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Recent Advances in Heavy Oil Upgrading Using Dispersed Catalysts

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ABSTRACT: Unconventional feedstocks, such as heavy vacuum residue (VR), have become potential candidates that could be positively exploited to meet the increasing demand of high-value transportation fuels, in view of the growing scarcity in other energy sources. However, such feeds contain extremely high-molecular-weight species, besides many impurities of heteroatom-containing organic compounds that lead to quick fouling, poisoning, and deactivation of catalysts. This causes a significant pressure decrease during the conventional hydrocracking in ebullated- or fixed-bed reactors. In contrast, slurry-phase hydrocracking has the ability to overcome these drawbacks through the enhancement of hydrogenation reactions in the presence of the dispersed catalysts. Slurry-phase processing is a resilient technology, which employs catalysts that are generally categorized as heterogeneous solid supported catalysts and homogeneously dispersed catalysts. The dispersed catalysts are classified into water or oil-soluble types and fine powders. Soluble dispersed catalysts show higher catalytic activity, compared to finely powdered catalysts, because of the in situ formation of infinitesimally minute active metal sites at high surface-area-to-volume ratios. Recent technologies and studies on heavy oil upgrading that implement the dispersed catalysts have been reviewed. Studies using a combination of two-phase catalysts have also been included.

1. INTRODUCTION

The depleting supply of light crude oil and the increasing demand for high-value clean fuels has encouraged petroleum refiners to process low-value feedstocks, such as fuel oil, bitumen, and residual oils (Figure 1). One of the most critical

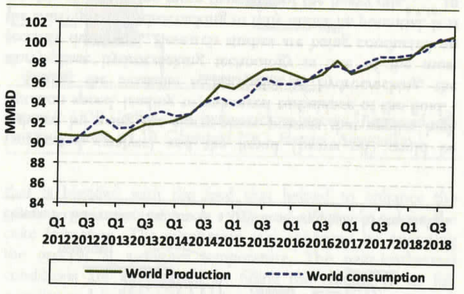

Figure 1. World's production and consumption capacity of liquid fuels. Adapted from ref 1.

issues that have accentuated the problem is the fact that the decrease in the availability of conventional crude oils, because of the massive dependence on light oil.[1] Consequently, the utilization of every fraction of heavy petroleum feedstocks represents the facile challenge to solve the issue of the increased demand for light transportation fuels and to reduce the dependency on conventional crude oil reserves. The source of heavy oil can be either straight-run or produced due to thermal/catalytic processes within the refineries. Naturally, heavy oil is found in the form of a high-boiling fraction of heavy crude oil or extra-heavy crude. Moreover, the heavy oil could be produced in the petroleum refineries because of the nondestructive physical separation processes that occurs in the atmospheric distillation, as well as the vacuum distillation that produce heavy residues, such as vacuum residue (VR) and vacuum gas oil (VGO).[2]

The technologies implemented in the refining industry to upgrade the heavy oil can be categorized as thermal or catalytic processes. The thermal processes include delayed coking, flexi-coking, visbreaking, and fluid coking.[2] On the other hand, the catalytic upgrading of heavy oil is accomplished through either catalytic hydrocracking or fluid catalytic cracking (FCC). In order to address the most problematic issue in heavy oil processing, which is the condensation of the polynuclear aromatics and the cause of coke formation, catalytic cracking conducted by utilizing hydrogen was a revolutionary leap and it was referred to as "hydrocracking". Catalytic hydrocracking has become an essential component for the petroleum refining industry for upgrading low-value feedstocks.[3−5] The hydrocracking was first introduced in Germany in 1915 to provide light valuable liquids derived from coal. In 1927, the first attempt to build a commercial hydrocracking unit was made in

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