Study on the Fluidization of Mixture of Plastic Waste and Alumina

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Abstract

This study explores the fluidization of systems composed of plastic waste and alumina – in different ratios and ranges of porous distribution – to assess the possibility of using a fluidized bed reactor for the catalytic conversion of plastic waste. A model for the prediction of the minimum fluidization velocity is proposed.

Introduction

As the global demand for sustainable energy solutions grows, innovative strategies to reduce dependence on fossil fuels are essential. One promising approach is the conversion of plastic waste into gas, repurposing discarded materials as valuable energy sources. Through catalytic processes—including pyrolysis, gasification, and hydrogasification—non-recyclable plastics can be transformed into syngas and hydrocarbons, providing an alternative to conventional fossil fuels while addressing environmental concerns.

The primary challenges in the plastics conversion industry include a low heat transfer coefficient and high energy demand. Fluidization can significantly enhance heat and mass transfer, enabling continuous operation. If optimized, fluidized beds can improve heat transfer efficiency by a factor of ten compared to melting vessels or tube reactors [2]. Additionally, reduced residence time during fast pyrolysis minimizes secondary reactions and unwanted by-products [3]. The primary products of plastic waste conversion in a fluidized bed reactor include waxy compounds, oils, gases, and monomers, depending on polymer type and operating conditions.

Despite its potential, few studies have explored fluidization for plastic waste conversion. Most research compares fluidized beds with fixed-bed reactors, focusing on product distribution [4]. This work investigates the fluidization properties of mixtures containing plastic waste and alumina-based catalysts. The plastic waste consists mainly of polyethylene (PE) and polypropylene (PP), with a significant paper fraction. Due to its irregular shape and low bulk density, plastic alone does not fluidize effectively. To overcome this, a secondary solid (γ-alumina) was added, chosen for its high surface area, thermal stability, tunable acidity-basicity, and strong metal-support interactions, making it an ideal catalyst support for reforming and methanation reactions.

Experimental and Discussion

Experiments were conducted in a quartz reactor (internal diameter: 26.6 mm) using nitrogen as the fluidizing gas at room temperature. The plastic waste was ground and sieved into the following size ranges (μm): <180, 180–355, 355–500, 500–1000, 1000–1250, 1250–1650, 1650–2500, >2500. Since fluidization behavior is size-dependent, a detailed analysis of particle distribution was necessary. γ-Alumina was sieved into these size ranges (μm): <45, 45–90, 90–180, 180–250, 250–355.

The first phase of this study characterized γ-alumina's fluidization behavior to confirm its suitability. As expected, minimum fluidization velocity (u_{mf}) increases with particle diameter, while plateau stability indicates stable fluidization, with minimal segregation or channeling. The Figure 1 shows the experimental u_{mf} values fitted with a model developed on the equation $Re_{mf} = [C_1^2 + C_2 \cdot Ar]^{1/2} - C_3$, where the constants were specifically optimized to fit the data) is the only one in good agreement with the experimental data.

Once alumina's fluidization properties were verified, plastic waste was introduced in various volumetric ratios. Additionally, mixtures were prepared with different average particle diameters and tested in the experimental set-up confirming that fluidization improves with higher alumina content.

Given the heterogeneous particle size distribution, mixtures with varying mean diameters were tested while keeping alumina dimensions constant. Figure 2 demonstrates that larger plastic particles increase umf and the minimum volume ratio required for fluidization. However, this threshold can be reduced

by increasing alumina particle size, promoting greater homogeneity in the mixture.

Finally, the addition of coke to the mixtures of plastic waste and alumina solids was tested to simulate a condition similar to the ones obtained in the conversion. Its presence doesn't affect significantly the fluidization properties which are worsen only if presents in quantities over 30 wt% with respect to the plastic.

Conclusions

The fluidization properties of mixtures of plastic waste and alumina solids were assessed with the aim to evaluate the possibility to performe catalytic conversion of plastic in fluidized bed. The results have showed that the volume ratio between alumina and plastic is the key to allow good fluidization; moreover, the minimum fluidization velocity is minimized when the two solids have similar particle size distribution. Finally, coke solid were added.

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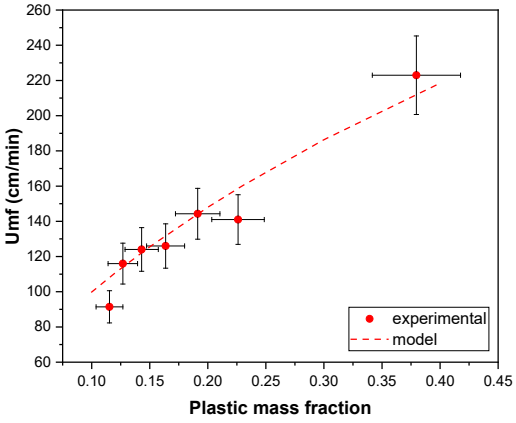

Figure 1 Fitting of the experimental data with this work model

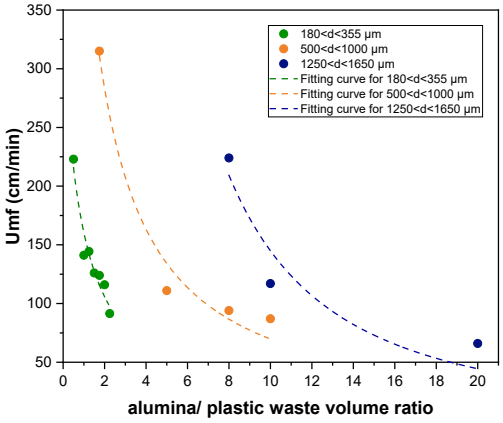

Figure 2 Umf for mixture of 90-180 alumina and plastic waste