Journal of Analytical and Applied Pyrolysis 118 (2016) 86–97

Contents lists available at ScienceDirect

Journal of Analytical and Applied Pyrolysis

journal homepage: www.elsevier.com/locate/jaap

Impacts of nickel supported on different zeolites on waste tire-derived oil and formation of some petrochemicals

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ARTICLE INFO

Article history:
Received 8 July 2015
Received in revised form 4 January 2016
Accepted 5 January 2016
Available online 8 January 2016

Keywords:
Pyrolysis
Waste tire
Nickel
Petrochemical
Zeolite

ABSTRACT

Waste tire-derived oils commonly contain the considerable valuable aromatics such as benzene, toluene, ethylbenzene, toluene, xylenes and etc., but they also contain a significantly-high amount of sulfur compounds, which cause a low quality of pyrolytic oil. Ni is a cheap metal, which exhibits hydrogenation/dehydrogenation and ring-opening like a noble metal, and widely used as promoter in desulfurization of fuels. In this work, Ni was expected to be a catalyst promoter of zeolites for reduction of sulfur content in oil and enhancement of petrochemical formation in oil. Therefore, the effect of 5 wt.% nickel loading on different four type zeolites (HZSM-5, HMOR, HY, HBETA) on the sulfur removal and quality of waste-tire derived oil was studied. The results show that the incorporations of nickel on all zeolites significantly reduced sulfur contents in oil. However, the quality of waste tire-derived oil did not only depend on the nickel promoter, but also strongly depended on zeolite supports. The introduction of nickel on HZSM-5 zeolite, which possesses a smaller pore size than HBETA zeolites, provided a lighter oil with higher proportion of gasoline and kerosene than Ni/HBETA catalyst, and produced a higher amounts of valuable aromatic such as ethylbenzene, toluene, cumene, and mixed-xylenes than Ni/HBETA catalyst. Moreover, the addition of nickel on HMOR zeolite, which possesses a 1D zeolite channel structure, also provided a lighter oil with a high proportion of gasoline and kerosene than the Ni-loaded on HBETA (3D zeolite channel structure), and exhibited a better petrochemical production with a higher concentrations of ethylbenzene, toluene, cumene and styrene in maltene. On the other hand, Ni/HBETA provided the lower sulfur content in oil than Ni/HMOR catalyst, but the sulfur removal ability by nickel species on HMOR was higher than nickel species on HBETA zeolite. Furthermore, the introduction of nickel on HY zeolite provided the heavier oil with higher proportion of gas oil, LVGO and HVGO and lower proportion of petrochemical than Ni/HBETA zeolite whereas the sulfur removal of nickel species on the HBETA support with higher acid strength was better than on the HY support.

1. Introduction

In recent decades, pyrolysis of waste tire is the useful process that can recovery valuable chemicals from waste tire and eliminate the environmental impacts from disposal of waste tire. Among the waste tire-derived products, waste tire-derived oils have received more attention since their properties are quite similar to those of commercial diesel and heating oil. Petrochemicals can be classified into olefins and aromatics, and utilized as a raw material in manufacturing of plastics, solvents, detergents, synthetic rubber, cosmetic products and pharmaceuticals. From past to present, petrochemicals such as ethylene, propylene, butadiene and BTEX are mainly produced via cracking of naphtha and ethane derived from crude oil and natural gas [1]. However, the production of petrochemicals via petroleum and natural gas is not sustainable since the petroleum and natural gas resources continuously decrease. As a result, several alternative processes for production of petrochemical by utilization of methane, coal, biomass and waste tire have attracted a great attention. Among these alternative processes, waste tire pyrolysis is considered as an effective process since it can eliminate waste tire problems by breaking up the tire molecules into valuable chemicals or fuel. Moreover, several studies reported that tire-derived oils contain a considerable concentration of valuable aromatics such as benzene, toluene, ethylbenzene, styrene, xylenes and etc [2] and [3]. How-

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http://dx.doi.org/10.1016/j.jaap.2016.01.001
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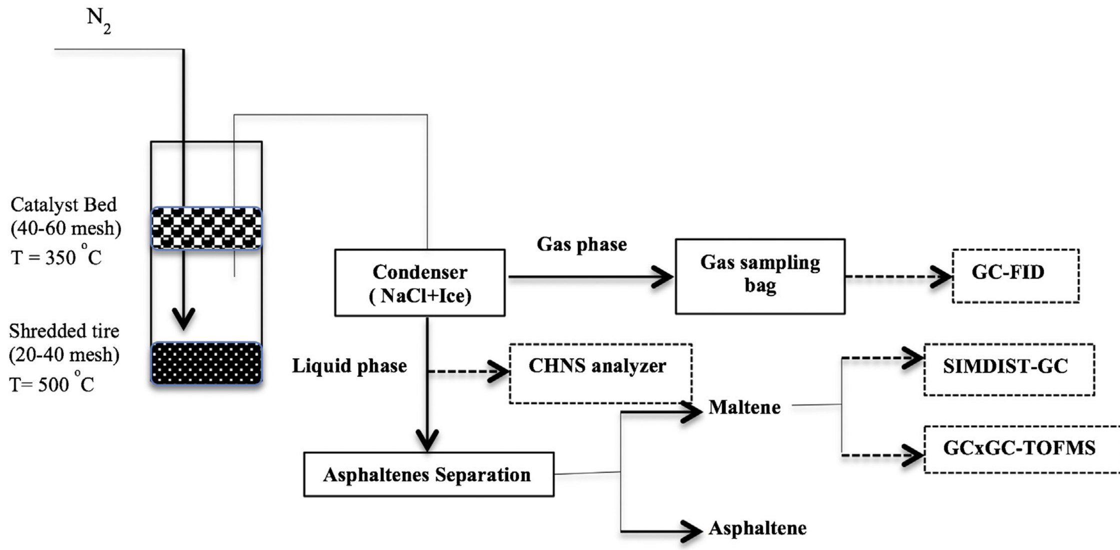

Fig. 1. Schematic of waste tire pyrolysis system for collection and analysis of products.

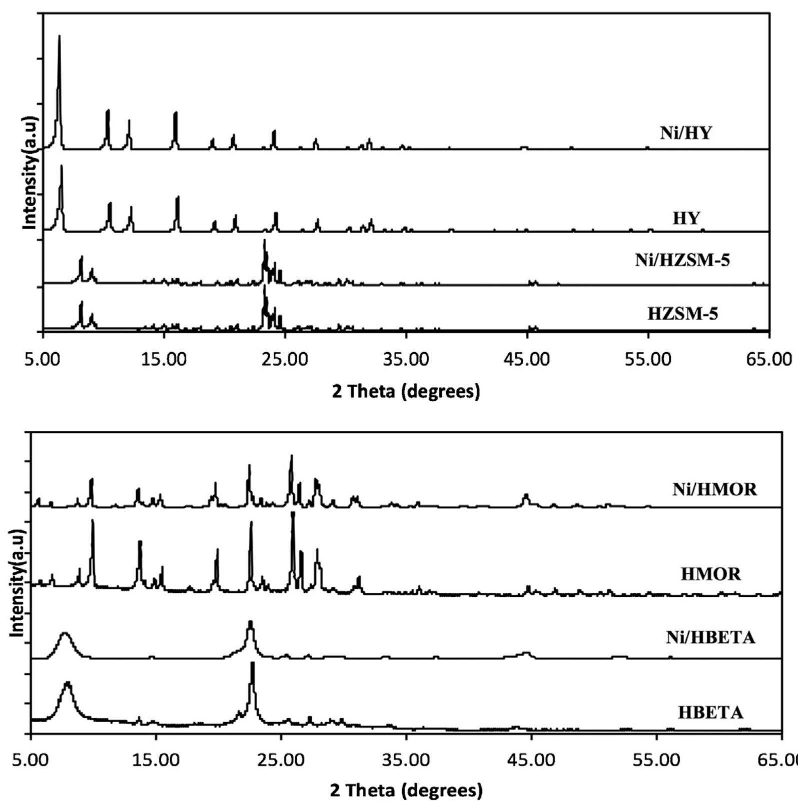

Fig. 2. XRD patterns of zeolites and impregnated catalysts.

ever, the major drawback is the relatively high concentrations of sulfur and nitrogen, which vary in the range of 0.5–3 wt.%, depending on the pyrolysis system and catalysts [4]. They contain a great amount of sulfur since the sulfur is an additive in vulcanization process. Acidic zeolites such as HBETA, HMOR, HY, HZSM-5 have been proven to be able to reduce sulfur content in oil and enhance the quality of tire-derived oil. Du˜ng et al. [5] stated that HMOR increased the concentration of mono-aromatics in oil, whereas the polycyclic aromatics, especially polar-aromatics significantly decreased. In addition, HMOR also increased the naphtha fraction in oil, whereas the heavy fraction drastically decreased. HBETA and HY zeolites increase naphtha and kerosene fractions, whereas the heavier fraction slightly decreased [6]. Thus, these studies indicate that different zeolites provide different product distribution because each zeolite has unique properties. In particular, HZSM-5 zeolite is commonly used as a catalyst in the petrochemical industry due to its pore size, strong acidity and strong resistance to deactivation. Boxiong et al. [7] found that the HZSM-5 enhanced the production of benzene, toluene and xylenes. The high acid strength of zeolite is favorable for production of valuable aromatics, but the high acid density is favorable for sulfur removal from oil. The pore size of zeolite plays an important role in governing the molecular