Experimental Investigation on Combustion Promotion of Liquid Fuel Spray by Utilization of Electro-Magnetic Wave in the Range of Infrared Ray

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1 Introduction

Recently, there are lots of problems around our environments such as exhaustion of fossil fuels, global warming by CO_2 emission, air pollution by NOx, SOx, PM and so on. We definitely have to protect our environments from such problems and also we have to establish the combustion technique to achieve the high energy saving, low CO_2 emission and high combustion efficiency for many kinds of combustors.The basic concept of energy saving for practical combustion means to reduce the fuel consumption without declination of combustion performance whether it is diffusion or premixed flames.

From this point of view, the present study has been carried out to develop the high efficiency combustion technique, which can realize the high energy saving and low emission of CO_2, by means of the utilization of electro-magnetic wave at the range of infrared ray. Especially, the study will be focused on the combustion of liquid fuel spray including the analysis of single fuel combustion. The experiments have been conducted to examine how the combustion of liquid fuel spray is affected by electro-magnetic wave at around 1200 cm^{-1} in wave number, because the substances like methane and its combustion precursors produced by thermal decomposition during combustion process have an ability to absorb the electro-magnetic wave around 1200 cm^{-1} of wave number.

Under this circumstance, the authors have developed the substances which can continually discharge the electro-magnetic wave of approximately 0.9 in spectral emissivity at wave number of around 1200 cm^{-1} as shown in Fig.1.The evaluation of electro-magnetic wave on liquid fuel spray combustion is examined by measuring the flame temperature distribution in the case where electro-magnetic wave exists or not. For single droplet combustion the evaluation of electro-magnetic wave is carried out to examine the combustion lifetime and flame temperature variation with elapsed combustion time. These data are obtained and analyzed by taking the direct color photographs with high speed digital video camera equipped with two-color pyrometer.

2 The Principal of Combustion Promotion by Means of Electro-Magnetic Wave

For the combustion process of hydrocarbon fuels regardless of diffusion or premixed flames, the combustion ultimately initiates including the reaction of methane or methyl with oxygen in air as a result of thermal decomposition during combustion process so that it is very important to examine whether methane combustions is promoted by electro-magnetic wave or not.

It is well known that the low-hydrocarbon fuels such as methane are able to absorb much electro-magnetic energy near the wave number of around 1200 cm^{-1}. [1] Such a wave belongs to the range of infrared ray. These rays may lead to more accelerate the spin and vibration modes of methane molecule and its reaction precursors generated by thermal decomposition, and then to enhance the collision energy and frequency between molecules of fuels and oxygen. Consequently the flame temperature gives rise to increase due to the acceleration

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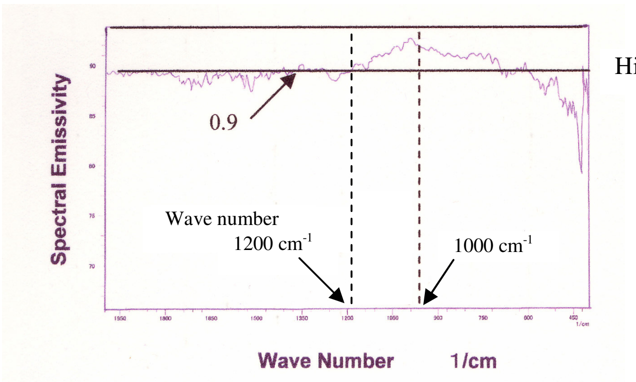

Fig.1. Spectral emissivity of energy sheet .

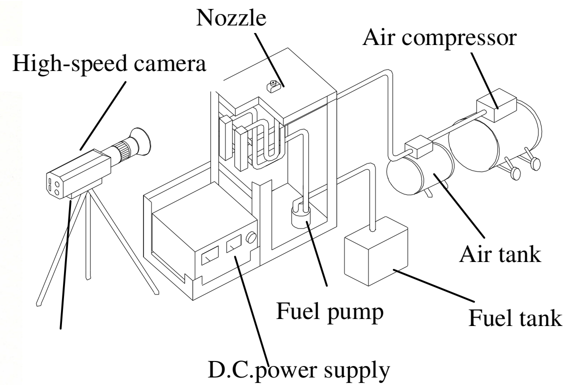

Fig.2. Experimental Setup.

of combustion reaction rate. The energy sheet used for the study is approximately 0.9 of spectral emissivity in the range of 1200 cm^{-1} of wave number.

3 Experimental Apparatus and Procedure

3-1 Liquid Fuel spray combustion

In Fig.2 is shown the outline of experimental apparatus for observation of kerosine spray combustion in the case where the electro-maganetic energy exist or not. The apparatus consists of spray combustion nozzle of 0.3mm in diameter, DC power supply, air and fuel flow meters, air tank, compressor and high speed digital camera. The energy sheet, which can contineously discharge the electro-magnetic energy, is attached the surroundings of the flame as making it possible to radiate the electro-magnetic energy into the location L and C of flame zone as shown in Fig.4 .

The combustion behavior of fuel spray in electro-magnetic field are observed by taking the direct photogrphs with high speed viudeo camera of 200 frames per second and the mean flame temperature of fuel spray combustion is estimated by image proccessing of two color thermal analysis based on the color photographs obtained with high speed digital video camera. The experiments have been performed in the condition of room temperature and one atmospheric pressure. The fuels used for the study are kerosine and heavy oil A. The fuel and air flow rates employed for the study are 0.4L/min and 4 to 7L/min, respectively.

3-2 Single Fuel Droplet Combustion

The experiments of single fuel droplet combustion have been carried out to verify and evaluate the acquisition on liquid fuel spray combustion. [3] Fig. 3 depicts the layout of fuel droplet and electro-magnetic energy sheet. The fuel droplet is surrounded by electro-magnetic energy sheet which is cylindrical shape of 80mm in inner diamter and 100mm in length. The observation of fuel droplets burning in electro-magnetic fields is carried out by taking the direct photogrphs with high speed video camera. The fuels used for the study are n-heptane, benzen and methanol. The silica filament (0.4mm in diameter and 50mm in length) for suspending the fuels droplet are located in the central position of the cylindrical energy sheet.

4 Experimental Results and Discussion

4.1 Liquid Fuel Spray Combustion in Electro-Magnetic Field

Figure 4 shows the direct photographs on flame behavior of kerosine spray combustion in the case where the energy sheet exists and not and in Fig. 5 also is shown the flame temperature distribution obtained by two-color pyrometer on the kerosine spray combustion, where the fuel and air flow rates are 0.4 L/min and 6 L/min, respectively. From these photographs it can be seen that the flame temperature on kerosine spray combustion in

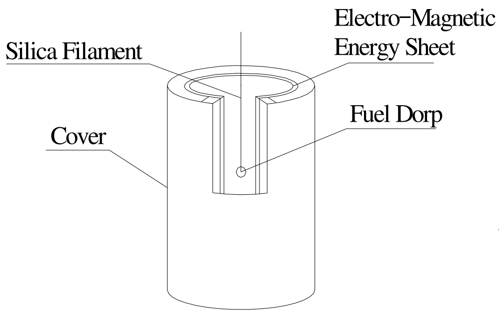

Fig.3.Layout of fuel droplet and electro-magnetic energy sheet.

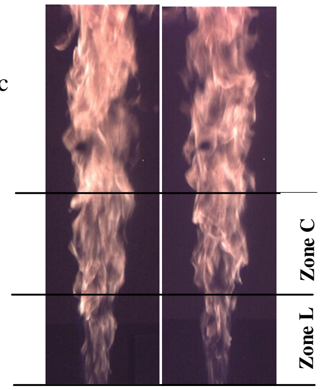

Fig.4. Direct photographs of spray combustion in electro-magnetic field(Left,location L) or not (Right).

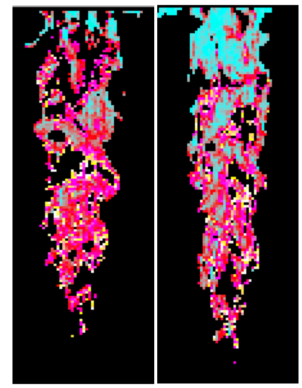

Fig.5. Flame temperature profiles of spray combustion in electro-magnetic field (Left,location L) and not(Right).

electro-magnetic field is clearly higher than that in non electro-magnetic field. The temperature rise in electro-magnetic field is approximately 150 to 200℃, comparing with that in non electro-magnetic field.

Figure 6 shows the variation of flame temperature of kerosine spray combustion against air flow rate in the case where electro-magnetic energy is radiated into the flame zone L and C as shown in Figs. 4, and in Fig.7 is also shown the temperature rising ratio of kerosine and heavy oil A against air flow rate when the energy sheet is located at L. As seen from Fig.6, the effect of electro-magnetic wave at the location L on flame temperature is larger than that at location C. This means that the discharge of electro-magnetic wave into the flame base, that is, thermal decomposition zone, is very effective to enhance the combustion reaction rate. Also from Fig.7 we can recognize that at 7 L/min of air flow rate, the temperature rising ratios of kerosine and heavy oil A are approximately 6.5% and 2.0%, respectively. Where the flame temperature rising ratio is defined as the ratio between flame temperatures with energy sheet and without energy sheet at the same air flow rate.

4.2 Single Fuel Droplet Combustion in Electro-Magnetic Field

Figure 8 shows the normal distribution for combustion lifetime of n-hepetane droplets burning in electro-magnetic field and not. In table 1 are shown the values of combustion lifetime and its reduction rate ε which is defined as $\varepsilon = (t_2 - t_1)/t_2$, where t_1 and t_2 are combustion lifetime with and without electro-magnetic energy sheet, respectively. These experimental results indicate that such electro-magnetic wave may be very effective to promote the burning rate of droplet combustion as well as that of kerosine spray combustion, though the value of reduction rate depends on the kinds of fuels.[2, 3]

In Fig. 9 is shown the typical example of the variation of flame temperature against the elapsed combustion

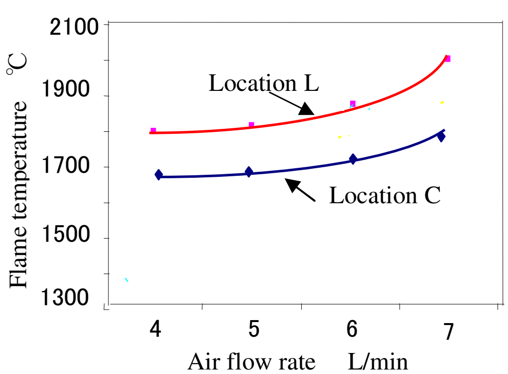

Fig.6. Temperature variation against air flow rate on kerosine spray combustion at the flame location L and C .

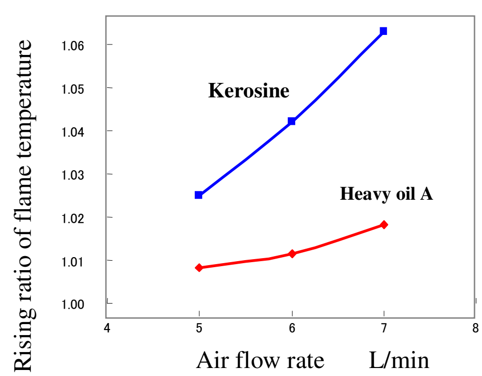

Fig.7. Temperature rising ratio on spray combustion.of kerosine and heavy oil A .at location L.

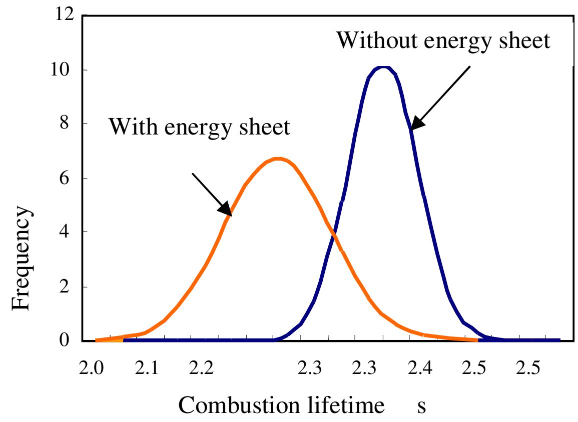

Fig.8. Normal distribution of combustion lifetime of n-heptane.

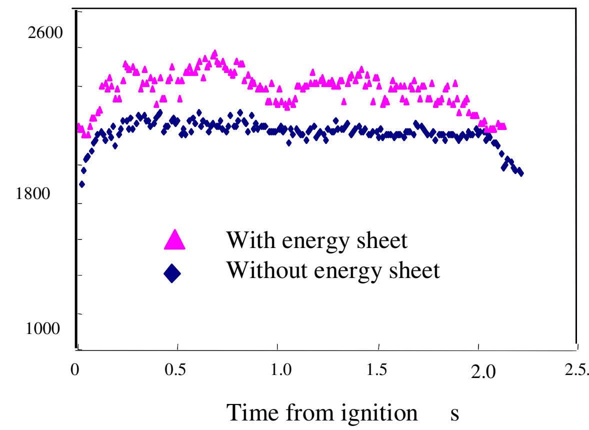

Fig.9. Flame temperature of n-heptane burning droplets.

Table 1. Combustion lifetime of single fuel droplets.

	C7H16	CH3OH	C6H6
Combustion lifetime(with Energy sheet) s	2.30	2.79	2.53
Combustion lifetime (Without energy sheet) s	2.41	2.84	2.55
Reductiion rate of combustyion time %	4.56	1.76	0.79

time in the case where the fuel droplet is surrounded by the elctro-msagnetic energy sheet or not. For n-heptane droplets, the flame temperature with energy sheet is always higher than that without energy sheet during combustion process.

5 Conclusion

Experiments have been performed to examine how the fuel spray combustionis is affected by electro-magnetic wave around 1200 cm^{-1} of wave number. The main results obtained for the study are as follows :

1) The electro-magnetic wave around of 1200 cm^{-1} in wave number and above 0.9 in spectrial emissivity is very effective to increase the flame temperatures of kerosine and heavy oil spray combustion.
2) The discharge of electro-magnetic energy into the region of thermal decopmposition is very effective to enhance the combstion reaction rate.
3) The effect of electro-magnetic energy sheet on flame temperature rising ratio of kerosine spray combustion is markedly higher than that of heavy oil A.
4) These results obtained by spray combustion under electro-magnetic field can verify from those obtained by single fuel droplets combustion.

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