FACULTY OF MECHANICAL AND CIVIL ENGINEERING
IN KRALJEVO
UNIVERSITY OF KRAGUJEVAC

XI TRIENNIAL
INTERNATIONAL CONFERENCE

HEAVY MACHINERY HM 2023

Proceedings

VRNJAČKA BANJA, SERBIA
June 21– June 24, 2023

FACULTY OF MECHANICAL AND CIVIL ENGINEERING IN KRALJEVO
UNIVERSITY OF KRAGUJEVAC
KRALJEVO – SERBIA

THE ELEVENTH TRIENNIAL INTERNATIONAL CONFERENCE

HEAVY MACHINERY
HM 2023

PROCEEDINGS

ORGANIZATION SUPPORTED BY:

Ministry of Science, Technological Development and Innovation, Republic of Serbia

Vrnjačka Banja, June 21–24, 2023

FACULTY OF MECHANICAL AND CIVIL ENGINEERING IN KRALJEVO
UNIVERSITY OF KRAGUJEVAC
KRALJEVO – SERBIA

PUBLISHER:

Faculty of Mechanical and Civil Engineering in Kraljevo

YEAR:

2023

EDITOR:

Prof. dr Mile Savković

PRINTOUT:

SATCIP DOO VRNJAČKA BANJA

TECHNICAL COMMITTEE

Doc. dr Aleksandra Petrović – Chairman
Bojan Beloica – Vice-chairman
Miloš Adamović
Goran Bošković
Vladimir Đorđević
Marina Ivanović
Marijana Janićijević
Aleksandar Jovanović
Stefan Mihajlović
Predrag Mladenović
Stefan Pajović
Anica Pantić
Nevena Petrović
Mladen Rasinac
Vladimir Sinđelić
Marko Todorović
Đorđe Novčić
Jovana Bojković
Tanja Miodragović
Jovana Perić
Slobodan Bukarica

No. of copies: 60

ISBN-978-86-82434-01-6

REVIEWS:

All papers have been reviewed by members of scientific committee

CONFERENCE CHAIRMAN

Prof. dr Mile Savković, FMCE Kraljevo, Serbia

INTERNATIONAL SCIENTIFIC PROGRAM COMMITTEE

CHAIRMAN

Prof. dr Radovan Bulatović, FMCE Kraljevo, Serbia

VICE-CHAIRMAN

Prof. dr Milan Bižić, FMCE Kraljevo, Serbia

MEMBERS

Prof. dr M. Alamoreanu, TU Bucharest, Romania
Prof. dr D. Atmadzhova, VTU "Todor Kableshkov", Sofia, Bulgaria
Prof. dr M. Banić, FME Niš, Serbia
Prof. dr M. Berg, Royal Institute of Technology-KTH, Sweden
Prof. dr G. Bogdanović, Faculty of Engineering Kragujevac, Serbia
Prof. dr H. Bogdevicius, Technical University, Vilnus, Lithuania
Prof. dr N. Bogojević, FMCE Kraljevo, Serbia
Prof. dr I. Božić, FME Belgrade, Serbia
Prof. dr S. Bikić, Faculty of Technical Sciences, Novi Sad, Serbia
Prof. dr M. Bjelić, FMCE Kraljevo, Serbia
Prof. dr M. Blagojević, Faculty of Engineering Kragujevac, Serbia
Prof. dr S. Bošnjak, FME Belgrade, Serbia
Prof. dr A. Bruja, TU Bucharest, Romania
Prof. dr S. Ćirić-Kostić, FMCE Kraljevo, Serbia
Prof. dr I. Despotović, FMCE Kraljevo, Serbia
Prof. dr M. V. Dragoi, Transilvania University of Brasov, Romania
Prof. dr B. Dragović, Faculty of Maritime Studies Kotor, Montenegro
Prof. dr Lj. Dubonjić, FMCE Kraljevo, Serbia
Prof. dr R. Durković, FME Podgorica, Montenegro
Prof. dr Z. Đinović, ACMIT, Wiener Neustadt, Austria
Prof. dr R. Đokić, Faculty of Technical Sciences, Novi Sad, Serbia
Prof. dr K. Ehmann, Northwestern University, Chicago, USA
Prof. dr I. Emeljanova, HGTUSA Harkov, Ukraine
Prof. dr O. Erić Cekić, FMCE Kraljevo, Serbia
Prof. dr V. Gašić, FME Belgrade, Serbia
Prof. dr D. Golubović, FME East Sarajevo, Bosnia and Herzegovina
Prof. dr P. Gvero, FME Banja Luka, Bosnia and Herzegovina
Prof. dr B. Jerman, FME Ljubljana, Slovenia
Prof. dr R. Karamarković, FMCE Kraljevo, Serbia
Prof. dr M. Karasahin, Demirel University, Istanbul, Turkey
Prof. dr I. Kiričenko, HNADU Kiev, Ukraine
Prof. dr K. Kocman, Technical University of Brno, Czech Republic
Prof. dr S. Kolaković, Faculty of Technical Sciences, Novi Sad, Serbia
Prof. dr M. Kolarević, FMCE Kraljevo, Serbia
Prof. dr M. Kostić, Northern Illinois University, DeKalb, USA
Prof. dr M. Krajišnik, FME East Sarajevo, Bosnia and Herzegovina
Prof. dr M. Králik, FME Bratislava, Slovakia
Prof. dr E. Kudrjavcev, MGSU, Moscow, Russia
Prof. dr Đ. Lađinović, Faculty of Technical Sciences, Novi Sad, Serbia
Prof. dr D. Marinković, TU Berlin, Germany
Prof. dr G. Marković, FMCE Kraljevo, Serbia
Prof. dr A. Milašinović, FME Banja Luka, Bosnia and Herzegovina
Prof. dr I. Milićević, Technical Faculty Čačak, Serbia
Prof. dr V. Milićević, FMCE Kraljevo, Serbia
Prof. dr Z. Miljković, FME Belgrade, Serbia

ORGANIZING COMMITTEE

CHAIRMAN:

Prof. dr Goran Marković, FMCE Kraljevo

VICE-CHAIRMAN:

Doc. dr Miljan Marašević, FMCE Kraljevo, Serbia

MEMBERS:

Doc. dr M. Bošković, FMCE Kraljevo, Serbia
Doc. dr V. Grković, FMCE Kraljevo, Serbia
Doc. dr V. Mandić, FMCE Kraljevo, Serbia
Doc. dr A. Nikolić, FMCE Kraljevo, Serbia
Doc. dr M. Nikolić, FMCE Kraljevo, Serbia
Doc. dr A. Petrović, FMCE Kraljevo, Serbia
Doc. dr B. Sredojević, FMCE Kraljevo, Serbia
Dr N. Pavlović, FMCE Kraljevo, Serbia
Doc. dr N. Stojić, FMCE Kraljevo, Serbia

PREFACE

Ladies and gentlemen, dear colleagues,

Welcome to Vrnjačka Banja, to the International Scientific Conference Heavy Machinery. The first conference was held in 1993, so this is the thirtieth anniversary of the Heavy Machinery conference.

This year the Eleventh International Conference Heavy Machinery is held by the Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, from 21 to 24 June 2023.

The conference has gained a unique recognizable form of exchange of information, ideas and new scientific research. It is held in the year when the Faculty of Mechanical and Civil Engineering in Kraljevo celebrates 63 years of university teaching.

During several decades of its existence, the Faculty has acquired a specific and recognizable form in domestic and foreign scientific circles thanks to its scientific and research results.

The goal of the Conference is to make the research in the fields covered at the Faculty of Mechanical and Civil Engineering in Kraljevo available and applicable within both domestic and foreign frames. Also, our scientists will have the opportunity to learn about the results of research done by their colleagues from abroad in the fields of transport design in industry, energy control, production technologies, and civil engineering through the following thematic sessions:

- Earth-moving and transportation machinery,
- Railway engineering,
- Production technologies,
- Automatic control and fluid technique,
- Applied mechanics,
- Thermal technique and environment protection,
- Civil engineering.

The high scientific reputation of domestic and foreign participants as well as the number of papers provide guarantees that the Conference will be very successful. The papers reflect the state-of-the-art and deal with a wide spectrum of important topics of current interest in heavy machinery.

I would especially like to thank the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for its support to the organization of the Conference and our efforts to promote science and technology in the areas of mechanical and civil engineering in Serbia. Also, I would like to express our gratitude to other sponsors of the Conference: Serbian Chamber of Engineers, TeamCAD d.o.o. Zemun-Belgrade, Banim reklame d.o.o. Kraljevo, Radijator Inženjering d.o.o. Kraljevo and Messer Tehnogas AD Belgrade.

My sincere thanks also go to all members of the scientific, organizing and technical committees, the reviewers, and all the participants including the invited speakers for their participation in the Conference and presentation of their papers.

Thank you and see you at the next conference in three years.

Kraljevo – Vrnjačka Banja, June 2023

Conference Chairman,

Prof. dr Mile Savković

PLENARY SESSION

SESSION A: EARTH-MOVING AND TRANSPORTATION MACHINERY

SESSION B: RAILWAY ENGINEERING

SESSION C: PRODUCTION TECHNOLOGIES

SESSION D: AUTOMATIC CONTROL AND FLUID TECHNIQUE

SESSION E: APPLIED MECHANICS

SESSION F: THERMAL TECHNIQUE AND ENVIRONMENT PROTECTION

SESSION G: CIVIL ENGINEERING

Artificial intelligence (AI) and the future of the machine elements design

Marko Popović[1*], Nedeljko Dučić[1], Vojislav Vujičić[1], Milan Marjanović[1], Goran Marković[2]
[1]Faculty of Technical Science, University of Kragujevac, Čačak (Serbia)
[2] Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Kraljevo (Serbia)

The document also contains defined quick-styles that may be used for fast formatting of the submitted papers. Artificial intelligence (AI), is becoming an important tool in the fields of mechanical engineering. AI have potential power, to give fast predict of the dimensions and shapes of the machine elements, trought optimisation process in initial and the final design stage. This paper give the review of the potential use of the AI in the field of the machine element design.

Keywords: Machine Design, Machine Elements, Artificial Intelligence (AI)

1. INTRODUCTION

Artificial intelligence (AI) technology is becoming increasingly important in people's lives as it becomes more widely used in people's daily lives, such as the widespread use of smart dishwashers and smart sweepers, which are the products of the fusion of AI and the mechanical manufacturing industry [1]. Indeed, AI has been widely utilized in the mechanical manufacturing business, which not only ensures production precision, but also enhances job productivity and workplace safety. The rise of AI has caused significant changes in the manufacturing industry as a whole.

With the continuous progress of science and technology, mechanical engineering is also constantly evolving and changing, from the traditional mechanical engineering to the state-of-the art mechanical engineering [2]. And its level of automation and intellectualization has a continuous improvement, it went into a new stage of development, thus, the combination of AI and mechanical engineering has become a hotspot. AI is applied under the premise of the development of computer technology, which improved the computer technology through the analysis of it to achieve the realization of intelligent technology.

The applications of AI in mechanical engineering is not only the use of computer technology, but also combined with information technology, psychology, linguistics and other knowledge. The AI is in fact the simulation of the process of data interaction of human thinking, hoping to understand the essence of human intelligence and then produce a smart machine, this intelligent machine can be the same as human thinking to respond and deal with the problem [2].

2. DESIGN OF MACHINE ELEMENTS

The design process of machine elements can be observed through processes of the analysis and synthesis of different informations and data. Objective of analysis, is to examine machines and/or machine elements for which sizes, shapes, and materials have already been proposed or selected, so that loading severity parameters (e.g., stresses) may be calculated and compared with critical capacities (e.g., strengths corresponding to governing failure modes) at each critical point [3]. Adjunct analyses might also be undertaken to calculate and compare such attributes as cost, life, weight, noise level, safety risks, or other pertinent performance parameters. The objective of the synthesis, is to examine performance requirements associated with a particular design mission, then select the best possible material and determine the best possible shape, size, and arrangement, within specified constraints of life, cost, weight, safety, reliability, or other performance parameters.

Design process is the first step in the process of conceptualising a machine components [4]. The design process involves analyzing a function and performance requirements, determining its materials and manufacturing methods, and then creating detailed drawings and specifications that can be used to manufacture the component [5]. The main phases in process of the design of the machine components, machine elements and machines are:

- *Conceptual Design.* The design process typically starts with conceptual design, where the basic requirements and constraints of the component are defined.
- *Detailed Design.* Conceptual design is followed by detailed design, where the component is designed to meet the requirements and constraints, considering factors such as materials, manufacturing methods, and cost.
- *Analysis and Optimization*. The design then goes through an analysis and optimization stage. Analysis and optimization rely on computer-aided design (CAD) and 3D mechanical engineering simulation (CAE) tools to ensure they will function as intended and meet performance requirements.
- *Multi-Objective Optimization.* Optimizing of the parts, assembly and machines means considering several objectives (sometimes contrasting) and constraints coming from targets on weight, cost, size etc. This is called multi-objective optimization.

Machine elements design is a very time consuming and responsible task. It is the first phase of the manufacturing process, and its aim is to anticipate the impact of external factors on the designed component [6]. Therefore designers must be able to correctly combine knowledge of many fields.

When the engineers designs the machine elements or the complete machines, they have to consider several important factors:

1. Functionality, high output and efficiency

*Corresponding author: Svetog Save 65, Čačak, marko.popovic@ftn.kg.ac.rs

2. Strength, stiffness and rigidity
3. The cost
4. Operational safety
5. Easy of assembly, and disassembly
6. Light weight and minimum dimension
7. Reliability
8. Durability
9. Accessibility
10. Compliance with state standards
11. Ergonomics and industrial design

3. ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS

In smart applications, the terms AI, machine learning, and deep learning are frequently used interchangeably [1]. However, there are distinctions between them. A part of machine learning is called deep learning. All machine learning applications are considered to be examples of AI since machine learning is a subset of AI that may operate intelligent applications (Fig.1).

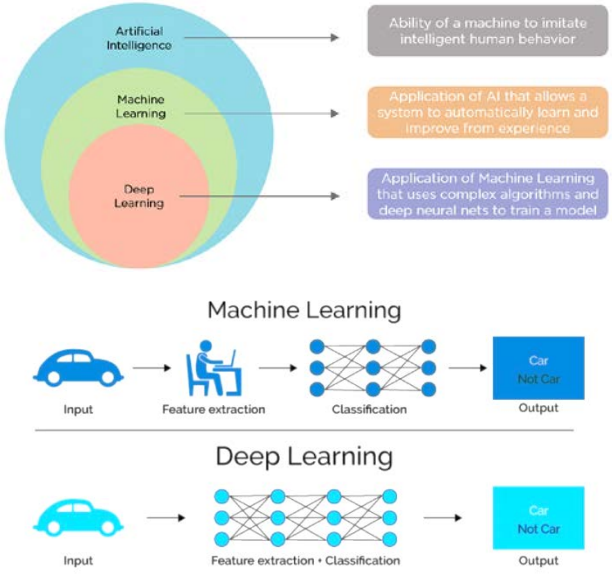

Figure 1: Fundamental differences between AI, machine learning, and deep learning [8], [9]

Generaly an entity that possesses the following properties is considered to be intelligent:

- *Generalized learning.* An adequate reaction of the machine to a new or changing external environment
- *Decision-making.* Decision-making based on given criteria and the current environment
- *Problem Solving.* Finding a solution based on the current environment and given input parameters

AI technologies often refer to methodologies like expert systems, genetic algorithms, fuzzy logic, artificial neural networks etc. [7], [1]. The expert system can be seen as a kind of specialized knowledge of computer intelligent program system, it can use expertise and experience provided by experts in specific areas and the use of reasoning techniques in AI to solve and simulate complex problems that can often be solved by experts [2].

Expert Systems (ES) give the possibility of solving specialized problems which require professional expertise, which means that they can replace an expert in a given field, often without a need of expert's support during program operation. A characteristic feature of this system is a division of knowledge gained from an expert, called knowledge base, and the rest of the system containing, among others, mechanisms of reasoning on the basis of knowledge resources from a given domain. Expert Systems can be generally divided into three categories:

1. *advisory* – systems presenting the user certain solutions, which are evaluated in order to choose the most adequate one, or to ask for another solution,
2. *taking decisions without human control (dictatorial)* – systems, which do not consult end results with the user,
3. *criticizing* – are characterized by taking input values related to the given problem and possible solution.

Expert Systems are able to: gather complete knowledge from a given domain and update it constantly, copy the way of thinking of an expert, which results in offering decisions and providing their variants, explain the way of thinking of the user to the adopted solutions, communicate in a language comfortable for the user.

4. AI AND DESIGN OF MACHINE ELEMENTS

There are various areas where AI finds applications in mechanical engineering. It comprises of data handling and automation, to perform the work with minimum of human intervention [4]. The fourth industrial revolution involves integrating the internet, big data, cloud computing, the internet of things, and AI into the mechanical manufacturing industry as of the beginning of the twenty-first century [1].

This big data inflow, is base start point for the AI application in mechanical engineering, especially in the fields such as machine design, manufacturing, crash simulation, predictive maintenance, robotics, industry 4.0 applications etc.

In his book [10], T.H.Davenport proposed the following advice on making AI technologies practical:

- Use AI to improve processes or products by automating the repetitive or structured aspects of design
- Look for "low-hanging fruit" opportunities to improve efficiency
- Create smart products that "work alongside smart people"

In according with previous, there are several ways AI may be used in mechanical engineering. The design and optimization of mechanical systems and parts, such as engines, gears, and bearings, may be automated using AI, for instance [12]. The performance of mechanical systems may also be simulated and analyzed using AI in order to forecast behavior, spot future issues, and suggest changes. AI may also be used to track and manage mechanical systems in real-time, improving their dependability and efficiency. Overall, applying AI to mechanical engineering may assist to increase the effectiveness, dependability, and performance of mechanical systems as well as promote the creation of novel and cutting-edge technologies.

Can engineers apply AI in the process of the machine element design? AI can be applied in the process of the machine elements design, because this process is characterized by the properties (*in terms of its structure and*

method of implementation), which are fully compatible with the AI technology:

- This design process have a structure and process algorithm
- It is a repeatable process
- It is an iterative process
- Machine elements are well structured and standardized
- The process requires adaptation to certain criteria (*typification, unification*)
- Great importance of the engineer's experience
- Good practice are often used in design process
- Machine elements information can be storage in the database
- Design of the machine elements, contains process of the optimization

In which stage of machine and machine elements design, engineers can use AI? AI can be use from early stage of design – conceptual design, through detail design with analysis and optimisation process, to the final stage, with generating of the detail technical documentation. *In the conceptual design,* the initial form of machine structure will affect both performance and cost of the machine [11]. In this context, the search for shapes becomes one of the key steps in the conceptual design phase, as its results are inputs for the next steps in the design process, in the subsequent construction phase, and throughout the life cycle of the machines. In the proces of the *simulation,* AI can improve the design proces, by combining different parallel analyses of physics, solid mechanics, fluid mechanics etc. It is possible to learn AI to distinguish between parts and different assemblies, which can be used in the future for designing a wide range of components and machines. Different *optimization methods* have matured in recent years due to extensive research conducted by applied mathematicians and engineers. In this context, the utilization and principles of AI, may be prevalent for using in the optimization process.

How engineers may use AI? There are several ways that AI may be used in the machine elements design, starting from conceptual, to the final design. In according, authors give the list of possible use of AI in the machine element design process:

1. Design assistent – *best shape, cost etc. application*
2. Generation of the state-of the-art collaborative framework
3. CAD/CAE integration – based on the proven designs and analysis
4. AI interactive CAD System
5. Big data and proven CAD models for optimization process
6. AI automated parts and assembly adoption – *date from databases (from local to the world database)*
7. Advance virtual prototypes
8. Shape and behavior prediction
9. AI evaluation of the design
10. Topology, shape and dimension optimisation – *AI fine tuning*
11. Reverse engineering – *automated generating 3D model from point cloud*
12. Virtual reality optimisation design
13. FEM model development
14. Alternative FEM models
15. Automated cost analysis – *started from the conceptual design*
16. Optimization from the aspect of the position and orientation of the parts – *the influence of the other parts in assembly to the considered part design*)
17. Generative design – *advance multi object optimisation*

Below are given several examples of the application of AI in the machine elements design process, which are currently in the different development stages.

At this moment, the most important field for implementation of AI for machine elements design is a CAD/CAE technology. As already appoinment in the paper [1], CAD uses AI that typically operates on knowledge-based systems. In CAD, design artifacts, rules, and issues are archived for subsequent use by CAD designers. AI and CAD are combined using model-based reasoning. Building a predictive model of machine element, machine and equipment, requires all the physics and components found in CAD and CAE models. Running simulations on the engineering model can then generate a dataset that an AI algorithm can use for processing [12].

When speaking about AI interactive CAD System, the main thing to point out is that drawing still takes too much of a designer's thought processing. In complex design tasks liberating the designer from the necessity of manually using slow interfaces will allow engineers to focus on the other important steps, that require much higher knowledge and responsibility. The research which is presented in the [6], involves the development of intelligent interactive automated systems for designing machine elements and assemblies, using descriptions of structural elements' features in a natural language. This new concept proposed a novel approach to these systems, with particular emphasis on their ability to be truly flexible, adaptive, human error-tolerant, and supportive both of design engineers and data processing systems. The foundation of interactivity is bi-directional communication between the data processing system and the user. Results of evaluation, performed with AI, of the designed solutions are used at as early as the design stage. This system can analyses of design engineer's messages, analyses of constructions, encoding and assessments of constructions, CAD system controlling and visualizations. It also presents the developed methodology for similarity analysis between structural features of designed machine elements and corresponding antipatterns allowing normalization of parameters of the analysed structural solutions.

An example of the used AI in the proces of the machine elements design - shaft design, is given on the following figure. At this figure are given a two stages of the interation process of the shaft design. Upper picture showen the first iteration proces of generation of the shaft shape, and on the below picture, is given design with AI suggestion for the shaft details. Suggestins are given in according with the shaft production technology and assembly process for gears and bearings.

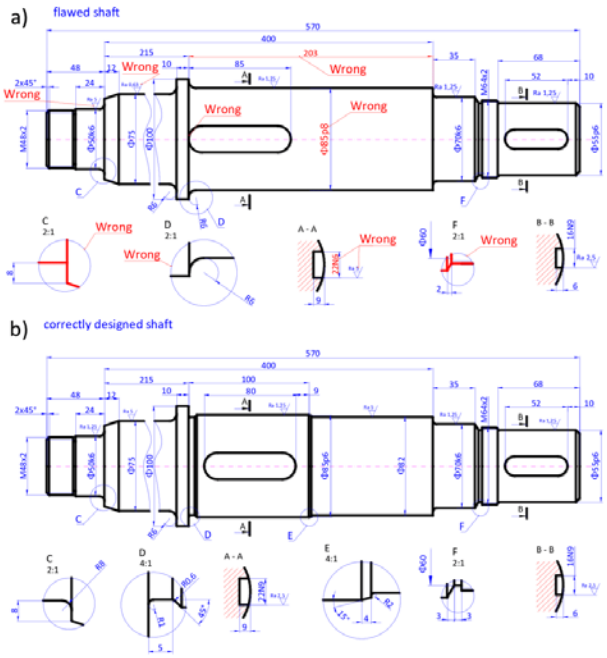

Figure 2: A machine shaft with highlighted errors: a) an antipattern, b) correct design [6]

When we consider AI automated parts and assembly adoption (date from different databases), in the study [13] examined a comprehensive, annotated benchmark of mechanical components for classification and retrieval operations. This dataset enables the data-driven study of machine component symptoms and enables data-driven feature learning for mechanical components. Examining the form description of machine elements is vital for all automatic processing from computer vision through the different industrial applications. The dataset enables data-driven feature learning for mechanical components.

Obtaining 3D models is difficult because annotating machine elements requires technical expertise. The primary contributions of this study are the establishment of a large reference collection of annotated machine elements, the definition of a hierarchical taxonomy for machine elements, and a comparison of the performances of deep learning classifiers for shape analysis applied to machine elements.

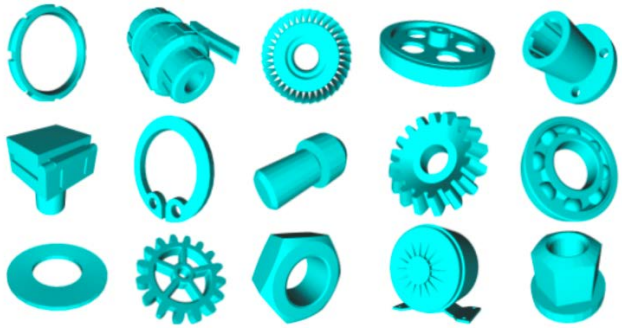

Figure 3: 3D machine elements objects for deep learning classifiers [13]

Generally, in the process of the machine design, cost analysis is one of the most important economic criteria for design adoption. Because of that, it is very important for engineers to track the cost from conceptual, to the final stage of machine design. In the paper [7], are given solution for the use of the AI in the process of the real time cost calculation through the whole design process.

The basic tool here is a dedicated expert system. A very significant stage of database design is determining the way of knowledge representation. On the basis of the conducted analysis, knowledge representation was accepted in form of frames and rules. Paper present methodology that delivers the particulars about real costs of products, realized processes and connected activities which constitute the basis for decision-making in the production process management.

In the presented methodology, production cost of a product covers the ensemble of activity cost, as a consequence of which a finished product of a given value is created from raw material or materials. The complexity of manufacturing is determined by the level of difficulty and constructional and manufacture connections taking place between different levels of a product (sets, subsets, elements).

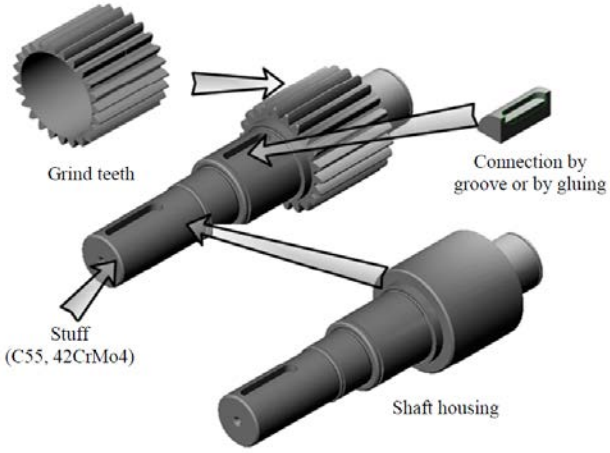

Figure 4: The main features of a sample designed element, for the cost calculation [7]

Generative design or multi objective optimisation, with rapid prototyping, represent the state of the art in the mechanical engineering, which may have a full potential of the using AI technology. Generative design leverages AI to turn engineering design processes into a sophisticated and natural interaction between computer and engineer [14]. The main part of the topology optimization and simulation is automatically conducted by the computing unit. Next-generation algorithms can be trained to not only optimize a design for specific engineering parameters, such as weight or durability, but also for commercial parameters, like production costs or even aesthetic requirements.

Generative design works best in conjunction with other technologies, like rapid prototyping. The 3D printing makes it possible to quickly prototype and test new designs without committing to a costly and time-consuming custom manufacturing run. On the other hand, 3D printing can produce extremely complex structures that traditional methods, such as milling and boring, are unable to manufacture.

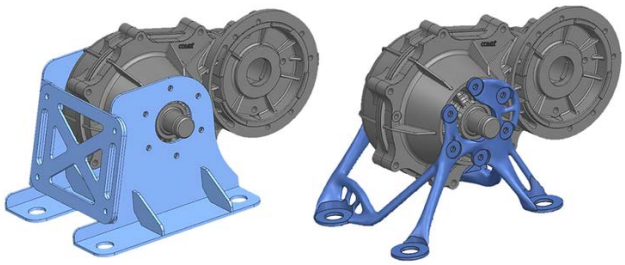

Figure 5: Generative design approach in design of the gearbox carrier [15]

5. CONCLUSION

Works aiming to develop basics of automation of processes in designing machine elements and assemblies with the use of AI in uncertainty and unrepeatability of processes have been started [6]. In machine element design process, based on the AI, where we can use a natural-language description of structural features and an intelligent interface of natural speech and hand-drawn sketches, application of design antipatterns, state of the art simulation, generative design etc., can have a great influence to the effectiveness and development of whole machine design process.

The design and optimization process of machine elements and parts, such as shafts, gears, bearings etc., may be automated using AI. On the other hand, the performance of machines may also be simulated and analyzed using AI in order to forecast behavior, spot future issues, and suggest changes.The majority of mechanical engineers at this moment can employ AI as a component of a CAD/CAM tool and FEA softwares, or to as assist data analysis and decision-making.

A workflow for combining AI and machine elements design, can be organised by three key following components:

1. Wellorganized dataset collected from the differnt sources (literature, existing databases, previous experiments and simulations, etc.)
2. AI model development, that is capable to learn and parse the representation for certain tasks
3. Well-defined research design problem that has not been addressed by conventional methods, or has been solved but can be outperformed by AI-based approaches.

Implementation of AI in the process of the design of machine elements aims at increasing efficiency and comfort of designers and speeding up creation of designs. The main benefits of AI used in the field of machine elements design will be:

- Reducing the human error rate
- Continuous operation 24/7 working hours
- Automation of repetitive tasks
- Digital use and assistants
- Faster decision-making
- Easy integration with current CAD/CAE tools
- Optimal final design (technical and economic criterias)

The evolution of engineering through history, shows that the "machine's desire" for autonomy, compensated by the machine's symbiosis with the human [16]. Therefore, AI machines will not replace people, and in the future that relationship will go towards a closer connection and the establishment of a new human-AI relationship. Such developments will certainly lead to the full application of AI in the process of machine design, which will achieve a complete symbiosis of human and AI. Advances in AI offer the perfect opportunity to integrate this technology into the an engineering design team, as a full member.

ACKNOWLEDGEMENTS

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Grant No. 451-03-68/2022-14/200132 with University of Kragujevac - Faculty of Technical Sciences Čačak.

REFERENCES

[1] F. Artkin, “Applications of Artificial Intelligence in Mechanical Engineering”, European Journal of Science and Technology, Special Issue 45, pp. 159-163, (2022)

[2] Q. Huang, “Application of Artificial Intelligence in Mechanical Engineering”, Advances in Computer Science Research, Vol. 74, pp.855-860, (2017)

[3] J. A. Collins, H. R. Busby, G. H. Staab, “Mechanical Design of Machine elements and machines - A Failure Prevention Perspective”, John Wiley & Sons, ISBN-13 978-0-470-41303-6, (2010)

[4] H. Mishra, V. Verma, M. A. Murtaza, “Artificial Intelligence and Applications in Mechanical Engineering”, International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Volume 9, Issue 6, pp.4237-4243, (2020)

[5] https://www.neuralconcept.com/post/how-is-ai-used-in-mechanical-engineering

[6] W. Kacalak, M. Majewski, K. D. Stuart, Z. Budniak, “Interactive systems for designing machine elements and assemblies”, Management and Production Engineering Review, Vol. 6, No.3, pp. 21–34, (2015)

[7] D. Więcek, “Implementation of artificial intelligence in estimating prime costs of producing machine elements”, Advances in manufacturing science and technology, Vol. 37, No. 1, (2013)

[8] https://www.simplilearn.com/tutorials/artificial-intelligence-tutorial/ai-vs-machine-learning-vs-deep-learning

[9] https://www.turing.com/kb/ultimate-battle-between-deep-learning-and-machine-learning

[10] T. H. Davenport,”The AI advantage - How to Put the Artificial Intelligence Revolution to Work”, The MIT Press Cambridge, Massachusetts, (2018)

[11] J. Jenis, J. Ondriga, S. Hrcek, F. Brumercik, M. Cuchor, E. Sadovsky, “Engineering Applications of Artificial Intelligence in Mechanical Design and Optimization”, Machines 2023, 11, 577, https://doi.org/10.3390/machines11060577, (2023)

[12] https://www.digitalengineering247.com/article/artificial-intelligence-beyond-the-hype/generative-design

[13] K. Sangpil, C. Hyung-gun,H. Xiao, H. Qixing, R.Karthik, “Large-scale Annotated Mechanical Components Benchmark for Classi_cation and Retrieval Tasks with Deep Neural Networks”, Purdue University, West Lafayette, USA, pp.1-17, (2019)

[14] F.Wunner, T. Krüger, B. Gierse, “How AI-driven generative design disrupts traditional value chains”, Industry X magazine (on-line), www.accenture.com, May 28, (2020)

[15] https://www.caexperts.com.br/

[16] G. Chapouthier, F. Kaplan, “L'Homme, L'Animal et la Machine”, CNRS Editions, ISBN 978-86-1002976-5, Paris, (2011)

[17] K. Guo, Z. Yang, C-H. Yu, M, J. Buehler, “Artificial intelligence and machine learning in design of mechanical materials”, The Royal Society of Chemistry, Mater. Horiz., 2021, 8, pp.1153–1172, (2021)

SUPPORTED BY:

The Ministry of Science, Technological Development and Innovation of the Republic of Serbia

The Serbian Chamber of Engineers

TeamCAD d.o.o. Zemun-Belgrade

Banim reklame d.o.o. Kraljevo

BRANDING BUSINESSES

Radijator Inženjering d.o.o. Kraljevo

Messer Tehnogas AD Belgrade

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

621(082)
621.86/.87(082)
629.3/.4(082)
622.6(082)
681.5(082)

INTERNATIONAL Triennial Conference Heavy Machinery (11 ; 2023 ; Vrnjačka Banja)
Proceedings / The Eleventh International triennial conference Heavy machinery
HM 2023, 21 – 24 June 2023, Vrnjačka Banja, Serbia ; [editor Mile Savković]. - Kraljevo : Faculty of Mechanical and Civil Engineering, 2023 (Vrnjačka Banja : SaTCIP). - 1 knj. (razl. pag.) : ilustr. ; 30 cm

Tiraž 60. - Str. 5: Preface / Mile Savković. - Bibliografija uz svaki rad.

ISBN 978-86-82434-01-6

a) Машиноградња -- Зборници b) Транспортна средства -- Зборници
v) Производно машинство -- Зборници g) Шинска возила -- Зборници
d) Аутоматско управљање -- Зборници

COBISS.SR-ID 120402697

Faculty of Mechanical
and Civil Engineering in Kraljevo
University of Kragujevac
Serbia, 36000 Kraljevo, Dositejeva 19
Phone/fax +381 36 383 269, 383 377

E-mail: office@mfkv.kg.ac.rs
www.mfkv.kg.ac.rs