Combustion behavior of rotary solid porous burners (RSPB)

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Abstract. The combustion behavior of rotary solid porous burners (RSPB), i.e., temperature (T), exhaust gas (CO and NO_X) and combustion efficiency (η_C) were investigated. The stainless wire-mesh type of porous media was selected as porous absorber with porosity of 0.82, thickness of 4.2 mm. The rice husk was used as the fuel with the humidity around 12-14%. The experiment showed that the T tends to increase following the rotating velocity (ω) rising around 0.5-1 rpm. When a ω increased to 1.5 rpm, a T had tendency decreasingly. Because, a ω was too high resulting in the fuel in combustion chamber were ejected quickly then the reaction time reduced not enough to burn fuel, leading to incomplete combustion. The air flow rate (Q_A) of 40 m^3/h and the fuel load input rate (Q_F) of 2.3 kg/h, gave the highest of T due to the system become complete combustion. Corresponding to the level of CO, the least level was obtained at ω = 1 rpm, Q_F = 2.3 kg/h and Q_A = 40 m^3/h. The η_C yielded highest with 93.7% at the same condition. The NO_X in this research was considered as low, not more than 40 ppm in all experimental conditions.

1 Introduction

In the past several decades, many researchers have been tried to find ways to create combustion technologies for effective and environmental friendly [1-4]. In order to use energy based on high valuable and low emission, porous burners was combustion technology that can solve these problems. Because porous materials had the ability to transform heat energy between convection and radiation. Therefore, if the combustion occurs in the porous media, the intake will be heated by exhaust gas using the heat transfer mechanism of the porous media itself, without addition heat exchangers in the process burn in any way. S. Jugjai et al. [5] studied the combustion characteristic of the liquid porous burner with many parameters such as equivalence ratios, thermal input installed the porous emitter. S. Jugjai and C. Pongsai [6] installed porous emitter in the porous burner so that radiating heat emitted to porous burner for evaporation and acting as a combustion burner in which the combustion occurs (Some or all) within it. T. Lakpradit and B. Krittacom [7] installed the porous emitter to the enhancement of the combustion of the liquid porous burner. B. Krittacom and

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P. Amatachaya [8] reported the combustion behavior of the porous burner with the porous emitter using the diesel oil as fuel. K. Keawchart and B. Krittacom [9] examined the influence of the stainless wire-mesh type of porous media on the combustion behavior solid porous burner. As mentioned above, most of the research was focused on porous emitter to increase the combustion efficiency, which was mainly based on heat radiation. Moreover, all were non-rotating. Therefore, the present work investigated the combustion behavior of rotary solid porous burner (RSPB). The temperature (T), the content of exhaust gas (CO and NOx) and the combustion efficiency (η_C) were discussed in this work. In experiment, the solid fuel was rice husk with humidity in the range of 12-14% similar with previous works [9].

2 Experimental

Figure 1 showed the schematic diagram of a rotary solid porous burner (RSPB) with rotating combustion chamber. The major components of the experimental equipment consisted of 3 parts. The first part was the injection zone, respectively. The second and third part were solid fuel feeder zone and combustion chamber zone. In experiment, the rice husk with humidity in the range of 12-14% was used as solid fuel. A rice husk was supplied from the solid fuel port and, then, was flowed along a screw conveyer into combustion chamber as shown in Figure 2. The fuel was ignited by pilot flame resulting to combustion was occurred. The stainless wire-mesh having porosity (ϕ) of 0.82 and thickness (H) of 4.2 mm was installed inside the chamber. The preheating process can be achieved by the cool air that was flowed passing this porous. The combustion zone was the rotary combustion chamber as propulsion unit for push the ash leave more conveniently from a combustion chamber. Meanwhile, the stainless wire-mesh type porous media had been used as porous absorber for preheating the supplying air. The combustion chamber was driven by motor. The rotating velocities of combustion chamber (ω) studied in the experiment were 0.5, 1.0 and 1.5 rpm. There were three fuel load input rate (Q_F) as investigated: 1.7, 2.3 and 2.9 kg/h, and air flow rate (Q_A) were 20, 30 and 40 m^3/h. The combustion behavior of this work were the temperature (T), the content of exhaust gas (CO and NO$_X$) and the combustion efficiency (η_c). The temperature (T) was monitored using a data logger with a type-N thermocouple at the inlet (x = 0 cm) and exit (x = 40 cm) of the combustion chamber. The content of exhaust gas (CO and NOx) have been verified by Testo M350-Model and have been reported on by excess oxygen 0% on a dry basis. The combustion efficiency (η_c) was defined by

$$\eta c = \frac{E_f - E_u - E_{co}}{E_f}$$ (1)

where E_f, E_u and E_{co} were energy of fuel (kJ), energy of unburned fuel (kJ) and energy loss as CO in the exhaust gas (kJ), respectively.
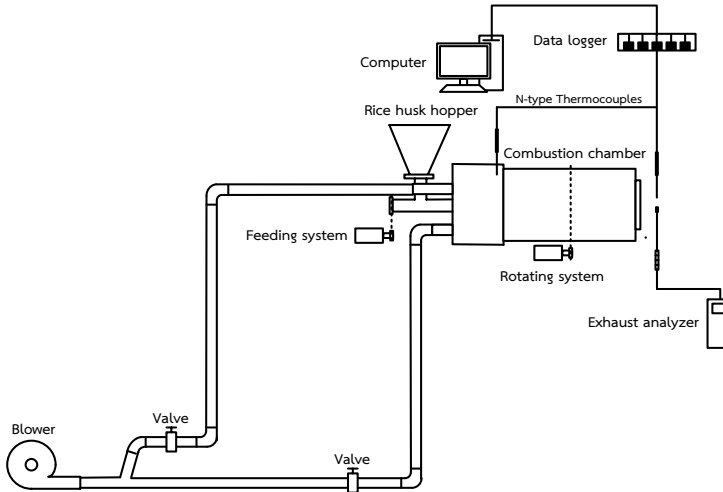
**Fig. 1.** Schematic diagram of a rotary solid porous burner (RSPB).
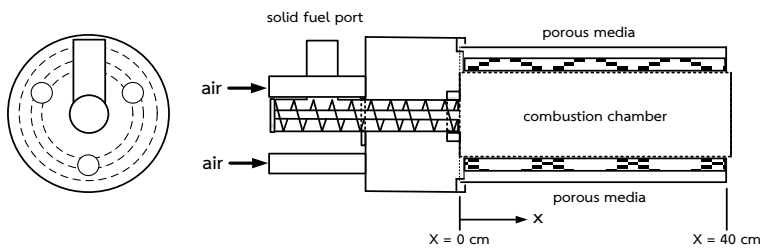
**Fig. 2.** Axial cross-section of a rotary solid porous burner (RSPB).

3 Results and discussion
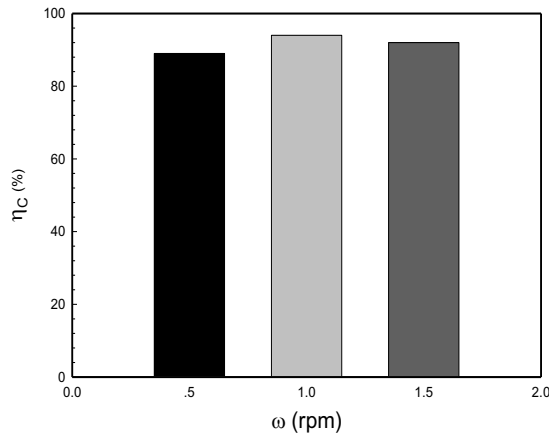
3.1 Effect of the rotating velocity of combustion chamber (ω)

Figure 3 showed the effect of the rotating velocity of combustion chamber (ω) on the inlet temperature (T_{in}) and the exit temperature (T_{exit}) of the combustion chamber. The condition studied in the experiment were the fuel load input rate (Q_F) of 2.3 kg/h, the air flow rates (Q_A) of 40 m^3/h, the porous absorber thickness (H) of 4.2 mm and the porosity (ϕ) of 0.82. It was found that the trend of T_{in} (x = 0 cm) was average of 40-45ºC. As for the T_{exit} (x = 40 cm), it was increased with ω increasing from 0.5 to 1 rpm, but when the ω become increased to 1.5 rpm, it was found that a T had a downward trend. This phenomenon can be explained that when ω was too high, solid fuel (rice husk) was expelled from the combustion chamber, enabling rapid time to react less insufficient fuel combustion. Which was consistent to ω increasing of carbon monoxide (CO) in Figure 4. As increasing, the level of NO$_X$ was quite low as increasing ω and was in the range not over 40 ppm. Similar phenomena of thermal NO$_X$ process had also been found in the literature [9]. Figure 5 shows the effect of the ω on the combustion efficiency (η_C). The highest η_C of an average of 93.7% was achieved at ω = 1 rpm.
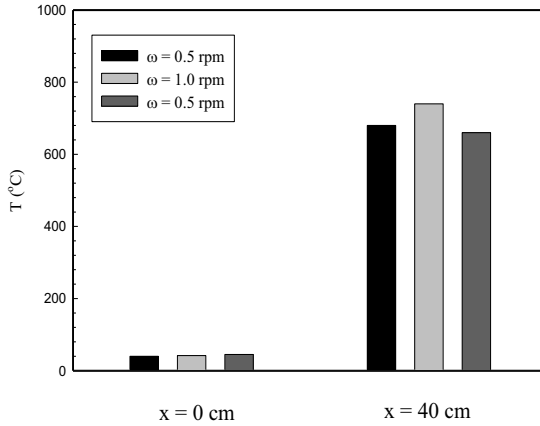
Fig. 3. Effect of the rotating velocity of combustion chamber (ω) on the temperature (T).
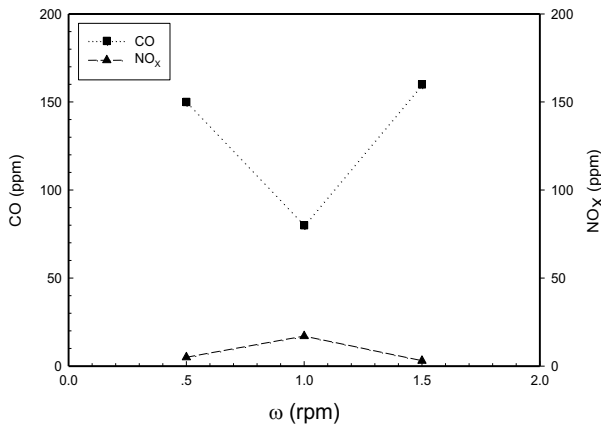
**Fig. 4.** Effect of the rotating velocity of combustion chamber (ω) on the content of exhaust gas (CO and NO$_X$).

**Fig. 5.** Effect of the rotating velocity of combustion chamber (ω) on the combustion efficiency (η$_c$).
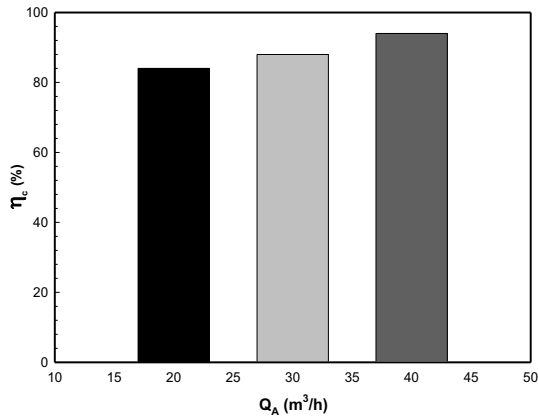
3.2 Effect of the air flow rates (Q$_A$)

Figure 6 showed the effect of air flow rates (Q$_A$) on the T$_{in}$ and T$_{exit}$. The condition studied in the experiment was the fuel load input rate (Q$_F$) of 2.3 kg/h, H = 4.2 mm and (ϕ) = 0.82. It was found that the trend of the T$_{in}$ (x = 0 cm) was in average of 40-45°C. T$_{exit}$ (x = 40 cm) was increased as increasing Q$_A$ from 20 to 40 m^3/h owing to because the fractional mixture between a fuel (rice husk) and the air was improved and sufficient for mechanisms of combustion leading to CO was decreased as shown in Figure 7. Similar results were also found in the literature [9]. The level of NO$_X$ was quite low as increasing Q$_A$ and was in the range not over 40 ppm. Similar phenomena of thermal NO$_X$ process had also been found in the literature [9]. Figure 8 showed that the η$_C$ was increased slightly with Q$_A$.
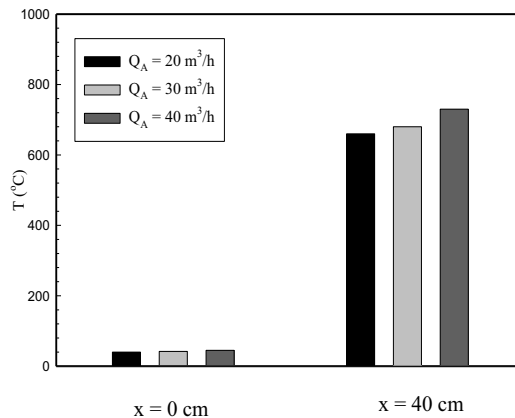
Fig. 6. Effect of the air flow rates (Q$_A$) on the temperature (T).
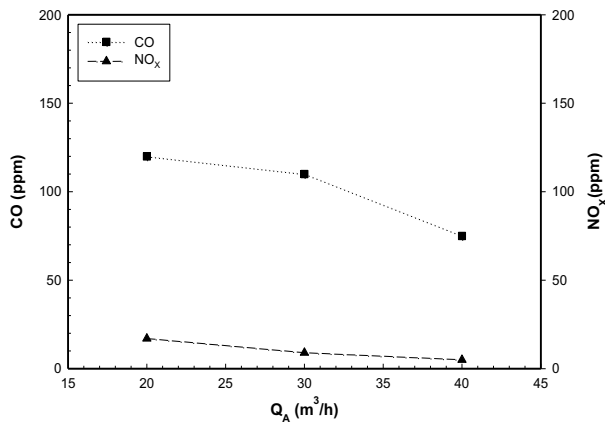

**Fig. 7.** Effect of the air flow rates (Q$_A$) on the content of exhaust gas (CO and NO$_X$).

Fig. 8. Effect of the air flow rates (Q_A) on the combustion efficiency (η_c).
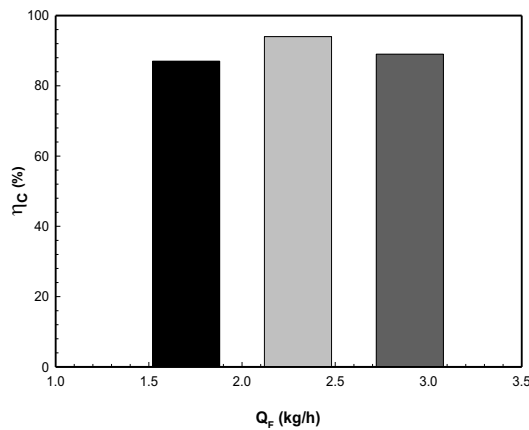
3.3 Effect of the fuel load input rate (Q_F)

Figure 9 showed the effect of the fuel load input rate (Q_F) on the T_{in} and T_{exit}. The condition studied in the experiment was the fuel air flow rate (Q_A) of 40 m³/h, H = 4.2 mm, ϕ = 0.82. The trend of T_{in} (x=0 cm) was in average of 40-45°C. The maximum T_{exit} (x = 40 cm) was appeared at Q_F = 2.3 kg/h. Similar results were also found in the literature [9]. However, the T was lower for Q_F = 2.9 kg/h due to Q_F was too high resulting to fuel can not burnt almost. Additionally, the amount of CO and NO_X were shown in Figure 10. The minimum CO was yielded at Q_F of 2.3 kg/h. The level of NO_X was quite low as increasing Q_F and was not over 40 ppm. Figure 11 showed the effect of Q_F on the η_C. The η_C was in the range of 93-95%.
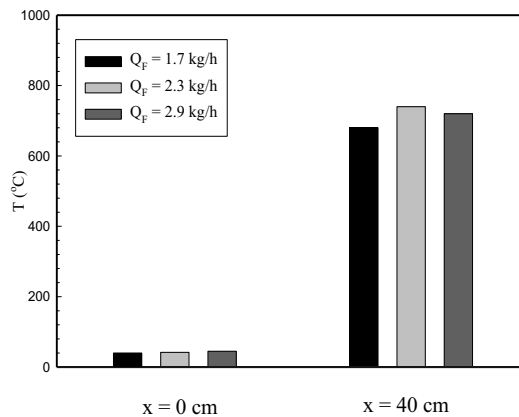
Fig. 9. Effect of the fuel load input rate (Q_F) on the temperature (T).
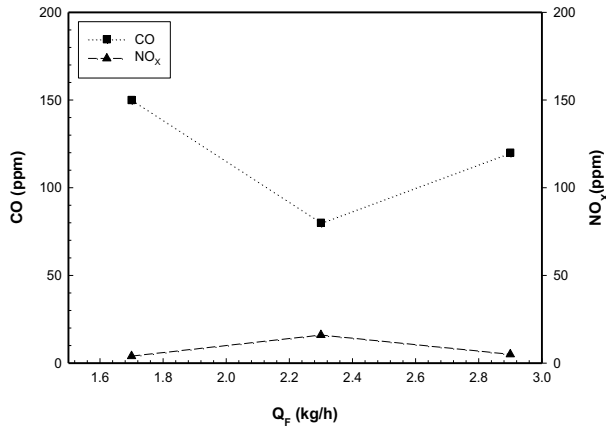
Fig. 10. Effect of the fuel load input rate (Q_F) on the content of exhaust gas (CO and NO_X).

Fig. 11. Effect of the fuel load input rate (Q_F) on the combustion efficiency (η_c).

4 Conclusions

1. The trend of T_{in} (x = 0 cm) was in average of 40-45ºC. T_{exit} (x = 40 cm) was maximum at ω = 1.0 rpm in the examined range of 0.5-1.0 rpm. T_{exit} had a downward trend of T_{in}. The CO was minimum at ω = 1.0 rpm and the NO_X was quite not changed (not over 40 ppm). The maximum η_C gave 93.7% at ω = 1.0 rpm.

2. The trend of T_{exit} (x = 40 cm) and η_C were increased with Q_A from 20 to 40 m^3/h. The CO was decreased with Q_A increasing and the NO_X was quite not changed.

3. The maximum T_{exit} (x = 40 cm) was appeared at Q_F = 2.3 kg/h in three examined cases $Q_F \geq$: 1.7, 2.3 and 2.9 kg/h. The minimum CO contented for Q_F = 2.3 kg/h but the NO_X was very little changed. The η_C was in the range of 93-95%.

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