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Intensification of the steam stimulation process using bimetallic oxide catalysts of MFe_2O_4 (M = Cu, Co, Ni) for in-situ upgrading and recovery of heavy oil

Ameer H. AL-Rubaye[3] · Muneer A. Suwaid[1,2] · Ameen A. Al-Muntaser[1,2] · Mikhail A. Varfolomeev[1,2] · Ilfat Z. Rakhmatullin[4] · Mohammed H. Hakimi[5] · Shadi A. Saeed[1]

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Abstract

In this study, bimetallic catalysts based on transition metals $CuFe_2O_4$, $CoFe_2O_4$ and $NiFe_2O_4$ are proposed for catalyzing aquathermolysis reaction during steam-based EOR method to improve in-situ heavy oil upgrading. All upgrading experiments were carried out under a nitrogen atmosphere for 24 h in a 300-ml batch Parr reactor at 250 and 300 °C under high pressure 35 and 75 bar, respectively. To evaluate the catalytic performance of the bimetallic catalysts used, comprehensive studies of changes in the physical and chemical properties of the improved oils, including the viscosity, elemental composition and SARA fractions of oils before and after upgrading processes were used. Furthermore, individual SARA fractions were characterized in detail by Gas Chromatography (GC), High-Performance Liquid Chromatography (HPLC) and Carbon-13 Nuclear Magnetic Resonance (^{13}C NMR), respectively. The results showed that bimetallic catalysts have high catalytic performance at 300 °C for the upgrading of heavy crude oil in viscosity reduction, increasing the amount of saturates (especially alkanes with low carbon number) as a result of thermal decompositions of high molecular weight compounds like resin and asphaltenes leading to their increasing. Furthermore, the upgrading performance is reflected in the improvement of the H/C ratio, the removal of sulfur and nitrogen through desulfurization and denitrogenation procedures, and the reduction in polyaromatic content, etc. $CoFe_2O_4$ gives the best performance. Generally, it can be concluded that, used bimetallic based catalysts can be considered as promising and potential additives improving in-situ upgrading and thermal conversion the heavy oils.

Keywords Heavy oil · Catalytic aquathermolysis · Bimetallic catalyst · Chemical composition · SARA analysis

Introduction

Due to the depletion of light crude oil reserves around the world, heavy crude oil production will rise, implying that heavy oil resources have enormous potential to meet future demand for petroleum products (Zhang et al. 2012). On the other hand, the International Energy Agency (IEA) estimated that fossil fuels such as heavy crude oil, coal and natural gas would reach about 60% of global demand growth by 2030 ("Forecasting Supply and Demand up to 2030," 2005). Heavy oil constitutes at least 25% of the world's oil reserves, a significant proportion of the estimated reserves of hydrocarbons. Huge deposits have proven to be associated with abundant light oil fields in a region like the Middle East. Moreover, there are thirty global countries listed with large heavy oil reserves, with the biggest reservoirs being the USA, Canada, and Venezuela (Hein 2006; Mokrys and Butler 1993). Heavy crude oil defined as unconventional crude

✉ Muneer A. Suwaid
suwaidmuneer@gmail.com

✉ Mikhail A. Varfolomeev
mikhail.varfolomeev@kpfu.ru; vma.ksu@gmail.com

1 Department of Petroleum Engineering, Kazan Federal University, Kazan, Russia 420008

2 Department of Physical Chemistry, Kazan Federal University, Kazan, Russia 420008

3 Department of Petroleum Engineering, AL-Kitab University, Altun Kupri, Iraq

4 Department of Solid-State Physics, Kazan Federal University, Kazan, Russia 420008

5 Geology Department, Faculty of Applied Science, Taiz Univrsity, 6803 Taiz, Yemen

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