REVIEW

from

Prof. Olympia Roeva, PhD

Institute of Biophysics and Biomedical Engineering - BAS

Bioinformatics and Mathematical Modeling Department

for awarding of the educational and scientific degree "Doctor of Philosophy"

Professional field:

4.6 Informatics and computer sciences,

Doctoral programme: 01.01.12 Informatics

with a candidate

Eng. Borislav Enchev Georgiev, M.Sc.

Dissertation title
"Investigation of oil refining processes using InterCriteria analysis"

1. Relevance of the problem developed in the PhD thesis in scientific and scientific-applied terms.

Petroleum is still the main fuel that satisfies humanity's energy needs. No matter how much work is done to increase the share of renewable energy sources, petroleum-based fuels will have the largest share for a long time. Due to this fact, increasing the efficiency of oil refining processes is essential, both economically and environmentally.

In the PhD thesis, problems related to the study of various processes in the processing of petroleum derivatives are considered and solved. The PhD thesis is relevant both scientifically (finding new knowledge) and in a scientific-applied sense (application of established knowledge in the refinery of "LUKOIL Neftohim Burgas" AD).

2. Degree of knowledge of the state of the problem and creative interpretation of the literature

The PhD student has presented in detail and systematized the state and problems in the field under consideration. An overview of the processes of hydrocracking of goudron and

catalytic cracking of vacuum gas oil in the processing of raw materials of different quality and catalysts with different properties is made. A literature review on the theory and application of InterCriteria analysis (ICrA) is also presented. The theory of ICrA is presented well, but in my opinion, the analysis for ICrA applications needs to be expanded a bit.

As a result, main conclusions were drawn and the aim of the dissertation work was formulated, namely "the study of the processes Hydrocracking of vacuum residue H-Oil" and "Catalytic Cracking Fluid Type" (FCC) in the conditions of processing of oil derivatives originating from different types of oil processed in the refinery of "LUKOIL Neftohim Burgas" AD using InterCriteria analysis."

To fulfil the set goal, five tasks have been defined:

1. To investigate the application of different techniques for the analysis of group hydrocarbon composition (SARA) of residues from different types of crude oil from all over the globe and to correlate the SARA data analysis of the hydrocracking feedstock to the operation of the industrial H-Oil plant at "LUKOIL Neftohim Burgas" AD and to investigate the evolution of the quality of the hydrocracked vacuum residue as the conversion of the goudron increases in the range 55 - 93%. Using InterCriteria analysis to determine those types of oil, whose goudron fractions are most suitable for processing in the refinery of "LUKOIL Neftohim Burgas" AD and lead to the highest profitability.
2. To investigate the possibilities of InterCriteria analysis for finding economically and technologically favourable conditions in the processing of technologically unfavourable types of oil.
3. To quantify the effect of the properties of vacuum gasoils produced in the vacuum residue hydrocracking process H-Oil on the vacuum gasoil conversion, yield distribution and product quality of the FCC process using InterCriteria analysis of experimental data.
4. To define the role of the catalyst in optimizing the performance of an industrial catalytic cracking unit using an InterCriteria analysis of the generated experimental data.
5. To evaluate the factors contributing to the increase of the vacuum residue conversion and the decrease of the pollution rate in the hydrocracking unit "Hydrocracking of vacuum residue H-Oil" at "LUKOIL Neftohim Burgas" AD by replacing the cascade with a parallel scheme for the supply of fresh catalyst to the reactors by applying the InterCriteria analysis.

3. General analytical characteristics of the PhD thesis

The PhD thesis is well structured and logically consistent according to the tasks to be solved. The work is in a volume of 203 pages. It contains an introduction, 5 chapters (one overview chapter and four research results chapters), a conclusion, contributions, a list of publications on the PhD thesis, noted citations, a declaration of originality, a bibliography (299 titles) and a Certificate of the practical application of the obtained results.

Chapter 1 is an overview and presents the state of the considered problem according to literature data. A bibliography numbering 299 sources was used, including fundamental publications for the field, as well as current publications from the last 10 years.

Chapter 2 presents the results of an industrial study of "H-Oil hydrocracking" at a goudron conversion of 55 - 93%. Data for 138 types of oil were analyzed with ICA. Besides the known relationships of the density of direct distillate goudron with the content of aromatic structures, a weak positive consonance ($\mu = 0.75$) of the content of saturated hydrocarbons with the colloidal instability index (CII) was found.

Chapter 3 presents the results of a study of the catalytic cracking process of various vacuum gas oils obtained by hydrocracking of goudron. Using ICrA, the evaluation values of the relationships between 11 characterizing parameters of heavy gas oils and H-Oil residues and the efficiency of catalytic cracking type fluid were found. The results of the ICrA and the knowledge gained from previous studies on the cracking propensity of vacuum gas oils were used to derive regression equations relating the properties of H-Oil heavy oil fractions to conversion, and product yields and quality concerning catalyst /raw material of 7.5 wt./wt.

Studies of the role of the catalyst in optimizing the efficiency of the catalytic cracking fluid in the processing of H-Oil goudron hydrocracking gas oils using ICrA are presented in Chapter 4. Two feedstocks from the industrial catalytic cracking plant and three gas oils obtained from the hydrocracking process of H-Oil goudron in the "H-Oil" plant at "LUKOIL Neftohim Burgas" AD were cracked in a laboratory plant for advanced catalytic assessment (ACA) on five different catalysts. By performing refinery profitability estimates using the linear programming model (Honeywell RPMS software) and ICrA, it was found that the single factor that most affected refinery profitability was the depth of refining. In addition, catalysts that, in the processing of various feedstocks for catalytic cracking, allow for the minimization of sludge production from the fluid-type catalytic cracking plant, lead to an increase in the profitability of oil refining in a refinery.

Chapter 5 presents the results of the application of ICrA to improve the performance of the "H-Oil goudron hydrocracking" process when processing unfavourable raw materials. Data from an industrial pseudo-fluidized-bed catalyst vacuum oil residue hydrocracking plant that processes vacuum residues derived from three crude oils: Urals, Siberian Light, and Basra Heavy were analyzed with ICA to determine the factors contributing to an increase in conversion of 70 to 82 wt.% while keeping levels of sludge formation and equipment fouling within reasonable limits. The results show that the activity of the catalyst in the first reactor affects the rate of HDM (hydrodemetallization) and sludge formation to a greater extent than the activity in the second reactor.

4. Evaluation of contributions of the PhD thesis and their significance

I accept the contributions formulated in the dissertation as follows:

Scientific contributions

1. Based on the InterCriteria analysis, a methodology is proposed to evaluate the suitability of a specific type of oil for processing its goudron fraction in the Hydrocracking of the Goudron H-Oil process. The proposed methodology can be used and applied to all hydrocracking processes of goudron.

2. Quantitative relations between the characteristics of H-Oil vacuum gasoil and the products obtained in catalytic cracking are derived, which can be used in the production planning process in a refinery to optimize the profitability of oil refining.
3. Based on the results of the InterCriteria analysis of data from the industrial catalytic cracking plant at "LUKOIL Neftohim Burgas" AD, the factor that controls the profitability of this process is identified. This is the slurry yield. Catalysts and additives that minimise the slurry yield lead to improved economic performance of the refinery.
4. The factor improving the economic performance of the Hydrocracking of vacuum residue H-Oil has been defined using InterCriteria analysis. This factor is the parallel addition of the fresh catalyst to the two reactors in the ebullated bed of the catalyst of the Hydrocracking plant. The economic effect amounts to 6.8 million USD/month.

5. Assessment of PhD thesis publications

7 publications are listed on the PhD work. Four of them are in journals with an impact factor (in one B. Georgiev is the first author) and one is in a journal with an impact rank as follows: ACS Omega (2 publications) (IF = 3.512), Chemical Engineering and Technology (IF = 1.728), Applied Sciences (IF = 2.838) and Oxidation Communications (SJR = 0.216). The publications are in prestigious journals and show the high scientific level of the research. 31 citations of 5 of the publications are also presented. The found citations are evidence of the relevance of the solved problems and the significance of the obtained results.

6. Assessment of the compliance of the autoreferate with the requirements for its preparation, as well as the adequacy of reflecting the main points and contributions of the PhD thesis

The autoreferate correctly reflects the content of the PhD thesis and gives an idea of the problems under consideration, the results obtained, as well as the contributions of the dissertation.

7. Critical notes on the PhD thesis

Borislav Georgiev has taken into account a large part of the previously made comments and notes. I believe that all the essential remarks are reflected in the dissertation work. I would like to note the following recommendations for this work:

I have the following comments on the final PhD thesis:

1. For a PhD thesis defended in a professional direction 4.6 Informatics and computer sciences, scientific speciality: Informatics does not make a good impression if part of mathematical expressions are presented as scanned objects.
2. In future studies with the application of ICrA, attention should be paid to the presentation of the results – μ- and ν-values in indexed matrices. The results shown in Tables 7, 18 and 19 are inaccurate. In Table 7, in the main diagonal

of the IM with ν the values are units, but they should be zeros. In Table 18, on the contrary, in the main diagonal of IM with μ the values are zeros, but they should be units. In Table 19 there is no main diagonal at all.

3. The cited reference [5] on page 21 is probably wrong.

8. Conclusion with a clear positive or negative assessment of the PhD thesis

Based on the above, I give a high rating to the scientific work done by Eng. Borislav Georgiev, M.Sc. and the achieved results.

All the requirements, conditions and criteria of Law on the Development of the Academic Staff in the Republic of Bulgaria, the Internal Regulations for its application, as well as the Regulations for the terms and conditions for acquiring scientific degrees and occupying academic positions in IBPhBME – BAS have been fulfilled. I give a positive assessment of the PhD work and recommend to the respected Scientific Jury to award Eng. Borislav Georgiev the educational and scientific degree "Doctor of Philosophy" in the professional field: 4.6 Informatics and computer sciences, doctoral programme: 01.01.11 Informatics.

13.03.2024 г. Scientific Jury member: .....

Sofia /Prof. Olympia Roeva/