FABRICATION OF HYDROTHERMAL CARBONISATION PLANT FOR CARBONISATION OF MUNICIPAL SOLID WASTE

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Abstract. This research work presents the carbonization of the municipal solid waste (MSW) and cost analysis to establish its economic aspects. The hydrothermal carbonisation (HTC) is used to carbonise MSW, converting the biomass into a substance that resembles coal. A comparative analysis is also presented for the before and after carbonization of MSW samples. The HTC process of carbonization procedure is presented by considering the characteristics including duration, temperature, and pressure. The results reveals that the carbonization process of MSW is very much effective to reduce the CO2 emission and global warming.

1. Introduction

The hydrothermal carbonization (HTC) process converts biomass to coal in 12 hours by a chemical reaction that transforms natural wastes into coal [1]. For the treatment of biomass waste that generally contains moisture, two forms of treatment have been used: anaerobic and classic thermochemical processes. A significant amount of moisture content is normally present in municipal solid waste (MSW) and the sewage sludge [2]. The HTC method of carbonization has solved most of the issues connected with the previous chemical and anaerobic based methods. By reacting a substrate in a liquid water environment, solid enhanced carbon known as hydro char is produced, which is utilised in the burning of low-graded fossil coals [3]. HTC is a thermochemical conversion or pyrolysis process that has kindled many researchers for further enhancement due to its efficient conversion [4]. When compared to other process methods, HTC has considerable advantages, such as killing pathogens and other active components from pharmaceutical wastes. Similarly, by adopting the HTC technique of carbonization, greenhouse gas emissions can be considerably reduced. [5]. Figure. 1 shows the possible input materials for HTC.

The generation of micro-scale digester (MSD) and its disposal as land filling is a major source of pollution in the environment, owing to the discharged waste that results in land filling. MSD is a viable energy generation alternative that uses the biogas process to outsmart fossil fuels. Various researchers throughout the world have performed HTC studies to efficiently employ the MSD for energy production and coal-like product manufacture in impoverished nations [6-7]. Hydrocar fabrication can be utilised as an alternative material for next-generation nano-electronics devices in a variety of electronic products. [8-9]
2. Materials and Methods

The methodology of HTC process involves from waste collection to reactor function. Figure 2 depicts the HTC process for municipal solid waste [10]. The Reactor is prepared before the MSW wastes are loaded into it, and then the organic wastes and solid wastes are separated. When the wastes are put into the reactor, factors including pressure, temperature, and residence time are adjusted to meet the requirements. Finally, the carbon content of the generated carbon is examined.

Figure 1. Possible input materials for HTC [5].

Figure 2. HTC Process for MSW
The HTC reactor is built of SS 304 stainless steel with a thickness of 6.3mm. The reactor has a diameter of 20 cm and a height of 75 cm, with a volume of 23.5 litres. The reactor's pressure and temperature ranges are 10-15kg/cm² and 160-200°C, respectively. This procedure requires a maximum working temperature of 179.9°C and a pressure of 10 bar. To carry out the experimental investigation in SS 304 material made reactor for the HTC of MSW, the pieces are welded with Tungsten inert gas welding to bear a pressure of 20 kg/cm² and a temperature range of 200oC. After the welding of the reactor, pipe heaters (2.5 KW power) are provided on the bottom of the reactor to heat the water inside the reactor. For controlling the heat, thermostat was provided in the reactor wall and then the thermostat has been connected to the temperature controller for controlling the temperature inside the reactor.

3. Results and discussion

Two raw MSW samples are obtained and it is categorized based on proximate, ultimate and calculated analysis technique. The moisture content (MC), ash-content (AC), volatile matter (VM) and fixed carbon (FC) are determined using proximate analysis for the obtained raw samples. Likewise, carbon (c), hydrogen (H), oxygen (O) and nitrogen (N) were obtained using ultimate analysis. The higher heating value (HHV) in terms of MJ/ kg is obtained for both proximate and ultimate analysis. The characteristics of MSW samples are tabulated and it is shown in Table 1. Figure 3 shows the plot of fixed carbon for the various process parameters. It is observed that the HTC process has successfully increased the percentage fixed carbon and heat energy by conducting the process at higher temperatures, pressures, and processing times. Table. 2 shows the MSW Samples after carbonization.

As a result, the HTC method is technically appropriate for the carbonization of MSW. HTC uses a chemical method to convert MSW into a useful form of carbon. In terms of climate change and the role of CO2, it is highly desired to reduce future CO2 emissions and sequester CO2 in the atmosphere. The process results before and after carbonization is shown in Table.3. The economic viability of the method is determined by calculating the capital investment required to complete the process as well as the operational expenses (variable costs) incurred during ordinary operations as shown in Table 4.

| Sl. No | Raw MSW Sample | Proximate Analysis % by weight | Ultimate Analysis % by weight | Calculated HHV MJ/ kg |
|-------|----------------|-------------------------------|-------------------------------|----------------------|
|       |                | FC   VM  AC  MC              | C   H   O   N                  | PA      UA          |
| 1     | Raw MSW I      | 5.6 82.7 3.7 46.5            | 40.2 6 26.9 1.1                | 16.1 18.9        |
| 2     | Raw MSW II     | 5.5 85.6 4 46.8              | 40.8 7 26.2 1.3                | 16 19          |

Table 1. Characteristics of MSW Samples
Table 2. MSW Samples after Carbonization

| Sl. No | Carbonised MSW sample | Sl. No | Carbonised MSW sample |
|-------|----------------------|-------|----------------------|
|       | % by weight          |       | % by weight          |
| FC    | VM                   | AC    | MC                   | C    | H    | O    | N    | PA   | UA   |
| 1     | Carbonized MSW I     | 9.16  | 86.6                 | 4.6  | 6.9  | 43.1 | 5.9  | 25.1 | 1.9  |
|       |                      |       |                      |      |      |      |      |      |      |
| 2     | Carbonized MSW II    | 12.6  | 85.7                 | 3.1  | 6.2  | 42.2 | 6.1  | 25.7 | 1.2  |
|       |                      |       |                      |      |      |      |      |      |      |

As can be seen from the preceding analysis, the conversion of carbonised MSW necessitates a large amount of heat. MSW that has been carbonised will only be used to generate heat for the same carbonization process. The capital expenditures for systems in the manufacture of combustion systems, pressure vessels, and fuel system loading in combustion systems have been considerable.

Figure 3. Fixed Carbon Vs Process Parameters
Table 3. Process Results

| Sl. No | Sample characteristic | BC   | AC   | % Change in variation |
|--------|-----------------------|------|------|-----------------------|
| 1      | Fixed carbon          | 5.55 | 10.9 | 61.91                 |
| 2      | Volatile matter       | 84.1 | 86.1 | (-) 4.95              |
| 3      | Ash content           | 3.84 | 3.85 | 17.28                 |
| 4      | Moisture content      | 46.7 | 6.55 | (-) 81.78             |
| 5      | Carbon                | 40.4 | 42.2 | 3.63                  |
| 6      | Hydrogen              | 6.27 | 5.87 | (-) 6.37              |
| 7      | Oxygen                | 26.5 | 25.5 | (-) 3.88              |
| 8      | Nitrogen              | 1.16 | 1.73 | 49.14                 |
| 9      | Energy content MJ/kg  | 17.5 | 17.9 | 2.16                  |
| 10     | H/C ratio             | 0.15 | 0.14 | (-) 6.66              |
| 11     | O/C ratio             | 0.65 | 0.6  | (-) 7.69              |

(-) minus sign indicates downward trend, Note: BC: Before Carbonization; AC: After Carbonization

Table 4. Operational Expenditure

| Sl. No | Description of materials                              | Amount | Rs. P. |
|--------|-------------------------------------------------------|--------|--------|
| 1      | 200 mm diameter SS 304 pipe & length 750 mm           | 8,000.00 |
| 2      | Bottom dummy pipe 200 mm                              | 5,000.00 |
| 3      | Flange & dummy flange each 1 no                       | 2,000.00 |
| 4      | Heater 2KW capacity                                   | 5,000.00 |
| 5      | Temperature controller                                 | 5,000.00 |
| 6      | Drain valve ½" 1no                                    | 500    |
| 7      | ½" nipple 3nos                                        | 500    |
| 8      | Safety relief valve ½" and 15 kg/cm² 1no               | 15,000.00 |
| 9      | Pressure gauge ½" and 15 kg/cm² 1no                    | 500    |
| 10     | Tap valve ½" 1 No.                                    | 1,500.00 |
| 11     | Fabrication charges                                   | 15,000.00 |
| 12     | Transportation charges                                 | 40,000.00 |

Because of the aforementioned factors, the reactor's capital expenditure is higher. As a result, the benefits of this method cannot be considered economic. The carbonization process can be viewed as a solution to environmental issues such as CO2 emissions and global warming, based on the examination of the process. To satisfy the capital investment for process systems aimed at tackling environmental challenges such as MSW carbonization, a separate business is required.

4. Conclusions

HTC was adopted for carbonization of the MSW and its cost analysis was carried out to identify the economic aspects of the HTC method adopted carbonization process. The parameters such as time, temperature and pressure are also analyzed in the HTC process to compare it with the other carbonization methods. The proximate and ultimate analysis was performed for the raw samples to identify the various contents like MC, AC, H, O etc. The higher heating value was also obtained for both proximate and ultimate
analysis to verify the effectiveness. The characteristics of MSW samples are tabulated and the results revels that the HTC based carbonization of the MSW was very effective in reducing the pollution and generating carbon like material for energy production.

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