FABRICATION OF HTC PLANT FOR CARBONISATION OF INDUSTRIAL WASTE

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Abstract: Hydrothermal carbonization is an exothermal process that lowers both the oxygen and hydrogen content of the feed by dehydration and decarboxylation. This is achieved by applying temperatures of 160–200^{o}C in a suspension of biomass in water at saturated pressure for several hours. The objectives of the study were to carbonize the IW by the way of hydrothermal treatment process and produce a solid coal like product for application of energetic purposes. For carrying the carbonization experiment, the prototype HTC reactor has been fabricated. Organic fractions of IW collected were characterized. From the results, it was found that carbon content, energy potential can be increased by the treatment of hydrothermal carbonization in achieving carbonization of the IW.

Keywords: Pressure, Temperature and Residence time.

1. Introduction

Coal is formed by the decomposition of organic plant matter. In nature this gradual transformation takes place in the course of millions of years. Plants and trees covered by stagnating water go first through a decomposition phase and after long periods of time, sink in deeper layers. As it sinks, the pressure and surrounding temperature increase and the organic matter gradually go through a thermochemical transformation. In this process, the hydrogen and oxygen contents of the material decrease while H_2O and CO_2 are released from the molecular structure . This leads to an increase of the carbon content and to the formation of different kinds of coals depending on the degree of transformation. The higher the degree of transformation is, the higher the carbon content.

The conversion of biomass into products with higher carbon contents can take place by means of different thermochemical processes. Pyrolysis is for example a process which occurs under high temperature and in the absence of oxygen, and leads to the formation of charcoal. When pyrolysis is carried out in the presence of sub-critical liquid water, at high temperatures and pressures, the process is called wet pyrolysis or hydrothermal carbonization (HTC).The organic, biodegradable component of industrial waste is important, not only because it constitutes a sizable fraction of the solid waste stream in a developing country but also because of its potentially adverse impact on public health and environmental quality.

Due to the need for efficient conversion technologies, HTC has attracted some interest as a possible application for biomass in recent years and Research & Development (R&D) projects have been launched and discover additional possibilities for application. The carbonization of solid waste has strong potential to become an environmentally sound conversion process for the production of products such as cellulose and lignin.

HTC opens up the field of potential feed stocks for char production to a range of nontraditional renewable . HTC of biomass has a number of advantages when compared with common biological treatment. It generally takes only few hours to complete the process, permitting more compact reactor design. The high process temperatures in HTC can destroy pathogens and potentially organic contaminants such as pharmaceutically active compounds. It has the potential to reduce Greenhouse Gas (GHG) emissions associated with current waste management techniques (i.e., land filling and composting), while producing value-added products, such as activated carbon. The heterogeneous nature of industrial waste complicates its use as a feedstock for pyrolysis, potentially requiring the waste to be processed (i.e., shredded and sorted) prior to introduction in order to minimize operation and maintenance issues.

2. Literature survey

HTC is an exothermal process [1] that lowers both the oxygen and hydrogen content of the feed (described by the molecular Oxygen/Carbon (O/C) and Hydrogen/Oxygen ratio (H/O)) by mainly dehydration and decarboxylation. This is achieved by applying temperatures of 180–200^{o}C in a suspension of biomass and water at saturated pressure for several hours.

The carbonization of biomass residuals to char has strong potential to become an environmentally sound conversion process [2] for the production of a wide variety of products. In addition to its traditional use for the production of charcoal and other energy sectors, pyrolysis can produce products for environmental, catalytic, electronic and agricultural applications.

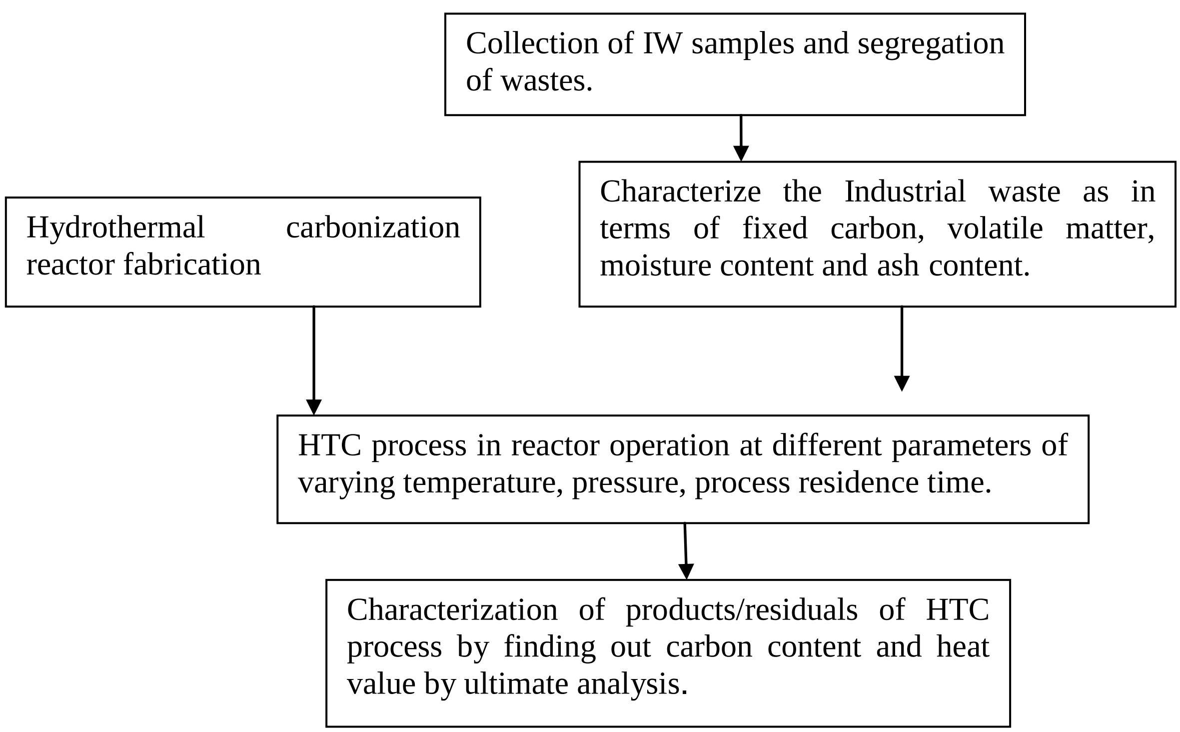
The high cost and high tech solutions are feasible only [3] for industrialized countries. Given the numerous advantages of HTC, our research explores the potential of an adapted HTC system for biowaste and faucal sludge treatment that is suitable for developing Countries. To assess the suitability of this technology for developing countries, a pilot HTC reactor was developed, built and is being tested.

Those feedstocks were chosen to represent major solid and liquid waste streams [4]. The following feedstock was chosen for evaluation: paper (33% (wt.) of waste discarded in landfills), food waste, mixed industrial waste (IW), and anaerobic digestion (AD) waste. Mixed IW was simulated using representative waste materials and mixed to achieve distributions typically land filled. Composition of the mixed IW (wt. basis) is as follows: 45.5% paper (shredded discarded office paper), 9.6% glass (crushed glass bottles), 16.4% plastic (shredded discarded plastic bottles), 17.6% Peel (crushed peel), and 10.9% metal (shredded discarded aluminum cans).

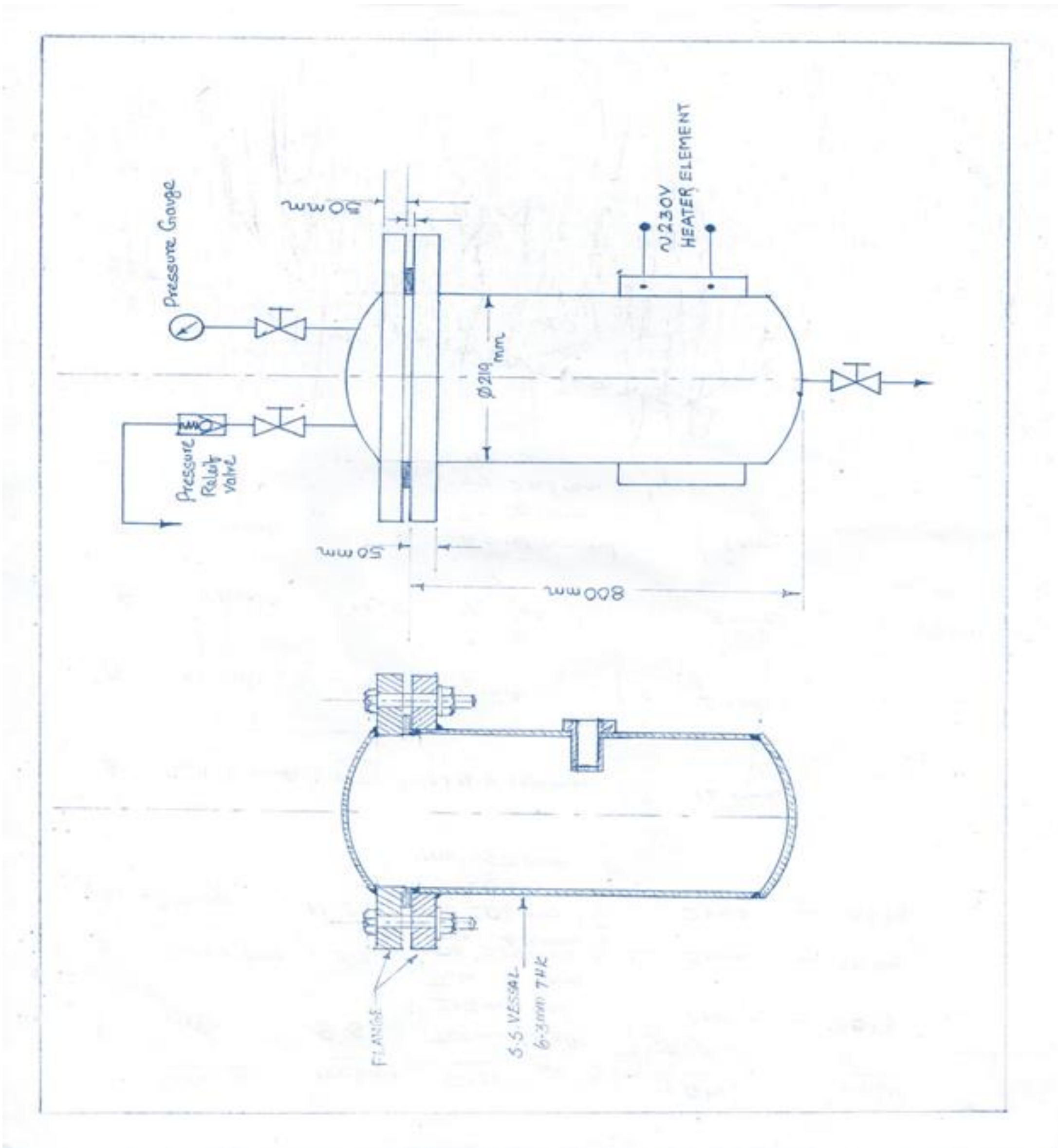
The autoclave (pressure-vessel) situated in the Laboratory of Waste Management and Landfill Technology has a 25-litre capacity and was used [5]. It has been re-fitted and equipped with computer supported a programme logic control (PLC). Since the start of project, well over 100 tests have been carried out and the resulting products analyzed. The tests have been carried out as batch-tests with and without the use of an open inner vessel. Stirring the suspension is not possible. The physical parameters temperature, pressure and energy consumption are continually recorded. The resulting gas is captured, and after the carbonization the HTC-Biochar is dewatered. Gas production potential of the input, composition of the input, composition of the solids ("HTC-Biochar"), analyses of the liquid phase and analyses of the gas phase is determined from the analysis.

3. METHODOLOGY

The methodology overview for HTC process of industrial solid waste is represented in following figure. First, HTC reactor fabrication has been made ready. Secondly, IW was selected from wastes. After that start the experimental analysis for varying parameters such as pressure, temperature and residence time. After the completion of experimental analysis, find out the enhancement of carbon content and calorific value of the processed waste.



4. HTC reactor fabrication drawing



5. HTC reactor requirement

The HTC reactor was required for the experimental analysis as above fig. The reactor has to be fabricated as per the following specifications:

Material	:	stainless steel (SS 304) (thickness 6.3mm)
Size of the reactor	:	20 cm dia x 75 cm height
Volume	:	23.5 litres

Pressure range : 05-15 kg/cm^2
Temperature range : 160 -240°C

The following accessories were installed in reactor for their proper functioning, measuring the process parameters and keeping the parameters for certain period of time

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i)	Pressure relief valve	:	1 no
ii)	Drain valve	:	1 no
iii)	Heater	:	1 no
iv)	Pressure gauge (0-15 kg/cm^2)	:	1 no
v)	Temperature controller	:	1 no

6. Experimental setup

7. Results and Discussion

The characteristic from proximate analysis, ultimate analysis of the mixed IW results and energy content are tabulated in Table 7.1 The characteristic from proximate analysis, ultimate analysis of the carbonized IW results and energy content are tabulated in Table 7.2 .From the results of both IW stream, the comparison will be made for analysis of the carbonization of the IW mixed waste how extend the process is attained towards the goal.

Table 7.1 Characteristics Of Raw IW Sample Carbonization

Sl. No	**Raw IW 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 Mixed IW	4.5	87.92	3.95	56.50	41.57	6.8	25.85	1.03	15.09	18.69

Table 7.2 Characteristics Of Carbonized MSW Sample

Sl. no	**Carbonized IW sample**	**Proximate Analysis % by weight**				**Ultimate Analysis % by weight**				**Calculated HHV MJ/ kg**	
		FC	**VM**	**AC**	**MC**	**C**	**H**	**O**	**N**	**PA**	**UA**
1	Carbonized Mixed IW	8.64	84.55	4.60	5.96	42.92	5.30	24.79	1.80	15.61	18.92

From the raw IW sample characteristic, it is known that the calorific value of the solid waste samples comes around 15-19 MJ/kg. The physical composition of the % of Fixed carbon comes around 4-7 % and volatile matter 86-91%. The Moisture content increases, % of the fixed carbon decreases. The physical composition of the Carbon % comes around 35% to 40%. Calorific value of the IW is low. Hence, it is essential to increase the calorific value of the IW as in the way of increasing the carbon percentage. The physical composition of the % fixed carbon of the produced hydro char ranges around 8% to10% increased from 6% to 8% and the percentage of increase has been observed nearly 25% to 50%.The % volatile matter of the produced hydro char ranges around 80-85% decreased from 85% to 90% and the percentage of decrease has been observed nearly 5% to 8%.% ash content of the produced hydro char ranges around 2% to 3% increased from 3% to 4% and the percentage of increase has been observed nearly 25% to 50%.The % variation between raw mixed IW and carbonized IW in the characteristic are tabulated in Table 7.3.

Table 7.3 Glance of process results

Sl. No	Sample characteristic	BC	AC	% change in variation
1	Fixed carbon	4.5	8.64	61.91
2	Volatile matter	87.92	84.55	(-) 4.95
3	Ash content	3.95	4.60	17.28
4	Moisture content	56.5	5.96	(-) 81.78
5	carbon	41.57	42.92	3.63
6	Hydrogen	6.8	5.3	(-) 6.37
7	Oxygen	25.85	24.79	(-) 3.88
8	Nitrogen	1.03	1.80	49.14
9	Energy content MJ/kg	17.53	17.91	2.16
10	H/C ratio	0.15	0.14	(-) 6.66
11	O/C ratio	0.65	0.60	(-) 7.69

(-) minus sign indicates downward trend

Note: **BC:** Before Carbonization; AC: After Carbonization

The chemical composition of the carbon content of the produced hydro char ranges around 40% to 45% increased from 35% to 40% and 5% gain has been observed due to the hydrothermal process. The hydrogen, oxygen, nitrogen of the produced hydro char has been reduced to certain extent and the change % shows in the Table 7.3. Due to hydrothermal process, H/C and O/C ratio has been reduced to certain extent. It is known that % Fixed carbon was steeply increased from 9.64% to 11.64 in varying process temperature and time from the Table 7.1 & 7.2.But, at the time, % Fixed carbon content was remaining in same position in varying pressure from 10 kg/cm^2 to 15 kg/cm^2.Hence, temperature and processing time mainly plays a crucial role in conversion of solid waste to carbonized material. The volatile matter was decreased nearly 5 % due to the process parameters. The ash content was increased 17% due to the process parameters.

8. Conclusion

15 MJ/kg of heat requires for conversion of carbonization IW for one hour in solid waste carbonization process of 1 kg Industrial waste. From the results of carbonization process, it is known that process parameters is to be maintained a minimum of 08 hours for optimization in achieving the enhancement of raw solid waste carbon content and higher heat value. At the same time, the cost incurred for the reactor and operating costs towards conversion of the solid waste for developing the required temperature are higher. Hence, the legislation revision is required to create an investment – friendly framework for the secure use of clean, ecologically conversion of hydro char as fuel to implement intelligent, sustainable material and energy flows.

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