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Review
of the doctoral dissertation of Dineshkumar Musalekar, M.Sc,
entitled: *New approach to dynamic management of technical knowledge to construct a smart and flexible Die Casting Mould Manufacturing towards intelligent manufacturing*

Dissertation supervisor:	Professor Justyna Patalas-Maliszewska, Ph.D., Eng., Institute of Mechanical Engineering, University of Zielona Góra
Field:	Engineering and Technology
Discipline:	Mechanical Engineering

1. Formal basis of the review

This review of the doctoral dissertation submitted for evaluation has been prepared in accordance with my knowledge and experience, considering the criteria, requirements, and procedures contained in the applicable formal documents governing the doctoral procedure in Poland, in particular in:

- a letter from the Chairman of the Discipline Council for Mechanical Engineering, Radosław Maruda, PhD, Eng., Prof. UZ, dated June 17, 2026,
- the Resolution of the Discipline Council for Mechanical Engineering of the University of Zielona Góra dated June 10, 2026,
- the Act of July 20, 2018, the *Law on Higher Education and Science* [*Ustawa z dnia 20 lipca 2018 r. Prawo o szkolnictwie wyższym i nauce*], hereinafter referred to as the "Act."

2. General overview and formal evaluation of the thesis

The doctoral dissertation was submitted for evaluation as a written work in A4 format, 132 pages long, consisting of six chapters supplemented by summaries in Polish and English, a table of contents, a bibliography, a list of figures, tables, and appendices. **The form of the dissertation thus meets the requirements for doctoral dissertations set forth in sections 3 and 4 of Article 187 of the Law on Higher Education and Science.**

The work is primarily applied in nature. It addresses a scientific problem using the example of a die-casting process implemented in real industrial conditions. The discussion begins with an introduction to the subject matter, providing a clear justification of the reasons for undertaking the topic and its importance, as well as identifying the objectives, research problems, hypothesis, and, in my opinion, prematurely, research methods. The following chapters present an analysis of the state of the art in the field of dynamic technical knowledge management and management methods in accordance with the 4.0 concept. Chapters 4 and 5 present the structure of the proposed model and its implementation in real industrial conditions. The work concludes with a set of findings that highlight its contribution to the development of the discipline of mechanical engineering and outline directions for further research.

I assess the overall structure of the dissertation positively – the work is presented in a generally accurate and logical manner, and the order of the main chapters reflects the adopted approach to solving the research problem. The inclusion of short, organizing summaries at the end of chapters 2, 3, and 4, containing guidelines as well as an indication of their significance for further considerations, was beneficial to the reader's understanding. I also appreciate the use of extensive research data and photographic materials from a company operating in Poland. This emphasizes the applied nature of the dissertation and allows for a better understanding and illustration of the production process under study and its complexity.

Despite the correct overall structure of the dissertation, the organization of the content within individual chapters is not always equally clear, and in some places, appears not to have been fully thought out: in several places, the same or very similar information is repeated, for example[1]: the objectives of the work are formulated on p. 16 and repeated on p. 17; content from pp. 21^{1-4} is repeated on pp. 21_{5-8}; content from pp. 71_{6-12} appears again on pp. 76^{1-9}; and content from pp. 89^{1-4} to 90^{1-16} is repeated on pp. 91_{1-21}). Some bulleted section of the text seems detached from the rest, without an introduction, for example, on pp. 36-38. On pp. 86-87, a description appears, most likely referring to the elements of the application diagram, but there is no corresponding figure. Furthermore, in chapters 2, 3, and 4, review-type content is interwoven with descriptions of the methodology and elements constituting the research results, which makes it difficult to clearly demarcate these parts. In my opinion, the dissertation would gain in clarity and in the quality of presentation of the scientific achievement if the part covering the analysis of the current state of knowledge was more clearly separated from the part presenting the original achievements of the PhD candidate.

The dissertation cites a total of 70 literature items, the vast majority of which have been published in the last few years. These publications are closely related to the topic of the dissertation. They cover intelligent manufacturing, Industry 4.0 and 5.0 concepts, technical knowledge management, IoT systems, artificial intelligence, and machine learning, as well as their applications in production processes. However, the limited number of literature items devoted specifically to the die casting process and the use of AI in its optimization is somewhat disappointing. Supplementing the literature in this area would clearly highlight the research gaps addressed by the dissertation and further emphasize the originality of the proposed solution. **Therefore, the literature selection should be assessed as accurate and relevant to the topic of the dissertation, albeit with the minor caveat mentioned above. This confirms the PhD candidate's familiarity with the literature and the current state of knowledge in the analyzed area and demonstrates his ability to select and organize the relevant knowledge thoughtfully.**

The linguistic style of the dissertation is communicative and facilitates a proper understanding of the content, but it does have some imperfections that require further refinement. Unfortunately, the text, both in English and Polish, contains minor grammatical, syntactical, and stylistic errors, as well as imprecise wording that complicates the understanding of the presented issues, for example:

- p. 5, in the list of abbreviations: "PC – Persona computer" instead of "Personal computer"; "MLP – Multilayer Preceptor" instead of "Multilayer Perceptron"; "mm – mili meters" instead of "millimeters;
- p. 10^{15}: „inteligentnego i elastycznego produkcji produkcji form";
- p.15_{20-22}: grammatical error – "According to the definition of the concept, I5.0 provided by the European Union Commission manufacturing process should shift from smart manufacturing to human-centric technology development and adoption (Park et al. 2018)";
- p. 20_{2}: „levels ib the";
- p. 21_{6-8}: grammatical error – "The die casting mould life, which is measured as the number of good shots (shots in which good parts are produced).";
- p. 24^{8}: "table in to" should be "table into";
- p. 44^{1}: "we highlighted" should rather be "it was highlighted";
- p 47_{2}: "dis assembled" should be "disassembled";
- p. 52^{4-5}: grammatical error – "So, for the analyzed process (section 4.1) further elements of the novelty method (figure 2) were presented process of data and information acquiring";

[1] The numbers placed in the lower or upper index next to the page number indicate the line number on the page counting from the bottom or top, respectively.

- p. 60^{1}: “out let” instead of “outlet” and “ration” instead of “ratio”;
- p. 62: in the headings of Tables 2 and 3, “meausre” should be “measure”.

Basically, the PhD Candidate uses correct technical, professional, and scientific terminology in his argument, although there is sometimes a lack of consistency in the use of concepts and abbreviations, e.g. the designations i4.0, i5.0 and I4.0 and I5.0 were used as abbreviations for Industry 4.0 and 5.0, respectively; Root Mean Square Error was designated once as “RMSE” and once as “RSME”; Long Short-Term Memory was alternately designated as “LSMT” and “LSTM”; Production Part Approval Process was incorrectly marked as PPAA (it should be PPAP); the terms “approach”, “method”, “model”, “framework”, “system” and “concept” were used interchangeably to describe, for example, predictive models or the developed technical knowledge management procedure.

There are also some minor editorial inaccuracies in the work. These include, for example: the lack of references to the literature after the phrases “studies emphasize” and “literature also highlight” (e.g. pp. 14_{12-15}, pp. 15^{2-5}, pp. 27^{12-21}, pp. 42_{11}); the occasional use of sentences beginning with the authors’ surnames in parentheses (e.g. p. 16: “(Kasinathen et al. 2022) et al. studied […]”); the lack of numbering of equations (e.g. p. 41); incomplete consistency in references to figures and tables (e.g. Figures 7, 9-29 and Table 8 were not cited, the figure on p. 100_{13} was incorrectly cited as “picture x”) and leaving graphic elements without captions (e.g. pp. 58-61). These comments are of an organizational nature and do not affect the overall assessment of the substantive value of the dissertation.

In summary, the work submitted for evaluation meets the formal requirements for doctoral dissertations. Although it is not free from editorial and linguistic imperfections that may interfere with the reception of the content, these do not in any way affect the cognitive, applied, or substantive value of the presented achievements. It demonstrates the doctoral candidate's knowledge of the subject matter and his ability to conduct a logical and coherent scientific argument.

3. Evaluation of the timeliness, significance, and originality of the addressed research problem

The thesis focuses on mechanical engineering issues related to intelligent manufacturing systems, technological process monitoring, and the use of artificial intelligence methods in production quality control. The doctoral candidate successfully developed a methodology for dynamically managing technical knowledge in the form of expert knowledge and measured data on process parameters, using the die casting process as an example, for the purpose of controlling and supporting decisions regarding process quality and efficiency by means of artificial intelligence methods. The elements related to knowledge management, ERP systems, IoT, and artificial intelligence serve as tools in the thesis to support the solution of the technological problem. In my opinion, the primary focus of the thesis is not information management itself, but rather the improvement of the stability, quality, and efficiency of the mold and die-casting manufacturing process. **I declare that the topic of the thesis has been appropriately assigned to the discipline of mechanical engineering.**

I consider the choice of topic justified and relevant, aligning with the current research trend in mechanical engineering regarding the development of intelligent, adaptive production systems. Modern manufacturing systems must meet a number of requirements imposed by national and EU legislation (including the assumptions of the Green Deal, the Circular Economy, etc.) regarding safety, environmental sustainability, and other requirements resulting from their operation on the market, such as ensuring high product quality, efficiency, effectiveness, process flexibility, and production continuity. Fundamentally, the quality, effectiveness, and sustainability of the final outcomes of a production process depend on the interrelated technical conditions of its execution, including design, material, and technological factors. The multitude of factors influencing the quality and efficiency of production processes and the complex relationships between them, as well as the dispersion of knowledge across various areas and forms, such as technologists' knowledge, documentation records, and sensor readings, necessitate their integration into advanced systems that enable proper interpretation and use of this knowledge for process control. This is particularly important in the case of complex, multi-stage manufacturing systems requiring the production of repeatable, high-quality products, such as die casting. The production of die-casting molds is a process encompassing design, material selection, machining, heat treatment, assembly, technological testing, operation, tool regeneration, and maintenance. The quality of the mold and the method of conducting the casting process directly impact the dimensional accuracy of the castings, their functional properties, tool durability, casting cycle time, and machine efficiency. The process of designing and manufacturing molds, as well as the subsequent production of castings, requires extensive knowledge of, among other things, the mold design, the geometry of the gating and venting system, the cooling system, alloy parameters, speed and pressure in individual process phases, mold temperature, cycle time, and maintenance principles. As the PhD candidate rightly points out, much of this knowledge is dispersed across the experience and expertise of designers, technologists, operators, technical documentation, and the company's IT systems. In this context, the need to integrate and transform this knowledge into a single system supporting process control was rightly identified in order to improve quality and efficiency indicators. The relevance of this topic is confirmed by the use of artificial intelligence methods, IoT technologies, and ERP systems to address the scientific problem. These are currently key tools in the development of intelligent, adaptive, and data-driven manufacturing systems. Their application to the acquisition of process data, building predictive models, and supporting technological decisions aligns well with the development directions of Industry 4.0 and 5.0. **It should be emphasized, therefore, that the issues addressed in this dissertation are multidimensional and partially interdisciplinary, requiring extensive knowledge of manufacturing and die-casting technology, mold design and operation, process diagnostics, production systems, data acquisition and processing, and artificial intelligence methods**. The complexity of the phenomena occurring during the casting process makes it difficult to derive simple mathematical models, which stem directly from the nonlinearity and interdependencies between individual process parameters and process quality or efficiency, thus necessitating the use of artificial intelligence models. **The search for solutions supporting the development of methods enabling the organization of engineering knowledge and its dynamic use to predict the state of the process is therefore justified from the point of view of modern mechanical engineering.**

The significance of the research problem addressed in this dissertation lies in its cognitive, scientific, and, above all, practical dimensions. Cognitively, the work provides a source of systematic knowledge regarding the impact of design, material, and process parameters on the quality and efficiency of the die casting process, as well as methods for acquiring, processing, and implementing distributed engineering knowledge into decision-making processes in the production environment. The primary scientific value of this work lies in the developed method for the dynamic management of distributed technical knowledge, which crucially involves the collection, integration, and transformation of information, including through the use of IoT systems, ERP, and models based on artificial intelligence solutions, enabling the identification of important process parameters and the prediction of product quality. The application value of the proposed methodology and the resulting comprehensive AIMS system implemented in the die casting process should be emphasized. This system provides ongoing monitoring of casting quality, detects irregularities, and provides information to production operators regarding recommended actions.

The originality of this solution lies in its methodological and practical dimensions. The novelty lies in the integration of established tools (e.g., management, monitoring, and data acquisition systems, as well as neural networks) into a proprietary framework for a dynamic knowledge management system, implemented and verified under real-world industrial conditions. The original achievements described in this thesis include:

- the development of a dynamic knowledge management framework encompassing process identification and modeling, knowledge acquisition, representation and structuring, sharing, real-time application, feedback, and continuous learning;
- the creation of a knowledge base for the die casting process;

- the development of a model for predicting the quality of cast components using neural networks based on real-world industrial data;
- the implementation of a feedback model in the AIMS system to support decision-making in the production process.

I consider the presented achievements of the PhD student to be original, although not groundbreaking, and to constitute an effective attempt to actively use the collected data for the control of industrial processes.

In summary, I consider the scientific problem addressed and solved in this dissertation to be significant and timely from the perspective of the development of intelligent, adaptive, digitally supported systems in line with the assumptions of Industry 5.0. The developed technical knowledge management methodology and predictive models, implemented in a real industrial process, represent an original solution in terms of the application of the PhD candidate's own research results in the economic sphere. I believe that, in terms of the originality of the solution to the research problem and its significance for the discipline of mechanical engineering, <u>the requirements specified in Article 187, Section 2 of the applicable Act on Higher Education and Science have been met.</u>

4. Substantive assessment

The strengths of the scientific discourse presented in the dissertation

Dineshkumar Musalekar, M.A., began his dissertation with an introduction, properly justifying the need for and importance of the research topic. He correctly identified the research gap between the availability of process data and its actual use as structured technical knowledge supporting decision-making in production processes. He aptly pointed out that, for complex production processes, despite the availability of process data, such data remain dispersed and difficult to process and use directly in process monitoring to improve quality and efficiency, a situation further hampered by the interdependencies between design and technological parameters. Based on this, the doctoral candidate correctly formulated the objective of the thesis, fundamental research questions, and research thesis, which served as the starting point for the research. In my opinion, these fundamental methodological elements reflect the practical nature of the research and are coherent with each other. A significant advantage is that the problem addressed is embedded in real industrial conditions and effectively attempts to move from data recording and static information collection to their active use in the decision-making process. **The formulation of the research problem and the justification provided for its implementation demonstrate the doctoral candidate's good understanding of the area under analysis and his research maturity. They demonstrate his ability to critically analyze real-world scientific problems, identify relevant determinants, and translate the observed needs of industrial practice into well-formulated research goals and tasks.**

The second and third chapters introduce key issues that constitute essential elements of the presented proprietary method for managing technical knowledge. These include intelligent manufacturing, Industry 4.0 and 5.0, technical knowledge management, methods for acquiring, storing, structuring, and sharing knowledge, as well as the application of machine learning and neural network methods. The literature analysis conducted reflects the doctoral candidate's thorough knowledge of the identified problem areas, demonstrating his ability to synthesize information, identify gaps, and draw conclusions from the current state of knowledge, as well as applying theoretical concepts in practice to solve complex technological and managerial problems in industry.

As a result of the analysis and synthesis of the current state of knowledge, a technical knowledge management method was developed. This method encompasses knowledge acquisition, representation, structuring, sharing, and real-time application using feedback and machine learning. **I consider the structure of the technical knowledge management approach to be correct, coherent, logical, and,**

importantly, applicable, as demonstrated by the PhD candidate in subsequent chapters through its application to control systems and quality assessment in real-world industrial die casting processes.

However, I consider the content presented in Chapters 4 and 5 to be the most valuable, documenting the implementation of the developed technical knowledge management methodology using the example of the die casting process for two different components. It describes the successive stages of the technological process, starting with design, mold production, selection of mold material, considering hardness and heat treatment, gating system geometry, venting, cooling, melt flow rate, and the parameters governing the subsequent stages of piston movement. It is noteworthy that these descriptions are not merely theoretical in nature; they reflect the PhD candidate's actual experience with the industrial process under consideration. This clearly demonstrates a thorough understanding of the process and an awareness of the complexity of the phenomena occurring within it, including the interdependence between process parameters and product quality, as defined by characteristics such as porosity, the occurrence of misruns or material discontinuities, changes in dimensional accuracy, mold durability, etc.

A crucial element in identifying the process analyzed in this thesis was the organization of technical knowledge, the expert knowledge of designers and technologists, as well as data automatically acquired from monitoring systems—into a single knowledge base, enabling its further processing and use in a predictive model. It is noteworthy that this knowledge is treated not merely as a collection of documents and procedures, but as a dynamic resource updated with sensor data, information from the ERP system, and employee experience, which is incorporated into the decision-making model. **This also highlights the advantage and originality of the proposed methodology: the use of data from various sources, with different formats and varying degrees of formalization,** such as piston position sensors, pressure systems, temperature measurements, the ERP system, technical documentation, and expert interviews, followed by their integration and encoding in a way that allows for the prediction of process quality.

A predictive model for assessing the quality of manufactured components was built using a set of 9,919 observations described by 39 input parameters, encompassing design, material, and process characteristics. The modeling utilized data from real industrial processes. The doctoral candidate correctly described the data preparation method, including the encoding of logical and categorical variables, parameter normalization, and the assignment of the output classes BAD, LOK, LOT, OK, and OUT. He analyzed various neural network configurations and selected a model with a single hidden layer and 20 neurons as the target structure, based on the classification accuracy criterion. This made it possible to integrate distributed information sources into the predictive model and link the results to the possibility of taking corrective actions in the actual production process.

In the final stage of the research, a decision support system based on the predictions of the computational model was proposed. Prediction results and corresponding messages sent to operators via the interface, email, or text message were assigned to three color-coded categories: green – continued production; yellow – supervision and corrective actions required; and red – production halt. This confirms the practical application potential of the proposed methodological solution.

The transition from problem formulation and method development, through the construction of a predictive model, to its implementation in a real-world production process is a significant asset of this dissertation. It demonstrates the PhD candidate's ability to conduct interdisciplinary research and to combine cognitive, methodological, and implementation aspects when solving a specific mechanical engineering problem.

Remarks and points for discussion

Despite the undoubted cognitive and practical value of the dissertation, it contains certain methodological inconsistencies and issues for discussion, primarily concerning the documentation and potential for replicating the research and applying the model to other industrial processes. I present my comments and observations in the order in which the issues in question appear in the dissertation. These reservations are intended to be both systematic and constructive and do not undermine the doctoral candidate's achievements.

1. The review of the state of knowledge on the subject matter is undoubtedly comprehensive and includes the most important issues that form the background for the developed methodology. In my opinion, however, it lacks content that clearly highlights the novelty and originality of the proposed approach to technical knowledge management. While various methods for managing and modeling production processes using artificial intelligence are presented, no comparison with the proposed solution is provided. Little attention is paid to examples of technical knowledge management in die casting processes. This raises the following questions: Can existing solutions, methodologies, and procedures for technical knowledge management be found for die casting processes? What advantages does the proposed approach offer over existing models?
2. Figures 2 (p. 22) and 3 (p. 32) schematically present a new method and approach to dynamic technical knowledge management. It is unclear whether these figures represent two different methods, or whether Figure 3 constitutes a supplement to or extension of Figure 2.
3. For the mold design and die casting process, the predictive model included as many as 39 input parameters. How were the parameters included in the model selected? Why was it necessary to include parameters with constant values? Was the impact of the selected parameters on casting quality analyzed, and was it verified that all of them were significant from a quality perspective? While the importance of selected parameters and their interdependencies in the die casting process was briefly explained based on observations and the literature, in my opinion, even a brief analysis of the variability of the data and a demonstration of their impact on casting quality are missing, especially since some parameters assumed constant values.
4. Chapter 3.3 reviews and compares machine learning methods based on artificial intelligence (Convolutional Neural Networks, Recurrent Neural Networks, and Long Short-Term Memory Networks) for applications in technical knowledge management. The proposed solution, in turn, utilizes a Multilayer Perceptron (MLP) neural network. Why was this model chosen? Was it compared with other, simpler models (e.g., logistic regression or decision trees) to assess its adequacy for the analyzed problem?
5. On page 75, it is indicated that the MLP model uses the actual power demand of the CNC machine as one of the parameters in the training set. However, this parameter is not present in any of the attached datasets. Was then the CNC machine power demand included as an input parameter in the model?
6. On page 84, the results of deliberate changes to selected process parameters intended to ensure that parts are classified into the appropriate quality category are presented. This approach may indicate parameters related to the model's decision, but it does not prove that changing them will improve the quality of the actual process. Changing individual parameters independently can also create technologically impossible or unsafe combinations. Were permissible ranges of parameter changes established? Was the model verified to ensure that the predicted quality improvement did not result from parameter combinations that are technologically impossible or inadmissible? Furthermore, the parameters are marked as "Feature" followed by a numerical value. Which process parameters correspond to these feature designations?
7. On page 88, it was noted that the model sends an alert when the input parameters deviate from their optimal values. What, therefore, were the optimal values of the parameters used in the model?
8. On page 112, the impact of using the developed models and the AIMS system in the production process is summarized. Among others, it is shown that machine breakdowns were reduced by 16%, OEE increased from 71% to 78%, and TEEP increased by 8%. However, there is no information on how OEE and TEEP were determined. What data were used to calculate these indicators?

Summary

The scope of the dissertation indicates that the PhD candidate possesses well-established knowledge of the pressure die casting process, mold design and operation, production process organization, data acquisition methods, and the application of predictive models in dynamic knowledge management systems within the discipline of mechanical engineering. I state that, despite the certain inaccuracies and debatable issues related to the documentation of the research process, the PhD candidate demonstrated the ability to independently conduct research by identifying the research problem, building the model, preparing research data, and implementing his own solution in practice. Therefore, I believe that the requirement contained in Article 187, Section 1 of the Law on Higher Education and Science, has been met.

5. Final conclusions

Based on the analysis of the Mr. Dineshkumar Musalekar's doctoral dissertation entitled *"New Approach to Dynamic Management of Technical Knowledge to Construct a Smart and Flexible Die Casting Mold Manufacturing Towards Intelligent Manufacturing,"* I conclude that:

- It addresses a timely, cognitively and scientifically significant, and above all, practically relevant problem in mechanical engineering, concerning the use and management of technical knowledge and actual production data for intelligent, dynamic control and decision support in the mold manufacturing and die casting processes;
- The literature review, methodology, and research descriptions contained therein confirm the PhD candidate's extensive and well-established knowledge of mold design and manufacturing, die casting process parameters, product quality, intelligent production systems, and the acquisition and management of technical knowledge within the mechanical engineering discipline;
- The presented approach to formulating the research problem and objectives, conducting the research, and developing the scientific argument, despite occasional methodological and terminological inconsistencies and imperfections in the structure of the argument, language, and editing, confirms the candidate's ability to conduct research independently;
- It contains an original solution to the research problem in the form of a dynamic technical knowledge management methodology developed and applied in the economic sphere, integrating data from IoT and ERP systems, expert knowledge, and a predictive model based on an artificial neural network, used for quality classification and decision support in the die casting process.

Considering the above, I conclude that Mr. Dineshkumar Musalekar's doctoral dissertation meets the requirements specified in Article 187 of the Act of 20 July 2018 – Law on Higher Education and Science. I therefore recommend that the dissertation be accepted and admitted to public defense.

Bydgoszcz, 07.09.2026 r.

PODPIS ZAUFANY
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KRUSZELNICKA
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Dokument podpisany elektronicznie podpisem zaufanym