

Catalytic hydrothermal gasification of automotive fluff in a continuous system

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1. Keywords

Hydrothermal gasification, Hydrogen, Catalyst, Plastic waste

2. Highlights

Hydrothermal treatment can be used for valorization of plastic waste to H₂ and chemicals. This process is suitable for contaminated, mixed, non-recyclable plastic wastes.

3. Purpose

The limited lifespan of plastics, the presence of impurities, and the difficulty of recycling contribute to only 9% of plastic waste being recycled in Canada and the remainder being landfilled, already utilized for waste-to-energy or released into the environment [1]. Polyethylene (including LDPE, HDPE, and PET) and polypropylene (PP), make up a substantial portion, accounting for up to 50% of plastic waste [2][3].

The present research consists of an assessment of the hydrothermal gasification (HTG) of automotive fluff, a waste material that contains numerous polymer types and impurities. The goal is to valorize the waste through conversion into hydrogen (H₂) fuel using a continuous HTG system. This study aims to determine the conversion efficiency and shed light on the challenges associated with its commercialization and scaling up when using real-world, contaminated waste as a feedstock, as opposed to model compounds. The produced gas, liquid, and solid production were analyzed to determine the optimized pathway to valorize the challenging plastic waste and avoid its release into the environment.

4. Materials and methods

Automotive fluff (AF) was sourced from a local automotive recycling company. Before its utilization in the continuous Hydrothermal Conversion System (HCS), manual separation of larger inorganic particles such as rocks, glass, and metal parts was carried out, followed by grinding to less than 1mm using a knife mill. Sodium hydroxide catalyst (NaOH) was procured from Fischer Scientific and was used as received, without any additional purification steps.

All experiments were conducted within the National Research Council's HCS. The system includes a preheater and a gasifier. It is electrically heated, pressure regulation is achieved through a back pressure regulator and solids are removed with a sintered metal filter. Before initiating the reactions, the system was filled with water and brought to the desired temperature. The necessary quantities of automotive fluff, NaOH, and water were mixed and loaded into a piston pump. Throughout all experiments, the mixture was introduced into the system at a flow rate of 1 ml/min. The resultant gas and liquid products were separated in a collection downstream of the particle filter and back-pressure regulator. A bagged gas sample was collected analysis was performed using a TCD-GC (Gas Chromatograph). Liquid analysis was carried out using both Liquid Chromatography–Mass Spectrometry (LC-MS) and Gas Chromatography–Mass Spectrometry (GC-MS). Fine solid particles were separated from the liquid using a paper filter.

5. Results and discussion

In most experiments, the gas analysis showed only H₂ in the produced gas (Figure 1). NaOH as a catalyst provided a basic condition that improved plastic degradation into organic soluble components, that further gasify into CO and eventually into CO₂ through the water-gas shift reaction. NaOH then reacts with the produced CO₂ and converts to sodium carbonate or sodium bicarbonate removing CO₂ from the gas phase and increasing H₂ production by shifting

the water-gas shift reaction toward H_2 formation. Depending on the reaction conditions, between 3 to 19 g_{H_2}/kg_{feed} was formed. The effect of pressure, temperature, feedstock, and catalyst concentrations were investigated. Among them, feed concentration has the most effect on H_2 production. Increasing the catalyst concentration eliminates CO from the gas phase. Preheating the feedstock before gasification not only increases the H_2 formation but also, eliminates the CO observed in the gas phase while gasified without preheating. H_2 formation improves at higher pressure. Methanol, ethanol, acetone, 2-propanol, tert-butanol, n-butanol, acetate, 2 ethylbutyrate, etc. were observed in the liquid phase. The solid product (carbonate and hydrochar) showed a mesoporous structure, indicating potential for (Figure 2).

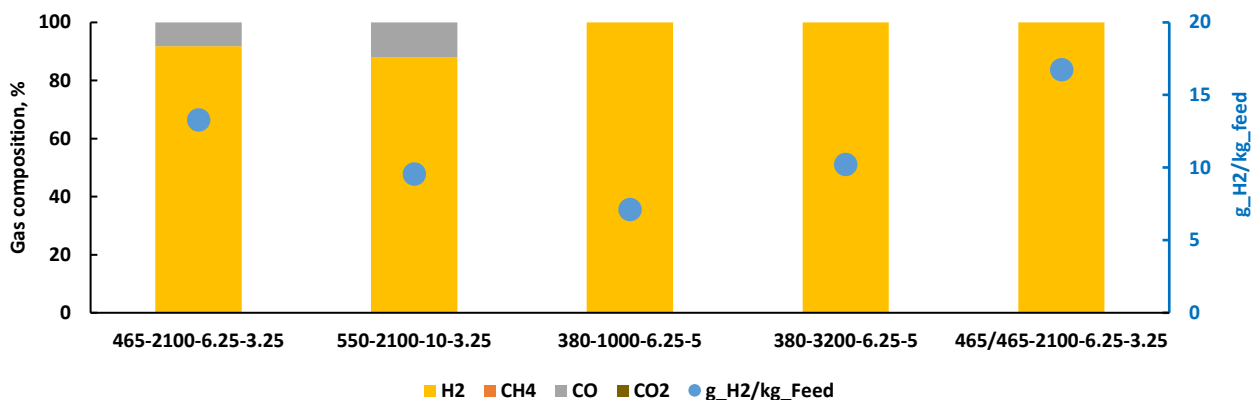


Figure 1. Gas composition (left axis), and hydrogen production (right axis) from automotive fluff in the NRC-hydrothermal continuous system, label nomenclature: Pre-heater Temperature($^{\circ}C$)/Gasifier Temperature($^{\circ}C$)-Pressure(psi)- AF concentration (wt%)- NaOH concentration (M)



Figure 2. SEM of hydrochar formed from automotive fluff in the NRC-hydrothermal continuous system.

6. Conclusions and perspectives

H_2 was produced through the continuous HTG of plastic waste. This work demonstrates a potential method for the conversion of contaminated, mixed, and end-of-life plastic waste into valuable fuel and chemicals rather than their release into the environment. Further studies are needed to determine the commercial viability of the system, overcome material corrosion issues, and determine the effectiveness of heterogeneous catalysts.

7. References

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