STEAM GASIFICATION OF PLASTICS IN A CONICAL SPOUTED BED REACTOR

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Abstract

Steam gasification of HDPE has been carried out in a bench scale plant provided with a conical spouted bed reactor. The effect of temperature over the gasification process has been studied in the 800-900 ºC range. The products obtained have been classified into three different fractions: gas, tar and char. The gas yield at 800 ºC is relatively low, but an increase of 100 ºC raises the gas amount and reduces the tar and char yields. Hydrogen content of syngas increased with temperature due to the fact that the hydrogen formation reactions are endothermic. Finally, tar and char content are low so they can be used to provide heat to process.

Keywords: *conical spouted bed reactor, HDPE, hydrogen, steam gasification, temperature.*

1. Introduction

The amount of plastic wastes produced is growing year by year and the fraction of plastics making up municipal solid wastes and refuse derived fuels is also increasing progressively in the world. Among the different chemical recycling techniques, gasification process appears to be an interesting option in the development of full scale processes for the upgrading of solid wastes to more usable and energy dense materials, such as gas fuel.

Hydrogen is an important raw material widely used in the chemical industry. Moreover, it is considered to be a clean alternative to fossil fuels provided that can be produced from renewable. Steam has been used as gasification agent because the main objective is to maximize hydrogen yield. But the utilization of steam as the only gasifying agent requires heat supply to the endothermic process [1].

2. Materials and Methods

2.1. Experimental equipment

The gasification unit consists of the following components: (1) solid feeding device, (2) water feeding device, (3) reaction system and (4) separation system.

The feeding system of the raw material to the gasification reactor consists of a cylindrical piston which is actuated electrically. To generate the required steam for the gasification process, the plant has is a pump of type HPLC outside the hot box which feeds water to the gasification reactor. The reaction system consists of the following elements: gasification reactor, evaporators and a cyclone. All the elements are located inside a hot box which is kept at a temperature of 400 ºC in order to prevent the condensation of heavy compounds. The reactor is a spouted bed of conical geometry with a cylindrical upper section. The bottom of the reactor is a gas preheater to raise the temperature of the steam to the required by the gasification process. The gaseous stream leaves the reactor and goes to a cyclone to remove particles entrained from the bed. The stream that leaves the cyclone is conducted to a “T” which permits to take a sample for the analysis in gas chromatograph connected online and the rest of the stream in conducted to a gas-liquid separation system.

2.2. Experimental procedure

The gasification runs have been carried out in continuous mode by feeding 1.5 g/min of HDPE. The bed was made up of 70 g of silica sand (particle size 0.2-0.3 mm), and plastic to water ratio was maintained at 1:1 in all the runs. In order to study the effect of gasification temperature on product distribution, the runs have been conducted at 800, 850 and 900 ºC. Products analysis has been carried out on line, analyzing the reactor outlet stream by means of a gas chromatograph (HP 6890). The line from the reactor outlet to the chromatograph is heated up to 250 ºC in order to avoid the condensation of heavy compounds. Furthermore, noncondensable products have been monitored using a micro chromatograph (Varian 4900). The identification of the liquid products has been performed in a GC/MS (Shimadzu QP2010S) and the gaseous products have also been analyzed by means of a micro GC connected to a mass spectrometer (Agilent 5975B).

3. Results and Discussion

Gasification is a thermochemical process to produce high amounts of gas being the tar (containing benzene and compounds of higher molecular weight) and char two fractions formed at small extent.

The main effect of temperature is the increase of gas fraction due to the more severe cracking of the molecules that lead to the formation of gaseous products. As a result of the gas yield increase to 178.66 % for 100 g plastic fed at 900 ºC, the amount of tar is reduced to 4.8 %, moreover the char gasification is also enhanced and consequently the solid fraction yield is lower at high temperatures. Thus, the gasification is more efficient obtaining a higher carbon conversion 92 % and consequently most plastic is transformed into gaseous products.

Figure 1 shows the effect of temperature over the gaseous fraction composition, as observed the gaseous fraction is mainly made up of hydrogen, carbon dioxide, carbon monoxide, methane and light olefins. The temperature increase gives way to a reduction in the yield of light olefins, however an increasing trend of the methane yield is observed.

The use of steam as gasification agent leads to the transformation of hydrocarbons into hydrogen and carbon monoxide, in addition carbon monoxide formed is converted into carbon dioxide and additional hydrogen. As observed in Figure 1 hydrogen yield is influenced by temperature, this is due to the fact that the hydrogen formation reactions are endothermic. The water gas shift reaction is exothermic so when increase the temperature this reaction loses importance [2]. Therefore the amount of carbon dioxide is less at higher temperatures. The gas composition obtained at 900 ºC is especially interesting because the molar ratio of H_2/CO could be useful for chemical syntheses such as methanol, Fisher Tropsh, etc [3].

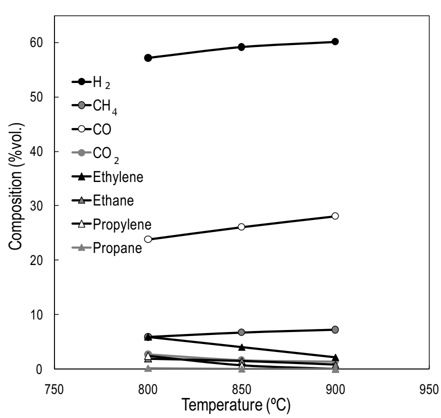

Fig. 1. Influence of temperature on the composition of gaseous product.

The tar is the condensable fraction obtained in the gasification process and is mainly made up of aromatic hydrocarbons, including benzene. Tars are formed during gasification in a series of complex reactions.

Due to the high reaction temperature, secondary reactions occur in the gas phase which converted heavy hydrocarbons compounds to light hydrocarbons and olefins, precisely these olefins are precursors of aromatic compounds that lead to the formation of aromatic rings by Diels-Alder reactions. Subsequently the condensation reactions take place and larger polyaromatic hydrocarbons (PAH) are formed.

Based on the molecular weight of tar compounds, tar was divided into four groups, as shown in Figure 2. These four groups are considered like light aromatics, light and heavy PAH and unidentified products by GC/MS.

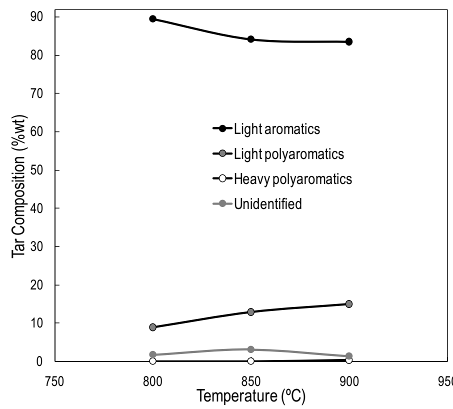

Fig.2. Distribution of functional groups of tar (%wt) at different temperatures.

4. Conclusions

The conical spouted bed reactor is a suitable technology for the plastics steam gasification. The temperature increase leads to a higher gas yield (up to 96.5%) and a reduction of tar and char yields. The main product of gaseous fraction is hydrogen, the maximum yield has been obtained at 900 ºC being around 60%. Together with the increase of hydrogen the yield of CO increases and decreases CO_2 because the raise of temperature disfavour exothermic reaction. The tar is composed mainly of light aromatics.

References

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