Energy Balance Analysis for Integrated Energy Production System from Water Hyacinth Operated with no Electricity Supply

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Abstract. The aims of this paper are to investigate the energy balance on an integrated energy production system using water hyacinth as biomass fuel with no electricity supply to the system. The conceptual framework of the present study is to use water hyacinth as primary energy source input into gasifier through the gasification process. The producer gas produced will be used as energy input to drive the other parts of the system that be connected with the gasifier. The integrated energy production system comprise of three main parts such as (1) collection system of fresh water hyacinth from canal or river (2) briquetting system of water hyacinth and (3) gasification system using briquetted water hyacinth as biomass fuel. Based on the concept of the system that will be operated with no electricity supply to the system, thus every engines of the production system will be driven with the producer gas. The investigation was conducted based on the calculation of energy balance in the system. The calculation results based on the average value of biomass gasification rate showed that the gasifier with the capacity of 100 kg/hr can produce the producer gas at the rate of 300 m³/hr. And the total amount of the producer gas required to operate the engines installed within the system are 165.75 m³/hr in which equivalent with the amount of briquetted water hyacinth around 55 kg/hr. Thus from the energy balance analysis found that the producer gas produced from the gasifier with the capacity of 100 kg/hr can supply the energy to drive all engines installed at the site. Moreover there are the extra amount of water hyacinth briquettes produced from the system around 45 kilogram per hour.

1. Introduction
Water hyacinth is considered as a highly invasive aquatic weed, infecting dam, lakes and irrigation channels in most tropical and subtropical regions. One major problem associated with water hyacinth is its rapid growth rate [1]. It can easily adapt and compete with other aquatic plants causing a major threat to the aquatic environment. The utilization of water hyacinth is crucial need to solve those problems. There are various technologies for energy utilization from water hyacinth such as biogas production through anaerobic digestion, briquetted water hyacinth production through briquetting process, producer gas production through gasification process and etc. [2]. In case of using the technology of thermochemical conversion process for water hyacinth, the gasification should be suitable according to water hyacinth has high moisture content. Also the water hyacinth for gasification process should be briquetted to increase the density and reduce the moisture content from
fresh water hyacinth [3]. Thus, the aims of this research to study the producer gas production through gasification process by using briquetted water hyacinth as biomass fuel. In order to decrease the management cost for energy utilization from water hyacinth, the onsite energy production system to run along the canal or river is proposed. To complete the onsite energy production system, the energy or electricity required to supply for running the whole processes of each parts in the system will be produced from water hyacinth.

2. Conceptual framework for energy utilization from water hyacinth
The concept framework for energy utilization from water hyacinth based on gasification process is the producer gas produced from briquetted water hyacinth will be used as the main energy source to drive for every parts of the system with no need the energy or electricity required from outside. The conceptual framework of this study showed in figure 1.

Figure 1. The conceptual framework.

3. Energy balance analysis
The energy balance analysis for energy production system is essential to analyze how much the energy required for each sub process so that the researcher can approximate the optimum capacity of the system that meet the requirement and to plan and understand to operate the project completely. Based on the conceptual framework for integrated energy production system by using water hyacinth as biomass fuel to produce the producer gas and use the producer gas produced to supply for each sub process. The energy balance will consider from energy required for demand side and supply side. For energy required for supply side will consider based on the gasification rate from briquetted water hyacinth and the energy required for demand side will consider from the producer gas required to drive the engine that be used for the whole system in which comprise of eight processes.
3.1. Energy required for demands side

The energy required for demand side will consider from the producer gas required to drive the engine that be used for the whole system in which comprise of eight processes such as (1) the producer gas required to drive the engine for moving the boat. (2) the producer gas required to drive the engine for collecting WH from the river/canal. (3) the producer gas required to drive the engine for driving the conveyor belt to carry WH from the boat. (4) the producer gas required to drive the engine of the squeezing machine. (5) the producer gas required to drive the engine for chopping WH. (6) the producer gas required to drive the engine for briquetting. (7) the producer gas required to drive the blower for gasifier. (8) the producer gas required for drying process. For the energy balance analysis to calculate the amount of producer gas required for driving the engine will present respectively.

The energy balance analysis to calculate the amount of producer gas required for driving the engine for boat, starting with calculation of the power input required to drive the engine as the detail showed in table 1.

Table 1. Energy balance for driving the engine for sailing the boat.

| Engine for driving boat | Engine power (hp) | Engine Power (kW) | Efficiency (%) | Power input Required (kW) |
|-------------------------|-------------------|-------------------|----------------|--------------------------|
| 3.5                     | 2.61              | 15.63             | 16.7           |

From the results in table 1 showed that for the engine with the rated power of 3.5 hp and the efficiency of 15.63%, the power input required to run the engine properly is equal to 16.7 kW. The energy balance at the engine for driving the engine for driving the boat showed in figure 2.

Figure 2. Energy balance at the engine for driving the boat.

The amount of producer gas required for driving the engine for driving the boat showed in table 2. The result showed the amount of producer gas required for driving the engine is 17.28 m³/hr.

Table 2. The amount of produce gas required for driving the boat.

| Producer gas required for driving the boat | Power input required (kW) | Energy per hour (MJ/hr) | Heating value of producer gas (MJ/m³) | Producer gas required (m³/hr) |
|------------------------------------------|---------------------------|-------------------------|--------------------------------------|-----------------------------|
|                                          | 16.7                      | 60.12                   | 3.48                                 | 17.28                       |

Considering from the whole sub process found that for the process 1 to 5 and the process 7 will use the engine at same power rated. Thus the amount of the producer gas required for the process that be stated above will be 17.28 m³/hr.

The energy balance analysis to calculate the amount of producer gas required for driving the engine for briquetting, starting with the calculation of the power input required to drive the engine as the detail showed in table 3.
Table 3. Energy balance for driving the engine for sailing the boat.

| Engine power (hp) | Engine Power (kW) | Engine Efficiency (%) | Power input required (kW) |
|-------------------|-------------------|-----------------------|--------------------------|
| 6.5               | 4.85              | 15.63                 | 31.03                    |

From the results in table 3 it showed for the engine with the rated power of 6.5 hp at the efficiency of 15.63%, the power input required to run the engine properly is equal to 31.03 kW. And from the power input required can calculate the amount of producer gas required for driving the engine of briquetting. The amount of producer gas required for driving the engine is 32.10 m³/hr as the results showed in table 4.

Table 4. The amount of produce gas required for driving the engine for briquetting.

| Power input required (kW) | Energy per hour (MJ/hr) | Heating value of producer gas (MJ/m³) | Producer gas required (m³/hr) |
|---------------------------|-------------------------|--------------------------------------|-----------------------------|
| 31.03                     | 111.71                  | 3.48                                 | 32.10                       |

The amount of producer gas required for drying process of water hyacinth was calculated based on the assumption to reduce the moisture in briquetted water hyacinth from 40% to 15% and enthalpy of vaporization is 2.675 MJ/kg. Thus the energy required for drying process is 17.06 kW and then the producer gas required for drying process was calculated as the results showed in table 5.

Table 5. Producer gas required for drying process.

| Power input required (kW) | Drying efficiency % | Power input required (kW) | Energy per hour (MJ/hr) | Heating value of producer gas (MJ/m³) | Producer gas required (m³/hr) |
|---------------------------|---------------------|---------------------------|-------------------------|--------------------------------------|-----------------------------|
| 17.06                     | 60                  | 28.43                     | 102.35                  | 3.48                                 | 29.41                       |

From the amount of the producer gas required for driving the engine from the sub process 1 to 8 as showed above. The total amount of producer gas required and the amount of briquetted water hyacinth required based on the calculation with the specific gasification rate for biomass is 3 m³/kg. The amount of producer gas required to drive all the engines for eight sub processes and the amount of briquetted water hyacinth required for producer gas production in each sub process showed in table 6.

Table 6. The amount of producer gas required to drive all the engines for eight sub processes and the amount of briquetted water hyacinth required for producer gas production in each sub process.

| Process | Detail | Producer gas required (m³/hr) | Briquetted water hyacinth required (kg/hr) |
|---------|--------|------------------------------|------------------------------------------|
| 1       | drive the engine for moving the boat. | 17.28 | 5.76 |
| 2       | drive the engine for collecting WH   | 17.28 | 5.76 |
| 3       | drive the engine for driving the conveyor belt to carry WH from the boat. | 17.28 | 5.76 |
| 4       | drive the engine of the squeezing machine | 17.28 | 5.76 |
| 5       | drive the engine for chopping WH     | 17.28 | 5.76 |
| 6       | drive the engine for briquetting     | 32.10 | 10.7 |
| 7       | drive the blower for gasifier        | 17.28 | 5.76 |
| 8       | drying process                       | 29.41 | 9.8 |
| Total   |                                  | 156.19 | 55.06 |
3.2. Energy for supply side

Energy for supply side will consider from the production rate of briquetting machine in which it has the capacity of 100 kg/hr. Based on the gasification rate of biomass is 3 kg/m³, can calculate the amount of the producer gas produced at the supply side. The results showed that the input energy from supply side produced from 100 kg/hr of water hyacinth can produce the producer gas with the amount of 300 m³/hr as the results showed in table 7.

| process     | Biomass Input | Biomass gasification rate | Producer gas produced | Equivalent with WH briquetting |
|-------------|---------------|---------------------------|-----------------------|-------------------------------|
| gasification| 100 kg/hr of WHB | 3 kg/m³                   | 300 m³/hr             | 100 kg/hr                     |

3.3. Energy balance of the energy production system from water hyacinth

Considering from the energy required for the demand and supply side, the energy balance of the energy production system from water hyacinth can calculated as showed in table 8. Thus from the energy balance analysis found that the producer gas produced from the gasifier with the capacity of 100 kg/hr can supply the energy to drive all the engines installed at the site. Moreover there are the extra amount of water hyacinth briquettes produced from the system around 45 kilogram per hour.

| Input energy from supply side (m³/hr) | Output energy from demand side (m³/hr) | Energy balance (m³/hr) | Net briquettled WH (kg/hr) |
|---------------------------------------|----------------------------------------|------------------------|---------------------------|
| 300                                   | 156.19                                 | 134.81                 | 45                        |

4. Conclusion

Based on the concept of the system that will be operated with no electricity supply to the system, thus every engines of the production system will be driven with the producer gas. The investigation was conducted based on the calculation of energy balance in the system. The calculation results based on the average value of biomass gasification rate of 3 m³/kg showed that the gasifier with the capacity of 100 kg/hr can produce the producer gas at the rate of 300 m³/hr. And the total amount of the producer gas required to operate the engines installed within the system are 165.75 m³/hr in which equivalent with the amount of briquetted water hyacinth around 55 kilogram per hour. Thus from the energy balance analysis found that the producer gas produced from the gasifier with the capacity of 100 kg/hr can supply the energy to drive all engines installed at the site. Moreover there are the extra amount of water hyacinth briquettes produced from the system around 45 kilogram per hour.

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