**Experimental Study of Inductive Heating-Assisted Catalytic Hydrocracking of Naphthalene and Tetralin as Model Compounds of Heavy Oil.**

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**Highlights**

* Hydrogenation upgrades poly-aromatics into light hydrocarbon components.
* Dehydrogenation causes condensation of poly-aromatics exemplar of heavy oil.
* Ni enhanced the hydrogenating activity of the catalyst compared with Co.
* The rate of naphthalene hydroconversion is higher than tetralin.

**1. Introduction**

The demand for transportation fuels is rising with the major source of supply being declining crude oil reserves. To meet the demand-supply gap, the exploitation of lower quality but abundant deposits of heavy oil and bitumen is necessary, while waiting for the transition to renewable fuels. Partial upgrading of heavy oil can be achieved in situ through Toe-to-Heel Air Injection (THAI) and its catalytic variant CAPRI; however, to attain the required temperature in the catalytic zone necessitates a rapid heating method such as inductive heating [1].

Poly-aromatic hydrocarbons account for remarkable portion of heavy oil and bitumen, and give them high viscosity and low American Petroleum Institute (API) gravity. In the process of catalytic upgrading, the poly-aromatics are readily condensed to form coke, especially in a hydrogen limited environment which rapidly deactivates and plugs the catalyst pores [1,2].

The hydrocracking of poly-aromatics in heavy oils with inductive heating-assisted catalysis was studied. Typical hydrotreating catalysts (e.g., NiMo/Al2O3 and CoMo/Al2O3) were evaluated for hydrocracking reactions. The formation of coke based on the number of aromatic rings was also studied using naphthalene and tetralin. This study is conducted as part of the evaluation of incorporating inductive heating to augment the temperatures in the vicinity of the catalyst zone in the THAI-CAPRI process in order maximise catalyst performance and increase upgrading.

**2. Methods**

Commercial catalysts NiMo/Al2O3 and CoMo/Al2O3 quadra-lobe shaped (AkzoNobel) with dimensions (5 ± 2.1 mm × 1.4 mm × 1.21 mm) were used. The feedstock was naphthalene (99+%, Alfa Aesar), tetralin (99.5%), solvent n-hexadecane (99%, Alfa Aesar) and H2 supplied by BOC, UK.

The inductive heating system comprises of a fixed bed reactor of quartz glass tube (440 mm × 20 mm i.d × 40 mm o.d) rated 20 bar pressure (Inductelec Ltd and assembled by C-Tech Innovation, UK). The height of the induction coil wound around the tube is 230 mm, which also represent the catalytic bed height. The catalyst bed is heated inductively by steel balls susceptors of size 3 mm mixed the catalyst in a volume ratio of 70% (v/v). The steel balls convert the electromagnetic field into heat, to heat the catalyst bed volumetrically. The reactants were preheated to 200 °C with the aid of trace heater cable wrapped around the line and mixed with hydrogen prior to being delivered into the reactor from the top. A hydrogen flow rate of 200 mL.min-1, temperature 300 ºC, catalyst-to-steel balls ratio (CTSBR) 70% (v/v), pressure 18 barg, and LHSV 0.75 h-1 condition obtained from optimisation were used in the experiment.

The liquid product was analysed using an Agilent 6890N GC equipped with a capillary column HP-5 (30 m × 0.320 mm × 0.25 μm), and a thermogravimetric analyser, TGA (TG 209 F1 Iris® instrument, NETZSCH-Geratebau GmbH) was used to determine the amount of coke on the catalyst.

**3. Results and discussion**

Induction heating provided an effective means of heating the catalyst bed, with 70 %v/v CTSBR the bed could be heated to 250°C within about 3 minutes. In previous study with NiMo/Al2O3 alone, we found that with induction heating the catalytic activity was enhanced and the spent catalyst coke content was lower when compared to conventional heating. Figure 1 shows hydrogenation of naphthalene and tetralin. The NiMo/Al2O3 exhibited a superior hydrogenating activity than CoMo/Al2O3, which promoted further hydrogenation from tetralin to (*trans*/*cis*) decalins and thus significantly improved the selectivity to decalins (Figure 1a).

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**Figure 1.** The hydrogenation of (a) naphthalene with NiMo/Al2O3 and CoMo/Al2O3 and (b) tetralin with NiMo/Al2O3 at 300 ºC, 18 bar, 0.75 h-1 and CTSBR 70% (v/v).

The sequential reaction scheme shown in Figure 2, can be confirmed in Figures 1a and b, the intermediate tetralin can either undergo further hydrogenation to (*trans*/*cis*) decalins or dehydrogenation to naphthalene. However, the direction of the reaction is largely dependent on the catalyst type and the process conditions.

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**Figure 2**. Reaction scheme

**4. Conclusions**

Induction heating of catalytic bed was studied for hydrogenation and hydrocracking of typical poly-aromatics found in heavy oil. Alumina supported NiMo and CoMo catalysts were investigated, while Ni increased the production of *trans*- and *cis*-decalins than Co, the rate of naphthalene hydroconversion was higher than tetralin for NiMo/Al2O3 catalyst.

**References**

1. A. Hart, J. Wood, Energies. 11 (2018) 636.
2. P.A. Rautanen, M.S. Lylykangas, J.R. Aittamaa, A.O.I. Krause, Ind. Eng. Chem. Res. 41 (2002) 5966-75.