electric field in the hot combustion products, as well as an interaction between the electromagnetic field of the plasma discharges and the charged species constituting the flame. Additionally, the effect of the mixture itself is assessed by comparison of the NRP discharges in air and in an air-methane mixture. An explanation for the significant increase in length of the discharges following methane addition in air is proposed. This explanation is linked to a modification in the spectroscopic properties of the inter-electrode gas by modification of the gas composition.

In the final chapter, premixed methane-air flames in the same two experimental configurations from the previous chapter. In the first configuration, application of NRP corona discharges in a direction parallel to the laminar premixed methane-air flame induces the flame to move upstream, closer to the electrodes. The upstream displacement of the flame increases with the voltage amplitude of the NRP discharges. The laminar flame speed is determined and compared without and with application of NRP discharges and an enhancement of up to 2.2% in this configuration is displayed. In the second configuration, where NRP discharges are applied in a perpendicular direction to the flame front, the transient response of the flame to application of NRP discharges is first investigated with another setup, and a model for deduction of flame speed increase based on this transient response is presented; the enhancement of laminar flame speed reaches up to 9 %. On the second setup with perpendicular electrode configuration, the flame also moves upstream under plasma discharge application, all the more when the PRF of the discharges is increased. Additionally, a deformation of the flame's surface is observed.

In this same chapter, the thermal and chemical effects of NRP plasma discharges are also estimated by the establishment of a numerical model. The thermal production of the discharges results in an increase of fresh gas temperature while the chemical effect focuses on ozone generation by the discharges. Once determined, the influence of these thermal and chemical effects on the laminar flame speed and the adiabatic temperature of a one-dimensional axisymmetric premixed methane-air flame is estimated and yields a maximum enhancement of 35% in the laminar flame speed and of 4% in the adiabatic flame temperature.