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Catalyst Properties and Catalytic Performance of Char from Biomass Gasification

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ABSTRACT: Gasification provides a mechanism to convert solids, such as biomass, coal, or waste, into fuels that can be easily integrated into current infrastructure. This paper discusses the use of residual char from a biomass gasifier as a catalyst for tar decomposition and presents an investigation of the catalytic properties of the char. Poplar wood was gasified in a fluidized bed reactor at temperatures ranging from 550 to 920 °C in reaction environments of 90% steam/10% N_2 and 90% N_2/10% CO_2. The properties of the char recovered from the process were analyzed, and the catalytic performance for hydrocarbon cracking reactions was tested. Brunauer–Emmett–Teller (BET) measurements showed that the surface area of the char was higher than conventional catalyst carriers. The surface area, which ranged from 429 to 687 m^2 g^{-1}, increased with temperature and reaction time. The catalytic activity of the char was demonstrated through testing the catalytic decomposition of methane and propane to produce H_2 and solid carbon. Higher char surface area resulted in increased performance, but pore size distribution also affected the activity of the catalyst, and evidence of diffusion limitations in microporous char was observed. Clusters of iron were present on the surface of the char. After being used for catalytic applications, carbon deposition was observed on the iron cluster and on the pores of the char, indicating that these sites may influence the reaction. When the char was heated to 800 °C in an inert (N_2), atmosphere mass loss was observed, which varied based on the type of char and the time. ESEM/EDX showed that when char was heated to 1000 °C under N_2, oxygen and metals migrated to the surface of the char, which may impact its catalytic activity. Through investigating the properties and performance of biomass gasification char, this paper demonstrates its potential to replace expensive tar decomposition catalysts with char catalysts, which are continuously produced on-site in the gasification process.

1. INTRODUCTION

Biomass has the potential for meeting a significant portion of the demand for energy and transportation fuels in the near future. Gasification is a method for converting biomass into synthesis gas, and it has been gaining increasing attention in recent years. This process involves partial oxidation of a solid feedstock, such as biomass or waste, with a coreactant (e.g., air, CO_2, or steam) in order to generate synthesis gas, which is a mixture of CO and H_2. This can be combusted in a gas turbine or fuel cell to generate power and heat or can be used to make fuels and chemicals via Fischer–Tropsch (F-T) synthesis. Synthesis gas can also be used to make methanol, dimethylether (DME), or synthetic natural gas (SNG). Gasification produces three main components: gas, tar, and solid residue (classified as ash or char, depending on its carbon content). The gas, which consists primarily of H_2, CO, CO_2, and other small hydrocarbons, is the desired product that is used for fuels synthesis or direct electricity or heat production. Tars are liquid organic hydrocarbons that are primarily aromatic compounds. They are formed from solid fuel that has not been fully decomposed to gas phase products. Ash consists of the minerals or metals that are inherently present in the raw material and are not converted to gas or liquid phase products. Char is a residue that is primarily composed of solid unreacted carbon and also contains ash. Char may be burned for energy recovery or directly disposed of in a landfill, similar to ash disposal. Currently, there are limited uses for ash or char from gasification systems, aside from use in construction applications or as alternate daily cover for landfills.[1] There is active research in the area of soil amendment use, but this has yet to be deployed on a large scale.[2]

This paper investigates the catalytic properties and performance of char from biomass gasification. While the objective of gasification is to achieve high conversion of carbon to gas phase products, gasifiers typically produce a solid residue that is rich in carbon. For example, a pilot plant that gasified wood sawdust and sunflower seeds pellets with air reported that the carbon content of the solid residue was >80%. Temperatures in that reactor were measured to be as high as 1109 °C.[3] Therefore, it is relevant to investigate uses for char that is recovered from gasifiers. Ash, which is present in char, contains metals that are used in catalytic applications. Generally, catalysts are supported on high surface area materials such as alumina, zirconia, ceria, or carbon through an impregnation process. Char from gasification provides a high surface area support for the ash, which is already impregnated in the char, thereby producing a supported metal catalyst. However, the location and dispersion of the metals, as well as their activity in this state needs to be determined. The surface area of char is similar to or greater than that of common catalyst carriers. For example, typical catalyst carriers have surface areas ranging from 50–400 m^2 g^{-1},

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