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Problems Found in the Adaptation of a Fluid Cracking Catalytic Pilot Plant for Studying Second Generation Biofuel Production by Pyrolysis

Marco A. G. Figueiredo[a], Fabio L. Mendes[b].

[a]State University of Rio de Janeiro. Technology and Sciences Center - Chemistry Institute, Petroleum and Petrochemicals Engineering and Technology Laboratory of. PPET - Room 403.

[b] Research Center - Leopoldo Miguez de Melo - Petrobras - Cidade Universitaria, Ilha do Fundão, Quadra 7

mgaya@uerj.br

As a means of reducing dependence on oil and mitigate climate change, the use of biomass as energy source has proven to be a promising option. The fuels produced from biomass are classified as first and second generation. The first-generation biofuels are mainly produced from sugar, starch and vegetable oil using conventional technologies, the most important in this segment are ethanol and biodiesel. Ethanol is produced from biomass such as sugarcane, beet sugar and starch crops (maize and wheat).

The second-generation biofuels are produced from lignocellulosic biomass mainly consisting of agricultural waste, forestry and industrial. With the purpose of studying routes for the processing of lignocellulosic biomass was performed a survey of the main technology routes are opting for a pilot plant scale for assessing the conditions of processing via fast pyrolysis. The aim of this paper is to present the main operational problems and its alternatives taken to resolve them, recorded during the tests and pre-conditioning operation of the pilot. The test conditions were based on data identified in literature, namely, temperature: 450 – 550 °C, residence time: 0.5 to 5 s heating rate is too high. Preliminarily found that the pilot unit respond well to temperature changes but noted the need to systematically study the load power, addressed this point, there was a drop in efficiency associated with the formation of coke. Additional tests in progress aims to adjust the operating conditions, assess the difficulties to achieve the overall mass balance of the plant and initiate studies on the process itself.

1. Introduction

As a means of reducing dependence on oil and mitigate climate change, the use of biomass as energy source has proven to be a promising option. According to the report "International Energy Outlook" of the 2009 Energy Information Administration (EIA), among the available energy resources, consumption of renewable energy is the fastest growing in the world at a rate of 3% per annum (Aperger and Payne, 2010) and currently represents 14% of all energy consumed in the world (Zhang et al., 2010).

Biomass is considered a renewable resource, ie, its sustainable use as a fuel is an important aspect of their potential contribution to reducing the greenhouse effect, because it allows the CO2 generated by burning biomass is recycled through its absorption by the process of photosynthesis for growing a new plant biomass (Mohan et al., 2006 and Zhang et al., 2010; Aperger and Payne, 2010).

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The fuels produced from biomass are classified as first and second generation. The first-generation biofuels are mainly produced from sugar, starch and vegetable oil through conventional technologies. The most important first-generation biofuels are ethanol and biodiesel. Ethanol is produced from biomass such as sugarcane, beet sugar and starch crops (maize and wheat). Biodiesel is produced from vegetable oils through transesterification process (Cherubini, 2010).

According to balance the International Energy Agency, 2010, world production of first generation biofuels to 82 billion liters in 2008, with 28 billion liters (34 %) were produced by Brazil, the second largest producer in the world, behind only the United States. Of this total production in Brazil, representing 1.1 billion gallons of biodiesel production, which currently is mixed with diesel in the proportion of 2% (B2), with the goal of increasing to 5 % (B5) in 2013. The rest of the Brazilian production is represented largely by producing ethanol from sugar cane. Brazil has pioneered the use of ethanol as fuel in large scale, more precisely through the program PROALCOOL between 1975 and 1986. Currently, all gasoline sold in the country is blended with ethanol in proportions ranging from 20 to 25 %. Cars fuelflex represent 90 % of cars produced in Brazil (Lora and Andrade, 2009).

The second-generation biofuels are produced from lignocellulosic biomass mainly consisting of agricultural waste, forestry and industrial. Investments in the development of processes for production of second generation biofuels have grown considerably in recent years, mainly because of the raw material is cheap and plentiful and not compete with food production, both factors advantages over fuel first generation. The potential for energy derived from forest and agricultural residues worldwide is estimated at 30 million GJ / year, while energy demand is around 400 million GJ / year (McKendry, 2002).

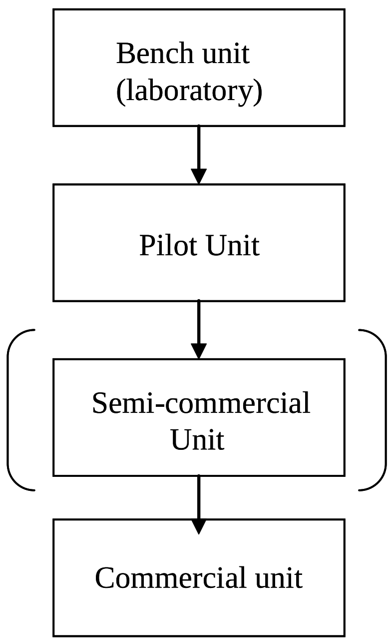

Figure 1: Steps used in technology development

2. Experimental Method

2.1 Development Unit in Pilot

The Figure 1 means that drawing on data from bench scale, we can see the suitability of a pilot project or a specific unit for larger trials aimed at generating products in sufficient quantity for testing more structured.

This step, with the attraction process, these data are used for scale up, seeking a larger unit which will be tested not only the route developed in laboratory scale and tested in a pilot plant, but all the associated unit operations. This scale will also aim to evaluate all coefficients unit that will enable effective design process for the final stage which is the implementation of an industrial-sized unit.

2.2 The pilot plant to study the fast pyrolysis process

2.2.1 General considerations

In Brazil, the potential for using agricultural waste as energy source is pretty big. For the cultivation of sugar cane, for every ton processed, are produced 150 kg of sugar, 140 kg of bagasse and 140 kg of straw (lora and Andrade, 2009). Second report of the United Nations Development Programme (UNDP) 2005, 93 % of the bagasse produced is burned inefficiently for energy generation in the refining plants. Bioethanol production using cellulose is still at the level of laboratory and pilot plants, yet no real meaning in the context of energy, technological and economic hurdles to overcome.

The sugar cane straw, different bagasse, is mostly burned in the field for the subsequent harvest of sugarcane. But now, even in mechanized farming, straw is left on the ground and still have their energy potential tapped.

Among the processes of developing biomass conversion, the thermochemical process called fast pyrolysis has the advantage of producing a liquid product called bio oil, which can be stored and transported in small units, located near the crops, reducing transport costs of raw materials. In contrast, the bio oil produced has acid characteristics and is very unstable, which makes its direct use as fuel.

Among the fast pyrolysis technologies that have been developed, circulating fluidized bed reactors have been very attractive in terms of process. A characteristic of this type of reactor, continuously burning of coal and coke produced in the pyrolysis reactions, presents a significant advantage over other technologies. A similar technology is commercially used for production of LPG and gasoline at oil refineries, called the Fluidized Catalytic Cracking (FCC).

Based on this information we performed a survey to identify the state of the art regarding the use of fast pyrolysis process to process sugar cane bagasse, bio oil in obtaining the information found possible the elaboration of the project to adapt the pilot plant of existing FCC with capacity of 1000 g / h (Figure 3) to study the processability of sugar cane bagasse as filler and silica bed stock.

2.1.2 Assembly and conditioning tests

The adequacy of the charging system to the use of a solid biomass was crucial in the process of adaptation of the unit. In all, four types of loading systems for biomass. All systems were based on the use of screw conveyors for feeding biomass into the reactor and flow control.

It was essential at this stage the use of an acrylic replica of the reactor for testing the flow of biomass, commonly called a mock-up, aiming to predict possible operational problems before installing the system in the pilot plant itself. The first three systems were composed of screw conveyors for flow control associated with pneumatic conveying of biomass to the reactor, and the last screw directly coupled reactor.

One of the main barriers in the project was the type of biomass used in the case of the straw sugar cane. Due to the shape of fibrous particles, problems such as clogging at the entrance of the screw and large angle of repose had to be balanced with the use of agitators in silo loading and proper sizing of the screw conveyor. Despite obtaining a reliable and robust, could not find a way to measure the flow of the biomass fed into the reactor, this being accomplished by mass difference before loaded into the silo and drained after the test. Another important change was the role switching equipment unit (Figure 2). The regenerator to produce a greater volume came to be used as a fluidized bed reactor, and then the stripper from the function of a regenerator. The riser, the reactor of the FCC process, now used only as a catalyst transfer line between the reactor and regenerator.

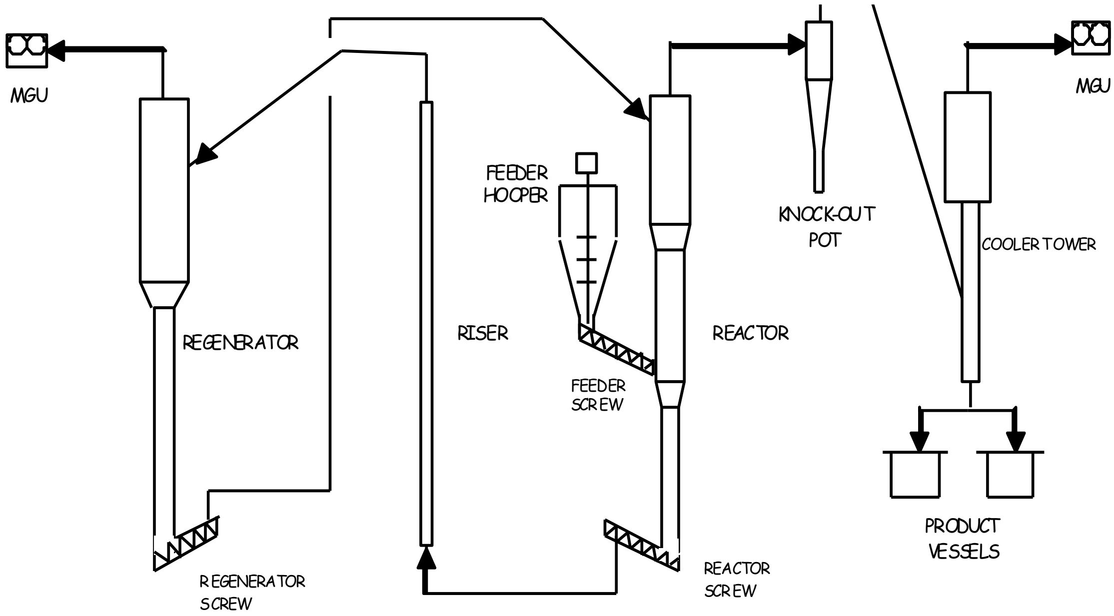

Figure 2 Flowchart of the fast pyrolysis pilot plant

Since then, tests were made for the introduction of conditioning load in the bed catalytic reactor unit, where the effects of high temperatures, flow of cargo and type of catalyst could be evaluated. In tests of conditioning were observed instability in some variables in the process, among them the flow of product gas unit, indicating a possible discontinuous feeding of biomass in reactor.

This instability prevented a longer tests performed due to excessive formation of coke and coal in reactor. We then performed additional tests on mock-up, causing changes in the stem of the silo mixer. Refashioned the nail in the silo installed on the drive, it was possible to prove the efficiency of this through an improved control unit by the operator, providing greater operational continuity.

3. Results and discussion

After completion of conditioning phase charging system, was a series of 12 tests following an experimental design. Varying the flow of cargo, reaction temperature and type of catalyst, duplicates were performed for each test. Was obtained in all this good series continuity, without any need for corrective maintenance for long periods of time. The operational stability can be established on the plots of product gas flow and regeneration, where only small variations were observed.

One of the main operating parameters of a pilot plant is the mass balance. This is an important tool for identification of possible losses in the process in pilot scale. In the case of a pyrolysis unit three chains make up the mass balance: liquid (bio-oil), gas and solid (coke and coal). The mass of liquid is obtained by weighing the effluent. The amount of gas generated is measured using a wet gas meter (MGU). The current sound is measured by counting the mass of carbon gas regeneration.

In initial tests mass balances were obtained between 60 and 70 % were considered acceptable when between 95 and 105 %. To solve the problem each chain was analyzed separately, identifying the main points of weight loss. In a liquid stream of important factors is the phase hold-up or pre test. This phase precedes the test and aims to ensure that the output currents have their composition and flow rate constant over time.

The historical operating a pilot plant FCC indicates that this condition is achieved by applying of phase holdup duration over 30 min. In the case of pyrolysis increases were achieved by 8 % in the mass running with hold time up to 1 h. Improvements in the condensation of pyrolysis vapors also provided increased mass of liquid collected in the tests. In current solid was identified as the coal and coke formed on the catalyst were not being burned efficiently, resulting in the accumulation of these vessels and the regeneration reactor. Improvements in the distribution of currents of air and oxygen in the regenerator contributed to a better catalyst regeneration, made possible a more accurate accounting of petroleum coke and coal. Regarding the gas stream, carrying out more stringent tests of pressure ensured that there would be no loss of gas connections in the lines and equipment.

Despite all the efforts were not obtained mass balances above 90 %. That there are still a variation in mass balance between 80 and 90 %, the repeatability of the tests, as it relates to income from products, was impaired.

4. Conclusion

Completed the planned series of tests, we conclude that the FCC pilot unit adapted for the Pyrolysis reached its operating limit. Because of these limitations is not yet possible to scale up a prototype for a drive with the data generated. This will require modification in the design of equipment. In the case of the regenerator, a larger vessel that will be designed and constructed in order to increase the regenerative capacity of the unit, allowing the use of larger cargo flows.

The design of a new reactor will be needed. In this case the decrease of the vessel is required because it was featured as the residence time of the vapors in the reactor was over 15 s when the guidelines for a pyrolysis unit is between 2 and 5 s. The data obtained from this first series of tests were very important towards understanding the pyrolysis process and gain operational experience from the operation team, thus allowing the modifications described above will be conducted in a more assertive and optimized.

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