

REVIEW

by **Corresponding Member Lyubka Doukovska, DSc**
from the Institute of Information and Communication Technologies,
at the Bulgarian Academy of Sciences,
on the Thesis for awarding educational and scientific degree **PhD**,
under the Scientific Field: **4. Natural Sciences, Mathematics and Informatics**,
the Professional Area: **4.6. Informatics and Computer Sciences**,
the Scientific Specialty: **Informatics**

Author of the PhD Thesis: **Eng. Borislav Enchev Georgiev**

PhD Thesis Title: **Investigation of oil refining processes using intercriteria analysis**

In accordance with Order No. 73 from 24.01.2024 of the Director of the Institute of Biophysics and Biomedical Engineering at the Bulgarian Academy of Sciences, I have been appointed as a member of the Scientific Jury regarding the PhD thesis of **Eng. Borislav Enchev Georgiev** for awarding the educational and scientific degree “Doctor of Philosophy” (PhD) in the Scientific Field **4. Natural Sciences, Mathematics and Informatics**, the Professional Area **4.6. Informatics and Computer Sciences**, the Scientific Specialty **Informatics**. The scientific advisors are Acad. Krassimir Atanassov, DSc and Prof. Dicho Stratiev, DSc.

As a member of the Scientific Jury I have received:

1. Order No. 73 from 24.01.2024 of the Director of the Institute of Biophysics and Biomedical Engineering;
2. Application for opening a procedure for acquiring the educational and scientific degree PhD;
3. European Curriculum Vitae;

4. Diplom of Master's degree;
5. Protocols and certificates of passed exams according to the individual study plan of the PhD student;
6. List of the publications included in the PhD thesis;
7. Copies of the publications included in the PhD thesis;
8. List of the citations on the publications included in the PhD thesis;
9. Abstract of the PhD Thesis;
10. Dissertation for the educational and scientific degree PhD.

In order to form the final evaluation of the dissertation, the requirements of the *Development of Academic Staff Act in the Republic of Bulgaria* are implemented the specific requirements in the Act's Institutional Regulation shall be taken into consideration, where the respective norms are:

1. Pursuant to Art. 6 (3) of the *Development of Academic Staff Act in the Republic of Bulgaria*, PhD thesis should contain scientific or scientific-applied results, which represent an original contribution in science. The PhD thesis must indicate that the candidate has in-depth theoretical knowledge of the relevant specialty and ability for independent research.

2. According to Art. 27 (2) of the specific requirements in the Act's Institutional Regulation, PhD thesis should be presented in a form and volume corresponding to the specific requirements of the primary unit. The PhD thesis should contain: a cover page; content; introduction; exhibition; conclusion - a summary of the results obtained with a declaration of originality; bibliography.

I. Actuality and significance of the PhD thesis.

The relevance of the PhD thesis is determined by the field of research presented, namely Artificial Intelligence. Artificial Intelligence is the science of the concepts, methods and means of creating intelligent models for the study of natural intelligence.

The PhD thesis submitted for review is dedicated to the use of intercriteria analysis as a tool for the diagnosis and improvement of the efficiency of processes in oil refining, such as Hydrocracking of H-Oil Tar and Catalytic Cracking of Vacuum Gasoline.

The aim of the PhD thesis is „to study 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 achieve the goal, the following tasks are defined:

1. To investigate the application of different techniques for the analysis of group hydrocarbon composition (SARA - Saturates Aromatics Resins Asphaltenes) 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 JSC and to investigate the evolution of the quality of the hydrocracked vacuum residue as the conversion of the gudron increases in the range 55-93%. By means of intercriteria analysis to determine those types of oil, whose gudron fractions are most suitable for processing in the refinery of LUKOIL Neftohim Burgas JSC and lead to the highest profitability.

2. To investigate the possibilities of intercriteria analysis for finding economically and technologically favorable conditions in processing of technologically unfavorable 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 JSC by replacing the cascade with a parallel scheme for the supply of fresh catalyst to the reactors by applying the intercriteria analysis.

II. Summary of the PhD thesis.

The PhD thesis consists of 207 pages. Its structure includes an introduction, five chapters, a conclusion - a summary of the obtained results, a list of publications on the dissertation work, a list of citations, a declaration of originality of the results, a bibliography and a certificate of practical application.

In the introduction, the need to apply the intercriteria analysis in the field of petrochemicals is presented, which will lead to an increase in the efficiency of the entire oil refinery. The purpose of the dissertation work is formulated and the main scientific tasks that will be followed in order to realize the purpose are described.

In the first chapter „A brief literature review on the application of intercriteria analysis in the research of chemistry and technology of petroleum”, the progress in the scientific field and the motivation for the dissertation research are traced. It defines concepts fundamental to the work, such as the Intercriteria Analysis (ICA). Aspects of the catalytic cracking and catalytic Hydrocracking of H-Oil tar processes are described, related to the influence of the type of raw material processed and the type of catalyst used, as well as the industrial application of these processes.

In the second chapter „Industrial investigation of Hydrocracking of vacuum residue H-Oil at 55-93% vacuum residue conversion using intercriteria analysis” results obtained from analytical physicochemical methods for evaluating the parameters (reaction temperature and volume rate) influencing the conversion and the yield of products from the process, together with the properties of the raw material for twelve operating modes of Hydrocracking of H-Oil tar in LUKOIL Neftohim Burgas JSC.

Results of the analysis of data for 138 oil types (the number of oil types that are traded globally is more than 150), by applying ICA, are presented. The known relationships of the density of direct distillate tar with the content of aromatic structures were confirmed, as well as relationships between the content of saturated hydrocarbons and the index of colloidal instability were established.

The analysis of the data obtained by means of ICA confirms the conclusion that the level of tar conversion is statistically dependent on the reaction temperature and the volumetric rate.

In the third chapter „Investigation of catalytic cracking process of various vacuum gas oils produced by Hydrocracking of vacuum residue H-Oil using intercriteria analysis”, ten EBVRHC catalyst fluidized bed hydrocracking vacuum gas oils and one deasphalted EBVRHC vacuum residue, which were cracked in a laboratory advanced catalytic evaluation (ACE) facility on an industrial equilibrium catalyst.

Intercriteria analysis was used to evaluate different oil feedstocks in different oil refining processes, such as the relationships between the properties of eleven characteristic empirical parameters of heavy oil fractions - gas oils and H-Oil residues and their performance in the fluid type catalytic cracking process.

In the fourth chapter „Investigation of the role of catalyst in optimizing the efficiency of fluid catalytic cracking process during cracking of hydrocracked gasoils from Hydrocracking of vacuum residue H-Oil using intercriteria analysis”, the profitability (the profitability of oil refining in LUKOIL Neftohim Burgas JSC) and product yields in catalytic cracking.

It is shown, using the model developed with Honeywell's RPMS (Refinery and Petrochemical Modeling System) software and using data generated from the application of four catalysts and one catalyst plus ZSM-5 additive, that the predominant factor controlling refinery profitability associated with the action of the industrial fluid-type Catalytic Cracking plant, is the production of sludge. In other words, catalysts that, when processing different feedstocks for catalytic cracking, allow for the minimization of sludge production from the fluid-type catalytic cracking plant will lead to an increase in the profitability of oil processing in a refinery.

In the fifth chapter „Using intercriteria analysis to improve the performance of the "Hydrocracking of vacuum residue H-Oil" process during processing difficult feeds”, various process variables characterizing the performance of H-Oil fluidized bed vacuum residue hydrocracking are evaluated. Fluidized bed hydrocracking and slurry hydrocracking are the conversion technologies that can provide the highest conversion level ≥ 90 wt% among all vacuum residue conversion technologies. The conversion rate of heavy oil residues is the factor that controls the profitability of a modern refinery.

In the conclusion, a summary of the obtained results is presented, which are summarized into twelve conclusions.

The cited sources are sufficiently diverse and for the most part they are written by foreign authors. The presence of Bulgarian authors in the literature used also makes a good impression.

III. Evaluation of the PhD thesis's contributions.

During the achievement of the main goal and solving the tasks related to it, the following main results were obtained, and in summary:

1. On the basis of the intercriteria analysis, a methodology is proposed to evaluate the suitability of a specific type of oil for processing its tar fraction in the Hydrocracking of Gudron H-Oil process. The proposed methodology can be used and applied to all hydrocracking processes of gudron;

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, the factor that controls the profitability of this process is identified. This is the slurry yield. Catalysts and additives that minimise the slurry yield led 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.

I accept that the contributions so formulated could be considered to have scientific and common application. This separation would allow detailing the results obtained in accordance with the specificity of their significance.

IV. Assessment of the submitted publications.

Seven publications are included in the presented list of publications on the dissertation work. All posts are co-authored. Five of the publications are referenced in the global databases SCOPUS and/or Web of Science, with two in quartile Q2, two in quartile Q3 and one in quartile Q4. One publication was included in the proceedings of the 17th National Conference on Catalysis, Sofia, Bulgaria and one publication was included in the proceedings of the International Scientific and Practical Conference “Deep Processing of Heavy Oils and Oil Residues”, Kazan, Russian Federation.

The published results are original and I am not aware of any legally proven plagiarism in scientific works. A list of 31 citations for the dissertation work is also presented.

The data presented in this way give me reason to conclude that the research has been given the necessary publicity among the scientific community.

V. Evaluation of the PhD abstract.

The PhD abstract is consisting of 49 pages. It reflects the essence and content of the dissertation, including the purpose, subject, object and tasks of dissertation research and the ways of their realization.

VI. Remarks and recommendations.

In order to form the final evaluation of the PhD thesis, the requirements of the *Development of Academic Staff Act in the Republic of Bulgaria* and its Implementation Rules are to be taken into account, according to which I have the following remarks and recommendations:

1. Style errors are noted in the text of the PhD thesis.
2. The formulation of the PhD thesis contributions does not allow emphasizing the individual contribution of the PhD student.
3. The PhD student should direct his efforts to increase his contributions to reputable international publications.

VII. Conclusion.

I accept that the requirements of the *Development of Academic Staff Act in the Republic of Bulgaria* and the specific requirements in the Act’s Institutional

Regulations for its implementation, the Rules for the conditions and the order for acquiring academic degrees and for the occupation of academic positions in the Bulgarian Academy of Sciences (BAS) and the Rules for the specific conditions for acquisition of academic degrees and occupation of academic positions at the Institute of Biophysics and Biomedical Engineering - BAS are accomplished.

After my introduction to the PhD thesis and its publications, an analysis of their significance and the contributions they make, I give my positive assessment and I recommend to the Honorable Jury to award the educational and scientific degree “Doctor of Philosophy” (PhD) to **Eng. Borislav Enchev Georgiev** in the Scientific Field **4. Natural Sciences, Mathematics and Informatics**, the Professional Area **4.6. Informatics and Computer Sciences**, the Scientific Specialty **Informatics**.

05.03.2024

Sofia

Signature: .

/Corr. Member Lyubka Doukovska/