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燃料液滴列の冷炎燃え広がり実験用点火装置の開発

Development of Ignition Device for Experiments on Cool Flame Spread along a Fuel Droplet Array

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1. Introduction

Spray combustion is widely applied to the combustion engines.　Because spray combustion is a complicated phenomenon, there are still unknown areas in the spray combustion..　It is well known from the studies on homogeneous gas mixtures that the low-temperature oxidation reactions, which induce cool flame, are the dominant reactions for spontaneous ignition of most hydrocarbon fuels.　　The cool flame has a great effect on outbreak of the hot flame.　Therefore, clarifying cool flame is important to elucidate combustion mechanism of spray combustion.　The purpose of this study is to elucidate the cool flame dynamics using droplet array.　If the output of the igniter is not controlled, igniting the droplet by the hot surface ignition method will generate a hot flame.　In this research, we have developed a new ignition device that can control the temperature of the ignition line according to the ambient temperature.　This report describes the details of the ignition device and results.

2. Experimental Apparatus and Procedure

This experiment was conducted to investigate the effect of the initial droplet diameter　on cool flame ignition delay time. Figure 1 shows experimental apparatus. The apparatus consists of droplet holder, Igniter, UV senser, and High　speed camera.　The droplet holder consists of stainless frame and silicon carbide fiber of 14 ◎m in diameter.　The droplet was suspended at the tip of the SiC fiber.　The droplet was located at the center of the spiral part of the nickel wire.

The ignition device consists of an ignition unit, a circuit unit, and a power supply. The ignition part consists of a heating wire and a body. A nickel wire with a diameter of 0.10 mm and a length of 28 mm was used as the heating wire, and a spiral shape was used for the purpose of heating the droplets evenly. For the body, a copper single core wire with a diameter of 1.0 mm and a length of 150 mm was used. The nickel wire and the copper wire were fixed by soldering. The ignition circuit used the device developed by Waga et al. 1). The ignition circuit consists of a Wheatstone bridge, a differential amplifier, a transistor, and other components.

After that, the ignition device was operated at a preset temperature.　The igniter temperature at this time is 700° C.　This experiment was performed 50 times with the initial droplet diameter d_0= 0.55 to 1.2 mm.　Fig. 2 shows the droplet supported by the SiC fiber. The diameter of the droplet was measured by a scale from an image projected onto a backlit CCD camera. The voltage waveform was recorded with an oscilloscope. After that, the effect of the initial droplet diameter on the ignition delay time was investigated. In addition, the current waveform recording start time was synchronized with the power-on time. The ignition delay time is defined as "the time from the power-on time to the combustion start time". At this time, the combustion start time was defined as "the time when the voltage value deviated from the constant voltage value by 2% was measured.

Formaldehyde is generated as an intermediate reaction product of a low temperature oxidation reaction that induces a cool flame. In other studies, a camera with a built-in image intensifier is used to observe the self-emission of formaldehyde. In this research, a self-emission of formaldehyde detection device using a UV sensor were developed that can be mounted in a small space and has high resistance to vibration. The self-emission of formaldehyde is very weak. Therefore, the UV sensor was used in combination with the output amplification device. The output amplifier is a self-made circuit, and the gain is set to about 10,000.

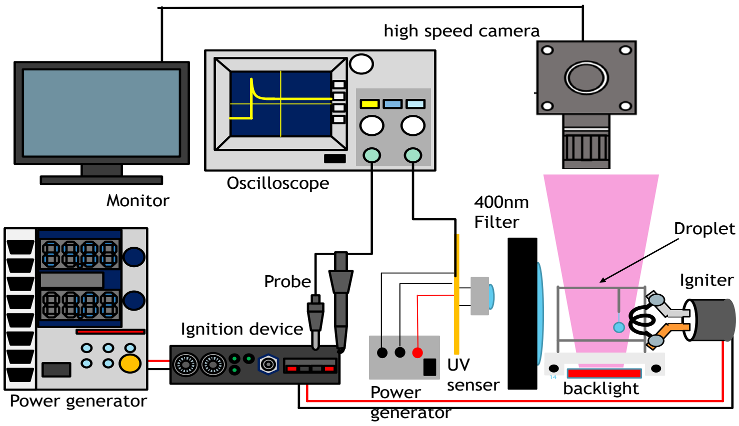

Fig. 1 Experiment apparatus.

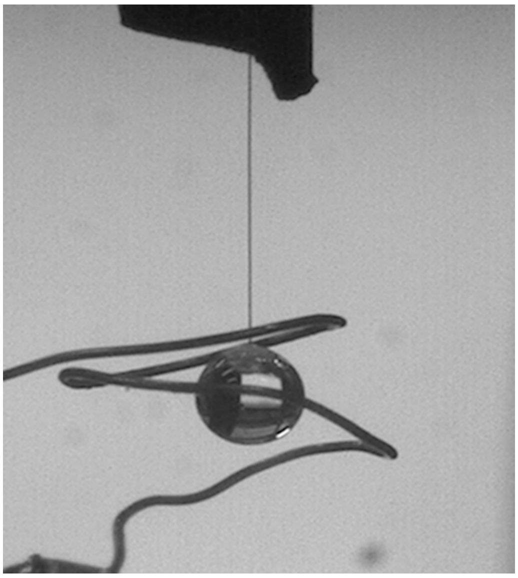

Fig. 2 Droplet supported by the SiC fiber.

3. Results and Discussion

Fig. 3 shows the relationship between the igniter current and temperature. It can be seen that the temperature rises in a curve from 0 to 0.7 A, and then rises linearly from that point onward. Since the temperature range used for cold flame ignition is around 400 ° C, this linear part can be used to convert the current into temperature

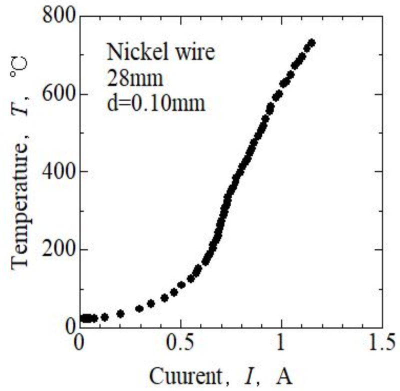

Fig. 3 Relationship between the igniter current and temperature.

Fig. 4 shows the oscilloscope waveform during the cold flame of the igniter. For comparison, the waveform when ignited without droplets is shown in Fig. 5. From Fig. 4, it can be seen that the current value temporarily rises sharply and then falls immediately because the heat rays at room temperature are heated at t = 0 s. A gentle valley was observed in the current value at t = 1.0 to 3.0 s. This indicates that the heat rays were heated and the working amplifier in the circuit reduced its output in an attempt to return it to its default value. At this time, the heat flame could not be visually confirmed. Therefore, it is considered that a cold flame is occurring. Compared with Fig. 3, the temperature was found to be 700 ° C.

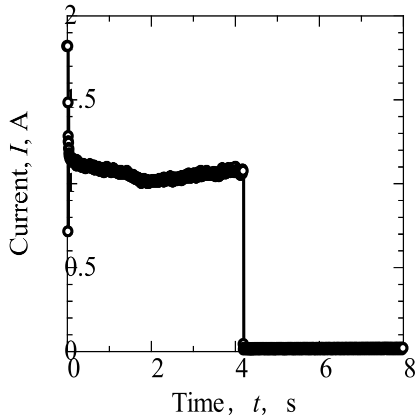

Fig. 4 Signal waveform during cold flame of igniter.

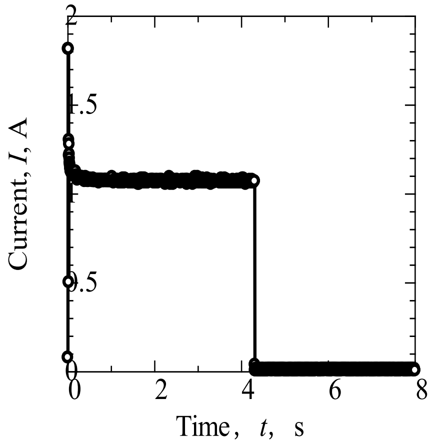

Fig. 5 Signal waveform when ignited without droplet. (igniter)

Fig. 6 shows the oscilloscope waveform during the cool flame of the UV sensor. For comparison, the waveform when ignited without droplets is shown in Fig. 7. In Figure 6, peaks were seen at the voltage values at t = 1.0 to 3.0 seconds. The voltage value of the UV sensor rises at the timing when the igniter lowers the current value and a cold flame occurs, observing the cool flame.

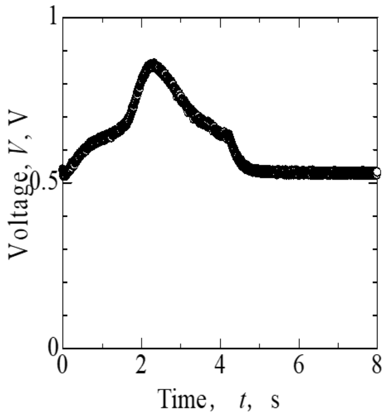

Fig. 6 Signal waveform during cold flame of UV sensor.

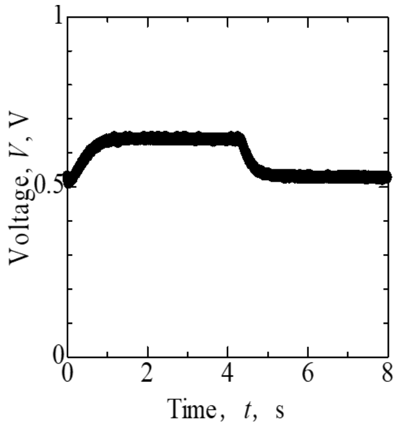

Fig. 7 Signal waveform when ignited without droplet. (UV sensor)

4. Conclusions

Current-voltage conversion for cold flame spread observation designed and manufactured the circuit.

Nickel wire for the current flowing through the igniter temperature characteristics revealed.

Acknowledgment

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