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Study on Micro-cogeneration System with Biomass Briquette in Mongolia

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Abstract: In Mongolia, approx. 200,000 herder families are breeding the livestock for their livings. Nearly half of them are not able to use the energy in proper or sustainable manner yet. Both the herd population and number of domestic animals reach 70.0 million in Mongolia. It is assumed that the power demand for a typical herder family is around 10 to 20 kWh/day. In addition, there is a demand of heat for the herder families, especially in winter season. The herder family moves around for the fresh grass for their livestock. Therefore, they need to have a portable power supply source. There is an abundant biomass resource in their living circumstances. The 2.0 kW portable biomass micro-cogeneration systems were designed to supply electricity and heat to herder family. The residue of the biomass in the steppe emits greenhouse gas (GHG) indeed. It is necessary to use biomass as an energy source, especially for electricity to reduce emitting of the GHG.

Key words: Herder family, portable biomass micro-cogeneration system.

1. Introduction

Approximately, 200,000 herder families are breeding the livestock for their livings. Nearly half of them are not able to use the energy in proper or sustainable manner yet. Both the herd population and number of domestic animals reach 70.0 million in Mongolia [1]. The residue of the biomass in the steppe emits greenhouse gas (GHG) indeed [2]. The herder family is not a nomad. Usually the herders have a contract with their local administration office to own certain land to stay for each four seasons. At least they have four different places to stay for spring, summer, autumn and winter and move around to these four places during a year. The place for spring is called "*havarjaa*", for summer "*zuslan*", for autumn "*namarjaa*" for winter "*uvuljuu*" in Mongolian language.

The herder needs to move when livestock finish the grass at their staying area. They have to travel to somewhere for searching the grass even in the winter. If any grass is not available, the herder families have to move without permission from their local administration office. In this case they called "*otor*" meaning semi-nomadic life style.

The herder family stays in a GER which showed in Fig. 1. The GER is Mongolian ancient, traditional, round shaped accommodation. The GER is designed by flexible and light materials, and its inside is warm in winter season. The construction is strong for storm and easy to disassemble and assemble for transportation. There are several sizes of the GER and the *otor* is using the small one.

The average area of the GER is around 31.15 m^2; diameter is 6.2 m with 3 to 4 m at maximum height. According to the annual export report of the country, the number of GER which was exported abroad has been increasing year by year especially to Europe.

It is necessary to adapt reliable power source to supply electricity in their house. There are many kinds of renewable energies available in Mongolia. Total renewable energy potential for the power development is estimated at 300 GWh/year [3]. Most of the herder families are using solar PV as portable source of power

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Fig. 1 GER, Mongolian traditional house.

supply. Demand of electricity is high in winter season because sunshine time is short during the period. On the other hand, solar PV generates smaller amount of electricity in winter comparing to that generated in summer [4]. Therefore, considering the high demand of electricity and heat in winter, small scale of biomass co-generation system can be the most appropriate technology for them. There are lots of biomasses anywhere in the steppe land and herders collect them anytime even in winter.

Generally, the electricity demand for GER is around 10 to 20 kWh/day [5]. The main use of electricity is for lighting, TV and refrigerator. Table 1 shows the typical demand of GER.

2. Portable Biomass Gasification Micro-cogeneration System and Fuel

2.1 Apparatus

Fig. 2 shows schematic diagram of the portable biomass micro-cogeneration system for experiments. It includes gasifier, cyclone, filter, gas analyzer and petrol engine generator. The type of gasifier is downdraft and the temperature in the gasifier is recorded at the oxidation and reduction layers.

The volume of this gasifier is around 10 L and outer surface is covered by heat insulator. The 2000 VA, EG-2050D petrol engine generator was used for this experiment. Two valves are attached to control both the flow of air and produced gas into the engine.

2.2 Analysis of Biomass Briquette

The herder families use usually the cow dung for their heating and cooking in Mongolia. The calorific value and gas content of the cow dung briquette were completed at Tanzania Industrial Research and Development Organization (TIRDO). The result of proximate analysis is shown in Table 2.

The mixture ratio of the biomass in the briquette is as shown in Table 3. The first five samples include saw dust and it means saw dust group. The second five samples include coal and it means coal group.

The results of proximate analysis and ultimate analysis are summarized in Table 4.

2.3 Experiments on Produced Gas

The experimental tests on the biomass were carried out by using small updraft rocket stove. To produce the condition in gasifier, rocket stove was used in the experiments. Fig. 3 shows the experimental setup.

For the experiments, 10 briquette samples were prepared and dried. The moisture of the briquettes was around 11%. In the experiment, the briquette was heated with the wood in the stove. Around 100 g of the briquette was settled in the container. The container was put at the top end of rocket stove. Through the water sealing produced gas will be supplied into the gas analyzer.

Table 1 Average power demand of the *GER*.

	No.	Power (W)	Time (hour)	Energy consumption (Wh)
Lighting	2	80	16	1,280
TV	1	100	10	1,000
Refrigerator	1	200	24	4,800
Battery charger	1	100	10	1,000
Hot water boiler	1	1,000	5	5,000
Total	6	1,480.00		13,080

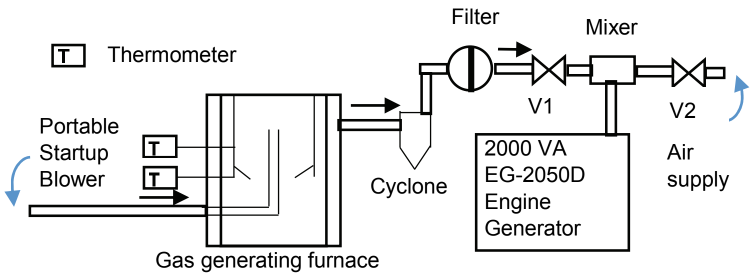

Fig. 2 The schematic diagram of the portable biomass micro-cogeneration system.

Table 2 Proximate analysis of cow dung.

Cow dung	Proximate analysis				GCV (gross calorific value)	
	M (%)	Ash (%)	VM (%)	FC (%)	kcal/kg	MJ/kg
1	14.77	30.76	51.82	2.65	2,342	9.80
2	6.39	21.28	50.10	22.23	4,713	19.74

Cow dung #1 is almost pure cow dung which was separated from wood pieces.
Cow dung #2 was delivered directly from the farm and it includes wood up to 50%.

Table 3 Biomass fraction in the briquette.

SN	Paper (%)	Saw dust (%)	Cow dung (%)
1	20	10	70
2	20	20	60
3	20	30	50
4	20	40	40
5	20	50	30
SN	Paper (%)	Coal (%)	Cow dung (%)
6	20	10	70
7	20	20	60
8	20	30	50
9	20	40	40
10	20	50	30

Table 4 Test result of the briquette.

S/N	Proximate analysis				GCV	Ultimate analysis		
	Mois (%)	VM (%)	Ash (%)	FC (%)	kcal/kg	C (%)	H (%)	S (%)
1	7.2	71.5	21.7	6.9	3,400.7	37.2	4.0	0.2
2	9.5	50.4	19.4	30.2	3,288.0	34.9	4.5	0.3
3	6.1	66.1	18.7	15.2	3,348.0	35.2	4.1	0.1
4	5.7	70.5	17.4	12.2	3,397.3	36.9	4.7	0.6
5	5.5	73.4	14.2	12.4	3,725.4	42.6	3.4	0.1
6	6.7	69.7	22.3	8.0	3,658.6	40.6	4.5	0.4
7	5.8	72.0	20.4	7.6	4,006.6	44.5	3.6	0.5
8	5.0	68.9	19.1	12.0	4,392.1	46.2	4.4	0.1
9	5.3	70.8	20.6	8.5	4,719.1	49.0	3.2	0.0
10	4.3	74.6	14.4	11.0	4,872.4	53.8	3.9	0.5

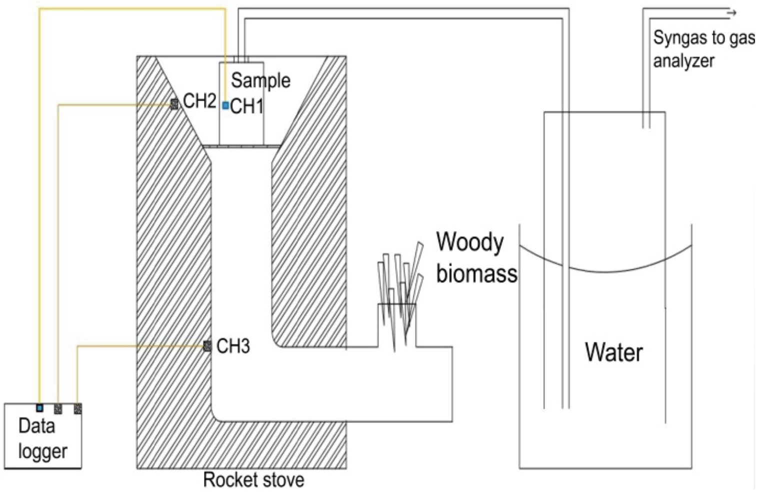

Fig. 3 Experimental setup.

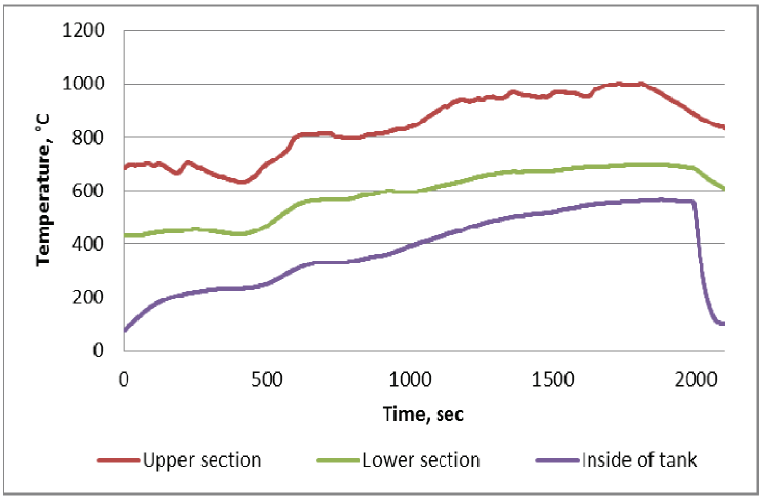

Fig. 4 Temperatures in the experiments.

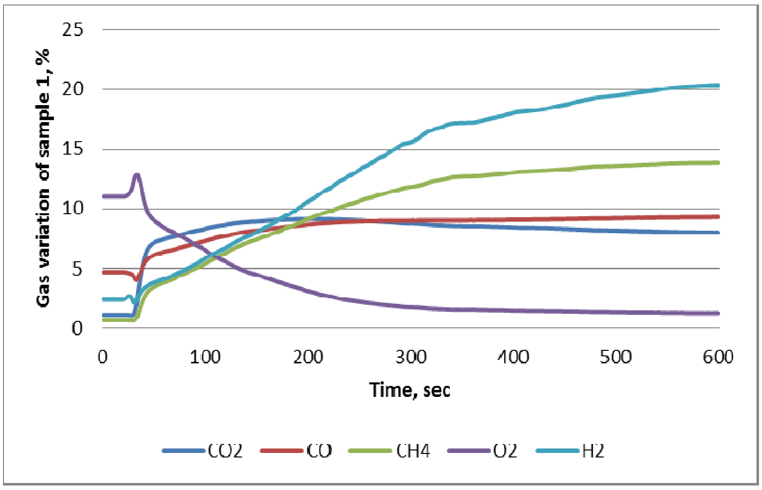

Fig. 5 Main gas variation in exhaust gas from tank.

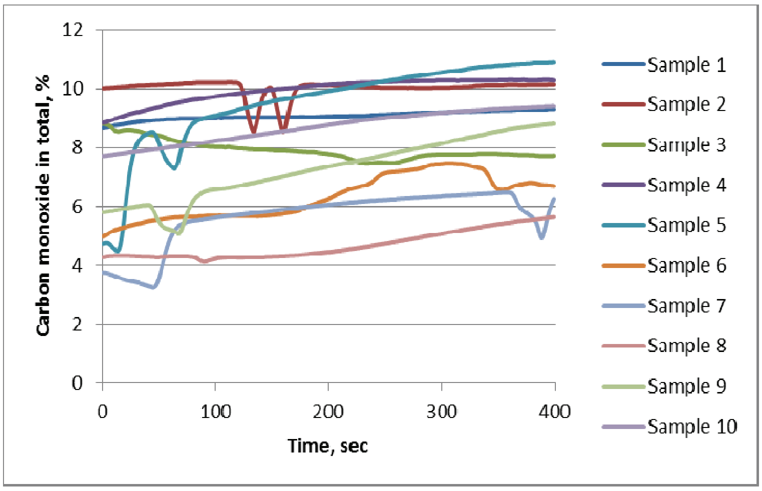

Fig. 6 Variation of CO by sample.

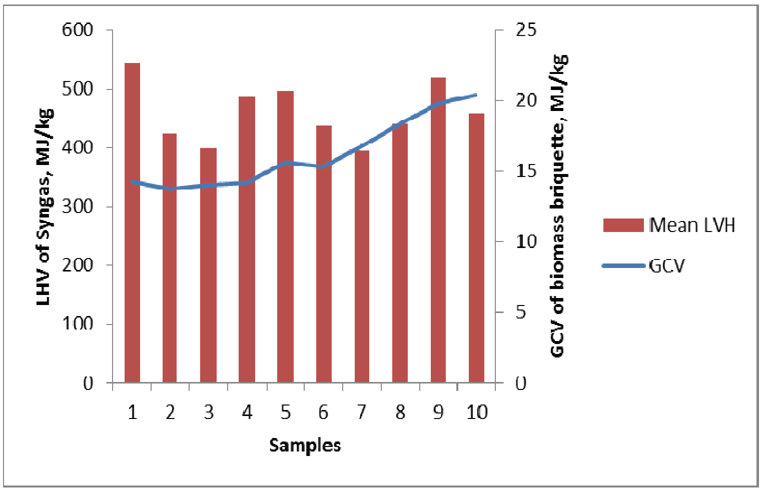

Fig. 7 Comparison of GCV and lower heating value (LHV) with each sample.

Fig. 4 shows the temperatures in the rocket stove. Average temperatures were 850 °C in upper section, 600°C in lower section and 400 °C in the tank respectively.

The main gas contents in the exhaust gas such as carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), oxygen (O_2) and hydrogen (H_2) were monitored by the gas analyzer. Fig. 5 shows the result of experiment with sample #1.

Content of the produced gas is different than the content of biomass briquette. The CO content becomes higher with increase of the ratio (%) of saw dust in the briquette as shown in Fig. 6. The briquette samples were prepared by two groups. One is paper, cow dung and saw dust and the other is paper, cow dung and coal. The result shows that the biomass briquette with coal produces CO lower than that with saw dust.

The LHV of syngas is varied for all 10 samples, but obviously the caloric value increases when the sample includes coal portion (Fig. 7).

3. Conclusions

The briquette samples were divided into two groups, one contains sawdust and one contains coal. The carbon monoxide content in the syngas produced from the briquette of sawdust group was higher than that of coal group. However, the calorific value of the coal group briquette was higher than that of saw-dust group.

In general, temperature of gasification for coal is higher than the temperature of gasification of wood.

Therefore, it seems that the differences come from the gasification temperature that made different calorific values syngas.

The average number of sunny day in Mongolia is over 300 days in a year. Currently, most of the herder families are using PV module for power generation. It is possible that the herder family may use PV module during day time and use biomass micro-cogeneration system during night and other days such as snowy, rainy etc. This micro-cogeneration system is suitable technology in the climate of Mongolia and for herder families.

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