



The Effect of Porous Emitter on the Combustion of Diesel Oil Porous Burner

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Abstract

The combustion of diesel oil in the porous burner (PB) installed the porous emitter (PE) was experimented to investigate evaporation mechanism, combustion behavior. The pebbles carefully chosen in the same size like the solid sphere homogeneously had been adopted as the porous media. The tested apparatus was divided into 4 sections. The first section is fuel injection chamber. PB or porous absorber having porosity (ϕ) of 0.45 is the second section. The combustion or flame position is located in the third one which three ways swirling air (Q_A) is supplied in this section. The final one is defined as PE section. The PE with different two porosities of 0.45 and 0.52 were examined by installing below PB with distance of 20 cm. The fuel was supplied dropwise from the top through the PB and evaporated in the porous media followed by the combustion on the bottom side. Axial profiles of temperature along the burner length were measured to clarify the evaporation and combustion phenomena. The pollutant emission characteristics were monitored at the burner exit. From the experiment, it was found that the temperature profiles decreased with the three ways swirling air flows (Q_A) increasing. On the other hand, the temperature profiles increased with fuel heat input (Q_F). Remarkably, a better combustion and higher temperature profiles were achieved by PE having porosity of 0.52.

Keywords: Diesel oil, Porous burner, Temperature profile

1. Introduction

Combustion of liquid fuels is commonly conducted using a spray burner for industrial applications such as furnaces and boilers. Many investigations on the spraying liquid combustion placed the emphasis on the size of the droplets sprayed through a nozzle [1, 2], flame structure [3, 4] and the emission of pollutant, i.e., NO_x and soot emission [5, 6]. Kaplan and Hall [7] performed experiment of combustion of liquid

heptane spray within a cylindrical porous ceramic burner. The stable and complete combustion of their experiment can be achieved by using a pressure atomizer for spraying heptane fuel into porous section with a fixed flow rate of 0.025 lpm and with the fuel droplet diameter in the range 50-100 μm . Numerical and experimental studies of sprayed liquid heptane combustion in the porous inert media (PIM) burners were conducted by Tseng and

Howell [8]. The experimental setup was constructed similar to that of Kaplan and Hall [8], and the numerical model was performed in a one-dimensional laminar flow. They reported that the stable combustion was achieved as lean as equivalence ratio ϕ equal 0.3, and the comparison results between numerical and experimental results showed good agreement. Takami et al. [9] operated experimentally to investigate the combustion of kerosene oil on the ceramic plate in which the fuel was supplied dropwise, instead of droplet spray, to the top surface of a horizontal porous ceramic plate burner. They revealed that the porous ceramic plate was effective for preheating of vaporized kerosene and stabilization of the flame on the surface of the porous ceramics. Martynenko et al [10] proposed the mathematical model of self-sustaining combustion of the gaseous mixture with simultaneous evaporation of fuel droplet in the porous medium by considering the phase change under the complex heat transfer including convective, conductive and radiative heat transfer. Jugjai and co-worker [11-12] studied experimentally based on the work of Takami et al. [10]. They presented more detail of the heat transfer phenomena, the evaporation mechanism inside the porous burner, and the combustion characteristics with the effects of the swirling air supply and the bed height of the packed bed emitter installed downstream of the burner system. Park and Kaviany [13] examined the model of a regenerative diesel engine using an in-cylinder reciprocating, porous regenerator. They found that thermal efficiency of this model approached 53 percent, and was higher than the conventional diesel engine (43 percent). Fuse et

al. [14] performed experimentally to substantiate the concept of combustion self-sustained by kerosene vaporization enhanced by radiation through a higher Al_2O_3 porous ceramic plate, for the development of the practical work in electric power saving of the boiler for home use.

From the above-mentioned works, there is very little information of the combustion of liquid fuel in the pack bed sphere burner (PB). However, the authors [15] have carried out the complete combustion of diesel oil in the PIM burner that the pebble was adopted as porous medium. The present study therefore aimed to extensively investigate the interacting effects of a packed bed sphere emitter (PE) installed downstream of burner. The merit of this result is to prepare the fundamental data to a practical work, particular in the diesel engine of automobiles.

2. Nomenclature

d_p	diameter of a packed bed sphere, m
Q_A	three swirling air flow, m/s
Q_F	fuel load input, kW
T	temperature, °C
T_b	boiling temperature, °C
x	geometrical length of porous, m
β	extinction coefficients, m^{-1}
ϕ	porosity
τ	optical thickness

3. Experimental Apparatus and Procedure

3.1 Experimental Apparatus

Figure 1 shows the schematic diagram of the experimental apparatus. The burner consists of 4 sections: a fuel injection chamber, porous burner (PB), mixing & combustion and porous emitter (PE). The experimental setup is

constructed similar to that of Ref. [15] but developed by combining the downstream porous emitter (PE). The cylindrical shape of the present burner is based on a 104-mm inner diameter stainless steel pipe with the length of 100, 100, 180 and 120 mm for the fuel injection, PB, mixing & combustion and PE section. Both porous sections are made of the pebbles which carefully chosen in the same size like the solid sphere homogeneously. Porosity of PB is 0.45 whereas 0.45 and 0.52 for PE are examined.

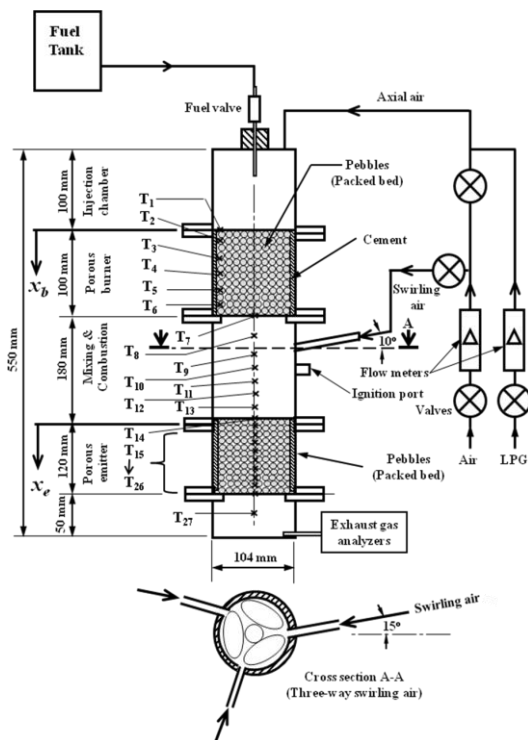


Fig. 1 Schematic diagram of the experimental apparatus

3.2 Optical Thickness

Two average diameters of the pebbles d_p used in examinations were 5 mm and 15 mm, and thus the apparent porosity ϕ were 0.45 and 0.52 respectively. From these data, optical thickness of two packed bed (τ) calculated by equation of Kamiuto and Yee [16] were exhibited in Table. 1.

Table. 1 Physical properties of porous media

Properties	PB	PE	
		PE#1	PE#2
d_p (cm)	0.50	0.50	1.50
ϕ	0.45	0.45	0.52
β (m^{-1})	362.38	362.38	100.53
x (m)	0.10	0.12	0.12
τ	36.24	43.48	12.06

3.3 Experimental Procedure

The combustion characteristics were determined from temperature profiles along the burner axis and the composition of the gases at the exit of the burner. To gain the profile of temperature, 27 N-type thermocouples of 0.5 mm diameter were installed in the burner and rearranged into 3 groups. The first group, N-type thermocouples of T_1 to T_7 , was installed axially at the circumferential surface of the injection chamber section (inserted through the cement insulator). This arrangement prevented the change of flow pattern of liquid phase from the disturbance of the protrusion of the thermocouples and to validly describe the evaporation mechanism. The second group, thermocouples of T_8 to T_{14} , was used to measure the flame temperature along the centerline in the mixing & combustion chamber in order to determine the combustion characteristic. Finally, 10 thermocouples were inserted in the PE section to observe the phenomena of energy absorption and thermal feedback. The thermocouple signals were digitized by a general-purpose data logger then interpreted to a personal computer. The Testo M350 model was used to monitor the emission of the dry sampling gas products at the chamber

exit. The concentrations of NO_x and CO were especially tuned to electrochemical sensors to ensure long-time stability and accuracy of the measurement, which were corrected to 0% excess oxygen on dry basis.

The procedure of the experimental operation of the present burner is similar to that of Pipatana and Krittacom [12]. We did not describe again in this paper owing to they [12] discussed thoroughly.

4. Results and Discussion

4.1 Effects of three swirling air flow, Q_A

4.1.1 For PE#1 case

Figure 2 shows the temperature distribution along the burner length with the effects of three swirling air flow Q_A at a constant fuel load input $Q_F = 2.51$ kW. Optical thickness of PB (τ_{PB}) and of PE#1 (τ_{PE}) used in the present burner were 36.24 ($\phi = 0.45$) and 43.48 ($\phi = 0.45$) respectively. With decreasing Q_A from 160 to 480 LPM, the temperature profiles of both porous sections were increased. The trend of profiles in the mixing & combustion chamber should be discussed as two regions separately: above and below the position of swirling air. For the above region, the peak temperature was appeared in position of T_8 and increased with Q_A . The temperature profile of below one is illustrated similar to both the porous section. This profile is described by the fact that when a higher air-flow rate of swirling air was supplied; an excess air of the combustion was dominated resulting in the stabilized flame movement toward the lower surface of PB.

Figures 3 show effects of the Q_A on the CO and the NO_x emissions under the same

condition as Fig. 4. As seen in Fig. 5, the CO concentrations were slightly increased as increasing Q_A which was in the range of 180 to 230 ppm. This is again clarified by effect of an excess air and much energy feedback from PE of a higher Q_A : the temperature profile in Fig. 2 is evidence. The level of NO_x emission was occurred in the range of 20 to 100 ppm that it is almost unchanged as Q_A increased. This trend is explained by two main reasons. The first reason, a peak temperature is not befallen and the low temperature of combustion is obtained for the second reason.

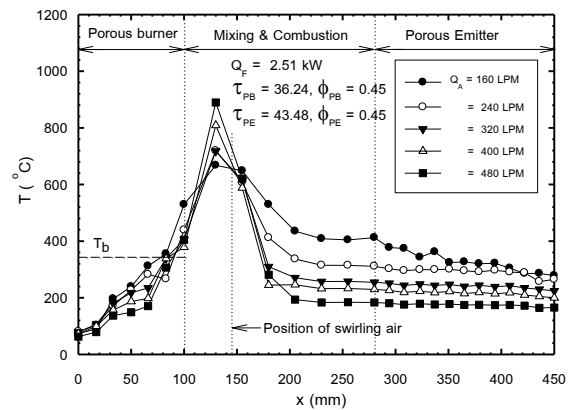


Fig. 2 Temperature profile along the burner length for effects of Q_A

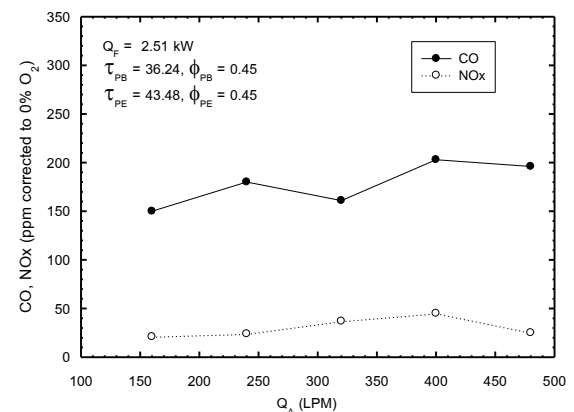


Fig. 3 Effects of Q_A on CO and NO_x emissions for PE#1 case

4.1.2 For PE#2 case

Figure 4 shows the temperature distribution along the burner length with the effects of Q_A at $Q_F = 2.51$ kW as well as τ of PB (τ_{PB}) and PE#2 (τ_{PE}) were 36.24 ($\phi = 0.45$) and 12.06 ($\phi = 0.52$) respectively. The temperature profiles of both porous sections were increased. When Q_A was decreased, the temperature profiles of both porous sections were explicitly increased. In the mixing & combustion chamber was still discussed as two regions separately. For the above position of swirling air, the temperature profiles increased with Q_A . The reverse results were found in the below region. The maximum temperature was again observed at T_8 . The excess air is the significant parameter of this phenomena corresponding to Fig. 5. As seen from Fig.5, the level of CO was increased as increasing Q_A because of the effect of an excess air and much energy feedback from PE of a higher Q_A . In the NO_x case, it was relatively low and almost unchanged with Q_A owing to no peak temperature and a low distribution of combustion temperature.

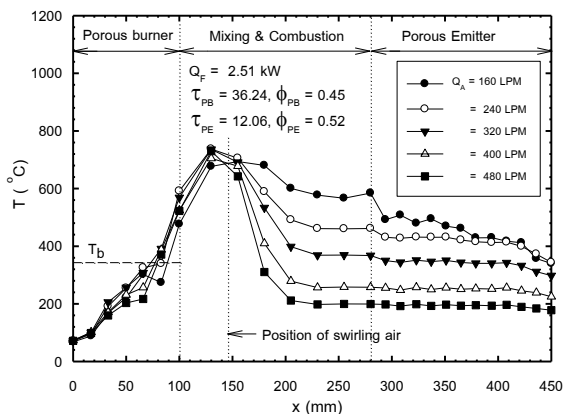


Fig. 4 Temperature profile along the burner length for effects of Q_A

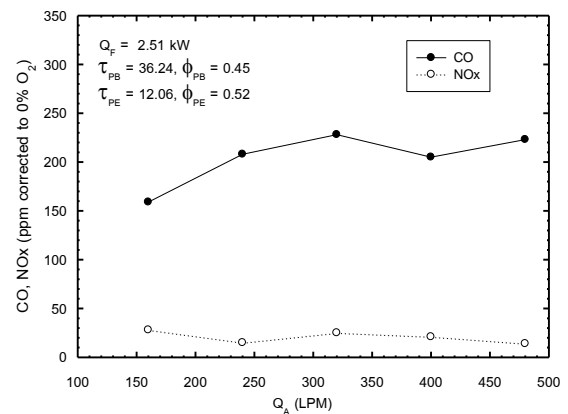


Fig. 5 Effects of Q_A on CO and NO_x emissions for PE#2 case

4.2 Effects of Fuel Load Input Q_F

4.2.1 For PE#1 case

Figure 6 shows the temperature distribution along the burner length with the effects of the fuel load input Q_F at a constant of Q_A as well as τ of PB (τ_{PB}) and PE#1 (τ_{PE}) were 36.24 ($\phi = 0.45$) and 43.48 ($\phi = 0.45$) respectively. Varying Q_F was achieved by adjusting droplet diesel flow rate as Q_A was kept constant. For increasing Q_F from 0.71 to 4.42 kW, the temperature profiles were slightly increased throughout the burner system. As seen in PB section, the temperature at lower surface of porous burner (T_7) was higher than boiling temperature of diesel fuel ($T_{boil} \approx 340$ C°) [17]: it can be said that the evaporation is completed before the fuel passed through PB. From this phenomenon, auto-ignition may be enabled by this fuel vapor, and thus the flame position is stabilized between PB and the swirling air as presented by the maximum temperature at T_8 .

Figure 7 reveals effects of Q_F on the CO and the NO_x emissions. As seen from Fig. 5, the

CO concentration was increased with Q_F and approached 250 ppm. An increase in CO emission was established owing to the incomplete combustion of diesel vapor strongly depended on Q_F . This characteristic can be confirmed by a low level of NO_x concentration. Therefore, a further increase in Q_F was not necessary.

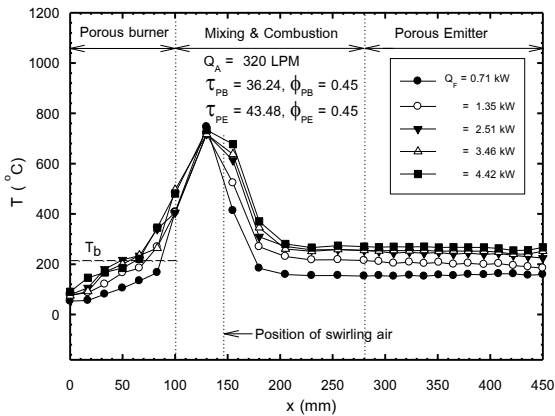


Fig. 6 Temperature profile along the burner length for effects of Q_F

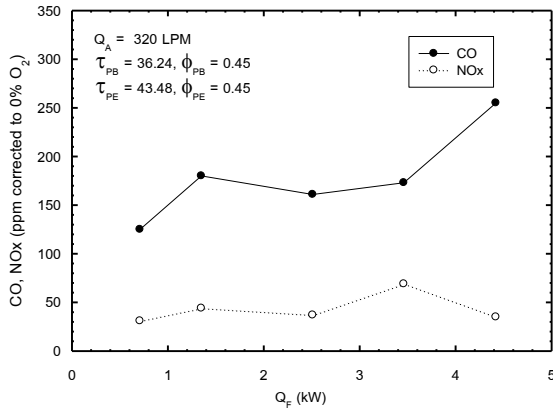


Fig. 7 Effects of Q_A on CO and NO_x emissions for PE#1 case

4.2.2 For PE#1 case

Figure 8 shows the temperature distribution along the burner length with the effects of Q_F at a constant of Q_A as well as τ of PB (τ_{PB}) and PE#1 (τ_{PE}) were, respectively,

36.24 ($\phi = 0.45$) and 12.06 ($\phi = 0.52$). The temperature profiles were increased throughout the burner system with Q_F . As seen in PB section, the temperature at lower surface of porous burner (T_7) was also higher than boiling temperature of diesel fuel leading to the evaporation is completed before the fuel passed through PB. However, a rapid increase in CO emission was established as shown in Fig. 9. It is elucidated by the incomplete combustion of the rich mixture between diesel vapor and swirling air. The level of NO_x was relatively low because of no peak temperature and a good temperature distribution of the burner length.

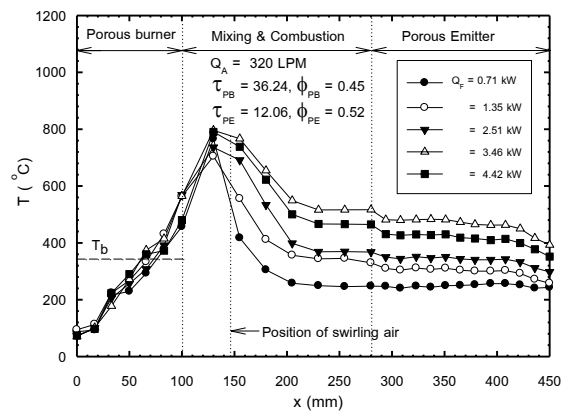


Fig. 8 Temperature profile along the burner length for effects of Q_F

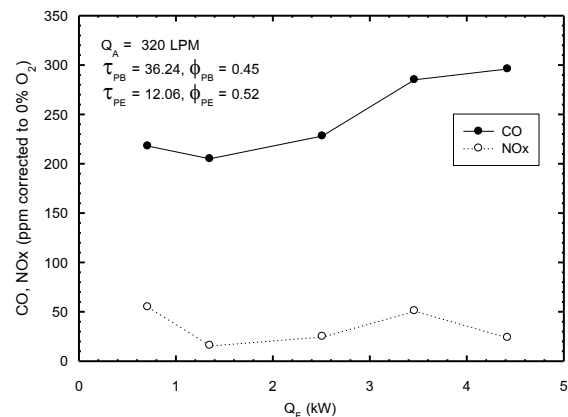


Fig. 9 Effects of Q_A on CO and NO_x emissions for PE#2 case



5. Conclusions

The major conclusions that can be drawn from the present study are summarized as follows:

(1) The profiles of temperature along the burner length of both porous sections are decreased with increasing Q_A but a peak temperature is appeared in the position between swirling air and PB.

(2) The temperature profile is increased throughout the burner system with Q_F and the temperature at lower surface of porous burner (T_7) was higher than the boiling temperature of diesel fuel: it is confirmed that the evaporation is completed before the fuel passed through PB.

(3) The level of CO and NO_x emission observed under the operating range are relatively low and the CO concentration is strongly dependent on the fuel load input Q_F .

(4) The evaporation of a diesel liquid fuel is possibly completed by the preheating in packed bed (porous burner) because the effect of the thermal radiation feedback from the PE into PB. Therefore, the packed sphere medium can favourably serve as the liquid fuel distributor, the thermal radiation absorber-emitter, the liquid fuel evaporator and the fuel vapor preheated

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7. References

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