REVIEW

On the defence of the dissertation **"CFD modeling of membrane separation through nanofiltration"**
for obtaining the scientific degree **"Doctor"**
Professional field **4.2. Chemical Sciences**,
Specialty **"Processes and apparatus in chemical and biochemical technology"**

Author of the dissertation: **Eng. Stella Plamenova Paniovska**
Institute of Engineering Chemistry at BAS

Reviewer: **Iliya Krastev Iliev, Ph.D., Professor**
Ruse University

1. Brief biographical data and characteristics of the scientific interests and scientific activity of the candidate for PhD degree

Eng. Stella Plamenova Panyovska graduated from the University of Chemical Technology and Metallurgy – Sofia, with a Master of Science degree in CAD/CAE in Chemical Technology on 16 February 2017. During the period 1 March 2017 – 23 February 2020, she worked as a chemist at the Institute of Engineering Chemistry, Bulgarian Academy of Sciences. On 24 February 2020, she was appointed as Assistant Professor at the same institute, where she continues her academic career.

Her research and applied scientific activities are in the field of engineering chemistry, with emphasis on experimental and theoretical studies of extraction, distillation, absorption, and adsorption processes in reactors. In the course of her work, she has acquired solid expertise in computational fluid dynamics (CFD), 3D design and simulation, stirred and aerated reactors, airlift reactors, tray columns, and hydrodynamics.

Eng. Panyovska is a member of the Union of Chemists in Bulgaria, the European Chemical Society (EuChemS), and the Federation of Scientific and Technical Unions in Bulgaria. She is also a recipient of the "Ivan Evstratiev Geshov" Award for Young Scientists in the scientific field "Energy Resources and Energy Efficiency" for 2021.

2. Relevance of the problem developed in the dissertation.

The relevance and significance of the dissertation topic are determined by the growing importance of nanofiltration as a modern membrane technology that bridges the gap between reverse osmosis and ultrafiltration with respect to particle size retention, selectivity, and operating pressure. Nanofiltration continues to develop and find new applications in drinking water production, wastewater treatment, the food industry, and the chemical and pharmaceutical sectors, among others.

Despite its promising potential, several unresolved issues still hinder the large-scale application of nanofiltration. The present dissertation addresses a topical and important problem by applying computational fluid dynamics to achieve a comprehensive investigation of membrane filtration processes.

The significance of the work is further enhanced by its clearly defined objectives, namely the application of mathematical modeling of hydrodynamics and mass transfer in nanofiltration in order to determine optimal operating conditions for several important configurations: a dead-end filtration cell with a stirrer and flat-bottom membrane; a round cross-flow filtration cell with tangential feed; and a rectangular cross-flow filtration cell.

The systematic use of CFD tools and modeling capabilities unequivocally positions the dissertation as relevant, timely, and scientifically significant.

3. Review of the dissertation and analysis of the results

The dissertation consists of seven chapters with a total volume of 151 pages, including 19 pages of references and the author's publications. It contains 62 figures and 2 tables and is prepared in compliance

with the formal requirements for dissertations of this type.
The literature review, presented in Chapter 1, analyzes 169 references, all published in Latin script. Over 32 pages, the author reviews existing types of nanofiltration membranes, polymers used in membrane fabrication, and their applications in wastewater treatment, solid waste management, and the chemical and petrochemical industries. Particular attention is paid to nanofiltration membranes based on carbon nanomaterials.
An integrated membrane separation bioreactor is analyzed with respect to its ability to separate compounds with sufficiently different molecular weights from complex multicomponent systems. The review highlights current research trends, including innovative reactor designs, reduced energy consumption, improved fouling control, and economic evaluation. The necessity of CFD modeling is convincingly justified, including mass and momentum balances, turbulence modeling, and additional sub-models describing membrane separation and fouling phenomena.
The author provides a critical analysis of models describing permeate flux decline due to increased membrane resistance and concludes the chapter with five clearly formulated conclusions, demonstrating a thorough understanding of the research field.
Chapter 2 defines the goals and objectives of the dissertation. The main goal—mathematical modeling of hydrodynamics and mass transfer in nanofiltration to determine optimal process conditions—is appropriately formulated. Six specific tasks are derived from the literature review.
To accomplish these tasks, a comprehensive methodological framework is employed, centered on CFD modeling using the ANSYS Fluent R13.0 software package. The solver numerically resolves the Navier–Stokes equations under defined boundary conditions and provides detailed information on velocity fields, shear stresses, and mass transfer characteristics. The chosen methodology is fully adequate and well aligned with the stated objectives.
Chapter 3 presents CFD-based models for nanofiltration, including detailed results on velocity distributions, shear stress, and mass transfer coefficients in dead-end filtration. Minimum, maximum, and average mass transfer coefficients at the membrane surface are quantitatively evaluated.
Chapter 4 focuses on the specific geometry of the filtration cell and stirrer. CFD simulations reveal a highly non-uniform shear stress distribution on the membrane surface, varying within one order of magnitude, mainly due to the unfavorable stirrer-to-cell diameter ratio (0.41). The results demonstrate that thicker boundary layers and higher retention coefficients intensify concentration polarization. The boundary layer thickness ranges from 60 to 430 nm, with an average of approximately 250 nm, substantiating the need for concentration polarization models.
Chapter 5 summarizes the author's main contributions, which are grouped into scientific, scientific-applied, and applied categories.
Chapters 6 and 7 present the analyzed literature sources and the list of publications, respectively, including four journal articles and eight conference contributions related to the dissertation topic.

4. Key scientific, applied scientific and applied contributions

I accept the reference of the dissertation for the main contributions Eng. Stella Plamenova Panyovska, who did not present an assessment of her contributions in the presented works, which are of a scientific, scientifically applied and applied nature. Below I have arranged the contributions in accordance with my assessment and recognition.

- *4.1. Scientific contributions*

1. CFD simulations reveal solute concentration distributions in the feed channel, extending existing flow models with new insights into mass transfer and concentration polarization mechanisms.
2. Hydrodynamic and mass transfer knowledge in mechanically stirred dead-end filtration cells is enriched through detailed analysis of local velocity profiles, boundary layer thicknesses, and local mass transfer coefficients.

- *4.2. Scientific and applied contributions*

3. The understanding of tangential-flow nanofiltration for concentrating biologically active compounds

from plant extracts is expanded, with analysis of solute concentration and cross-flow velocity effects.
4. CFD simulations complement experimental studies by determining velocity and shear stress distributions, enabling identification of optimal operating ranges that balance membrane fouling and biomass stress.

➢ *Applied contributions*

5. A CFD-based methodology is developed for evaluating mass transfer efficiency in membrane bioreactors, offering broad applicability for comparative analysis of design solutions.

5. General description and assessment of the submitted materials

The author of the dissertation, Eng. Stella Plamenova Panyovska, has submitted all the necessary documents, in accordance with the Regulations on the conditions and procedure for acquiring scientific degrees and for holding academic positions at the Bulgarian Academy of Sciences and the Regulations for the implementation of the Act on the Development of the Academic Staff in the Republic of Bulgaria.

The coverage of the minimum national requirements for candidates for the National Academy of Sciences "PhD" by groups of indicators is as follows:
Indicator A: Dissertation work for the award of the educational and scientific degree "doctor" (50 points)
Indicators D: Scientific publications in publications that are referenced and indexed in world-renowned databases with scientific information (Web of Science and Scopus), outside the habilitation work (min. 30 points)
4 works are presented, as follows: (D1, D2, D3, D4,) (55 points);
Indicators E: Citations or reviews in scientific publications, referenced and indexed in world-renowned databases with scientific information or in monographs and collective volumes (Web of Science and Scopus); not required for the ONS "PhD", but regardless of this, the dissertation student Eng. Stella Panyovska has submitted a list of citations.
33 citations of 2 works are presented. The evidentiary part includes bibliographical data for the citing publication, a reference to the relevant database and excerpts from the citing publication with the relevant citation.
When comparing the presented materials with the minimum requirements (Table 1) for taking the ONS "Doctor" in professional fields according to the PPZRASRB and PURZAD of the Bulgarian Academy of Sciences, it follows that the minimum requirements for taking the ONS "PhD" have been met and significantly exceeded.

Table 1. Group of indicators Minimum number of points 4.2. Chemical sciences. Number of points of the candidate

Group of Indicators	Minimum points	Points of the candidate
A	50	50
Г	30	55
Total	**80**	**105**

The candidate has presented evidence that he/she also meets the additional criteria of the Institute of Chemical Engineering at the Bulgarian Academy of Sciences, which is well illustrated in Table 2.

According to the criteria of the Bulgarian Academy of Sciences, the candidate's dissertation must be based on at least two publications, one of which must be in a journal with an impact factor or impact rank. In our case, the candidate has presented a total of 4 publications in journals, one of which is Q1 and two Q3 publications, which significantly exceeds the accepted criteria of the "Regulations on the conditions and procedure for acquiring scientific degrees at the Bulgarian Academy of Sciences" Appendix No.: Professional field 4.2 Chemical Sciences, Table 2, Group of indicators D, Indicator 7.

6. Reflection of the scientific publications of the candidate in the Bulgarian and foreign

literature

Data on the citations of the candidate's scientific works and representativeness of the publications

According to the attached author's reference, the works presented in the dissertation have been cited in publications referenced in WoS (a total of 35 citations); A significant number of the scientific publications have an impressive number of citations in prestigious international publications, such as:

Publication (Separation of glucose, other reducing sugars and phenolics from natural extract by nanofiltration: Effect of pressure and cross-flow velocity, in *J. Chemical Engineering Research and Design*) has been cited 24 times; (CFD simulation of cross-flow filtration in *J. Chemical Engineering Transactions*) - 11 times.

The author of the dissertation, Eng. S. Panyovska, has an h index of 2 (with a total number of citations in Scopus 24) (https://www.scopus.com/authid/detail.uri?authorId=57203368391), which indicates a very high reflection of his scientific publications, especially in foreign literature.

7. Critical remarks and recommendations

The dissertation work in terms of volume, relevance and presentation of the results in the world scientific literature fully meets the criteria for such work. It is striking that the main scientific results have been published in the most renowned world publications and it would be difficult to find serious gaps due to the fact that these publications go through several levels of review by world-renowned specialists in the field. However, my remarks relate to the structure of the content of the dissertation work. The author has separated the goals and objectives of the dissertation work in a separate chapter (chapter 2). In my opinion, their place is in chapter 1, since it is logical for the goals and objectives to be presented as a consequence of the critical literature review. In a similar way, the last chapters (6, 7 and 8) can be presented as appendices to the dissertation work, and not as separate chapters.

8. Personal impressions and opinion of the reviewer

I do not personally know the author of the dissertation, Eng. Stella Paniovska. I have an insight into the scientific activity of her scientific supervisor, Prof. Daniela Djonova, in her capacity as a reviewer for the competition for the academic position of "Professor". Although I did not find a reference for language proficiency in the submitted documents, I assume that Eng. Stella Paniovska has a high level of English proficiency, which gives her the opportunity to monitor scientific exchange, work on important international projects, participate in international scientific events and create a modern experimental scientific research base.

CONCLUSION

The presented materials meet the requirements of ZRASRB, the Regulations for its application, and the internal Regulations for the terms and conditions for holding scientific degrees at the Institute of Chemical Engineering, BAS. Based on the acquaintance with the presented scientific publications, their significance, the contributions contained in them, I find it reasonable to propose Eng. Stella Plamenova Paniovska to take the scientific degree "PhD" in the professional field 5.2. Chemical Sciences, specialty "Processes and apparatus in chemical and biochemical technology".

Date: 15.01.2026

MEMBER OF THE JURY

(Prof. Iliya Iliev, PhD)