§21. Optimization of Long-distance Electric Discharge Formation by Laser Breakdown

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In the development of the internal-combustion engines, there are many investigations to improve its efficiency. The attempts for the reduction of the friction losses, for the optimization of the air/fuel ratio, etc. have been done. The “Laser-Breakdown Assisted Long-distance Discharge Ignition (LBALDI)” has a potential to improve the burning efficiency of engines on vehicles. The LBALDI method is that the focused laser is irradiated to a gas to produce the arbitral path of the plasma enabling the long distance spark discharge which does not obey the Paschen’s law. The LBALDI can produce a plasma under the condition of the wide range of the density and temperature. Hence, it might be applied to the startup of fusion plasmas by supplying the pre-ionized gas.

To clarify the basic character of the spark discharge in the atmosphere, the correlation between the spark voltage and the spark length is investigated varying with the size of the spherical electrodes. The theoretical prediction by the Paschen’s law is shown in fig. 1 as a dashed line. The experimental observations are plotted by symbols of squares (diameter of the electrode is 10mm), circles (20mm), and triangles (30mm), respectively. In all cases, it can be seen that the spark voltage increases with spark length. And it is found that the data for the electrode of 20mm (circles in fig. 1) are along the Paschen’s law (dashed line in fig. 1). This means that this experimental setup configuration should be used to see the effect of the LBALDI expecting the deviation from the Paschen’s law.

The laser system composed of Nd:YAG laser (λ = 532nm, pulse length = 7ns) and the collective lens (f = 150mm) is used for the LBALDI [1)]. The pulsed laser is irradiated to the atmosphere in between the electrodes before the spark discharge. When the time the laser is irradiated is almost same as the spark discharge ($\Delta t \sim 0$), the threshold of the discharge voltage requires above 2.3kV as shown in fig. 2. On the other hand, if the delay time Δt is far from the time of the spark discharge ($\Delta t \sim$ -200 [μs]), higher threshold voltage is also needed. It can be seen that the optimized delay time is Δt -50[μs], which enables us to reduce the threshold of the discharge voltage by producing the laser break down plasma before the spark discharge.

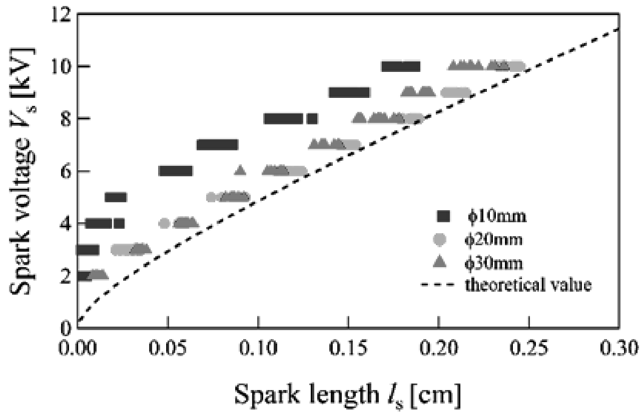

Fig. 1 Correlation between spark voltage and spark length. Dashed line indicates Paschen’s law. Symbols of square, circles, and triangles mean diameter of electrode of 10mm, 20mm and 30mm, respectively.

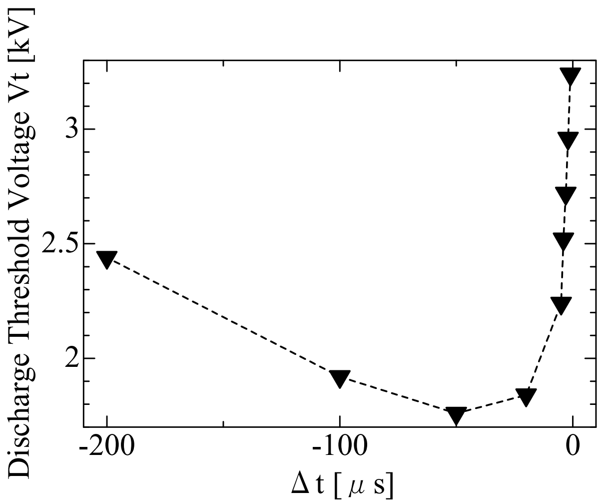

Fig. 2 Threshold of discharge voltage as a function of delay time of laser irradiation from spark discharge. Plots are determined by the 50% probability of spark discharges.

1) “Laser Breakdown-assisted Long-distance Discharge Ignition”, Yuya Fukumi, et al., Powertrains, Fuels and Lubricants (JSAE 20159221/ SAE 2015-01-1897)