Numerical simulations on ignition using NRPD under high-speed flow conditions

Y. Morii*, H. Nakamura*, and K. Maruta*,**

* Institute of Fluid Science, Tohoku University, Sendai, Miyagi, 980-8577, Japan

** Far Eastern Federal University, Russky Island, Vladivostok, Russia

The lean burn would be one of the solutions to improve the thermal efficiency of SI engines. The advantage of lean burn is that it has a high specific heat ratio and low heat loss. However, ignition becomes quite difficult as high-intensity turbulence is required to enhance flame speed under lean burn conditions. Therefore, a new concept of the ignition system is necessary. In this study, we focused on nanosecond repetitive pulse discharge (NRPD), which is one of the ignition methods using non-equilibrium plasma. Since the ignition phenomenon using non-equilibrium plasma is instantaneous and local, and it is difficult to understand it in detail experimentally. Therefore, numerical simulations were performed on the ignition problem using NRPD under high-speed flow conditions.

First, zero-dimensional simulations were performed to determine one-dimensional simulation conditions. The initial conditions of mixture gas were stoichiometric methane/air, pressure 1 atm, and temperature 300 K. The frequency of NRPD was 100 kHz and the discharge time is 100 ns. The reduced electric field was assumed as a sine function of time and maximum reduced electric field were 120, 140, and 160 Td. As a result, in the case of 160 Td, ignition occurred after one pulse, and in the case of 140 Td, ignition occurred after two pulses. However, in the case of 120 Td, no ignition occurred. In order to see the coupling of the unburnt gas mixture and ignition kernel under high-speed flow conditions, 160 Td was selected as the reduced electric field in this research.

Next, one-dimensional simulations were performed. The governing equations are the compressible Navier-Stokes equations with chemical and plasma reactions. The simulations were performed along the direction normal to the central axis between the two electrodes. Therefore, the drift of charged particles between electrodes was neglected. The inflow velocity was varied to check the coupling of the unburnt gas mixture and ignition kernel under high-speed flow conditions. The radius of the plasma source was assumed as 2.5×10^{-4} m. The other conditions were the same as the zero-dimensional case. As a result, it is found that the higher the inlet velocity, the larger the flame zone. In the poster, we will show a study about other reduced electric field conditions, and we will discuss these phenomena in detail.