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Formation Characteristics of PM and SOF by Spray Combustion of Marine Heavy Fuel Oil

Houng-Soo Kim† · T Murakami* · Osami Nishida* · H Fujita* · W Harano*

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Abstract : This study is intended to check a temperature of the flame to raise by burning A heavy oil in a boiler, to measure the concentration of DS and SOF after collecting the PM(Particulate Matters), and to analyze the components ingredients of SOF by G.C Mass for presupposing the generation of particulate matters(soot). It is thought that the methyl(CH3) of the cyclic compound is changed to the materials of 2 cycles and 3 cycles after becoming CH by dehydrogenation and also mixing with the CH of a chain compound, form H-·C=C·-H that is mentioned before , in order to become Polycyclic Aromatic Hydrocarbon.

Key words : Marine pollution control, SOF, DS, MPM, Hydrocarbon, Soot

1. Introduction

The characteristics of the heavy oil used for a ship are very different from the fuels which used for a car on land or another energy sources commonly and its quality is extremely low. Its main component is hydrocarbon but contains lots of sulfur, nitrogen, and carbon.

The components of the aerosol are generated by the combustion of the fuel but it is not clear enough to grasped at the moment. At the same time IMO keeps seeking about measure by a clear grasp of the state of the particulate matters as air pollution materials discharged from a ship and working out a countermeasure to reduce those particles are needed. In this study, the particulate matters generated by the combustion of the fuel, low quality for a ship are defined as MPM(Marine Particulate Matters). MPM is divided into SOF(Soluble Organic Fraction) and DS(Dry Soot) on the basis of fusibility against an organic catalyst. The components of the particles are different largely, according to the components of the fuel and the process of its combustion. It is thought that sulphide by S and N ingredients, that is included SOF PCAH as a pre-soot. DS includes soot generated from PCAH made

† Corresponding Author(Graduate School, Kobe University, Japan), E-mail : ignore01@hotmail.com
* Kobe University, E-mail : co007014@cc.kshosen.ac.jp, nisida@cc.kshosen.ac.jp, fujita@cc.kshosen.ac.jp

after the complex reaction of acetylene gas(C_2H_2), a partial oxide, carbon, a minute quantity of ash contained in materials added to lubricating oil, various metal ingredients contained in water vapor and fuels that are mixed to become smog or smoke and cause smog. But there is often little detailed information about the generation of particulate matters as the atomizing combustion by the heavy oil enough to has not been elucidate.

This study is intended for that object to check a temperature of the flame of a boiler by burning A heavy oil in a boiler at the same time, to check the generated quantity of DS and SOF after collecting the PM(Particulate Matters) in gas generated after burning the oil, and to analyze the ingredients of SOF for presupposing the generation of particulate matters (soot).

2. Experimental apparatuses and methods

2.1 Burner and fuel used

Figure 2.1 is shown the whole experimental apparatus. A stady flow type atomizing furnace of the low-quality heavy oil whose internal diameter is 430mm and height is 250m has the water-cooling compulsive braziers of 5 stages and 6 windows for internal observation.

This equipment is possible to burn the low-quality fuel of a few hundred cst(50), the quantity of fuel that can burn is 5~13kg/h, and its maximum output is about 5 X 104 kcal/h.

This study used the combustion atomizing nozzle and the diffuser(funnel cone of D/d=1.05 Type) for the burner. so It is possible to shape safe atomizing fire. The atomizing angle of the nozzle is 60. The fuel density is 0.87, its kinematic viscosity is 2.4mm2/sec., its main components are as carbon and hydrogen, and it contains not only a minute quantity of sulfur, nitrogen, but also ash in little capacity.

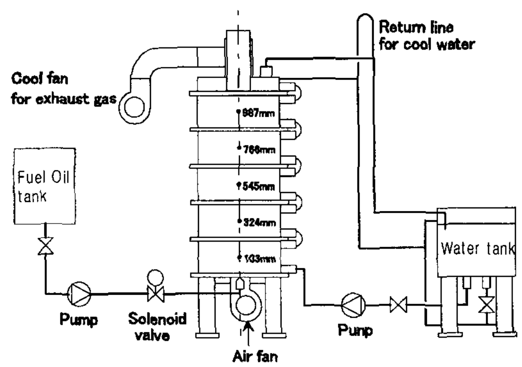

Fig. 2.1 Whole experimental apparatus

2.2 Experimental methods

To make a flame by burning A heavy oil with an atomizing combustion, we made the flux of the oil be 11.16L/h, the quantity of air for combustion be 163.4m3N/h, and the whole average ratio of air to be 1.51. As the flame for experiment was a normal atomizing flame of a kind of the same axle, it was made in a water-cooling furnace whose internal diameter is 430mm and whose height is 1250mm.

The amount of heat generated from the combustion in the furnace was substituted to cooling water. The sampling within the flame was conducted at the vertical locations of (Lc) 103, 324, 545, 766, and 987 from the vertical hem of the burner(funnel cone) and at an optional measurement point of each radius direction(R:mm), with a reference point being the center axle of the flame.

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2.3 The value of particulate matters and the analysis of the components of SOF

We classified DS and SOF after dissolving the particulate matters in Dichloromethane 20㎤ and measured the absolute quantity of each by using Miso-Jikchin. balance (manufactured by Simaju, a balance for a semi-micro electronic analysis, model AE-40SM, precision 0.01mg).

As PCAH(Polycyclic Aromatic Hydrocarbon) as a material that is deeply related to the generation of DS is contained much in SOF, it was analyzed by GC-mass (GC/3DQMSsystem of high-performance M-9000 type).

3. The result of experiment and its examination

3.1 The state of combustion and the generation and the characteristics of particulate matters

The flame whose length was 550mm was turbulent and showed a brass color. The temperatures measured at the locations of an axle direction (Lc) and a radius direction(R) are showed in figure 3.1 and 3.2. A high-temperature area of 1100 was formed at the center part near the nozzle and the temperature was decreased as the flame went outward. There was a small change of the temperatures in the radius direction and a premix combustion as the fuel and the air were well mixed.

The density distribution(g/m^{3}N) of the particulate matters in the direction of the flame axle is showed in figure 3.3(a) and (b).

Both types of distribution were similar but the density level of SOF is lower by about a few tens of %, compared to that of DS. Both components were generated and showed a high density near the nozzle, disintegrated at the outside, and rarely existed at the end part.

Figure 3.4(a) and (b) shows the values of DS and SOF measured in the radius direction of the height (Lc) 103 and 324mm locations from the vertical hem of the funnel cone. DS showed a high density at the center part and at the inside part of the flame and was dissolved at the outside of the flame but SOF showed comparatively a lower density.

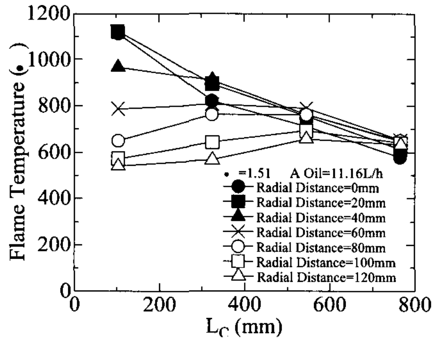

Fig. 3.1 Flame temperature with Lc

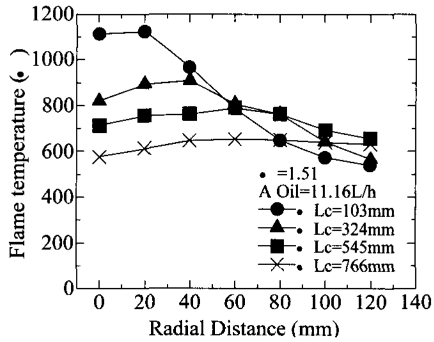

Fig. 3.2 Flame temperature with radial distance

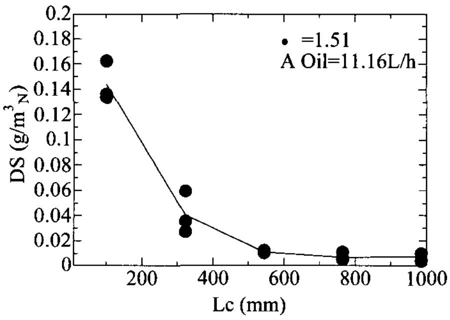

Fig. 3.3(a) D.S(Density) with Lc

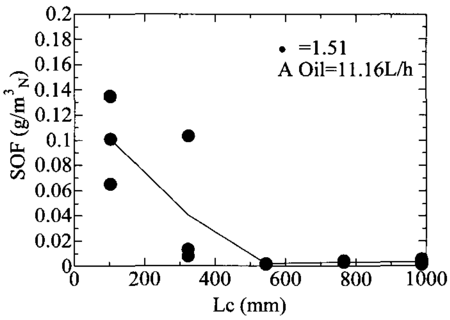

Fig. 3.3(b) SOF(Density) with Lc

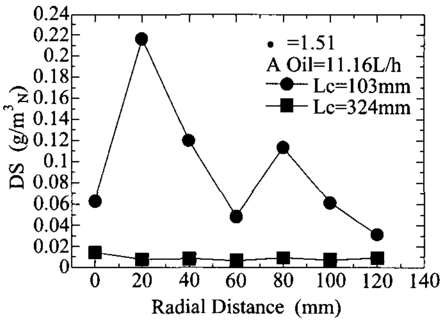

Fig. 3.4(a) D.S(Density) with radial distance

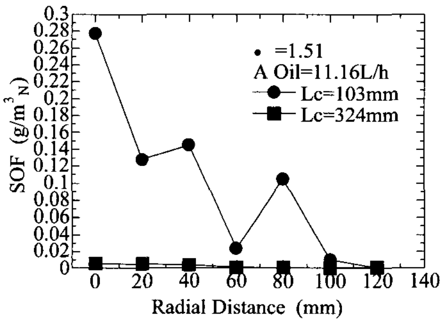

Fig. 3.4(b) SOF(Density) with radial distance

3.2 Analyzing the components of SOF by using GC-Mass

The sample of the fluid that I extracted from particulate matters sampled in a same condition by Dichloromethane 20㎤ was measured.

Figure 3.5(a) and (b) shows a Chromatographic distribution of the Chromatographic total ion at the location Lc=103mm where the thermal disintegration by a high temperature is active and at the location Lc=545mm where the quantity of SOF located near the vertical hem of the flame is decreased and shows the strength(counter value) of ion up to the retaining time of 56 minutes. It is generally known that the molecular weight and the boiling point of a peak material is high when the retaining time is high. The whole Chromatograph of the Chromatographic total ion shows an intense curve peak similar to a conversion from the retaining time of 15 minutes up to 50 minutes and there are many minute peaks in the middle. As the peaks all show the same mass specter pattern, the specter is intensely detected at the 14 mass, with the mass number of ion(m/z) of 100 and less. Also, 14 masses correspond to CH_2. The pattern of this stage is a pattern of a compound belonging to a chain type hydrocarbon and the change of specter

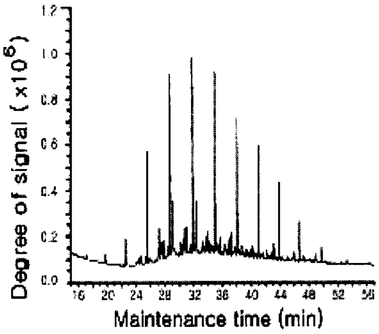

Fig. 3.5(a) Chromatogram Lc=103mm

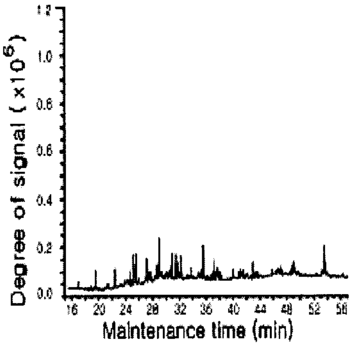

Fig. 3.5(b) Chromatogram Lc=545mm

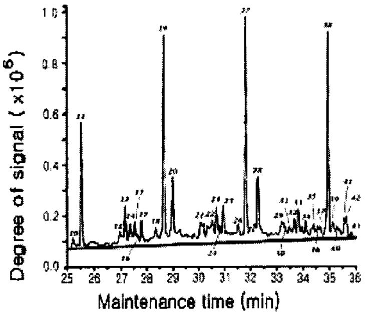

Fig. 3.6(a) Chromatogram(Lc=103mm, RT=25~36min)

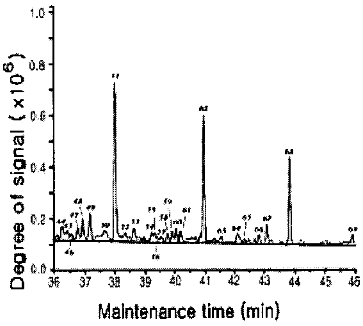

Fig. 3.6(b) Chromatogram(Lc=103mm, RT=36~46min)

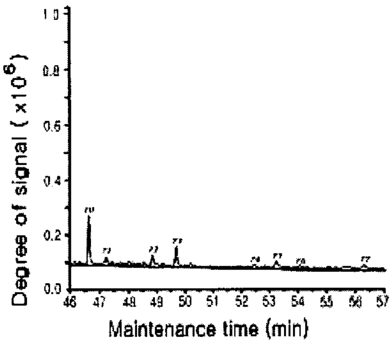

Fig. 3.6(c) Chromatogram(Lc=103mm, RT=46~57min)

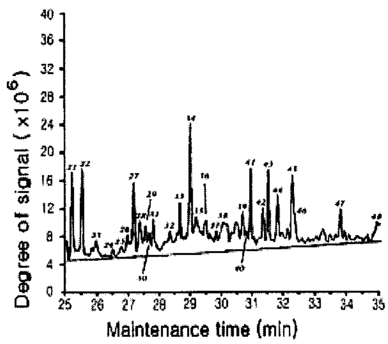

Fig. 3.7(a) Chromatogram(Lc=545mm, RT=25~35min)

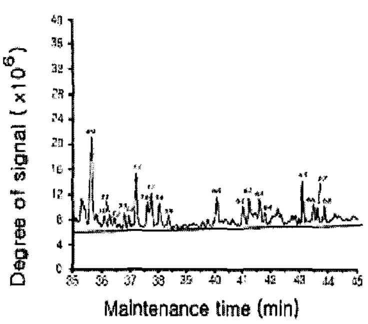

Fig. 3.7(b) Chromatogram(Lc=545mm, RT=35~45min)

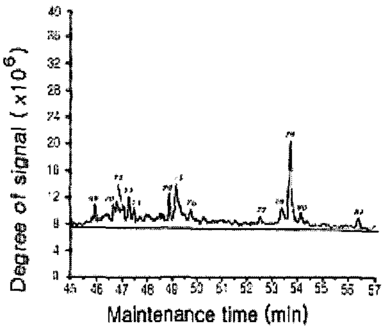

Fig. 3.7(c) Chromatogram(Lc=545mm, RT=45~57min)

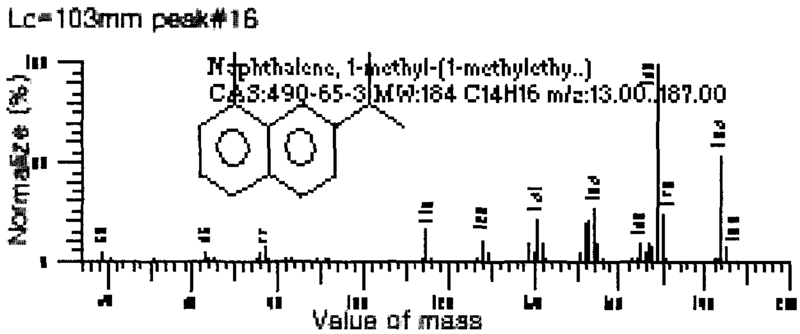

Fig. 3.8 Result of a mass spectrometer

patterns can't be clearly judged as hydrocarbons are all different.

A few of the target material PCAH was detected in the minute peaks placed between the peaks placed near a chain type hydrocarbon and it is thought that it exists only in a minute quantity.

The chart showing the result of Lc=103 up to the retaining time 59 minutes is enlarged in Figure 3.6 (a), (b), and (c). Numbers were put to the whole peaks. Figure 3.7 (a), (b), and (c) shows what was appeared at the location Lc=545mm. Comparing two figures, we can understand that, although a few high peaks appear in the RT=33~36min. of the location 103, peaks higher than that of Lc=103 appear in the RT=42~44min. and 46~50min. of Lc=545mm.

As it was proved by the analysis of the whole data that the temperature was higher and the reaction was active at Lc=103mm.

Each material of the table was estimated according to the reference of the data about its peak. For an example, the estimation about the peak No. 16 was shown in figure 3.8. The mass number of a material(m/z) was normalized(%) at the horizontal axis and its quantity was normalized at the vertical axis. In the figure, with the strength of the base ion whose number of the mass is 169 being 100, as the 184(169+15) of the 15 shift whose number of the mass of CH_3 is large is especially a material of an approximate value, it is estimated to be Naphthalene of a correlation value 58.

Most of materials are unsaturated compounds belonging to hydrocarbons of single cycle, 2 cycles, and 3 cycles, their bifurcation are well developed, and CH_3 is added to them within a vertical[an up-and-down] hem. Their molecular weights are within the scope of 182~266 and the larger they are, the larger their RTs(min.) are. They are 13~19 on the basis of hydrocarbon.

All hydrocarbons of the aromatic class that exist at each location of the flame axises are shown in figure 3.8. Material names, the strength of ion(X104), a formal character, and molecular weights are shown in the figure. In the figure, 13 materials exist at Lc=103mm placed near the nozzle but the number of materials is decreased at the lower course of the flame.

The number is reduced by half at Lc=545mm and 3 are left at 766 and 987mm. Molecular weights tend to increase at the lower course of the flame, with the number of cycles and bifurcation increased.

4. Conclusion

The existence Pre-Soot and SOF of particulate matters(soot) were examined through the flow of the flame. It is important to increasingly examine the structure the generation of hydrocarbons by increasing the number of cycles and the number of carbons on single cycle, 2 cycles, 3 cycles, based on the data.

The route of the generation of soot has been discussed from the past. Nisidas based on the experiment of the flame of propane gas, reported the Diels-Adler reaction in 1979. Since then, it has been discussed in the reports of Smyth, k.c. and Miller, J.H., Haynes, B.S and Wagner, H.Gg., Frenklack, M.,Clary, D.W., Gardiner, W.C.Jr., and Stein, S.E. and Irvin Grassman, and Nisidas.

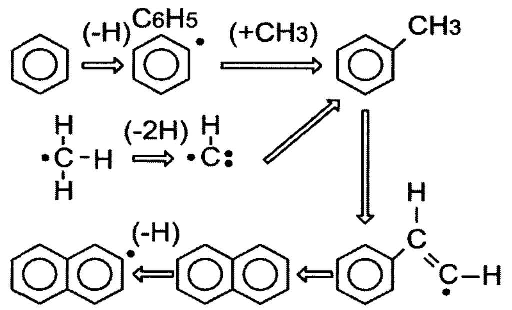

Fig. 4.1 Soot chain chemical process

A part of the generation process of soot are daringly examined, based on the data analyzed in this study. Figure 3.9 roughly shows the process. It is thought that the methyl(CH_3) of the bifurcation vertical hem of a chain type compound is changed to the materials of 2 cycles and 3 cycles after becoming CH by dehydrogenation and also mixing with the CH of a chain type compound mentioned above to form H-·C=C·-H, in order to become Polycyclic Aromatic Hydrocarbon.

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