

Pyrolysis-plasma reforming of waste plastics for hydrogen-rich syngas production

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Abstract: Pyrolysis-reforming has been used in thermal catalytic reactors to convert waste plastics into hydrogen-rich syngas. However, there are challenges to this process like high temperature and energy requirements and catalyst deactivation due to carbon deposition. In this study, plasma reforming will be used to reform the pyrolysis products from the waste plastic at low temperatures. In this paper, preliminary results on the non-plasma pyrolysis-reforming of polystyrene is presented as a first step before pyrolysis-catalytic plasma-reforming.

Keywords: plastic, plasma-reforming, hydrogen, catalyst

1. Introduction

Due to the waste plastic problem on the one hand and the need to source for alternative sources of hydrogen in an environment-friendly process, the aim of this study is to produce hydrogen-rich syngas from different waste plastics using a novel two stage pyrolysis-plasma reforming process.

Several studies have been carried out using pyrolysis-steam reforming of waste plastics for hydrogen production in thermal catalytic reactors [1]. However, this process faces some challenges like high temperature and energy requirement, and also catalyst deactivation due to carbon decomposition. These challenges can be overcome by a relatively new type of reforming method which uses plasma to generate reactive species that can break most chemical bonds at low temperatures. This method has not been used to reform pyrolysis gases from waste plastics. In this study, the plasma reforming will be used to reform the pyrolysis products from the waste plastic at low temperatures. Operating parameters of the process will be optimised for hydrogen production. Catalysts will then be prepared and investigated for enhanced hydrogen production.

To the best of our knowledge, the plasma reforming method has not been used to reform real pyrolysis gases from waste plastic. Also, compared to thermal catalytic reforming process, very few catalysts have been developed and studied for plasma reforming process. The knowledge of selecting the right catalyst for highly efficient plasma reforming process is still limited. Also, the synergy between the plasma and catalyst needs to be further studied. In this paper, preliminary results on the non-plasma pyrolysis-reforming of polystyrene is presented as a first step before pyrolysis-catalytic plasma-reforming.

2. Materials and methods

Three different waste plastics have been used for preliminary studies in a two stage fixed bed pyrolysis-thermal cracking reactor. The first stage is where pyrolysis

of the waste plastic takes place and the second stage is where the thermal cracking of the pyrolysis products take place. Operating parameters have been optimised for enhanced hydrogen production. Ni/Al₂O₃ catalyst, prepared by wet impregnation method, was used to further enhance the hydrogen production.

A new pyrolysis-plasma reforming reactor has been designed and commissioned for the next phase of research where a plasma-catalysis reactor is used for reforming (Fig. 1).

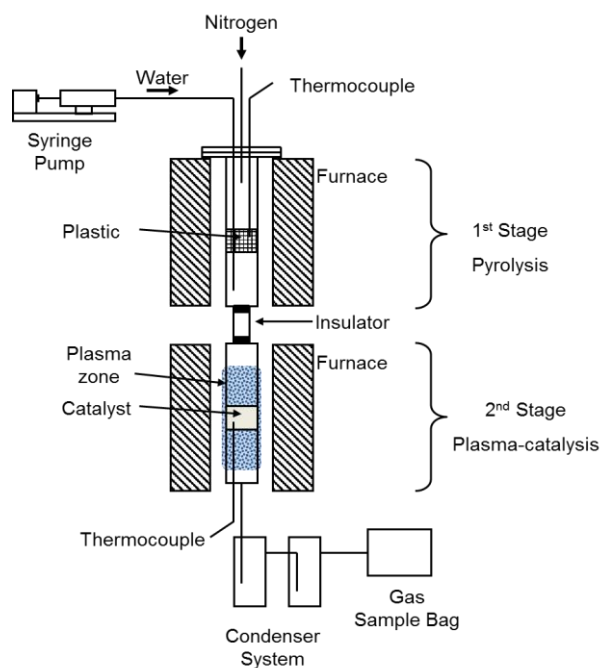


Fig. 1. Schematic diagram of the pyrolysis-plasma reforming reactor set-up

The plasma reactor consists of two co-axial electrodes that are separated by a dielectric material (quartz). The

inner electrode is connected to a high voltage source and the outer electrode is grounded. The discharge is generated in the annular gap between the electrodes. Pyrolysis products from the pyrolysis reactor enter the non-thermal plasma reactor where they will be reformed into hydrogen-rich syngas. The reformed gases exiting the reactor system will be collected in the Tedlar gas bag and liquid will be collected in the condenser tubes.

3. Results and Discussion

The preliminary results on the non-plasma pyrolysis-reforming of polystyrene was undertaken and the results shown in Fig. 2 show that increasing the gasification temperature from 700 °C to 900 °C enhanced the yield of hydrogen from 72.8 mmol/g to 103.8 mmol/g and carbon monoxide from 31.7 mmol/g to 61.7 mmol/g. In addition, the yield of carbon dioxide and methane decreased from 10.6 mmol/g to 6.7 mmol/g and 2.6 mmol/g to 1.7 mmol/g respectively. A similar trend was reported by Kaewpengkrow et al. [2] who found that hydrogen yield increased when gasification temperature was increased from 700 °C to 900 °C and attributed this to thermal cracking of heavier hydrocarbons and tars at elevated temperatures. Higher yield of hydrogen, CO and total gas was also reported by He et al. [3] when they investigated the effect of temperature on the gasification of polyethylene.

Increased yield of syngas by increasing the temperature is due to further thermal cracking of the heavy hydrocarbons which favours production of smaller fractions like H₂ and CO. Reactions like water-gas and methane dry reforming are also favoured at high temperatures due to Le Chatelier's principle to yield more hydrogen and CO.

At 900°C, the methane yield dropped to 1.7 wt. % while the H₂ and CO yields increased. This is due to methane steam reforming that consumes methane to form hydrogen and carbon monoxide which is favoured at elevated temperatures.

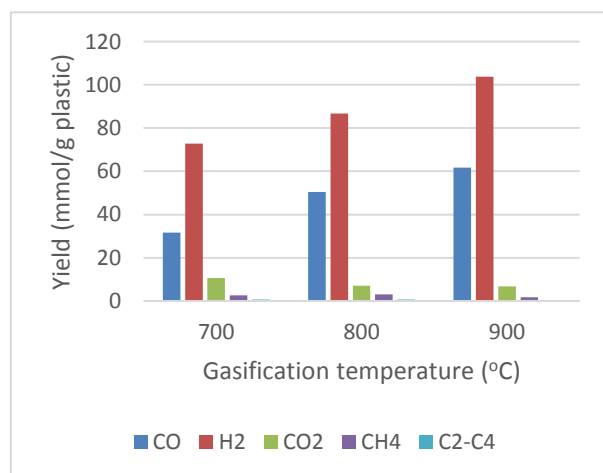


Fig. 2. Gas composition from pyrolysis-gasification of polystyrene at different gasification temperatures

4. Conclusions

Different types of processes have been used to convert waste plastics into hydrogen-rich syngas but to date there has not been a study which uses pyrolysis-plasma reforming for this conversion. This process has the advantage of flexibility, energy efficiency and can produce hydrogen-rich syngas at low temperatures.

5. References

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