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Catalytic pyrolysis of high-density polyethylene over nickel-waste chicken eggshell/HZSM-5

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ABSTRACT

The main objective of the current work is to investigate the effect of nickel–waste chicken eggshell modified Hydrogen exchanged Zeolite Socony Mobil-5 (Ni-WCE/HZSM-5) on pyrolysis of high-density polyethylene (HDPE). Ni-WCE/HZSM-5 was synthesized via the impregnation incipient wetness (IWI) method with Ni and WCE mass loading of 4 and 12 wt% respectively. HZSM-5, CaO, WCE, WCE/HZSM-5, and Ni/HZSM-5 were prepared for comparison purposes with Ni-WCE/HZSM-5. All the synthesized catalysts were characterized for phase analysis, metal loading, surface morphology, and textural properties. The impregnation of nickel and WCE had significantly affected the original framework of HZSM-5, where the crystallinity percentage and average crystal size of HZSM-5 dropped to 44.97% and increased to 47.90 nm respectively. The surface morphology of HZSM-5 has drastically changed from a cubic-like shape into a spider web-like surface after the impregnation of WCE. The BET surface area of HZSM-5 has been lowered due to the impregnation of nickel and WCE, but the total pore volume has increased greatly from 0.2291 cm^3/g to 0.2621 cm^3/g. The catalyst performance was investigated in the pyrolysis of HDPE via a fixed bed reactor and the pyrolysis oil was further analysed to evaluate the distribution of C_6 to C_9> hydrocarbons. Among the tested catalytic samples, the highest pyrolysis oil yield was achieved by WCE (80%) followed by CaO (78%), WCE/HZSM-5 (63%), HZSM-5 (61%), Ni/HZSM-5 (44%) and Ni-WCE/HZSM-5 (50%). For hydrocarbon distribution in pyrolysis oil, the Ni/HZSM-5 produced the highest of total C_6 and C_7 hydrocarbons at 12% and 27% respectively followed by WCE/HZSM-5 (4% and 20%), non-catalytic (5% and 13%), Ni-WCE/HZSM-5 (0% and 15%), WCE (0% and 10%), HZSM-5 (0% and 6%) and CaO (0% and 0%).

1. Introduction

Hydrogen exchanged Zeolite Socony Mobil–5 (HZSM-5) is a man-made zeolite which commonly used as a supported catalyst to enhance catalytic cracking in petroleum refineries for hydrocarbon productions (Al-asadi and Miskolczi, 2021). This is because, the HZSM-5 catalyst is deemed to such a high reputation than other acid catalysts due to higher catalytic cracking properties on heavy hydrocarbons (Dwivedi et al., 2021). The popularity of HZSM-5 is its solid-state properties, which have high porosity and good thermal stability during the cracking process (Ali et al., 2021). Consequently, the drawbacks of HZSM5 are its short product cycle where coke formation easily occurs which leads to low yield organic liquid and selectivity (Wang et al., 2021).

Interestingly, calcium oxide (CaO) is a base catalyst and was reported to be a reliable catalyst in the transesterification process (Rahman et al., 2019). Xing et al. (2018) reported that generally CaO was obtained from limestone quarry and also an alternative, environmentally friendly, and cheaper resource can be extracted from waste chicken eggshell (WCE). Coincidentally, based on the previously reported work we found that the applications of WCE in pyrolysis have not been well investigated. The CaO can act as both active metal and promoter catalyst to stabilize the acidic properties of HZSM5 and improve the synergy of hydrocarbon fuel properties (Awogbemi et al., 2021). Laca et al. (2017) found that CaO has a small surface area that limits the exposure of active basic sites which impacted the long reaction time needed for the completion of catalytic cracking of heavy compounds into light compounds. Hence, the

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