

Study on Warming Piglet in Hog Farm by Combustion Heat Energy of Biogas

Ying-Jen Huang, Cheng-Chang Lien, and Jun-Han Mei

Abstract—The biogas in the hog house is the product of anaerobic fermentation from swine wastewater treatment process. It is a renewable energy with very good development potential. Its scope of utilization is versatile, including combustion heat generation, biogas power generation etc. Due to physical trait, the piglets in the pigsty of hog farm are easy to die by catching cold, so it is necessary to keep the pigsty warm, especially at cold weather in winter. The aim of this research is to develop and design a set of biogas combustion hot water system, which can be used to warm the piglets in hog farm. The inclined-type biogas combustion furnace can increase the heating efficiency of water upon combusting biogas. It is also convenient to clear the discard products in the biogas combustion furnace. The hot water can be pumped to the pigsty through the pipe, in order to increase the surface temperature of insulation brick. The piglets can lie on the insulation brick to keep warm, avoid suffering from the dysentery by catching cold. The experimental results show that the surface temperature of insulation brick will be increased with the temperature of hot water by starting the biogas combustion hot water system. Under $0.043 \text{ m}^3/\text{min}$ of hot water flow rate, when the temperature of hot water is 45°C , the surface temperature of insulation brick will be most suitable for piglets to lie on the insulation brick for keeping warm. This biogas combustion hot water system can be applied for keeping the piglets warm, which can be used to replace the traditional heat lamp, save the electric energy consumption, reduce the greenhouse gas emissions, meet the energy conservation and carbon reduction policy, and comply with the green renewable energy application.

Index Terms—Hog farm, biogas, piglet, hot-water heating system.

I. INTRODUCTION

The biogas is a gas generated from the anaerobic fermentation of organic substances by the microorganism in the nature, which is a kind of renewable energy for substituting the energy demand in the future. The main ingredient of biogas is methane, and its content is about 55~70% [1], [2]. The biogas can be used as renewable fuel for combustion heat generation, power generation or car fuel etc. [3], [4].

As for the swine wastewater treatment way in the hog farm of Taiwan, a three-step treatment system is used, which includes solid-liquid separation, anaerobic treatment, and aerobic treatment, and a large amount of biogas will be

produced in anaerobic fermentation treatment [5]. As for the biogas, each cubic meter of biogas is equivalent to 9.4 kWh of electric energy after purifying. The heat generated by biogas is about $20.8\text{--}23.6 \text{ kJ/m}^3$, so the combustion heat of biogas is very considerable. If the combustion heat of biogas is recycled for warming the piglets in hog farm, a great deal of electric energy can be saved. So it is feasible to apply the heat energy generated by the combustion of biogas, and it will be the future trend [6]–[10].

The newborn piglets need to live by the secreted milk of sows. However, the physical trait of sows cannot stand hot weather, and the physical trait of piglets cannot stand cold weather. The thermal environment of pigsty will influence the production performance of piglets. The temperature of pigsty is one of the most important variables [11]–[13]. In Taiwan, most hog farms adopt the heat lamp for warming the piglets. It has the advantages of easy to use, and low cost, but it is easy to be damaged and the electric energy consumption is great. In addition, the heat lamp is suspended highly above the feeding bed, the piglets crouch down to keep warm under the heat lamp. The range of keeping warm is only on the back of piglets. In order to let the piglets have more comfortable growth environment, the belly heating way can be adopted, namely building a bed made up by hot water pipe and brick for the hot water to pass through it to offer the heat source, so that the piglets can crouch down on it to get warm. By the way, the air temperature in the closed pigsty can also be increased through the convection effect, and the piglets can also be kept warm indirectly.

The aim of this research is to develop and design a set of biogas combustion hot water system, which can be used to warm the piglets in hog farm. The inclined-type biogas combustion furnace with hollow burning spaces and sleeve type with small water flow can increase the heating efficiency of water upon combusting biogas. It is also convenient to clear the discard products in the biogas combustion furnace. The simple water scrubbing and desulphurization are carried for the biogas generated in the hog farm first, and then enter into the biogas combustion furnace to heat water. The hot water is transported through the pipe to the insulation brick bed in the closed pigsty, so as to increase the insulation brick surface temperature. The piglets can crouch down on the insulation brick for keeping warm. This kind of insulation brick bed will not consume a lot of electric energy like heat lamp, and it will not influence the washing and cleaning of pigsty too. It not only can meet the energy conservation and carbon reduction policy, and comply with the green energy idea, but also can reduce the production cost, and increase the production efficiency of the piglets.

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II. MATERIALS AND METHODS

A. Experimental Materials

There are about 700 piglets raised in the hog farm for this experiment. The biogas used for this experiment is generated from the anaerobic fermentation process in a three-step swine wastewater treatment system. The study subjects are 30 - 50 days old of piglets used in this biogas combustion hot water system for warming piglets experiment.

B. Experimental Method

1) Biogas combustion hot water system

The inclined-type biogas combustion hot water furnace is adopted. The hot water furnace body is a hollow and sleeve type. The hollow part is the biogas combustion chamber, and a small amount of water flows in the sleeve. When the biogas is burnt, the combustion flame in the hollow part can raise the heating efficiency of water. A biogas burner is installed at low end of hot water furnace. The products of biogas combustion can be cleared conveniently after it is opened. The high end is the waste gas emission side after biogas combustion. In addition, there is automatic water replenishment equipment installed above the high end. A float device is used to supplement water in the sleeve of biogas combustion furnace automatically. In the biogas combustion heating process, in order to prevent the insufficient biogas or unable to start the biogas combustion furnace, an auxiliary electric heating device is added additionally, which makes the biogas combustion hot water system to run in the whole year.

When the hot water temperature is lower than the setting of hot water temperature, the steering valve will not be started, and the hot water in the combustion furnace is flowed to the steering valve, electric heater and frequency conversion motor (AEHL-BA, TECO, Taiwan) through the pipe. The flow meter (IPG14, GWF, Schweiz) is used to measure the flow rate of hot water. The hot water is transported to the insulation brick in the pigsty through the steel pipe for heat exchange, in order to increase the insulation brick surface temperature. The hot water after heat exchange is flowed back to the biogas combustion furnace for finishing the cycle. When the hot water temperature is higher than the setting of hot water temperature, the steering valve will be started, the recycled warm water from the pigsty will not be heated by the biogas combustion furnace, and the hot water is flowed to the steering valve, electric heater and frequency conversion motor through the bypass pipe directly, and the hot water reached setting temperature is sent to the pigsty for circulating. The average air temperature T_M in the pigsty is recorded to be regarded as the ventilation basis. The biogas combustion hot water system is illustrated in Fig. 1.

2) Hot water insulation brick

Fig. 2 illustrates the schematic diagram and actual diagram of hot water insulation brick on the high bed in the pigsty. There are insulation bricks made up of staggered steel pipe and brick installed on the high bed of pigsty with hot water flowing through them, which are used as the lying bed for warming the piglets. The bed surface in width is made of 5 insulation bricks and 4 hot water steel pipes. The left and right sides of steel pipe are attached by the insulation bricks

tightly. The insulation brick bed surface is 71 cm wide. The width of bed surface can meet the body length of piglet upon crouching down. The top of hot water steel pipe is covered the cement, to prevent the scalding of piglet's belly from touching hot water pipe directly. When the water is heated by the combustion of biogas, the hot water flows through the steel pipe and conducts heat to the bricks at both sides by the conduction way, to increase the surface temperature of insulation brick on the high bed. The brick material can have more uniform temperature, and the piglets crouch down on the insulation brick for keeping warm in the pigsty.

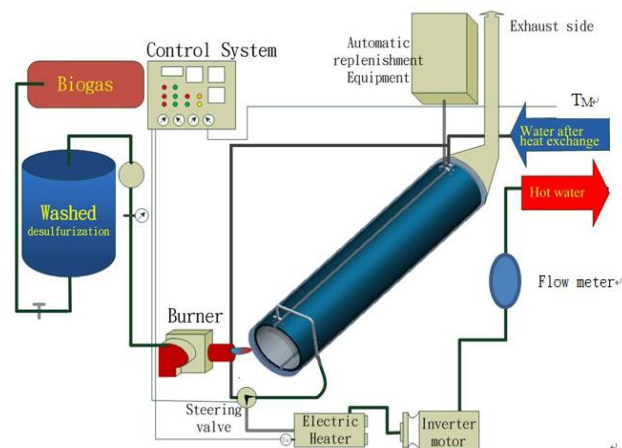
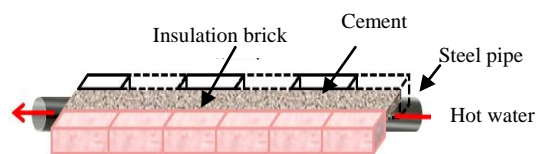


Fig. 1. Schematic diagram of the biogas combustion hot water system.



(a) Schematic diagram (b) Actual diagram
Fig. 2. Schematic diagram and actual diagram of hot water insulation brick on the high bed in the pigsty.

3) Experimental steps

The field test is carried out from p.m. 4 to a.m. 9 for the biogas combustion hot water system. The thermocouple temperature recorder (U10-003, HOBO®, USA) with thermocouple temperature probe (UX120-014M, HOBO®, USA) is used to measure and record the temperature of hot water passes in and out the steel pipe, the surface temperature of insulation brick, and the air temperature at different places in the pigsty. The experimental planning is described as follows. Three air temperature sensing recorders are suspended above 90 cm away from the high bed in the pigsty, in order to avoid being destroyed by the piglets. The air temperature and humidity at front section, middle section and back section are measured respectively, as shown in Fig. 3. The thermocouple temperature recorder with thermocouple temperature probe is installed on the insulation brick. Four measurement points are set at the top of hot water passes in and out the steel pipe as well as at both sides of insulation brick surface, in order to measure the temperature of hot water passes in and out the steel pipe, and the insulation brick surface temperature change, as shown in Fig. 4. The surface temperature of piglet's belly was measured by infrared thermometer, as shown in Fig. 5 [14].

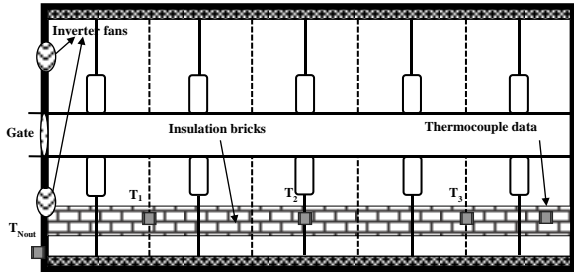


Fig. 3. Positions for installing temperature sensors on insulation brick bed surface.

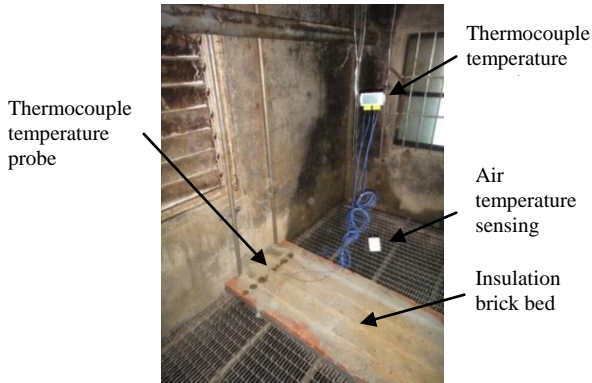


Fig. 4. Installing thermocouple temperature recorder on insulation brick bed surface.



Fig. 5. Measuring the surface temperature of piglet's belly by infrared thermometer.

III. RESULTS AND DISCUSSIONS

The flow rate of hot water is $0.043 \text{ m}^3/\text{min}$. The temperature of hot water T_{water} is set at 40, 45 and 50°C , respectively. The biogas combustion hot water system is started and closed at a specific time period, the air temperature T_{Nout} of outside pigsty, the air temperature $T_M = (T_1 + T_2 + T_3)/3$ of inside pigsty, and the surface temperature of insulation brick $T_B = (T_{\text{Bin}} + T_{\text{Bout}})/2$ are measured at different trial day and under different hot water temperature T_{water} , as shown in Fig. 6. From March 6 to March 8 and March 12, the temperature of hot water T_{water} is set at 40°C . But from March 9 to March 11 and March 13, the temperature of hot water is set at 50°C , because it is comparatively cold at the outside of pigsty. It is known that the air temperature is highest at noon of 12 o'clock, and the air temperature is lowest at a.m. 1-2 every day outside the pigsty. The change of air temperature T_M over time every day is not significant inside the pigsty, and has small change between $25\text{--}28^\circ\text{C}$. It shows that the change of air temperature T_M inside pigsty is quite small and stable. In addition, it can

be seen that when the setting of temperature of hot water T_{water} is higher, the surface temperature of insulation brick T_B is also higher from the figure.

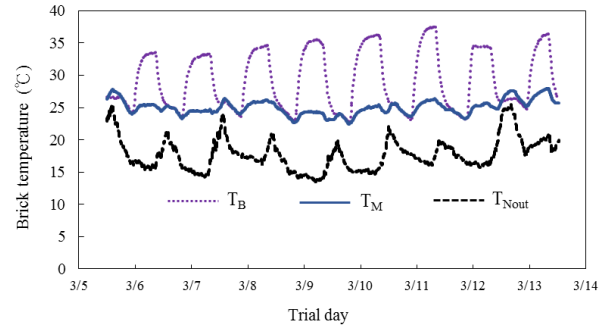


Fig. 6. The typical the air temperature T_{Nout} of outside pigsty, the air temperature T_M of inside pigsty, and the surface temperature of insulation brick T_B at different trial day and under different hot water temperature.

TABLE I: CHANGE OF INSULATION BRICK SURFACE TEMPERATURE T_B BY USING DIFFERENT HOT WATER TEMPERATURE IN HOG FARM

$T_B^1 (^\circ\text{C})$	$T_{\text{water}} (^\circ\text{C})$		
	$40 \pm 1^\circ\text{C}$	$45 \pm 1^\circ\text{C}$	$50 \pm 1^\circ\text{C}$
Total of trial day	9	9	9
Mean ² ($^\circ\text{C}$)	33.4^c	34.3^b	36.3^a
std. ($^\circ\text{C}$)	0.7	0.7	0.7
$T_{\text{Nout}} (^\circ\text{C})$	15.4^a	15.0^a	16.4^a

$$^1 T_B = (T_{\text{Bin}} + T_{\text{Bout}})/2$$

² Mean with different superscripts in the same row are significantly different ($P < 0.05$), using the Scheffe test.

TABLE II: STATISTICAL DATA FOR EPIDERMIS TEMPERATURE ON BELLY OF PIGLETS WITH DIFFERENT DAYS OLD IN HOG FARM

$T_{\text{pig}} (^\circ\text{C})$	Days old of piglet		
	50	42	30
n	29	18	17
Mean ¹ ($^\circ\text{C}$)	35.1^a	35.2^a	35.4^a
std. ($^\circ\text{C}$)	0.6	0.6	0.8

¹ Mean with different superscripts in the same row are significantly different ($P < 0.05$), using the Scheffe test

From Table I, it can be seen when the temperature of hot water T_{water} is set at 40, 45 and 50°C , the corresponding surface temperature of insulation brick is 33.4, 34.3 and 36.3°C , respectively. There is significant difference between the temperature of hot water and the surface temperature of insulation brick. The surface temperature of insulation brick will be increased with the temperature of hot water. The statistical data for epidermis temperature on belly of piglets with different days old in hog farm are shown in Table II. The epidermis temperatures on belly of 32, 42 and 50 days old of piglets are 35.1°C , 35.2°C and 35.4°C , respectively. There is no significant difference between the days old and the epidermis temperature on belly for piglets. The suitable surface temperature on the insulation brick for warming piglets should close and not exceed the epidermis temperature on belly of the piglet. After analysis and comparison, the best temperature of hot water T_{water} should be 45°C for the piglets to crouch down for keeping warm. The activity situation of piglets in pigsty with or without starting the biogas

combustion hot water system at different time periods is shown in Fig. 7. It can be observed when the biogas combustion hot water system is started at night, all the piglets will crouch down on the insulation brick for keeping warm, the hot water system display the warm keeping effect of insulation bricks.



(a) Without starting at daytime



(b) With starting at night

Fig. 7. Activity situation of piglets in pigsty with or without starting the biogas combustion hot water system at daytime and at night.

IV. CONCLUSION

When the flow rate of hot water is $0.043 \text{ m}^3/\text{min}$ and the temperature of hot water is set at $40, 45$ and 50°C , the field test is carried out at different time period with or without starting the biogas combustion hot water system. From the test result, it shows that although the air temperature of outside pigsty is significantly varied with time every day, the change of air temperature of inside pigsty is quite small and stable. When the air temperature of outside pigsty is lower, the biogas combustion hot water system is started to maintain the air temperature of inside pigsty at $25\sim 28^\circ\text{C}$. When the biogas combustion hot water system is started and the temperature of hot water is set at $40\sim 50^\circ\text{C}$, the surface temperature of insulation brick will be increased to $33.4\sim 36.6^\circ\text{C}$. The surface temperature of insulation brick will be increased with the hot water temperature. When the hot water temperature is 45°C , the corresponding surface temperature of insulation brick is most suitable for the piglets to crouch down for keeping warm.

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