Study on Ni-based mono and bimetallic catalysts supported on alumina and ceria support for steam reforming of heavy oil

Anamika Maurya, Rajesh K Upadhyay, Sweta Sharma*

Department of Chemical Engineering & Technology, IIT (BHU) Varanasi, U.P.-221005, India
* Corresponding Author: Sweta Sharma Email: shweta.che@iitbhu.ac.in

Highlights

- Synthesis of Ni-based catalysts for steam reforming of heavy oil
- Characterization of the catalyst shows good metal dispersion
- Activity testing of the catalysts show good hydrogen selectivity for bimetallic catalysts

1. Introduction

The continuous increase in energy demand across the globe has forced to extract more crude oil which is critical resource for energy generation. Currently, in the proven reserve of petroleum crude around 70-80% is of unconventional heavy crude oil [1]. High content of heavy fractions, high viscosity, resin and asphaltic intricate the operation of heavy crude oil. However, due to the increased energy demand the unconventional heavy oil stocks are considered as a future of petroleum industry. Therefore, it is critical to develop the methodology to convert the heavy oil to useful fuel. Hydrogen is considered as a next generation fuel for power generation and transportation applications. Therefore, it is vital to convert heavy oil to hydrogen to enhance the economical value of the same. Steam reforming is a conventional and efficient process to convert any carbonaceous feed stock to hydrogen. However, the excessive coke formation during the steam reforming of heavy creates major issues by destabilize the bed an deactivating the catalyst. In current work, effort is being made to generate hydrogen from heavy crude oil produced from Dwarka basin of India. The heavy oil used in current work is very viscous and does not flow at room temperature. Therefore, it is heated up to 100 °C and mixed with 20% water to increase its flowability. A Ni-based mono metallic and bimetallic catalysts are prepared on alumina and ceria support. Initially, the effect of support on conversion, hydrogen selectivity and coke formation are analyzed. Thereafter, bimetallic catalysts are synthesized by combining the Ni with Co, Fe, La, and Rh. The effect of each metal on performance of steam reforming are analyzed. The experiments are performed at different temperatures (500-850°C), inlet flow rates, steam to carbon ratio, and metal loading to optimize the complete process.

2. Methods

Commercial ceria and θ-alumina support is used in current work to prepare the catalyst. The Ni/Al_2O_3 and Ni/CeO_2 catalyst is prepared by using wet impregnation method. To prepare the bimetallic catalyst nitrate salt of each metal is used in the ratio the metal needs to be deposited. The prepared catalysts are characterized by using BET, XRD, SEM, and TEM. The experiments are performed in a conventional packed bed reactor of 11mm OD and 60 cm length. The catalyst is packed at the center of the reactor to maintain the uniform temperature. For each experiment 0.5 gm catalyst mixed with same amount of quartz particle is used. The heavy oil is initially heated up to 100 °C and mixed with 20% water to increase the flowability. The mixture is fed by a peristaltic pump with desired flowrate. The remaining water is fed through another line by using similar pump to maintain the pressure. The mixture is heated up to 300 °C before entering into the reactor. The experiments are performed at different temperature ranging from 500 °C to 850 °C, WHSV (10-30), steam to carbon ratio and metal loading.

3. Results and discussion

Initially, the synthesized catalysts are characterized by using BET, SEM, XED and TEM. Figure 1a and 1b show the SEM images of Ni/Al_2O_3 catalyst. The images show good dispersion of Nickel on alumina support. Figure 1c shows XRD graph of Ni/Al_2O_3 catalyst. In this graph peak of NiO at 2θ 72°, Al_2O_3 & NiO peaks at 2θ 136.8°, Ni & $NiAl_2O_4$ peaks at 2θ 162^0, $NiAl_2O_4$ peak at 2θ 216° and Al_2O_3 peak at 2θ 244.8 are observed. This confirms the Ni doping at different oxidation state of Ni on alumina support. Figure 1d shows the BET graph which shows Type IV isotherm. The surface area of Ni/Al_2O_3 is 106 m^2/g. Similarly, the characterization of each catalyst is performed which will be presented in the final manuscript. The activity testing of all the catalyst will also be presented in the final manuscript.

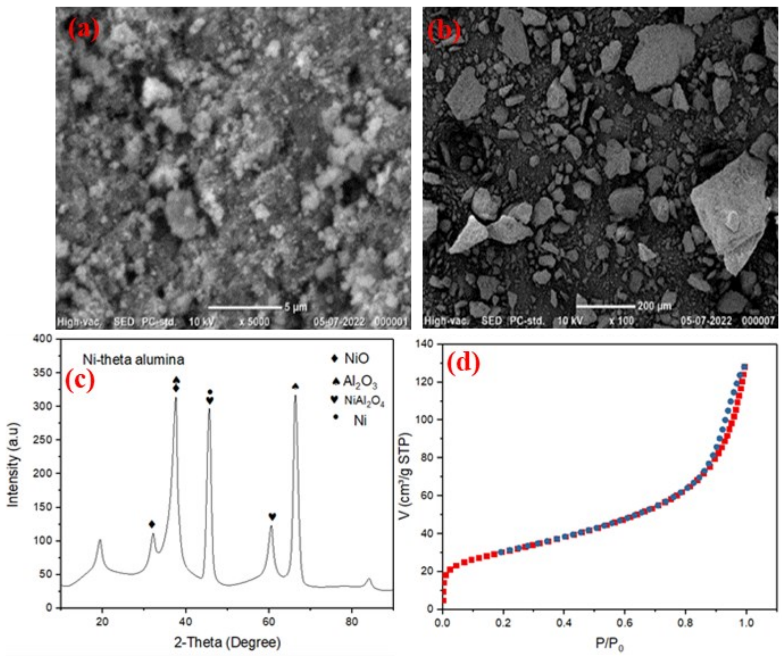

Figure 1. Characterization of Ni/Al_2O_3 catalyst (a) SEM image at 5 µm (b) Sem image at 200µm (c) XRD graph (d) BET graph

4. Conclusions

The current work presents the effort on developing the steam reforming process for heavy crude oil produced from Dwarka basin of India. Ni-based Mono metallic and bimetallic catalysts are synthesized on alumina and ceria support. The complete characterization of the catalysts is performed by using BBET, XRD. SEM and TEM. The activity of synthesized catalysts are tested in a packed bed rector to optimize the process conditions.

References

[1] Alboudwarej, H., Felix, J., Taylor, S., Badry, R., Bremner, C., Brough, B., Skeates, C., Baker, A., Palmer, D., Pattison, K., Beshry, M., Krawchuk, P., Brown, G., Calvo, R., Triana, J. A. C., Hathcock, R., Koerner, K., Hughes, T., Kundu, D., de Cárdenas, J.L., and West, C., Oilfield Rev. (2006), 18: 34–53.

Keywords: Hydrogen Production, Steam reforming of methane, Catalyst synthesis and testing