

**REVIEW**  
**of the official reviewer for the thesis work**  
**of Bergaliyeva Saltanat Amangeldinovna on the topic «Standardization of Recycled Plastic Materials for Additive Manufacturing»,**  
**provided for the degree of Doctor of Philosophy (PhD) in the educational program «8D07502 – Standardization and Certification (by**  
**industry)».**

№	Criteria	Compliance with the criteria (one of the options must be marked)	Justification of the position of the official reviewer
1.	The topic of the thesis (as of the date of its approval) corresponds to the directions of development of science and/or state programs	1.1 Compliance with priority directions of science development or state programs: 1) <b><u>The thesis was carried out within the framework of a project or target program funded from the state budget (specify the name and number of the project or program)</u></b> 2) The thesis was carried out within the framework of another state program (specify the name of the program) 3) The thesis corresponds to the priority direction of science development, approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (specify the direction)	Justification of the position of the official reviewer  The thesis work was conducted within the framework of the project “Improvement in resource efficiency and sustainability through the implementation of additive manufacturing methodologies for maintenance of facilities in the chemical industry”.
2.	Importance for science	The work <b><u>makes</u></b> /does not make a significant contribution to science, and its importance is <b><u>well disclosed</u></b> /not disclosed	The dissertation presents the results of a study on the advanced standardization of polylactide waste for additive technologies. Since such experimental studies have not been conducted before, the results of the dissertation make a significant contribution to the development of standardization and certification procedures for additive technologies, as well as to solving the problem of recycling polymer waste. The importance of the results for science and practice was revealed in the section Current state of the problem.
3.	Principle of independence	Level of independence: 1) <b><u>High;</u></b> 2) Medium; 3) Low; 4) There is no independence	The dissertation work, the choice of the research method, problem solving, conducting research on the thermomechanical properties of polylactide samples for additive technologies, and the development of regulatory and technical documentation were carried out by the author independently. The task statement and discussion of the results were conducted jointly with scientific supervisors.

4.	Principle of internal unity	4.1 Justification of the relevance of the thesis: 1) <b>Justified;</b> 2) Partially justified; 3) Not justified	The relevance of the research is fully justified. The results obtained in this dissertation work can be used for mechanical recycling of polylactide waste and certification of products from them.
		4.2 The content of the thesis reflects the topic of the thesis: 1) <b>Reflects;</b> 2) Partially reflects; 3) Does not reflect	The content of the dissertation reflects in detail the topic of the dissertation, its goals and objectives and the main provisions submitted for defense. The presented material is presented logically and consistently, the results and conclusions are consistent with each other and correspond to the topic of the dissertation.
		4.3 The purpose and the tasks correspond to the topic of the thesis: 1) <b>correspond;</b> 2) partially correspond; 3) do not correspond	The purpose of the work (advanced standardization of the thermophysical properties of filaments and granules for 3D printing obtained on the basis of polylactide waste) and the formulated tasks correspond to the topic of the dissertation.
		4.4 All sections and provisions of the thesis are logically interconnected: 1) <b>completely interconnected;</b> 2) the interconnection is partial; 3) there is no interconnection	All sections and statements of the dissertation are logically completely interconnected and have a structured character, which can be seen from the sequence of the presented scientific data.
		4.5 New solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with known solutions: 1) <b>there is a critical analysis;</b> 2) the analysis is partial; 3) the analysis does not represent the one's own opinions, but quotes from other authors	The dissertation presents a critical analysis of the current state of standardization of additive technologies in the country and the world, the standardized method of hydrothermal aging proposed by the author is reasoned and evaluated in comparison with the works of other authors and international standards available in the literature.
5.	Principle of scientific novelty	5.1 Are the scientific results and provisions new? 1) <b>completely new;</b> 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The proposed statements and the results obtained are completely new. For the first time, the standardized hydrothermal aging of 3D printed polylactide samples was carried out and the time period of operation, up to which the polylactide retains its thermomechanical properties, was determined. Mixtures based on pure and/or recycled and/or nanoparticles of titanium dioxide in various proportions for use in additive technologies were also produced for the first time, and their thermo-mechanical

			properties were determined. Standardization of numerical quality indicators was also carried out for the first time.
		5.2 Are the conclusions of the thesis new? 1) <b>completely new;</b> 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The conclusions drawn in the section “Conclusion” are new and fully correspond to the goals and objectives of the dissertation. The results are published in a rating journal with a high impact factor in the Scopus database and the Web of Science.
		5.3 Technical, technological, economic or management decisions are new and reasonable: 1) <b>completely new;</b> 2) partially new (25-75% are new); 3) not new (less than 25% are new)	Technical, technological and economic solutions are new and justified.
6.	Validity of the main conclusions	All the main conclusions are <u>based</u> /not based on scientifically sound evidence or well grounded (for qualitative research and areas of study in the arts and humanities)	All the main conclusions are well justified from a scientific point of view.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately: 7.1 Is the provision proven? <b>1) proven;</b> 2) rather proven; 3) rather not proven; 4) not proven 7.2 Is it trivial? 1) yes; <b>2) no</b> 7.3 Is it new? <b>1) yes;</b> 2) no 7.4 Level for application: 1) narrow; 2) medium; <b>3) wide</b> 7.5 Is it proven in the article? <b>1) yes;</b> 2) no	<b>Statement #1.</b> Standardized process of accelerated hydrothermal aging in standard of organization St JSC 002-2023 “Polylactide for additive manufacturing. Accelerated hydrothermal aging test” of 3D printed polylactide samples at 50 °C and 70 % humidity for 1344 hours results in a 33% reduction in tensile strength.  7.1 Numerical values of the mechanical properties of polylactide decrease after hydrothermal aging. 7.2 The statement is based on an adequate interpretation of the results obtained on the basis of modern views in the field of polymer materials. 7.3 According to the results of the literary review, for the first time in world practice, a test is conducted according to the methodology given in this dissertation. 7.4 The results of the study can be useful in materials science, polylactide waste recycling, additive technologies and standardization. 7.5 Statement # 1 has been proved in several articles.
		7.1 Is the provision proven?	<b>Statement #2.</b> Increasing the proportion of secondary

	<p><b>1) proven;</b>  2) rather proven;  3) rather not proven;  4) not proven  7.2 Is it trivial?  1) yes;  <b>2) no</b>  7.3 Is it new?  <b>1) yes;</b>  2) no  7.4 Level for application:  1) narrow;  2) medium;  <b>3) wide</b>  7.5 Is it proven in the article?  <b>1) yes;</b>  2) no</p>	<p>polylactide from 0 to 75 % in a mixture with pure polylactide increases the tensile strength of FFF printed samples from <math>44.20 \pm 2.18</math> MPa to <math>52.61 \pm 2.28</math> MPa.</p> <p>7.1 The mechanical properties of samples based on primary and secondary polylactide obtained by 3D printing and other production methods are different.  7.2 The test results were obtained using modern research methods.  7.3 The percentages of pure and recycled polylactide given in the dissertation are used for the first time for additive technologies.  7.4 The results of the study can be useful in materials science, polylactide waste recycling, additive technologies and standardization.  7.5 Statement # 2 has been proved in several articles.</p>
	<p>7.1 Is the provision proven?  <b>1) proven;</b>  2) rather proven;  3) rather not proven;  4) not proven  7.2 Is it trivial?  1) yes;  <b>2) no</b>  7.3 Is it new?  <b>1) yes;</b>  2) no  7.4 Level for application:  1) narrow;  2) medium;  <b>3) wide</b>  7.5 Is it proven in the article?  <b>1) yes;</b>  2) no</p>	<p><b>Statement #3.</b> Adding 18 % of pure polymer and 7 % of titanium dioxide nanoparticles to secondary polylactide increases the tensile strength and fluidity of FGF samples to match those of a standard sample during 3D printing.</p> <p>7.1 Mechanical recycling of polylactide waste with the addition of titanium dioxide nanoparticles and pure polylactide has a positive effect on the thermo-mechanical properties of the final product obtained using 3D printing.  7.2 The percentage of the nanocomposite mixture obtained in the dissertation is optimized.  7.3 The thermomechanical properties of the nanocomposite mixture obtained in the dissertation were investigated for the first time.  7.4 The results of the study can be useful in materials science, polylactide waste recycling, additive technologies and standardization.  7.5 Provision No. 3 has been proved in several articles</p>
	<p><b>7.1 Is the provision proven?</b></p>	<p><b>Statement #4.</b> Standard of organization St JCS 001-2023</p>

		<p><b>1) proven;</b>  2) rather proven;  3) rather not proven;  4) not proven  7.2 Is it trivial?  1) yes;  <b>2) no</b>  7.3 Is it new?  <b>1) yes;</b>  2) no  7.4 Level for application:  1) narrow;  2) medium;  <b>3) wide</b>  7.5 Is it proven in the article?  <b>1) yes;</b>  2) no</p>	<p>“Nanocomposites based on polylactide and its waste with titanium dioxide nanoparticles for additive manufacturing. Technical specifications" establishes the percentage of pure and recycled polylactide and titanium dioxide nanoparticles in proportions 25/75/0, 22/75/3, 18/75/7 for subsequent certification.</p> <p>7.1 The importance of standardization of the obtained material for subsequent certification is proved.  7.2 The interrelationship and originality of the tasks are traced.  7.3 The organization’s standard for the material obtained in the dissertation is being developed for the first time.  7.4 The results of the study can be useful in materials science, polylactide waste recycling, additive technologies and standardization.  7.5 Statement #4 has been proved in several articles.</p>
8.	Principle of reliability Reliability of sources and information provided	<p>8.1 Choice of methodology –is justified or methodology is described in sufficient detail:  1) <b>yes;</b>  2) no</p> <p>8.2 The results of the thesis work were obtained using modern methods of scientific research and methods of processing and interpreting data using computer technologies:  1) <b>yes;</b>  2) no</p> <p>8.3 Theoretical conclusions, models, identified relationships and regularities have been proved and confirmed by experimental research (for areas of training in the pedagogical sciences the results have been proved on the basis of a pedagogical experiment):  1) <b>yes;</b>  2) no</p> <p>8.4 Important statements are <b>confirmed</b>/partially confirmed/ not confirmed by references to relevant and reliable scientific literature</p> <p>8.5 Used literature sources are <b>sufficient</b>/not sufficient for a literature</p>	<p>The choice of methods and methodological approaches is justified and described in detail in the second section Experimental part.</p> <p>The results of the dissertation work were obtained using modern methods of research, processing and interpretation of data using computer technology.</p> <p>The theoretical conclusions of the dissertation have been proved by experimental studies, the relationship between the result of the experiment and the method of obtaining the material has been revealed, and discussed at international scientific conferences and scientific seminars.</p> <p>In all sections of the dissertation, the author provides links to relevant and reliable scientific literature.</p> <p>The literature sources used are relevant and sufficient for</p>

		review	a literary review.
9	Principle of practical value	9.1 The thesis has a theoretical value: 1) <b>yes;</b> 2) no	The thesis presents a regulatory framework consisting of two standards of the organization, which can form the basis for the development of national standards of the Republic of Kazakhstan.
		9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice: 1) <b>yes;</b> 2) no	The dissertation is of practical importance, as it presents the percentages of nanocomposites based on secondary polylactide, which can be used in 3D printing.
		9.3 Are the suggestions for practice new? 1) <b>completely new;</b> 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The suggestions for the practice are completely new.
10.	Quality of writing and design	The quality of academic writing is: 1) <b>high;</b> 2) average; 3) below average; 4) low.	The quality of academic writing is high. The style of the text corresponds to scientific writing.

### Conclusion on the possibility of awarding the degree of Doctor of Philosophy (PhD)

Thesis work performed on the topic: «Standardization of Recycled Plastic Materials for Additive Manufacturing» is a completed research work. I believe that the thesis on the relevance of the problems solved and the quality of the results obtained, in terms of their scientific and practical significance, is a serious scientific research and meets all the requirements of the rules of awarding the degree of Doctor of Philosophy (PhD) of the Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, and its author Bergaliyeva Saltanat Amangeldinovna deserves to be awarded the degree of Doctor of Philosophy (PhD) in the educational program «8D07502 – Standardization and Certification (by industry)».

### Official reviewer:

Head of the Department of «Standardization, certification and metrology», ENU named after L.N. Gumileva (Astana, Kazakhstan),  
Doctor of Technical Sciences, Professor

Baikhozhayeva B.U.  
(sign)

