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Pool Combustion of Iso-Propanol Fuel including IPA and PCBs in different Type Vessels

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Abstract : On the regulation demanded for a control of various toxic substances, PCBs(poly chlorinated biphenyl) has a fatal poisonous matter in the ecosystem and the environmental pollution as it is a kind of stable chemical substance. Especially, the gross product of PCBs is estimated at about one million tonnage all over the world. However, it is kept on storing in untreated state, then has a deterioration by the prolonged storage and a risk of overflowing. Therefore, this research examined the fundamental characteristics of combustion and emission for the target of using the IPA (iso-propyl alcohol) solution as a part of PCBs control. IPA was filled to three kinds of Vessel, i.e., Vessel Ⅰ, Ⅱ, and Ⅲ, and then was investigated as follows: combustion shape, flame temperature, mass burning velocity, and PM(particulate matter). A radial thermometer and a C-A thermocouple measured the flame temperature, and the optical extinction method by using He-Ne laser and the filter weight method used in the PM measurement.

As a result, with an increasing of L/S ratio, the flame length become shorter and the burning velocity is more rapid, but the particulate matters is higher. It is supposed that the air flow rate is high on Vessel뷁, and then the combustion is promoted in the surface area of the upstream zone. The future works plan to investigate the characteristics with an using of the mixing of IPA and PCBs

Key words : Pool Combustion, IPA, PCBs, PM(Particulate Matter), Burning Velocity

Nomenclature

τ : turbidity of the medium
I_R : Emerging light intensity (in equal unit of mV)
I_0 : Incident light beam intensity (in equal unit of mV)
D_a : Volume mean diameter of aggregated PM (mm)
P : Number density of aggregated PM (Particulate/cm^3)
L : Light path length (cm)
Q_{ext} : Extinction efficiency
V : Volume fraction of aggregated PM

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(cm^3/cm^3)

W : Mass fraction of aggregated PM (g/cm^3)

1. Introduction

Most of fire-disasters are due to the burning of overflowed combustibles and the spread of smokes, toxic gases etc., which are caused by a breakdown of inflammable storage vessels for a petroleum species or a miss of plant operation. Such pool (surface) combustion is mostly empiricism, and Blinov, V.I.[1] and Akita, K. et al[2] make merely a fundamental experiment using a small-sized cylinder vessel. And there are no more than the report which Nishida, O.[3] and Koseki, H. et al.[4] did a basic experiment against the oil spill fire on the sea. Moreover, there are not make any systematic study of it. On the other hand, it is said that the surface burning velocity and the combustion shape are much effected by heat transfer from flame to surface under the each different surface scales.

This research was carried out in a viewpoint of PCBs (poly chlorinated biphenyl) environmental pollution, dioxin synthesis, establishment protection and fire extinguishing in the case of pool combustion with treatment liquid as the chief ingredient. The combustion experiments were done with the different types of oil vessel using only IPA (iso-propyl alcohol), and investigated the flame temperature distribution and spread, the surface temperature, the burning velocity and the soot formation.

2. Experimental Apparatus and Procedure

Table 1 shows iso-propanol properties used in this experiment. There are filled up the each types of vessel with iso-propanol to investigate the behavior in the pool combustion. Fig. 1 shows the schematic of experiment. Especially, it is said that the PM products affect the dioxin synthesis. So, the experiment places great importance on the PM measurement, and investigate the each combustion and emission characteristics.

2.1 Vessel Types

As shown in Fig. 2, the vessels were used 3 types of vessel(Ⅰ, Ⅱ, and Ⅲ) that are all made with stainless steel material in about 2 mm of thickness. These all have the same area, but the length (L:S) ratios are different with the each other.

2.2 Burning Velocity

The burning velocity was measured the loss in quantity according to the elapsed times after ignited a charge of oil vessel which equipped with a weight instrument.

Table 1 Properties of iso-propanol

Item(Unit)	Value
Purity (%)	99.8
Density (g/cm^3 at 20℃)	0.786
Refractive index (n20/D)	1.377
Water (vol%)	〈 0.5
In-Volatile matter (vol%)	〈 0.004
Acid (vol%)	〈 0.004

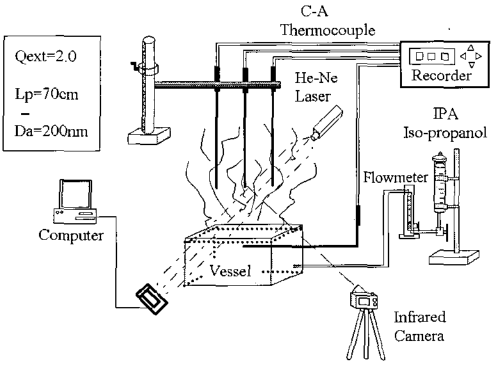

Fig. 1 Schematic Diagram of Experimental Apparatus

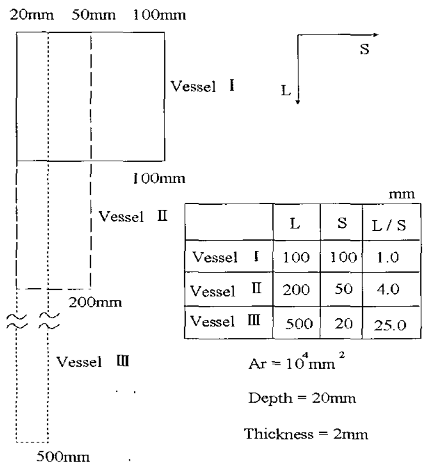

Fig. 2 Vessel Type

2.3 Flame Temperature

To measure the temperature in the each radial and axial position of flame, a radial thermometer(λ=0.8 - 1.1μm) was used in principle. It was set up that the radiation ratio(ε) was 0.1, the measuring distance, angle and standard circle(ϕ) were 1.2 m, 1/3 degree, 6.0 mm respectively. Besides, C-A thermocouple also was used to examine the validity in diffusion flame of the atmosphere opening shapes. And the surface temperature was measured by using the C-A thermocouple.

2.4 Particulate Matter

Firstly, according to Lambert-Beer Law, the relation between turbidity(τ) of aggregated PM in exhaust gas, emerged light I_R and incident intensity I_o can be written[5];

$$\tau = I_R/I_o \doteq \exp(-\pi D_a^2/4) \times P \times L \times Q_{ext} \quad (1)$$

On the other hand, the above-mentioned I_R and $I_0$are used our experimental values in term of light extinction method. So, the number density (P) of aggregated PM can be calculated as follows.

$$V = \pi \times D_a^3/6 \times P \times 10^{-21} \ (cm^3/cm^3) \quad (2)$$

And consider that the mass value per volume unit of PM is about 2.0g/cm^3, the mass concentration of aggregated PM become as follows.

$$W = 1.047 \times 10^{-15} \times D_a^3 \times P \ (g/m^3) \quad (3)$$

As shown in Fig. 3, the polarized helium-neon laser was used for light extinction method, and the incident lights from laser source were chopped by rotating disk(ϕ10cm, 1180Hz). An optical filter was used to avoid the over load

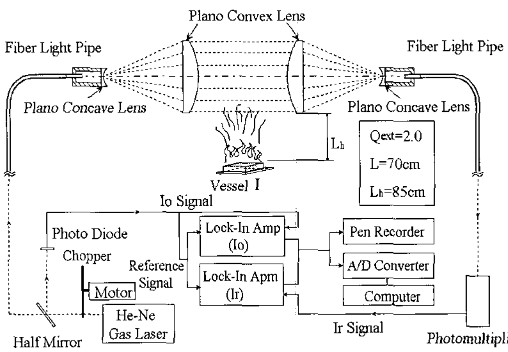

Fig. 3 Optical Measuring System

phenomenon of the light intensity signal received in a lock-in amplifier. All signals then have been sent to an oscilloscope and computer via analog-digital (A/D) converter. The number of signals sent to lock-in amplifier is one thousand signals once to avoid a manual fringe count. At the same time, the filter weight method was used to measure the PM.

3. Results and Discussion

3.1 Flame Photography

When ignited a full of vessel, the flame is made at all surface area in a moment. The camera keeps a shutter speed at a 1/125 in flame photography. As shown in Fig. 4, the whole have a high brightness, and is a diffusion flame. And those all are conglutinated to the rim of a vessel and strongly extended upwards for a buoyancy. The brightness is appeared by a difference of vapor concentration.

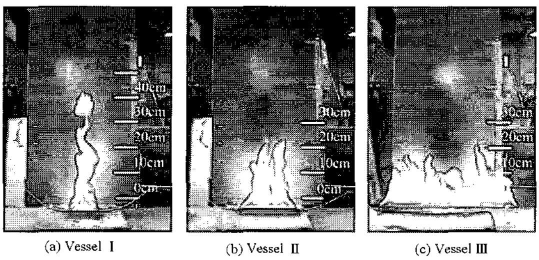

Fig. 4 Flame Photography

The vessel Ⅰ shows a diffusion flame from the rim of vessel to 30cm of axial distance and is changed as a pre-mixed flame in the downstream, and then is finished in a moment. The total length of vessel Ⅰ flame is about 40-45cm. The vesselⅡ shows the plural flame, but is divided in the downstream as a dominant diffusion flame of 25-30cm total length. The vessel Ⅲ is similar to the vessel Ⅱ on the whole except to the flame length.

Fig. 5 displays that the flame length is lowered with a increasing of L/S ratio. It is assumed that the flame length is shorter by hastened the combustion.

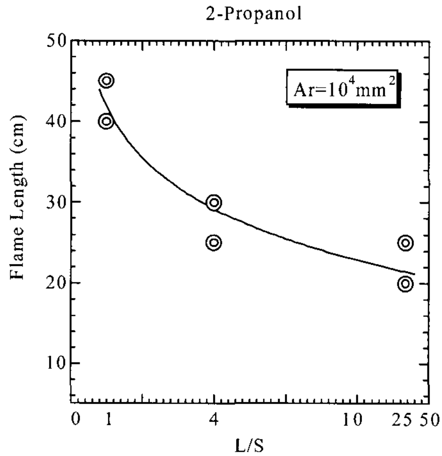

Fig. 5 Flame Lenght in relation to L/S Ratio

3.2 Temperatures of Flame and Surface

Fig. 6 presents the flame temperature distribution according to the axial distance (Lc) measured by C-A thermo-couple during about 15 minutes after the ignition. And it shows also the flame temperature investigated in the each both sides from the center(R=0mm) of the vessels. The highest temperature is about 800℃ between 20mm and 100mm of the axial distance, and there is a sharp decrease in the temperature to the flame length.

Fig. 7 depicts the flame temperature distribution measured by the radial thermometer in the 3 types of vessel(I , II, and III).

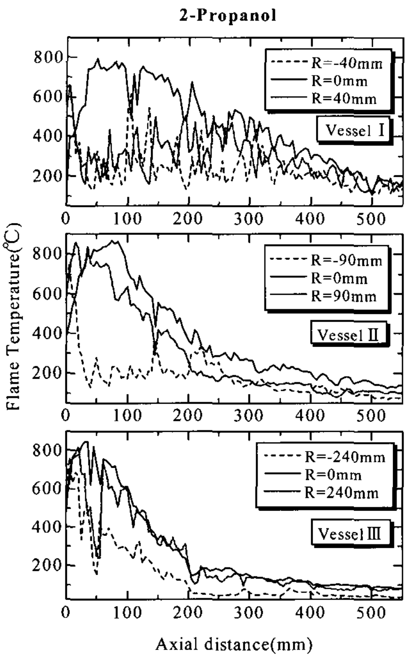

Fig. 6 Flame Temperatures in Pool Combustion(C-A Thermocouple)

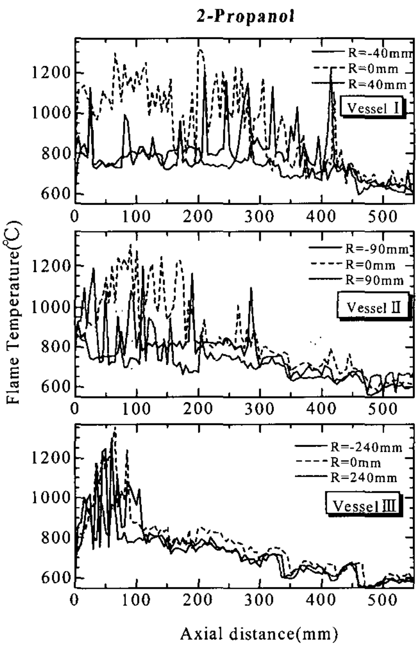

Fig. 7 Flame Temperature of Axial Distance(Radiation(ε)=0.1)

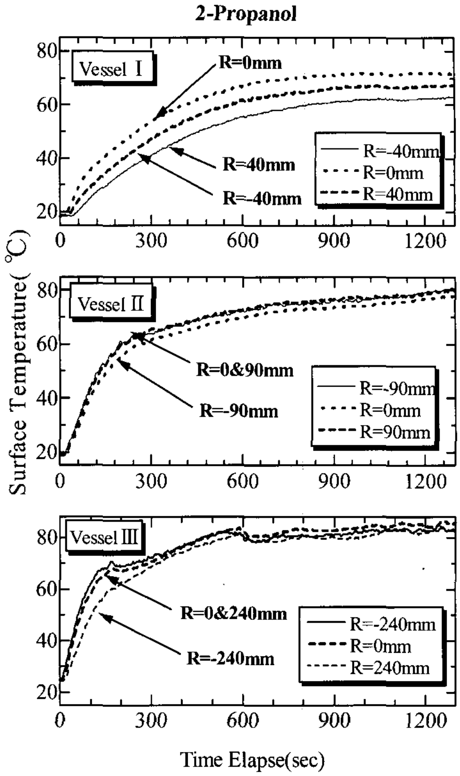

Fig. 8 Surface Temperatures in Pool Combustion(C-A Thermocouple, L_1=-5mm)

The temperature is high a variation of temperature due to the flickering, and the maximum is about 1200℃. Especially, the flame temperature of vessel III is decreased remarkably at about 100mm because the flame length is very short compared with the others.

Fig. 8 illustrates the surface temperature of vessel I, II, and III according to elapsed times. It is measured in the each 3 position that is under 5mm from the vessel rim. Before the ignition, the oil temperature is about 20℃. The temperature of vessel I shows a smooth distribution, but the others is increased suddenly until about 2 minutes after the ignition and then become stabled from about 20 minutes at 80℃.

3.3 Mass Burning Velocity

Fig. 9 illustrates the weight decreasing velocity for 20 minutes after the ignition (ΔWDV(g), m=g/cm^2s). The vessel Ⅲ is the most rapid to 197.7mg/sec, the vessel Ⅰ is 126.7mg/sec.

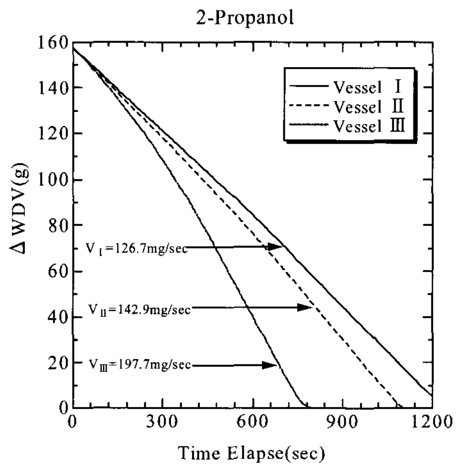

Fig. 9 Weight decrease velocity in Pool Combustion

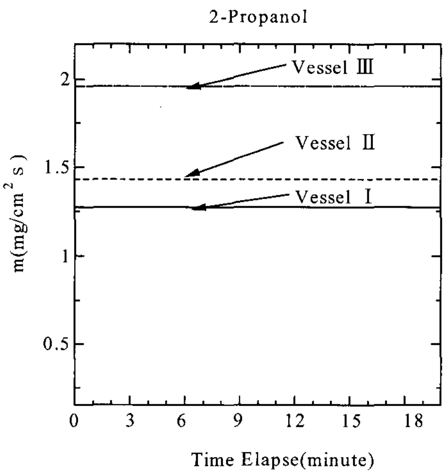

Fig. 10 Mass Buring Velocity in Pool Combustion

Fig. 10 appears the mass combustion velocity obtained from the above-mentioned. There is not appeared many changes with the lapse of time and the velocity is about 1.2 to 2.0mg/cm^2sec. Especially, the vessel Ⅲ shows the very fast value.

3.4 Particulate Matter

Fig. 11 shows the number density of particulate matter measured by light extinction method. It appears almost 0.25×10^9 - $1.5\times10^9 P_N/cm^3$ with fluctuating broadly at the downstream.

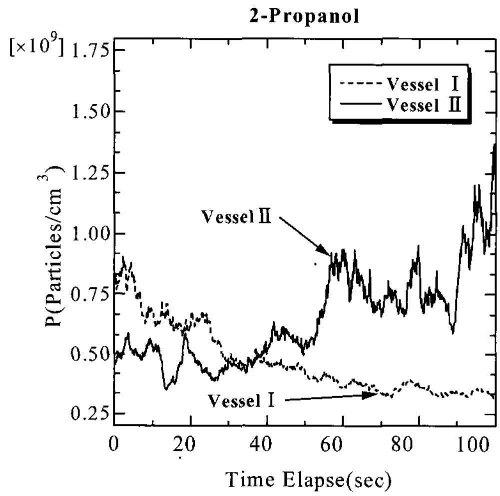

Fig. 11 Number Density of Emitted Particles in Pool combustion

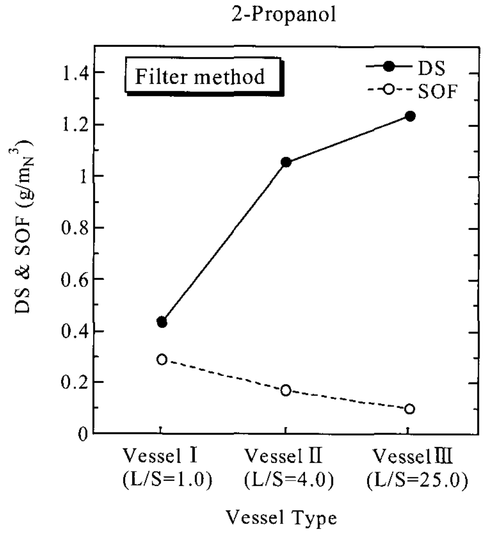

Fig. 12 DS & SOF Concentration

Fig. 12 presents PM emission measured by a filter weight method. As shown in Fig. 12, the dry soot of PM is higher, but the soluble organic fraction is lowered according to L/S ratio increased.

4. Conclusion

There are filled up the different types of vessel (L/S ratio=1, 4, 25) with iso-propanol in the pool combustion, the results show as follows.

With an increasing of L/S ratio, the flame length become shorter and the burning velocity is more rapid, but the particulate matters is higher. It is assumed that these are affected by the air entrainment and the evaporative capacity due to a radiant heat.

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