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Catalytic pyrolysis of Athabasca bitumen in H_2 atmosphere using microwave irradiation

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ABSTRACT

Microwave-assisted catalytic pyrolysis was carried out for upgrading of Athabasca bitumen. The bitumen can be heated to the desired target temperature (430 °C) for pyrolysis with silicon carbide (SiC), a heating element, in approximately 10 min under microwave irradiation. However, the pyrolysis with SiC only resulted in heavy and viscous liquid product having an API gravity of 17.14°. Addition of Nickel and Molybdenum nanoparticles as catalysts enhanced the pyrolysis performance in terms of liquid yield and quality. In the pyrolysis with Mo nanoparticles, the yield and the API gravity of the liquid product were 72.0 wt% and 20.98°, respectively. However, the separate existence of nanoparticles and SiC in the reactor and the recovery problem of nanoparticles, might limit their application in microwave-assisted pyrolysis. In order to prepare a composite with microwave susceptibility and catalytic activity in one body, transition metals were loaded on alumina coated SiC. When it is compared to the direct application of metal nanoparticles to the pyrolysis of bitumen, the NiMo/Al_2O_3/SiC catalyst showed enhanced catalytic performance. The API gravity and sulfur contents of the liquid products from the pyrolysis with NiMo/Al_2O_3/SiC were 22.42° and 2.84 wt%, respectively.

Keywords: Athabasca bitumen; Microwave heating; Pyrolysis of heavy oil; NiMo–SiC composite

1. Introduction

Concerns about the declining availability of conventional crude oil have led to the development of heavy crude, such as tar sands, natural bitumen and oil shale. Heavy crude reserves are approximately equivalent to one third of the world's total oil and gas reserves (Chilingarian, 1978) and their successful development could offset the decreasing production of conventional crude. Unfortunately, it is impossible to exploit heavy crude as it is because of its high density, viscosity and impurities. Therefore, a number of carbon-rejecting processes such as coking and visbreaking, and hydrogen addition processes including hydrocracking have been developed and used on a commercial scale (Furimsky, 2007).

Upgrading processes for heavy crude are generally operated at high temperature except for solvent deasphalting (Del Bianco et al., 1993; Rana et al., 2007). The objectives of the upgrading processes are to maximize light fractions through thermal treatment as well as to remove impurities; it is, therefore, necessary to control the reaction temperature precisely to suppress over- or under-cracking in the reactor. The development of new types of reactors with increased efficiency for the processing of heavy crude has been continuously attempted (Leadbeater and Khan, 2008; Wang et al., 2008). In this study, we adopted microwave irradiation for effective heat transfer and simple reactor design.

Microwave irradiation has been drawing increasing attention as a way of facilitating chemical reactions. It is often

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