GASIFICATION: AN INNOVATIVE APPROACH FOR THE THERMAL TREATMENT OF PLASTIC RESIDUES

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Abstract

The dual fluidized bed gasification system yields high quality producer gas and reaches high conversion efficiency on small scale (10-20 MW). In contrast to conventional combustion processes, not only heat and power production is possible, but also polygeneration by means of chemical synthesis or selective removal of valuable gases. Test runs in the gasification pilot plant demonstrate that gasification of different plastic residues (plastic from shredder light fraction and polyethylene) is feasible. The producer gas has high hydrogen, methane and ethylene contents, but also high tar loads have been assessed. Selective removal of valuable gases is a promising application.

Keywords: *steam gasification, dual fluidized bed gasifier, shredder light fraction, polyethylene, polygeneration*

1. Introduction

Modern societies generate more and more plastic residues every year, as the quantity of disposable commodities increases. The European Union aims to enhance recycling of waste streams and has established a waste hierarchy, which gives priority to prevention and recycling over recovery and disposal [1]. 35% of plastic residues have been recycled in a material-sensitive way in Austria in 2008. In the countries of EU27 the share of material-sensitive recycling of plastics amounts to 30% owing to initiatives for selective collection [2]. However, plastic residues are most commonly recovered thermally in waste incineration plants as a part of municipal solid waste.

2. Materials and Methods

Dual fluidized bed gasification

The dual fluidized bed gasifier has been developed at Vienna University of Technology. Since 2001 the demonstration plant of this technology is in operation successfully in Güssing (Austria). Now the dual fluidized bed gasifier is commercially available and several gasifiers at industrial scale are in operation or under construction in Europe.

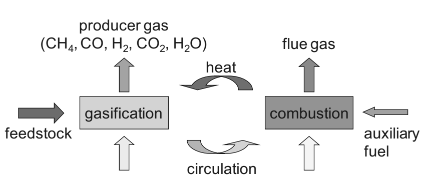

Fig. 1. Basic principle of the dual fluidized bed gasifier

Gasification is an innovative approach for thermal treatment of plastic residues. The gasification process has been originally designed for woody biomass and reaches high conversion efficiency on small scale (10-20 MW) [3].

In Figure 1 the principle of the gasification process is illustrated. The main characteristic of this gasification process is that gasification and combustion take place in spatially divided reactors. Bed material is circulating between the two reactors. The feedstock is inserted into the bubbling fluidized bed of the gasification reactor and it is gasified with steam. Residual ungasified char is transported into the combustion reactor together with the circulating bed material. There it is combusted with air. The hot bed material returns to the gasifier and provides the heat for the endothermic gasification reactions. Thus, high quality producer gas is yielded, which is rich in hydrogen and virtually free of nitrogen.

100 kW gasification pilot plant

At Vienna University of Technology, a gasification pilot plant is operated for scientific purposes. It is similar in design to the Güssing gasifier. Extensive gas analysis equipment is installed at the pilot plant for measurement of producer gas and flue gas properties.

In order to evaluate the suitability of the gasification process for the treatment of plastic residues, gasification experiments are conducted in the pilot plant. Two types of plastics are investigated: plastics from shredder light fraction (SLF) and polyethylene.

3. Results and Discussion

Gasification experiments

SLF-plastics is produced in a mechanical sorting plant, where shredder light fraction from end-of-life vehicles, plastics from commercial waste and electrical equipment are processed. It is selected for the experiments, because it is waste plastics, which also contains inorganic pollutants and cannot be used in material-sensitive way anymore. Polyethylene is selected, because it is used very frequently for the production of foils, plastic bags, food packages and other disposable products. Table 1 summarizes the properties of both samples.

Table 1. Properties of SLF-plastics and polyethylene

	SLF-plastics	polyethylene
LCV, kJ/kg	31946	43379
water, wt.-%	0.87	0.00
ash, wt.-%, dry	10.67	0.00
volatiles, wt.-%, dry	79.72	>99
C, wt.-%, dry	65.00	85.90
H, wt.-%, dry	7.95	14.08
O, wt.-%, dry	13.48	0.00
N, wt.-%, dry	0.93	0.09
S, wt.-%, dry	0.31	0.00
Cl, wt.-%, dry	1.67	0.00

During the experiments, the main operational conditions are kept constant, so that the results are comparable. The gasification temperature amounts to 850°C and the fuel input is 90 kW. In Table 2 the average producer gas composition is compiled.

Table 2. Producer gas composition, vol.-% (dry gas)

	SLF-plastics	polyethylene
H_2	45.0	36.5
CO	8.1	7.0
CO_2	16.6	7.8
CH_4	21.9	29.1
C_2H_4	4.8	14.4
C_2H_6	0.3	0.7
C_3H_8	0.5	0.6
others	1.7	3.9

Other gas compounds are light hydrocarbons, such as C_3H_6, that are gaseous, but cannot be measured with the installed analyzers. The producer gas is rich in H_2 and CH_4 and has an average lower calorific value of 17 MJ/m³ (SLF) and 25 MJ/m³ (PE). As there is no oxygen in polyethylene, the oxygen containing compounds CO and CO_2 are only formed by reaction of hydrocarbons with steam. C_1- to C_3-hydrocarbons are decomposition products of the polymers. Gasification of polyethylene yields a considerable amount of its monomer C_2H_4. As SLF-plastics contains nitrogen, sulfur and chlorine, also NH_3, H_2S and HCl are present in the producer gas. More details on that are available in [4]. The dual fluidized bed gasifier generates very low amounts of tars (condensable higher hydrocarbons), when biomass is gasified (~ 2 g/m³ gravimetric tar, 6 g/m³ GC/MS tars). Gasification of plastics yields markedly higher tar loads (SLF: 38 g/m³ grav. tar, 70g/m³ GC/MS tar, PE: 40 g/m³ grav. tar, 121 g/m³ GC/MS tars).

Producer gas application

In the dual fluidized bed gasification plants the producer gas is combusted in gas engines for heat and power production. Therefore, two stage-producer gas cleaning is implemented, which consists of a bag filter and an organic solvent for tar removal. If plastic residues are gasified, the tar scrubber has to be adapted to the high tar loads. According to the concentration of nitrogen in the fuel and the emission limit values, removal of NH_3 may be mandatory.

In contrast to conventional combustion processes, where only heat and electricity is produced, steam gasification allows polygeneration. Chemical synthesis converts the producer gas into synthetic fuels, such as Fischer-Tropsch diesel, methanol, etc. [6] By means of membrane separation processes, gas compounds such as hydrogen or methane can be separated selectively. [7] The producer gas from gasification of plastic residues appears to be well-suited for selective separation of CH_4 because of the high methane yield. In consequence of the low CO and CO_2 concentration, steam reforming of the producer gas would be necessary to adjust the H_2/CO ratio for other syntheses processes.

4. Conclusions

Test runs in the dual fluidized bed gasification pilot plant demonstrate that gasification of different plastic residues is feasible. The producer gas cannot only be used for heat and power production, but also in polygeneration processes. With appropriate gas cleaning (tar removal), the selective separation of valuable gas compounds is a promising application.

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