CHAPTER 6

CONCLUSIONS

This chapter presents significant conclusions drawn from this work based on the experimental and kinetic and modeling studies on hydrocracking process and its integration with other important secondary refining processes discussed in the earlier chapters. The suggestions for further work in the area of hydrocracking are also included in this chapter.

6.1 SUMMARY OF THE PRESENT WORK

In the present work, detailed experiments were conducted in a pilot plant trickle bed reactor to evaluate the performance of an industrial, distillate selective hydrocracking catalyst system and extensive data were generated using different operating conditions and feedstocks. A vacuum gas oil sample obtained from industrial vacuum distillation unit and a blend of 20% deasphalted oil collected from industrial solvent deasphalting unit and 80% vacuum gas oil were used as feedstocks for the hydrocracking experiments. The later feedstock was used in the pilot plant experiments to study the influence of feedstock quality on conversion, product yields and product quality. The reactor temperature was varied from 360 to 380°C, liquid hourly space velocity from 0.8 \( \text{h}^{-1} \) to 1.6 \( \text{h}^{-1} \) and operating pressure from 120 to 170 kg/cm\(^2\) at a constant \( \text{H}_2/\text{oil} \) ratio of 845 m\(^3\)/m\(^3\) to study the influence of operating conditions on conversion, product yield distribution, product quality and selectivity.
The hydrocracked product samples were further distilled in a true boiling point distillation unit to separate various fractions obtained by hydrocracking of the feedstocks and to assess their conversion, product yields and product quality. The feedstocks and various product fractions obtained from true boiling point distillation were characterized in detail for sulphur, nitrogen, saturates, aromatics and other important properties. The mechanism of hydrocracking process was investigated in detail based on the results obtained from pilot plant studies.

Different kinetic reaction schemes were proposed for hydrocracking process considering various reactions between discrete lumps of feedstock and product fractions. There were seven kinetic schemes presented in the present work each with increasing complexity. The model differential equations were formulated for all the kinetic schemes. The kinetic parameters were estimated using a SQP algorithm for all the schemes and presented. The yield distribution of all the products was predicted using these kinetic parameters. The proposed kinetic schemes were found to represent the hydrocracking process very well. The product selectivity of the hydrocracking catalyst was studied considering specific reaction schemes. The selectivity kerosene, diesel and middle distillates were studied using expressions derived analytically for the maximum yield and the time of maximum yield and presented.

The pilot plant reactor was simulated considering isothermal operation of the reactors. Hydrocracking, hydrodesulfurization and hydrodenitrogenation reactions were considered in the model. The model predicted the performance of pilot plant reactor very well. The industrial hydrocracker was modeled using kinetic parameters estimated from pilot plant experiments considering the non-isothermal nature of industrial reactor and using a scale-up factor. MATLAB software was used to solve the model
equations in all cases. The model applied to simulate the performance of both pilot plant and industrial reactors was found to agree well with experimental data at varied operating conditions.

The catalyst deactivation was analyzed assuming a simple linear relationship between the time on stream and required operating temperature using the data supplied by industrial catalyst supplier. Catalyst activity curves were generated for the two feedstocks used in the pilot plant study using a catalyst activity parameter.

Pilot plant experiments were carried out to study the various applications of hydrocracking process with respect to its integration with other secondary processing units in the refinery especially FCC unit and lube base oil manufacturing unit. Experiments were conducted to compare the options of hydrotreating and mild hydrocracking for FCC feed pretreating application using industrially available hydrotreating and MHC catalysts over a high nitrogenous vacuum gas oil. The conversion, product yields and quality during MHC operating was studied at various operating conditions. MAT experiments were conducted to compare the options of untreated and hydroprocessed vacuum gas oils on FCC unit performance. Different kinetic reaction schemes were presented for MHC process and kinetic parameters listed for all the schemes.

The use of hydrocracker bottoms as feedstock to lube base oil manufacturing unit was investigated with isodewaxing and solvent dewaxing options. Isodewaxing experiments were conducted in high pressure reactor system using an indigenous isodewaxing catalyst at different operating conditions. Solvent dewaxing of hydrocracker bottoms was carried out in a laboratory scale dewaxing unit.
6.2 SUGGESTIONS FOR FURTHER WORK

- In the present work, the effect of various catalysts on the performance of hydrocracking process was not studied. Further work can be taken up to evaluate different hydrocracking catalysts with varying metal/acid ratios to investigate their effect on the performance of hydrocracking process especially with respect to conversion, product yields, product quality and selectivity.

- Present experimental work did not study the effect of recycle of unconverted bottoms on the performance of hydrocracking process. The hydrocracking studies can be undertaken considering various configurations of hydrocracking process especially single stage recycle, two stage recycle etc.

- The kinetic modeling schemes used in the present work can be extended to incorporate mass transfer and hydrodynamic effects.

- In the present work, deactivation of hydrocracking catalyst was studied assuming catalyst life cycle given by the catalyst supplier. Further studies can be undertaken to develop a pilot plant method to estimate catalyst life cycles based on accelerated deactivation testing of the catalysts.