International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

Design and Construction of a Low Temperature Chemical Reactor for Biomass Pre-Treatment

Kolajo, T. E. and Onilude, M. A.
Department of Agricultural and Environmental Engineering,
University of Ibadan
Nigeria.

Abstract **- A batch loading low temperature chemical reactor was constructed for the purpose of chemical pre-treatment of ligno-cellulosic biomass. The reactor is a 7litre capacity with temperature range of between 0^0C to 120^0C and a pressure between 80kPa and 100kPa. The reactor vat is equipped with pressure limiting valve, seal ring, and reset frame and powered with a 1500Watts twin heating elements connected in series A k-type bare tipped thermocouple of 500^0C allowable temperature is used to regulate heat in the reactor vat. The support houses the heating elements and are designed to accommodate vat diameter of up to Ø250mm.Corn stover rind fractions used in performance evaluation gave an average yield of 41% of substrate at 16% oven dry biomass chemical concentration.**

Keywords: Biomass, Chemical Reactor, Thermocouple, Temperature, Pressure

I INTRODUCTION

A major portion of the ethanol produced worldwide is by the fermentation of sugars obtained from molasses, cereals, and fruits (Chandrashekhar et al, 2011). Sugars are the starting point for the production of bio-ethanol, and are readily obtainable in large quantities from food crops such as sugar beet, corn and wheat. Examples are Brazil and United States which use sugar cane molasses and corn respectively to produce ethanol. So far, most of the 1.9 million barrels of biofuel produced daily comes from corn or sugar, which in turn has pushed corn prices up and led to food-versus-fuel worries (EMES, 2013). An alternative is the manufacture of biofuels from cellulose biomass. In agri-food waste streams however, the sugars are effectively locked away in the structure of the plant material – mostly in the form of ligno-cellulose. Ligno-cellulose gives plant cells walls their rigidity and resistance, but this makes them harder to convert into biofuels. Therefore, a pre-treatment is needed to break open these structures, reducing the overall economic viability of the process (Adam Elliston, 2013).

The biomass pre-treatment process is achieved either through chemical, mechanical or a combination of both means with each having its merits and demerits. Although the most widely used means of defibration is the chemical means under temperature and pressure, there had been a restraint on the extent of research into some local biomass to test for their suitability as a feedstock for biofuel production due to the cost and sophistication associated with chemical and bioreactors. Technology has increased over the past century and its reception has been difficult for local entrepreneurs that are having a hard time keeping up with the pace of evolving new technologies. Hence, according to Chantramonklasri (1990), local or domestic technological capability is indispensable in order to alter, modify and adopt transferred technology to local conditions. And hence, the need for a locally developed technology. The design of the chemical reactor is targeted at pre-treatment schedules for mainly non-woody materials and other schedules that require low temperature and pressures.

II METHODOLOGY

The chemical reactor is designed to defibrate woody and non-woody biomass within 0^0C to 120^0C range, otherwise considered to be low pulping temperatures with a pressure of between 80kPa 100kPa. The chemical reactor's main component parts are the reactor vat, the heating elements, the control panel and the support. The vat is a 7liter capacity equipped with a pressure limiting valve, reset frame, seal ring, gasket and nut and exhaust pine. These are as shown in figure 2.

Design consideration

A General design considerations

These are general design considerations applicable to all machine parts. The machine components were made of materials that are strong enough to withstand stresses and strains that they may be subjected to during service. The material most suitable for each component part was designed for the fabrication of such parts. All joints and components expected to hold stock and prevent loss of internal pressure build-up. The components were designed in a simple manner to ease cleaning and maintenance. Construction materials are cost effective and can be locally sourced to ease maintenance and repairs. Resistance to corrosion is assured by the use of a stainless steel body as the pulping vat. The overall configuration and aesthetics value was also of importance.

B Features of the Reactor

The chemical reactor is powered by a twin 1500Watts heating elements connected in series. The connection is such that both heating elements can be used separately or simultaneously. The chemical reactor vat can also be varied in sizes ranging between Ø15mm to Ø25mm and a height up to 250mm. The pulping temperature can be preset and increased as the pulping progresses without stopping the process.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

C Specific design consideration

The chemical reactor set up can be divided mainly into: The reactor vat, The Electrical components and the support and frame

1. The Frame and Support

The support on which the chemical reactor vat is placed also serves as the housing for the heating elements. it is supported by a 25mm thick round metal bars which are formed into a tripod. The vat support is connected to two 610mm long round metal bars that serve as support for the control box.

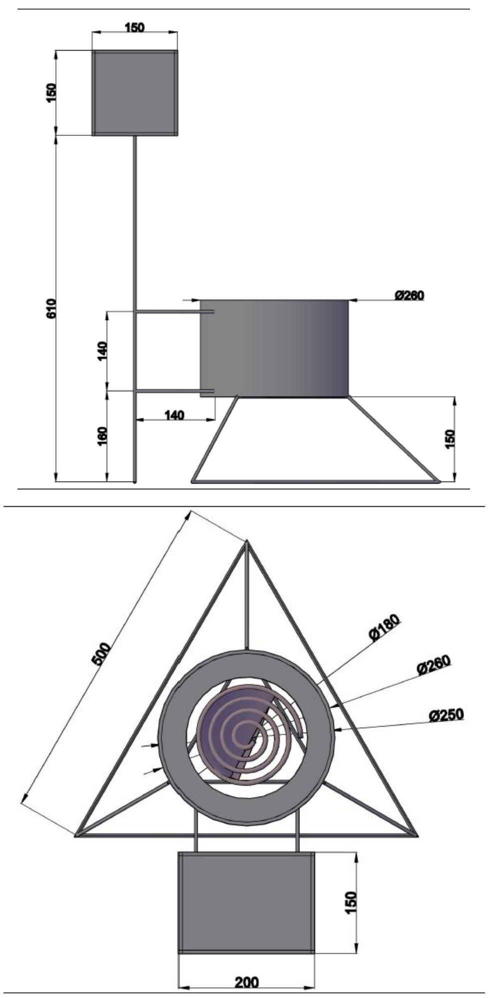
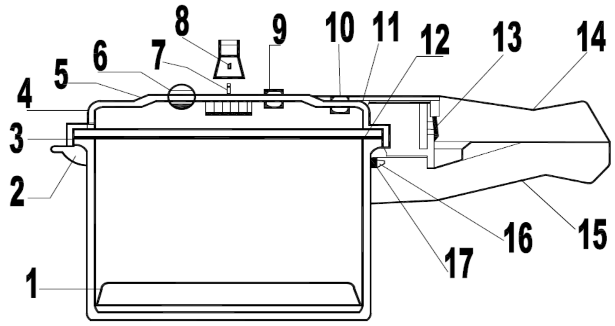


Fig 1: Elevation and Plan views of the Chemical Reactor frame

2. The Reactor Vat

The vat is a pre-fabricated stainless steel material equipped with a steam frame, handle, anti-block cover, pressure limiting valve, seal ring, reset spring, gasket and nut, control pole and pressure indicating valve. It has a height of 160mm, thickness of 40mm and a 7litre capacity designed for a maximum 5litre charge to leave clearance for foaming during the cook. It has a maximum working pressure of 80kPa. The reactor vat is shown in figure 3.1 below:



1	Steam frame	10	Pressure indicating valve
2	Small handle	11	Control pole
3	Body	12	Seal ring
4	Cover	13	Reset spring
5	Pressure alarm	14	Up handle
6	Anti-block cover	15	Down handle
7	Exhaust Pine	16	Gasket and nut
8	Pressure limit valve	17	Support
9	Thermocouple inlet		

Fig 2: The Chemical reactor vat

3. The Electrical Component

The electrical components of the chemical reactor includes the heating elements, the thermocouple, thermostat/temperature controller, a contactor, latch switch, indicator lamp, heat resistance cables and control box. The heating elements have a power rating of 1500watts each, with 250Volts and 4A. The thermocouple is a k-type with bare tip attached to the cover of the pulping vessel. The maximum allowable temperature for the thermocouple is 500^{0}C. A digital temperature gauge with a temperature range between 0^{0}C and 300^{0}C is used. A latch switch is used to control power supply to the vat, with a red indicator lamp. Heat resistant cables are used for connections between the heating elements and the control box. Figure 3.2 below shows the circuit connection for the electrical parts.

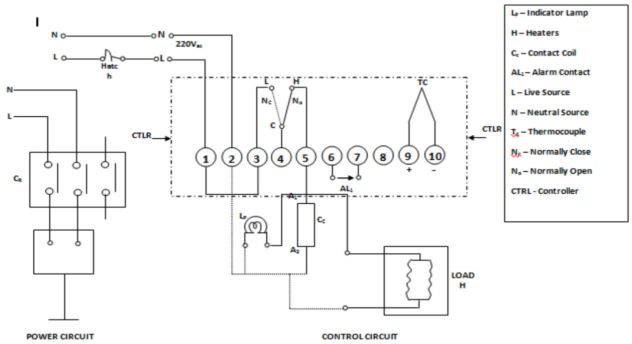


Fig 3: Circuit diagram for the Chemical reactor

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

III PERFORMANCE EVALUATION

The constructed chemical reactor was used to pre-treat the pith and rind fractions of corn stover fibres using the alkaline pre-treatment method with Sodium hydroxide as the pulping liquor. The tests were carried out using three different pre-treatment times of 60minutes, 90minutes and 120minutes at 16percent NaOH concentration and a liquor to biomass ratio of 8:1. Other fixed parameters are temperature at 120^{0}C and a pressure of 100kPa.

IV RESULTS

The constructed chemical reactor is shown in plate 1.

Plate 1:The Low Temperature Chemical Reactor

The results from the performance evaluation are as shown in the table below:

Table 1: Result of pre-treatment of the Rind using Sodium hydroxide schedule

Time (Mins)	Chemical Conc.	Yield	Kappa No.	Residual Lignin
60	16%	42%	39.26	5.10
90	16%	42%	37.64	4.89
120	16%	40%	41.28	5.37

*Fibres are disintegrated with some clusters visible
**Fibres fully disintegrated without clusters

From table 1, results of pre-treatment at 60minutes show a fairly pre-treated pulp, while at 90 and 120minutes, the corn stover rinds have been fully disintegrated. An average yield of 41% obtained correlates well with yield of 40 to 50% substrate expected from chemical pulping of wood fibres (Onilude, 2009). The kappa number of the pulp, which is a reflection of the residual lignin present in the pulp show that a considerable amount of lignin has been dissolved and the highest value of residual lignin (5.37) is within acceptable limits allowable for bio-ethanol production.

V CONCLUSION

The chemical reactor fabricated has been proven as a tool in pre-treating ligno-cellulosic biomass as a feed stock for bio-fuel production. Its design is suitable for both teaching and research purposes as well as for unlearned farmers. This will decentralize the production of cellulose substrate which can then be sold as raw materials to biofuel plants. Its use at cottage levels will also eliminate raw material losses due to microbial attacks that occur after harvesting. Its use can also be adopted for use in the manufacture of substrate for the production of paper and paper products.

REFERENCES

[1] Chandrashekhar B., Mohit S. M., Kavita Sharma and Sushma Dubey (2011). Bio-Ethanol Production from Textile Cotton Waste via Dilute Acid Hydrolysis and Fermentation by Saccharomyces cerevisiae. Journal of Eco-biotechnology 2011, 3(4): 06-09 ISSN: 2077-0464 www.scholarjournals.org

[2] EMES (2013). Environmental Management, Energy and Sustainability Newsletter. Accessed 22nd November, 2013.

[3] Adam Elliston (2013). Process of turning waste to biofuel works on paper. Institute of Food Research. Bioresource Technoloby doi:10.1016/j.biortech.2013.01.084

[4] Chantramonklasri N. (1990). The Development of Technological and Managerial capability in the developing countries. Technology Transfer in the Developing Countries. London, Macmillan: 36-50.

[5] Onilude, M.A. (2009). Pulp and paper Technology. (Unpublished). Lecture notes given in the Department of Agricultural and Environmental Technology, University of Ibadan, Nigeria