ABSTRACT

Pilot plant experiments were carried out to generate extensive data on the performance of a distillate selective hydrotreating/hydrocracking catalyst system procured from an industrial catalyst supplier. The conversion, product yield distribution and product quality of various fractions obtained from pilot plant hydrocracking experiments were studied using different feedstocks such as vacuum gas oil and blends of vacuum gas oil and solvent deasphalted oil collected from industrial units.

The reactor temperature was varied from 360 to 400°C and overall liquid hourly space velocity from 0.8 to 1.6 h\(^{-1}\) at a constant operating pressure of 170 kg/cm\(^2\) and H\(_2\)/oil ratio of 845 m\(^3\)/m\(^3\) to study the influence of operating conditions on conversion, product distribution and product quality. One experiment was conducted at a reactor temperature of 380°C, liquid hourly space velocity of 0.8 h\(^{-1}\), reactor operating pressure of 120 kg/cm\(^2\) and H\(_2\)/oil ratio of 845 m\(^3\)/m\(^3\) to study the effect of operating pressure on conversion, product yield and product quality during hydrocracking of vacuum gas oil feedstock fraction. The hydrocracked product streams from pilot plant were fractionated in a true boiling point distillation apparatus to separate into various fractions and assess their yields and quality. Detailed characterization of feedstocks and hydrocracked product fractions was done according to standard testing methods.
Different kinetic and modeling schemes were proposed to describe hydrocracking process using a discrete lumping approach. These kinetic schemes were based on known chemistry of hydrocracking process and validated using experimental data obtained from pilot plant hydrocracking experiments at varied operating conditions. The kinetic rate parameters for the proposed reaction schemes were estimated using sequential quadratic programming. The parameter estimation algorithm minimized the error between experimental and predicted product yields based on assumed initial kinetic parameter values. The product selectivity during hydrocracking of different feedstocks was discussed in detail using different reaction schemes.

The pilot plant hydrocracking reactor was simulated using an isothermal model based on the kinetic data obtained from pilot plant experiments. The pilot plant simulations were performed at varied operating conditions and verified with experimental data. A non-isothermal model was applied to simulate the performance of industrial hydrocracker reactor at typical operating conditions using kinetic parameters estimated from pilot plant experiments and incorporating a scale-up factor. This model was used to predict the concentration of feedstock and various product fractions along the length of the reactor. Temperature profiles in the industrial hydrocracker unit were generated. The kinetic model was found to simulate the performance of industrial hydrocracker unit adequately.

Catalyst deactivation was studied considering a linear relationship between the time on stream and required increase in operating temperature and incorporating a catalyst activity parameter.
Detailed pilot plant experiments were carried out to compare the options of hydrotreating and mild hydrocracking for FCC feed pretreatment application using a high nitrogenous vacuum gas oil over industrially available catalysts. MAT experiments were also conducted to compare the conversion and yields of untreated, hydrotreated and mild hydrocracked vacuum gas oil sample at constant operating conditions. The pilot plant studies showed that hydrocracker bottoms with higher saturate content would become a very good feedstock for fluid catalytic cracking unit in terms of increased conversion, better product yield pattern and quality. The effect of operating conditions on the conversion and quality of mild hydrocracked vacuum gas oil was also studied. Different kinetic schemes have been proposed for mild hydrocracking of VGO feedstock and the kinetic constants were listed.

The use of hydrocracker bottoms as a means to produce very high quality lubricating oils meeting Group-II base oil specifications was studied in a hydrotreating pilot plant and the data compared with conventional solvent processing. The pilot plant data showed that lube base oils produced from hydrocracker bottoms had very high VI and lower sulfur meeting stringent Group-II specifications.