REVIEW

of dissertation for the acquisition of:

educational and scientific degree " **doctor** "	X
scientific degree **"Doctor of Science"**	
	the true is indicated by the sign "X"

Author of the dissertation:

		Zlatka	Nikolaeva	Geshkova	University of Chemical Technology and Metallurgy
academic position	scientific degree	name	middle name	last name	workplace

Topic of the dissertation:

Mechanical behavior of corner joints in thermoplastic frames

Scientific area:

5	Technical sciences
code	Name

Professional area:

5.1	Mechanical Engineering
code	Name

Scientific specialty:

"Applied Mechanics"

The review was written by:

Assoc. Prof.	Dr.	Yordan	Nikolaev	Mirchev	Institute of Mechanics – BAS
academic position	scientific degree	name	middle name	last name	Workplace

1. Completion of the provided documents:

A) The dissertation and the competition documents are in full compliance with the Regulations.	4 points	**X**
B) The documents are complete but do not fully comply with the requirements of the Regulations.	2 points	
C) The documents are not completed in accordance with the requirements of the Regulations.	0 points	
		one of the answers given is marked with the sign "X"

Missing documents and violated standards must be described if response C is marked.

M.Sc. Eng. Zlatka Geshkova has submitted all the necessary documents for participation in the competition and meets all the minimum requirements according to the Law on the Development of the Academic Staff in the Republic of Bulgaria for the acquisition of the Educational and Scientific Degree "Doctor" as well as the Rules of the Ministry of Education and the University of Chemical Technology and Metallurgy -Sofia for its implementation. The requirements of the Law regarding the decisions of the governing bodies for the announcement of the competition have been met.

2. Meeting the minimum requirements under the Regulations:

A) The candidate meets the minimum requirements	20 points	**X**
B) The candidate doesn't meet the minimum requirements	0 points	
		one of the answers given is marked with the sign "X"

It must be filled in if answer B is marked. The publication activity of the candidate is analyzed. The response of the results achieved (quoted) is analyzed.
The candidate satisfies the minimum requirements for obtaining the Educational and Scientific Degree "Doctor" as shown by the following conclusions: - The doctoral student demonstrates good theoretical preparation in the field of the scientific specialty, thoroughly and confidently interprets and analyzes the obtained results. This gives reason to claim that he has the ability to conduct independent scientific research;   - The specified technical literature in the dissertation adequately reflects the current state of the scientific issues under consideration;   - The presentation of the dissertation work is concise, justified and consistent. After the obtained results, the conclusions from them are given in a synthesized form, which makes the explanation of the text more understandable. The text part is supported by graphic visual materials (tables, figures and diagrams);   - Of the presented 7 publications on the dissertation work, 1 is independent, two were published in refereed journals with SJR or IF. There are four presentations of the results of the work at international and national scientific conferences. It can be seen that a significant part of the dissertation work has been published in the publications as well as the main contributions of the dissertation.

3. The relevance of the topic of the dissertation:

A) The topic is relevant and new (there are no known results on the topic by other authors)	8 points	
B) The topic is relevant and results from other authors are known	6 points	**X**

C) The topic is not relevant, but results from other authors are known	2 points	
D) The topic is not relevant and no results from other authors are known	1 point	
E) The topic does not correspond to the level of dissertation	0 points	
		one of the answers given is marked with the sign "X"

The evaluation of the relevance of the dissertation must be substantiated
The object of research in the present work are T-joints of profiles for window frames (window elements - frame and sash) made of unplasticized polyvinyl chloride (UPVC) of Weiss Profil Bulgaria produced in the period of 2019. (five-chamber case and wing) and 2020. (six-chamber case), for which a detailed study of the mechanical behavior under static loads acting during operation or during transportation and storage was carried out.   The results of the experimental studies are used to validate a developed methodology for numerical investigation of window frames, under different external mechanical loads and temperatures. The approach using a numerical method investigates the propagation of stress cracks until profile failure at different temperatures. Validation of the numerical model allows to conduct studies of the profiles under different physico-mechanical loads by type, direction, density and location.   Studies have been conducted for: - the strength characteristics of the corner connections of welded profiles in laboratory conditions of a specialized testing machine. Failure is recorded by the initiation and propagation of a crack that may cross the profile of the joinery, follow the bond line, or both (mixed crack).   - Validation of a numerical model in ANSYS environment for the failure of corner connections of UPVC window frames, including the selection of an adequate mathematical model, identification of model parameters and validation of results. Validation of the model is carried out by comparing its results with results of analytical solutions.   - Determining the areas where material failure is most likely to occur and predicting the type of failure based on the degree of triaxiality and Lode angle with models using the apparatus of solid mechanics and considering the object as a continuous medium.   - obtaining the general characteristics using the linear theory of failure and the first stress intensity factor.   - For the development of the crack in the body of the polymer profiles using the Separating, Morphing, Adaptive and Remeshing Technology (SMART) method.   **The studies of the mechanical properties of materials for window frames with the developed methodology with a numerical model in the ANSYS environment are used to determine optimal conditions for transportation and operation of the objects and to estimate the service life under certain external operating conditions.**   **The application of the approach using a validated numerical model for the studied mechanical characteristics of windows profiles makes it possible to conduct numerous numerical simulations to determine the service life of the windows under different external operating conditions. This gives me reason to conclude that the proposed validated numerical research approach is an up-to-date application in terms of its ability to determine the service life of window frames.**

4. Knowledge of the problems, subject of research in the dissertation:

A) The doctoral student knows in detail the achievements of other authors on the topic of the dissertation	8 points	
B) The doctoral student is partially familiar with the achieved results on the topic of the dissertation	4 points	**X**
C) The doctoral student has no prior knowledge of the status of the problems in the dissertation	0 points	

		one of the answers given is marked with the sign "X"

The evaluation must be substantiated if answer C is marked.

The dissertation is 90 pages and contains 146 figures and 29 tables. It consists of an introduction, three chapters with conclusions, a conclusion, contributions and publications on the topic of the dissertation work. 81 literary sources were used.

In the first chapter, an analysis of the materials used for the sash and frame of the window frame is made. In the case of facades designed entirely or mostly as large-format glass units, installed in window frames of two elements - a wing and a frame, the most often used material for making the elements of the window frames is non-plasticized polyvinyl chloride.

The mechanical behavior of the load-bearing windows subjected to a significant external load was studied. It was found that one of the most vulnerable places of the windows are the corner connections of the welded profiles. The most common approaches for the experimental determination of the strength of welded angles from unplasticized polyvinyl chloride in laboratory conditions have been investigated.

From the literature review and analysis of the mechanical characteristics of the materials used in joinery, it was concluded that laboratory destructive testing methods are not always able to provide a complete picture of the destruction process under more complex types of loads. A broader study of the total load on the system structure is possible using numerical modeling and computer simulation. **The work does not present comparisons of the results of the doctoral student's numerical studies with the results of other authors, despite the limited availability of such in the World Scientific Databases.**

5. Type of research:

A) Theoretical	4 points	
B) Applied	4 points	
C) Theoretical with application elements	4 points	**X**
D) It does not correspond to the level of dissertation	0 points	
		one of the answers given is marked with the sign "X"

The level of research must be substantiated if answer D is marked.

The doctoral student conducted experimental studies to obtain the mechanical characteristics of the studied object. Destructive methods were used to test tensile, bending and strength of welded corner and T-joints, according to standard EN 514, ASTM D 638 and ASTM D 790. The results obtained from the conducted experimental studies are used as input data in the developed numerical model ANSYS based studies. The numerical model is validated with an analytical model using the same input data obtained from the experimental tests. **The developed approach for numerical studies of profiles (wings and frames) of window frames allows to determine the time for exploitation of the window frames, during which characteristics for use according to the technical specification are guaranteed.**

6. Objectives of the research:

A) Realistic and of scientific and / or applied interest	8 points	**X**
B) Realistic, but not of scientific and / or applied interest	3 points	
C) Unattainable (unrealistic)	0 points	

		one of the answers given is marked with the sign "X"

Objectives must be specified. The type of the set objectives must be justified.
The aim of the work is to create a methodology for the numerical simulation of the destruction of the corner connections of UPVC window frames, including: - selection of an adequate mathematical model, - identification of the model parameters related to the characteristics of the material and the welding process and - validation of results with laboratory tests. To achieve this goal, the following tasks have been solved: 1. Through laboratory experiments, the real mechanical properties of the materials used and the real mechanical behavior of the corner joints depending on the welding conditions were determined. 3. A model was created for computer simulation of the mechanical behavior of corner connections with the classical failure mechanics apparatus 4. Numerical model verification. 5. The created model is updated with the apparatus of contact separation method (Debonding) and with the technology of separation, transformation, adaptation and re-mixing (SMART Crack). 6. Numerical experiment to determine the fatigue limit of the studied elements under climatic conditions in Bulgaria. 7. Analysis of results. **The objective is well formulated and achievable, as well as substantiated with a conducted literature review and significant scientific and practical experience in this field by the candidate.**

7.Methods of research:

A) Adequate to research and set objectives	8 points	**X**
B) Partially appropriate, enabling part of the scientific objectives and / or applications to be achieved	4 points	
C) Inappropriate methods	0 points	
		one of the answers given is marked with the sign "X"

Methods must be specified. The type of methods used is justified.
Three methods were used: - destructive methods for tensile, bending and strength testing; - analytical method for determining the stress intensity factor K1; - numerical methods in the ANSYS environment for studying the mechanical characteristics of the tested object. The first method is applied according to current standards and is conducted to provide input data for the analytical and numerical method used. The analytical method is used to validate the developed approach for conducting numerical studies in the ANSYS environment. **The three methods are an application adequate to the set goals of the dissertation work.**

8. Contributions of the dissertation:

A) With lasting scientific and / or applied response, they form the basis for new research and applications	20 points	
B) They are of significant scientific and / or applied interest, complete and / or summarize previous research	16 points	
C) They are of scientific and / or applied interest	12 points	**X**

D) Lack of significant contributions	8 points	
E) Lack of contributions	0 points	
		one of the answers given is marked with the sign "X"

Contributions must be specified. The type of results achieved must be justified.
I accept the contributions claimed by the doctoral student in the dissertation as correct. They have an applied focus on and can be summarized as follows: SCIENTIFIC AND APPLIED CONTRIBUTIONS 1. An algorithm of a procedure for the numerical study of the destruction process of corner nodes of polymer profiles formed by thermal welding has been created, including the evaluation of the condition by triaxiality and Lod's parameter and modern models of the destruction. 2. A procedure for numerical modeling and computer simulation of failure of the node with a crack along the weld seam has been developed, including VCCT technology for the cases of brittle failure and CZM technology for the cases with the presence of plastic zones. 3. A procedure was developed for numerical modeling and computer simulation of crack propagation in the body of the profile with an unstructured element network and SMART technology. 4. A procedure was developed for numerical modeling and computer simulation of destruction under variable loads formed by environmental temperature fluctuations. APPLIED CONTRIBUTIONS 1. A theoretical-experimental approach was applied to validate the numerical model. 2. Experimental destructive tests were carried out to obtain mechanical characteristics of the material and to establish the type of crack propagation with the maximum stresses at its peak in the corner nodes of elements (case and sash) of the polymer window frames. 3. For the tested objects, the maximum values of the stress intensity factor and the maximum stress at the crack tip under operating conditions were obtained theoretically with analytical dependences 4. Using the developed algorithm for numerical studies, the service life of the elements of the joinery under cyclic loading from temperature changes, characteristic of the climate of Bulgaria, was determined.

9. Evaluation of the compliance of the dissertation summary with the dissertation:

A) Full compliance	4 points	**X**
B) Compliance of the main parts	2 points	
C) Lack of compliance of the main parts	0 points	
		one of the answers given is marked with the sign "X"

The evaluation must be substantiated if answer C is marked.
The abstract has been prepared according to the requirements, exceeding the standard volume and containing 39 pages. The exposition in it is detailed and correctly reflects the content of the dissertation work.

10. Participation of the doctoral student in the achievement of the results of the dissertation:

A) The doctoral student has at least an equal participation	8 points	**X**

B) The doctoral student has secondary participation	5 points	
C) The participation of the doctoral student is unnoticeable	0 points	
		one of the answers given is marked with the sign "X"

Critical notes must be provided if one of the items B or C is marked.
Presented by M.Sc. Eng Zlatka Geshkova dissertation work is an independent development of a completed research on a current topic in the field of design and operation of window frames and ensuring their reliable operation in accordance with the technical specification of the product.   The author's scientific achievements have been tested in projects and conferences. The candidate has conducted part of his dissertation research with a team within two contracts with NIS at University of Chemical Technology and Metallurgy from 2019 to now. Two of the papers were reported at international conferences, another two at national conferences with international participation.   **All this gives me reason to state that the research and results obtained in the dissertation work, as well as scientific contributions, are the work of the candidate with the guidance and assistance of his supervisor.**   **The candidate has signed a declaration of authorship of the work. No plagiarism was found in the dissertation submitted for evaluation.**

11. Critical notes:

A) Lack of critical notes	8 points	
B) Critical notes of a technical nature	7 points	**X**
C) Critical notes that would partially improve the results achieved	4 points	
D) Significant critical notes	0 points	
		one of the answers given is marked with the sign "X"

Critical notes must be provided if one of the answers C or D is marked.
Some minor technical omissions and spelling errors have been noted, which do not detract from the value of the work and do not cast doubt on the reliability of the results.   My recommendation is to shape the scientific and scientific-applied contributions. These can be grouped into several main and more significant contributions.

12. Conclusion

A) The evaluation of the dissertation is **POSITIVE**	This evaluation is assigned to a total number of at least 65 points	**X (85 points)**
B) The evaluation of the dissertation is **NEGATIVE**	This evaluation is assigned to a total number below 65 points	
		one of the answers given is marked with the sign "X"

To be filled in at the request of the reviewer

On the basis of the above, I consider that the presented dissertation work has been developed at a good scientific level and meets the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria and the Regulations on the Terms and Procedures for Acquiring Scientific Degrees and Holding Academic and Teaching Positions at HTMU- Sofia, which gives reason to the author of the dissertation, M.Sc. Eng. Zlatka Nikolaeva Geshkova to be awarded the educational and scientific degree "Doctor" in the Higher Education Department 5. "Technical Sciences", Professional Direction 5.1. "Mechanical Engineering", Scientific specialty "Applied Mechanics".

I recommend the respected scientific jury to award M.Sc. Eng. Zlatka Nikolaeva Geshkova, the educational and scientific degree "doctor".

18.09.2023	The review was written by:	
date		signature