Experimental Study on Combustion Promotion of Liquid Fuel Droplets using Electro-Magnetic Energy in Far Infrared Ray

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Abstract

The experimental study of liquid fuel droplets burning in the electro-magnetic environments has been carried out to examine the effect of electro-magnetic wave on spray combustion. The wave characteristics employed for the study are around 1200 cm^{-1} in wave number, which corresponds to the absorption band of methane wavelength, and 0.9 in spectral emissivity. For the combustion process of hydrocarbon fuels the combustion ultimately may includes the reaction of methane and methyl with oxygen in air as a result of thermal decomposition so that it is essential to examine whether methane combustion is promoted by electro-magnetic wave or not. The fuels used for the study are n-heptane, n-hexadecane, methanol and benzene. The initial droplet diameter is approximately 1.5mm. The acquisitions obtained here show that such electro-magnetic wave may be very effective to accelerate the combustion rate of liquid fuel droplets by utilization of resonance frequency.

1 Introduction

At present, the policies of energy saving on exhaustion of fossil fuels, realization of low emission of CO_2 on global warning and the reduction of air pollution substances such as NOx and SOx are strongly required. So, one has to develop the high efficiency combustion technique for realizing the high energy saving and low CO_2 emission even at any kinds of fuels[1-3].

Thus, the authors have developed the new combustion concept of electro-magnetic wave to achieve the high efficiency combustion for saving energy and low emission of air pollutant sunstances. At first, the authors have developed the electro-magnetic energy sheet, which continually discharge the electro-magnetic wave of approximately 0.9 in spectral emissivity and 800 to 2000 cm^{-1} in wave number as shown in Fig.1, and then the effect of such electro-magnetic wave on combustion of liquid fuel droplets is examined using the electro-magnetic energy sheet. The surface temperature of electro-magnetic energy sheet is room temperature and the evaluation of experimental data is carried out by measuring the combustion lifetime, mean flame temperature and flame size of fuel droplet combustion. These data are analyzed by taking the direct color photographs with high speed video camera equipped with two-color pyrometer.

2 Combustion Promotion principal by means of Electro-Magnetic Wave

It is well known that the low-hydrocarbon fuels such as methane are able to absorb much electro-magnetic energy around 1200 cm^{-1} in wave number[4]. Such wave belongs to the range of far infrared ray. The discharge

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of the ray to methane and its precursor may lead to more accelerate the vibration modes of these substances caused by resonance frequency, and then to enhance the collision energy and frequency between molecules of fuel and oxygen. Consequently the flame temperature gives rise to increase due to the acceleration of combustion reaction rate [5].

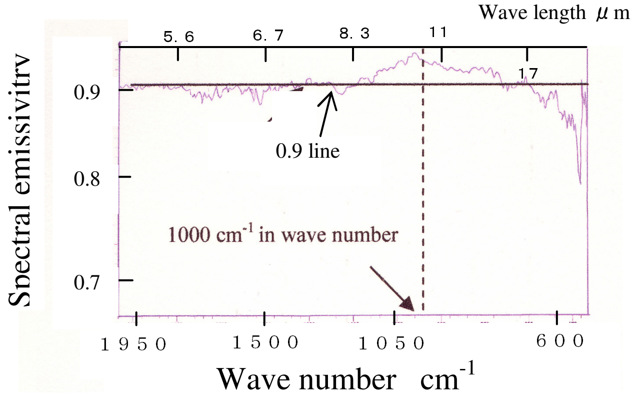


Fig.1. Spectral emissivity of electro-magnetic energy sheet.

3 Experimental Apparatus and Procedure

Figure 2 shows the experimental assembly which consists of combustion chamber, ignition equipment and high speed video camera. The combustion chamber is a rectangular shape of 200 ×200×180 mm. The quartz fibre for suspending the fuel droplet is located in the central position of the combustion chamber and the ignition is done by ellectrically heated fine nichrome wire. The liquid fuel droplet is surrounding by electro-magnetic energy sheet which can continuously discharge the electro-magnetic energy in the range of 800 to 2000 cm^{-1} in wave number and more than 0.9 in spectral emissivity. The configuration of energy sheet surrounding the fuel droplet is cylindrical shape of 80 mm in inner diameter and 120mm in length.

The behaviors of fuel droplets burning in electro-magnetic field are observed by taking the direct photographs with high speed video camera and the combustion lifetime of fuel droplet is measured to evaluate the effect of electro-magnetic energy on the fuel droplet combustion. The mean flame temperature during the combustion process of fuel droplet is determined by image processing of two color thermal analysis based on color photographs obtained with 8-mm high speed video camera of 200 frames per second.

The experiments have been carried out in the conditions of elevated pressure at the range of 0.1 MPa to 1.0 MPa and room temperature. The initial diameter of fuel droplet employed for the study is approximately 1.5 mm. The fuels used for the study are n-heptane, n-hexadecane, benzene and methanol as representative fuels of internal combustion engines. The experimental data adopted here are average values of 100 times tests and the statistical dispersion of these data is less than 1.5%.

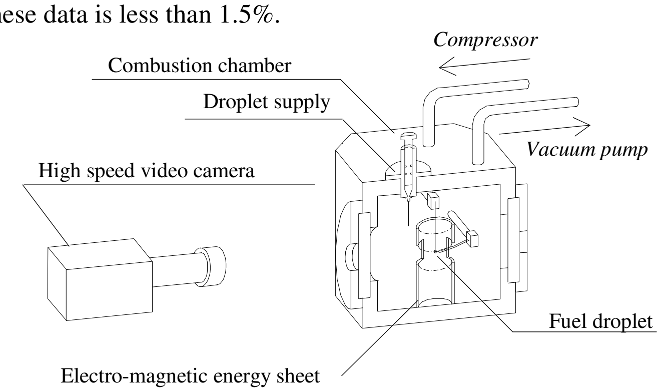
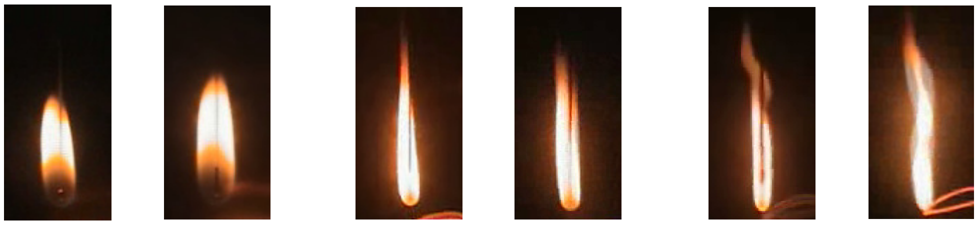


Fig.2, Test assembly.

4 Experimental Results and Discussions

Figure 3 depicts one shot photographs on combustion behaviour of n-hexadecane droplets under various ambient pressures in the case where energy sheet exists or not. From these photographs it may be suggested that the flame shape of n-hexadecane droplets with energy sheet is larger than that without energy sheet at any ambient pressure.



0.1MPa (non) 0.1MPa (with) 0.5MPa (non) 0.5MPa (with) 1.0MPa (non) 1.0MPa (with)

Fig.3. One shot photographs on combustion behavior of n-hexadecane droplets under various pressures in the case where the discharge of electro-magnetic energy exists or not.

In Table 1 are shown the values of combustion lifetime and its reduction rate for four kinds of fuel droplets. The reduction rate ε of combustion lifetime is defined as follows:

$$\varepsilon = (t_1 - t_2)/t_2$$

where t_1 and t_2 are the combustion lifetime with and without electro-magnetic energy sheet, respectively. From Table 1 it can be seen that the reduction rates of combustion lifetime n-heptane, n-hexadecane, methanol and benzene are 7.85%, 4.80 %, 1.96% and 0.70%, respectively. These discripancies on combustion lifetime of fuel droplets may result from the amount of methane and its reaction precursor generated by thermal decomposition[6].

Table.1. Comparison on combustion lifetime of fuel droplets at 0.1MPa and 298K.

	n-heptane	n-hexadecane	methanol	benzene
Combustion lifetime without energy sheet T_1(sec)	2.55	2.50	2.84	2.55
Combustion lifetime with energy sheet T_2(sec)	2.35	2.38	2.79	2.53
Reduction rate of combustion life time ε(%)	7.85	4.80	1.96	0.70

In Figs.4 and 5 are shown the typical examples of the variation of flame temperature T_F against the elapsed combustion time when the fuel droplet is surrounded by the electro-magnetic energy sheet or not. The flame temperature is analyzed by image processing of two-color pyrometer based on the experimental data obtained with high speed video camera. From these figures it can be seen that, for n-heptane droplet, the electro-magnetic wave employed for the study leads to increase the flame temperature during combustion process. The rise of mean flame temperature caused by the electro-magnetic wave seems to be 100℃ to 150℃. However, for benzene droplets there is no temperature rise even with electro-magnetic energy sheet.

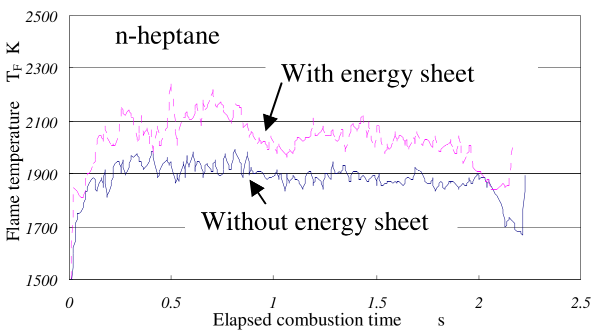


Fig.4. Flame temperature of n-heptane droplets burning at 0.1MPa and 298K with or without energy sheet

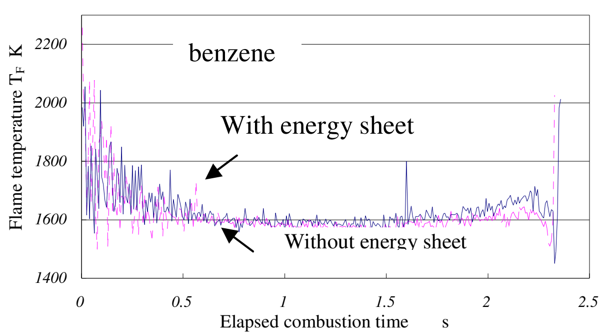


Fig.5. Flame temperature of benzene droplerts burning at 0.1MPa and 298K with or without energy sheet.

Figure 6 shows the combustion lifetime of n-heptane and n-hexadecane under elevated pressure at the range of 0.1MPa to 1.0MPa with the electro-magnetic energy or not. From this figure it can be recognized that the effect of the electro-magnetic wave on the combustion of fuel droplet may be unchanged even at environments of elevated pressure

From these experimental results obtained for the study, it would be summarized that the substances like methane and its combustion precursor produced by thermal decomposition of liquid fuel droplet during the combustion process may be able to absorb electro-magnetic wave around 1200 cm^{-1} in wave number so that the acceleration movement such as the vibration mode of these substances are encouraged by electro-magnetic wave.

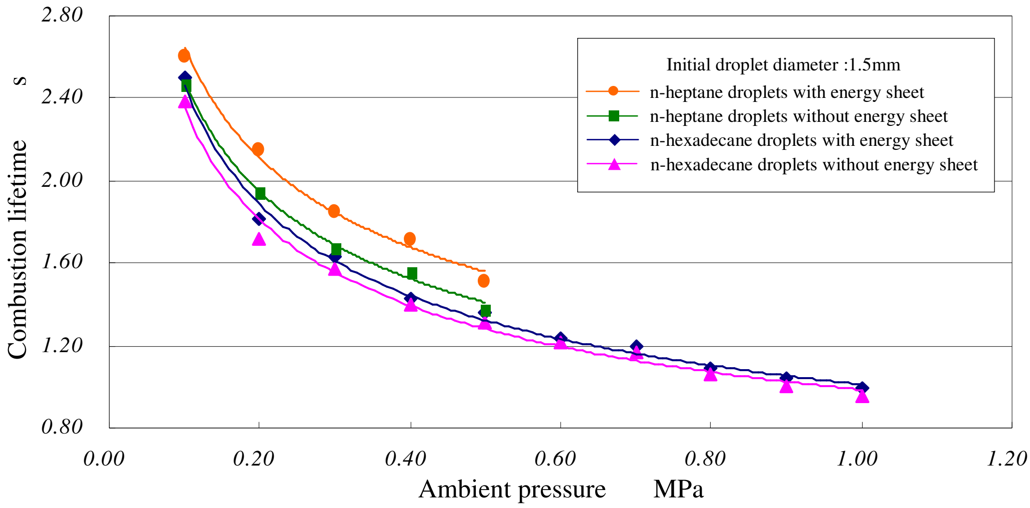


Fig.6, Combustion lifetimes of n-heptane and n-hexadecane droplets burning under elevated pressure and 298K with or without electro-magnetic energy sheet.

5 Conclusion

Experiments have been conducted to examine the effect of electro-magnetic wave emitted from electro-magnetic energy sheet on the promotion of spray combustion. The main results obtained for the study are as follows:

(1) The reduction rate of the combustion lifetime of fuel droplets burning in electro-magnetic field may be about 7.85% for n-heptane droplets, 4.80% for n-hexadecane droplets, 2.0 % for methanol droplets and 0.7 % for benzene droplets and the increase of mean flame temperature of n-heptane fuel droplets burning in electro-magnetic field is at the range of 100℃ to 150℃.

(2) The effect of electro-magnetic energy on the combustion of fuel droplets may be unchanged by elevated pressure.

(3) The electro-magnetic wave around 1200 cm^{-1} in wave number and more than 0.9 in spectral emissivity has an ability to accelerate the combustion rate of fuel dropletsas a result of resonance frequency. This means that such electro-magnetic wave may be very effective to accelerate the burning rate of spray combustion.

6 References

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