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Pyrolysis of some whole plastics and plastics–coal mixtures

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Abstract

This paper demonstrates the thermal and catalytic pyrolysis of some whole plastics and plastic–coal mixtures with and without solvent in an inert atmosphere of N_2 using a micro autoclave. The temperature was varied between 300 and 400 °C. The effect of some catalysts, i.e., $AlCl_3$ and Co–Mo, on the liquid yield was also studied. The results demonstrate that temperature has a promising effect on the yield; however high temperature, as well as high catalyst loading, caused a decline in liquid yield. The effect of the solvent was found to be significant. None of the catalysts show an impressive effect on the yield of the desired products. Among the plastics studied, high density polyethylene (HDPE) and polypropylene (PP) gave high yields even in the absence of a solvent and catalyst. The results are quite promising in terms of resource recovery, both from coal as well as plastics. The idea will also help in combating the environmental problems associated with plastics and coal.

Keywords: Synthetic oil; Plastic recycling; Depolymerization

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1. Introduction

Plastic waste management has been a focus of attention in today's modern world. Incineration of waste plastic is losing its importance due to operative cost and descending credibility in the environmental protection scenario. Therefore, it is a need of the day to explore alternative techniques for plastic recycling.

Conversion of polymeric materials into useful products has been attaining recognition in recent years. Extensive work is underway world wide on the liquefaction of plastics to useful products [1–4]. Apart from plastic liquefaction, chemical treatment of waste plastics is gaining importance, particularly when incorporated with coal to get the benefit of the hydrogen rich character of the polymeric plastic, thereby enhancing

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Abbreviations: PSt, polystyrene; PS, pentane soluble; PI, pentane insoluble; PP, polypropylene; HDPE, high density polyethylene; LLDPE, linear low density polyethylene; TLP, total liquid product.

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the coal conversion to liquid fuels [5,6]. This is a new avenue of research. During carbonization in an inert atmosphere, the polymeric structure of plastics is broken down, producing smaller intermediate groups, which can further react and produce smaller hydrocarbon molecules, liquids and gases [7–10]. The generation of such hydrocarbons could modify the thermal behavior of coal, especially in the temperature range between 400 and 500 °C, where the coal exists in a plastic state that finally resolidifies to give semi-coke, which is then transformed to coke [11–13]. The molecular species that evolved in the temperature range between 400 and 500 °C are responsible for maintaining a fluid system and play a fundamental role in the development of the coke properties [14–19]. When coal starts to soften, molecular fragmentation produces the release of smaller molecules caged in the coal micro-pores, which are hydrogen rich donor species. They tend to take part in the recapping of free radicals from thermal decomposition and to convert them into stabilized hydrocarbon molecules. As the carbonization temperature increases, an increase in the production of radical fragments takes place, together with an increase in the fluidity. If these radicals are highly reactive and they are not stabilized by hydrogen transfer reactions, they may recombine with other molecules, and then, a viscous (low fluidity) system is formed. As a consequence, the structure of the resulting carbon material is more disordered. However, when the free radicals are moderately reactive and stabilized by hydrogen transfer reactions, the low molecular mass molecules keep the system at an optimum fluidity level. Consequently, growth and orientation of the aromatic molecules take place, and a more ordered anisotropic carbon material is obtained. The formation and effective stabilization of free radicals by hydrogen transfer are influenced by the chemical composition of the raw materials. The incorporation of additives to the system modifies the available transferable hydrogen in the co-carbonization system. A high chemical activity of additives for enhancing fluidity can be related to the presence of molecules that exhibit high hydrogen donor ability, such as hydro-aromatic rings.

Our attention has been focused on how specific plastic waste influences the fluid stage of the coal under study. The plastics selected for the current investigation are beads of polypropylene (PP), two polyethylene, i.e., linear low density polyethylene (LLDPE) and high density polyethylene (HDPE), and polystyrene (PSt), i.e., packing material. We report on the liquefaction of the parent plastics and their mixture with coal.

2. The experimental methodology

2.1. Collection of samples

Different types of plastic beads imported from Saudi Arabia, i.e., high density polyethylene (HDPE), linear low density polyethylene (LLDPE) and polypropylene (PP), were collected from the local plastic bags manufacturing industry. Polystyrene (PSt) was obtained by collecting packing material from the local market. The coal used was from the Lakra coal mines, provided by the PMDC (Pakistan Mineral Development Corporation).

2.2. Preparation of samples

The plastic samples were used as such, while the coal was crushed using a pestle and mortar. The ground coal sample was then sieved using a screen of 53 μm size, dried and stored.

2.3. Pre-treatment of coal sample

2.3.1. Leaching of coal with HNO_3

The coal was slurried using a magnetic stirrer in 250 cm^3 of 1 M HNO_3 solution in a vat and allowed to leach for a time duration of 1 h. The slurry was then filtered using ordinary filter paper. The coal residue was exhaustively washed with a sufficient amount of deionized water until it was acid free. The filtrate was continuously checked for acid contents using pH paper. The acid free residual coal was dried in an oven at 110 °C to evaporate most of the water until a constant weight was registered. The dried acid extracted coal was stored in a clean plastic bottle for liquefaction studies.