Evaluating the energy potential of gas synthesis obtained from the destruction and gasification of hazardous hospital waste with a melting-plasma reactor

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Abstract

The gasification process of hospital waste, unlike traditional methods such as sterilization and burying waste and conventional incineration, has the ability to use the resulting synthetic gas to produce power and electricity in addition to satisfying environmental standards. In this article, the biomedical wastes of Farhikhtegan Hospital in Tehran were gasified with a molten-plasma gasifier reactor that has a 90 kW torch. Three parameters of equivalence ratio, temperature and gasification factor are considered to be effective factors on the molten-plasma gasification reactor, by keeping equivalence ratio parameters and gasification factor fixed, the gasification process was carried out at different temperatures for the gasification reactor and the gas synthesis resulting from It was analyzed elementally and the percentage of gases that make up gas synthesis includes; CO, H_2, CO_2 and CH_4 were determined. At the temperature of 1400 °C, the amount of CO and H_2 gases were measured as 37.1% and 32%, respectively, and at this temperature, the high heat value (HHV) of the gas synthesis mixture was 9.635 MJ/kg. Also pollutants such as; H_2S, NO_2 and SO_2 were observed in a very small amount in gas synthesis analysis. In the second phase of this research, the thermodynamic equilibrium modeling of the gasification process of this waste was investigated with Aspen Plus software in the temperature range of 1000 to 1800 °C. All gasification sub-processes including; Drying, pyrolysis, partial combustion and regeneration were modeled in equilibrium with the modules in the software. The results of this modeling of the gasification process were in very good agreement with the experimental results. And the next part of the gasification model was combined with the heater turbine, to check the amount of available electricity.

Keywords

syngas, renewable energy, gasification, hospital waste, Aspen Plus

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1. Introduction

According to a report announced by the Basel Convention in 1989, production waste in hospitals is classified as hazardous waste due to its potential to cause disease [1]. According to the announcement of the World Health Organization (WHO), by 2015, 2 million people were infected with hepatitis C and about 260 thousand people were infected with AIDS due to accidental exposure to infectious diseases [2]. In recent years, the plasma gasification method has been associated with stunning developments, and more attempts have been made to use this technology to destroy hazardous waste [3]. Gasification is a thermochemical process, in which solid fuel (here hospital waste) is converted into synthesis gas through partial oxidation at high temperatures, usually (800-900°C) [4]. The gasification process includes four sub-processes including drying, pyrolysis, partial combustion and reforming [5].

In this article, the synthetic gas from the destruction and gas waste of the hospital of Tehran Hospital was analyzed in PGM[2] reactor. Subsequently, using the Aspen Plus software and equilibrium thermodynamic model based on the minimum Gibbs energy modeling, combined with a turbine to determine the amount of electricity available from 1000m^3 of syngas at different operating temperatures.

2. Methodology

The PGM reactor of this research belongs to the Plasma Physics Research Center of Islamic Azad University. This reactor consists of air compressor, control room, electrical system, control system, feed supply system, contamination filters, jet fan, water source and insulation and cooling system. mass of flow is 100 kg/h inlet feed flow and the flow of the inlet air to the reactor is 60 liters per minute. The diameter of the gas column is 1.1m. The gas temperature is adjustable in the range of 1000 to 1800°C. And the temperature of the pyrolysis is 400°C. To achieve sustainable functioning conditions, the device requires 5 hours before.

Synthesis gas output from PGM reactor was analyzed and analyzed by three different methods. CO_2, O_2, NO, NO_2, CH_4, H_2S and SO_2 gases were analyzed and checked with the MRU VARIO PLUS device. N_2 and H_2 were collected in a Tedlar bag with a vacuum pump and analyzed and analyzed in the laboratory with a gas chromatography (GC) device from the Agilent brand, model 6860. CO was also analyzed and analyzed with FANPAYA device after dilution.

[2] Plasma Melting Gasifier (PGM)

Figure 1. PGM reactor of the current research

For the gasification process, parameters such as reactor pressure and temperature, feed type, feed particle size, residence time, equivalence ratio (ER), gasification agent, and catalyst can affect the gasification process [6]. In this study, only temperature will be a variable parameter and the gas synthesis composition will change based on it.

For the gasification process, parameters such as reactor pressure and temperature, feed type, feed particle size, residence time, equivalence ratio (ER), gasification agent and catalyst are effective on the gasification process [7]. In general, the gasification process and the quality of the resulting synthetic gas are also measured with things like gasification efficiency, cold gas efficiency (CGE) and high heat value (HHV) [8]. The HHV parameter for the resulting synthetic gas is defined as equation 1.

$$HHV_{Syngas} = 12.75[H_2] + 12.63[CO] + 39.43[CH_4] + 63.43[C_2H_4] \quad (1)$$

In this regard, [-] species concentration is in terms of molar ratio and HHV is in terms of kJ/kg.

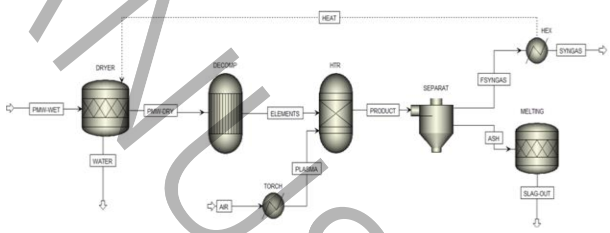

Figure 2. Modeling flow sheet in Aspen Plus software

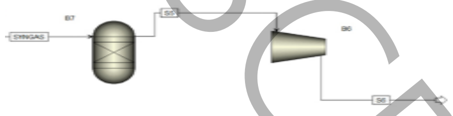

Figure 3. Power generation modeling flowchart in Aspen Plus software

3. Results and Discussion

Table 1. Analysis and investigation of gas synthesis at different temperatures

Gas	1000℃	1400℃	1800℃
CH_4(%)	1.07	1.19	1.64
H_2(%)	36.20	37.10	40.40
CO_2(%)	10	9.25	7.20
CO (%)	31	32	36
N_2(%)	20.85	18.50	14.05
Sum (%)	99.12	98.04	99.27
HHV (kJ/kg)	8805	9635	10497

Table. 4 Analysis and investigation of pollutants at different temperatures

Gas	1000℃	1400℃	1800℃
O_2 (ppm)	43	26	18
H_2S(ppm)	1	4	2
NO_2(ppm)	17	11	17
NO (ppm)	26	20	13
SO_2 (ppm)	6	4	1

Table 1. Results of numerical modeling

Temp (℃)	LHV (kJ/kg)	HHV (kJ/kg)	Power (MW)
1000	9.361	8.567	6.2554
1100	9.579	8.756	6.3941
1200	9.883	9.042	6.5903
1300	10.278	9.406	6.8509
1400	10.772	9.860	7.1577
1500	11.371	10.414	7.4879
1600	12.085	11.075	7.8536
1700	12.924	11.853	8.2569
1800	13.902	12.761	8.7187

4. Conclusions

The most important results of this study:

1- The H_2 gas forming the mixture exiting from the reactor at temperatures of 1000, 1400 and 1800℃ has occupied the values of 36.20%, 37.10% and 40.40% by volume. It can be seen that the value of H_2 has taken an upward trend.

2- The CO gas that forms the mixture exiting from the reactor at temperatures of 1000, 1400 and 1800℃ has 31%, 32% and 36% by volume.

4- The amounts of polluting gases such as NO, NO_2, SO_2 and H_2S are in a very desirable level from the environmental point of view.

5- The experimental values of the calorific value of the produced synthetic gas at temperatures of 1000, 1400 and 1800℃ have been assigned the values of 8.805, 9.635 and 10.497kJ/kg, respectively, which is observed, the amount of HHV It has taken an upward trend. Of course, the fact that the resulting gas becomes more favorable as the temperature increases, alone cannot be the right criterion for making a decision, because operation at high temperatures requires higher electricity consumption by the plasma

6- Based on the modeling done by combining the gasification reactor with a power generation turbine, 1000 m^3 of synthetic gas produced in the range of 6.25 to 8.71*MW* of electricity can be obtained.

5. References

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