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Integrating Machine Learning and Mathematical Programming for Optimisation of Electric Discharge of Machining Techniques

Ritu Gupta[1]

Former Associate Professor, Department of Applied Science and Humanities, Dr Akhilesh Das Gupta Institute of Technology and Management, New Delhi, India.

Mail id: r26jan@gmail.com

Anshul Srivastava[2]

Associate Professor, School of Business,

Galgotias University, Greater Noida, Uttar Pradesh, India\

Samreen Naqvi[3]

Assistant Professor, Department of Liberal Education

Era University, Lucknow, Uttar Pradesh, India

Tarun Lata Gupta[4]

Assistant Professor, Department of Applied Science and Humanities, Dr Akhilesh Das Gupta Institute of Technology and Management, New Delhi, India.

Abstract: This study explores the combination of machine guidance and several developing approaches to enhance both precision and effectiveness during Electricity-discharged Machining (EDM) business operations. The studies on quality control, energy efficiency, sustainable development, mathematical modelling within EDM optimization, and machine learning applications in EDM optimisation are all examined in this study. It highlights significant gaps in scientific knowledge, providing a pathway for the development of state-of-the-art EDM methods. The outcomes show that material decrease, energy efficiency, along EDM technique optimisation can all be enhanced. This study offers valuable information for future research within the field and contributes to the ongoing conversation about advanced manufacturing techniques. This project intends to revolutionise EDM by merging mathematical programming and machine learning. Three primary topics are investigated machining parameter optimisation, efficiency improvement using machine learning and environmental effect assessment. The goals of the study are met by using the deductive method, which gives a formal setting in which to examine hypotheses. Descriptive research designs allow for in-depth analyses of previously published works, mathematical models and automated learning programs. Finding commonalities and trends in qualitative data is the goal of the thematic data analysis technique. The results of this study provide useful resources, standards and sustainable perspectives for enhancing EDM procedures in manufacturing settings.

Keywords: EDM, Neural Network, ML, Extraction rate, Process optimization

I. INTRODUCTION

A. Project Specification

The primary objective of the project is to combine machine learning and programming mathematics to optimize electrically terminated machining (EDM) processes [1]. This study manages the need to grow the effectiveness as well as efficiency regarding the EDM methodology by carefully looking at the relevant variables charming the operation of machining [2]. The aim is to develop a sweeping framework that utilizes mathematical optimization techniques in conjunction with data-driven artificial intelligence algorithms to ascertain the optimal EDM parameter settings [3]. Improving substance extraction rate, device wear, and overall EDM process efficiency are the main objectives of the research. Ultimately, the goal of this research effort is to provide insightful analysis and practical solutions that help the manufacturing industry.

B. Aim and Objectives

Aim

The major goal of this analysis is to combine computational math as well as machine learning to enhance the effectiveness and efficiency of electrical Discharge Machining (EDM) guidelines.

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Objectives

- Examine the body of research on programming in mathematics and neural networks in relation to EDM improvement.
- Create models using mathematical programming to maximize the machining parameters.
- Analyze how well the combined strategy works to achieve increased sustainability and EDM efficiency.
- Provide useful guidelines for use in industry and make recommendations for directions to pursue further research in this area.

C. Research Rationale

This study's research justification is the urgent need to improve both the precision and effectiveness of electric discharge machining (EDM) procedures. EDM is a commonly used process for producing complex parts made of hard materials, and its optimization can result in significant cost savings and better product quality [4]. This research aims to close current gaps in existing scholarship and advance the creation of more robust and resilient EDM practices by combining machine instruction along with programming operating mathematics [5]. By enabling nearest form parameter adjustments including miscalculating waste, the influentialintegration of these processes holds the possibility to ultimately transform EDM as well as benefit considerableindustrial sectors.

II. LITERATURE REVIEW

A. Machine Learning Applications in EDM Optimization

Electric discharge machining (EDM) optimisation makes significant use of machine learning. It helps to automate one of the most important tasks in EDM optimization: choosing the machining settings [6]. Based on prior information, machine learning techniques like regression, choice trees, as well as neural networks can forecast a variety of EDM outcomes like surface finish, tool corrosion rate, and the amount of material removed (MRR). By taking into account numerous factors at once, these models make it possible to identify the ideal machining parameters, leading to improved precision and effectiveness of EDM processes.

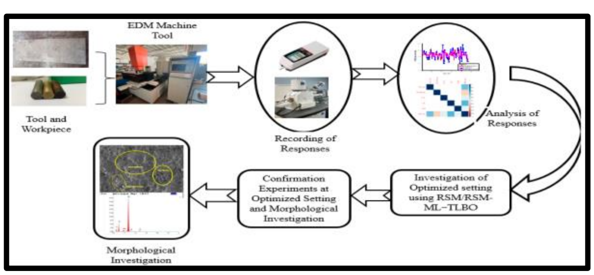

Fig. 2.1: Machine Learning Applications in EDM Optimization

Moreover, machine learning can help identify complex relationships within the machine settings and output variables by making it easier to find associations and patterns in huge datasets [7]. By increasing productivity, decreasing material waste, and reducing the need for human oversight, machine learning is used in EDM the improvement to improve the quality of goods and save costs.

B. Mathematical Programming in EDM Process Optimization

Electric discharge machining (EDM) process enhancement heavily relies on computational programming. This method entails creating a mathematical representation that illustrates the connections between different parameters related to machining and the intended process results, including tool wear, surface finish, along material removal rate (MRR) [8]. The best settings can be found by methodically experimenting with various combinations of machining parameters thanks to algorithms such as integer, nonlinear, and linear programming.

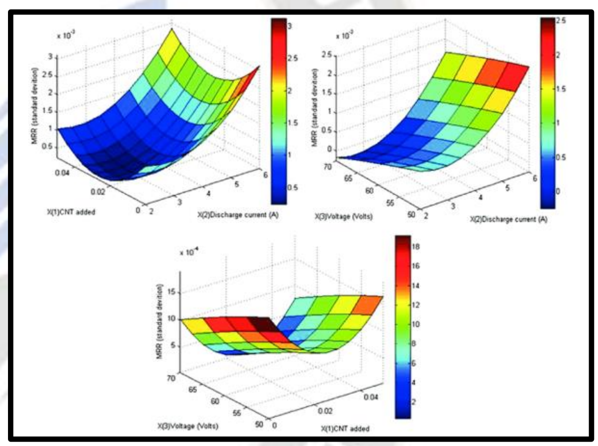

Fig. 2.2: Mathematical Programming in EDM Process Optimization

Creating objective processes, which stand for the goal to be enhanced or decreased, and limitations which stand for process drawbacks or restrictions, are common steps in these approaches to optimization [9]. It is possible to customize objective functions to meet particular EDM goals, like maximizing MRR and minimizing tool tears. Safety concerns, machine capacity, along power consumption are a few examples of restrictions. The EDM process performs better when the optimal parameter configurations obtained from solving these algorithmic programming models are used.

C. Quality Control and Inspection in EDM

Inspection and quality control are essential in the field of electromagnetic discharge machining (EDM). EDM is vulnerable to various factors that impact the overall performance of machined components, such as machine drift, conductive degradation, alongside tool wear [10]. Striving for

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the desired results requires strict quality control procedures. These usually entail a mix of post-machining assessments and in-process surveillance.

Fig. 2.3: Quality Control and Inspection in EDM

Real-time evaluation of machining settings, such as current consumption, and voltage along with servo settings, is a component of in-process monitoring. When there are deviations compared to the ideal parameters, they can be quickly identified and adjusted to keep the machining process's quality constant [11]. Modern sensors and surveillance systems are currently used to improve this part of quality assurance. Dimensional measurements, surface roughness evaluations, and integrity evaluations for what appear like holes alongside slots are all part of post-machining examinations.

D. Sustainability and Energy Efficiency in EDM

In Electricity Discharge Machining (EDM), sustainability along with energy efficiency are critical because they have a direct bearing on operational expenses and environmental issues [12]. Reducing waste from materials is a key component of sustainability in EDM since it helps preserve resources. This procedure reduces its environmental impact and is consistent with environmentally friendly manufacturing methods.

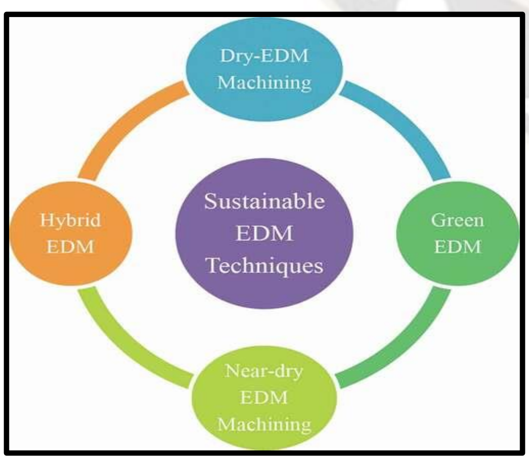

Fig. 2.4: Sustainability and Energy Efficiency in EDM

Optimization of energy use in EDM also helps to promote energy efficiency, which lowers operating costs and releases greenhouse gases. Improving material recyclability and reducing dielectric usage of fluid are two ways to improve sustainability. In addition, the use of energy along with tool wear is highly influenced by the design and selection of electrode materials [13]. Reducing the consumption of energy and resources through an emphasis on ecologically conscious procedures in EDM can make the manufacturing process both viable and profitable for the environment.

E. Literature Gap

There is a clear lack of integration between machine learning and programming methods in the literature that is currently available on electric discharge machining (EDM) improvement. While a large body of research has been done on computational programming along with applications of machine learning in EDM separately, little has been done to bring together these two strategies to produce complete process optimization. This vacuum in the literature offers a chance to better tackle the problems in EDM by utilizing data-driven approaches and rigorous mathematics to enhance machining settings, product performance, and resource efficiency. Practitioners as well as researchers can open up new possibilities for improving the EDM process as a whole by connecting this gap.

III. METHODOLOGY

A. Research Philosophy

A study's assumptions and methodology are heavily influenced by the chosen research philosophy that helps to integrate different study ideas. Positivism has been incorporated into the study to create a rational and empirical groundwork for the investigation of ML or MP integration for EDM optimisation [14]. A key factor of positivism is the pursuit of observable, measurable and repeatable results through the use of scientific rigour. This outlook provides a systematic framework for analysis, data collection and validation that is in line with the study's purpose to systematically analyse and improve EDM operations. This methodological rigour helps the development of EDM methods by providing a solid foundation for the generation of trustworthy insights and suggestions based on empirical observations and measurements.

B. Research Approach

The research approach that has been chosen provides a map for answering the study's questions and achieving its goals. Deductive reasoning has been used because it is systematic and focused on testing hypotheses. The process begins with the development of a theoretical framework, followed by the formulation of hypotheses that have been

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tested through the collection and analysis of empirical data [15]. The suggested work that attempts to combine mathematical programming and machine learning to enhance EDM, is ideally suited to this method. Learners can systematically determine the combined technique improves EDM processes by applying a logical approach to the testing and validation process.

C. Research Design

Choosing a research design is crucial because it determines how the data has been analysed and interpreted. The choice to use a descriptive research strategy in this investigation has been deliberate. The purpose of descriptive research is to paint a complete and accurate picture of the phenomenon being studied [16]. A descriptive research design is ideal for thoroughly investigating the current literature, mathematical models and machine learning techniques that are pertinent to EDM optimisation, given the purpose of merging these two approaches. This layout makes it easier to grasp where the field of study now stands, which in turn helps the development of well-informed guidelines and suggestions for professionals in the industry and future researchers.

D. Data Analysis and Collection Method

The goal of data collecting and analysis techniques is to methodically amass and evaluate data in order to draw reliable conclusions. The purpose of thematic analysis is to examine, extract and report overarching themes from qualitative data. Given the multifaceted nature of the study goals that include combining mathematical programming and machine learning for EDM optimisation, theme analysis permits a fine-grained investigation of these patterns and linkages [17]. Using this approach, scientists also identify essential studies including efficiency enhancement, EDM process parameter optimisation and environmental effect. It offers a methodical framework for condensing large amounts of data into actionable insights and suggestions for business use.

E. Ethical Consideration

All applicable government requirements have been maintained in order to facilitate a smooth implementation of the study. In cases where the information collected is not harmful to society, it is recommended that it be shared via public rather than private channels [18]. This firm Students take safety measures to reduce the risk of injury to themselves and others as a result of their participation.

IV. RESULTS AND DISCUSSION

A. Critical Analysis

The study project has a lot of potential, but there are also a lot of obstacles and things to think about. In order to start, smaller-scale firms have been unable to benefit from the combination of mathematical programming and machine learning if it requires a large computer infrastructure [19]. Another potential barrier in some industrial contexts is that the efficacy of the combined strategy has been greatly dependent on the quality and amount of accessible data. Even if the suggested sustainability evaluation is essential, it has been difficult to conduct a precise quantification of environmental benefits without resorting to a thorough life cycle study. The project's success depends on solid methodology, cross-disciplinary teamwork and the capacity to solve real-world problems in EDM implementation.

B. Theme 1: Optimising Machining Parameters with the help of Mathematical Programming

The major focus is on utilising mathematical programming approaches to optimise machining parameters in “Electrical Discharge Machining (EDM)”. Formulating and solving mathematical models is at the heart of mathematical programming, which is used to determine the optimal machining settings [20]. This method permits a systematic and rigorous investigation of the parameter space by taking into account variables such as tool material, pulse length, current intensity and workpiece material.

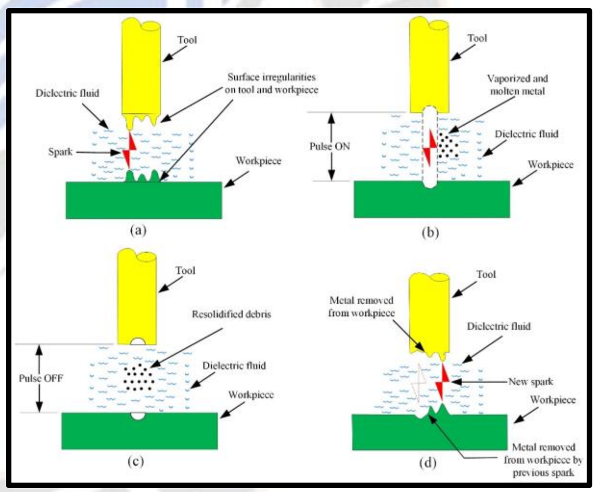

Fig. 4.1: Parameter optimization in the case of EDM

This subject also guides a literature assessment of mathematical programming methods as they pertain to EDM. As part of this process, there have been investigated mathematical models that outline the connections between various inputs and various measures of machining performance. Using mathematical programming, scientists are trying to zero in on the sweet spot for EDM process efficiency and precision [21]. Mathematical programming approaches have been investigated for potential application in optimising machining parameters. It has been required to create optimisation algorithms that seek the optimal set of parameters while also satisfying the requirements and goals unique to

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EDM. The goal of the study is to help engineers and manufacturers enhance their EDM procedures by providing them with the tools and methods they need to do so.

C. Theme 2: Enhancing EDM Efficiency through Machine Learning

In this section, there has been a shift in gears to discuss how machine learning algorithms are also included in EDM practises to improve their effectiveness. Modelling the intricate interplay between input parameters and machined outputs is a common application of machine learning techniques such as supervised and unsupervised learning [22]. This paves the way for the creation of prediction models that can serve as real-time decision-making tools. In-depth literature reviews of machine learning's EDM applications have provided the backbone of the study within this area.

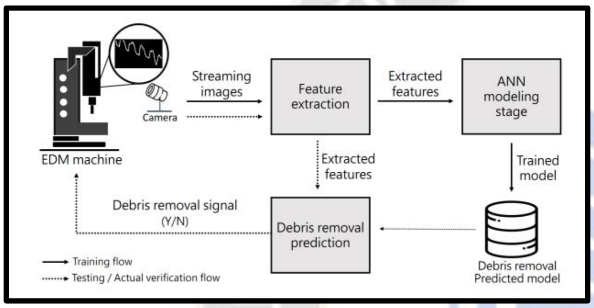

Fig. 4.2: Framework of EDM machine

This also includes research that makes use of machine learning methods such as neural networks and support vector machines to make predictions about machining performance given certain inputs. Researchers want to enhance EDM procedures over time by using machine learning to develop models with adaptable behaviour [23]. There has been an examination of the synergistic strategy of combining machine learning with mathematical programming. Mathematical programming approaches are used to initially explore a parameter space derived by machine learning models. The synergy between these techniques seeks to boost the accuracy and speed of parameter optimisation, ultimately leading to more efficient EDM operations.

D. Theme 3: Sustainability and Environmental Impact of Enhanced EDM Techniques

The larger ramifications of integrating the methods of mathematical programming and machine learning with EDM are highlighted in this section. It is possible to lessen EDM's impact on the environment by optimising machining settings and increasing productivity [24]. The benefits of the suggested technique have been quantified by measuring sustainability parameters including material utilisation, energy efficiency, and environmental impact.

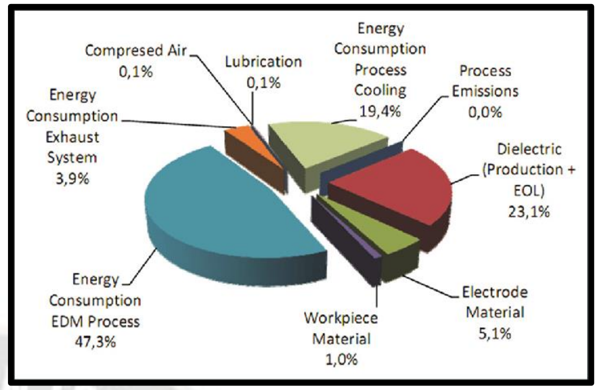

Fig. 4.3: Environmental impact of EDM machine

The study conducted on this subject also looks at the long-term effects that improved EDM methods have on the environment. This comprises studies that measure the environmental footprint of EDM activities before and after using the integrated strategy. This area of study hopes to aid the larger mission of encouraging ecologically responsible production methods by giving proof of the positive influence on sustainability [25]. There is substantial potential in combining mathematical programming with machine learning to advance Electrical Discharge Machining. Researchers want to improve EDM processes in industrial applications by providing insightful knowledge, useful tools and long-term answers by methodically examining these three issues.

E. Discussion

Using a holistic strategy, the study helps to improve the productivity and quality of EDM processes in a comprehensive way. The purpose of the study is to systematically enhance EDM procedures by optimising machining settings using a combination of mathematical programming and machine learning. The second uses machine learning to build prediction models for in-the-moment judgment while the first theme utilises mathematical programming to systematically probe the parameter space [26]. The study focuses on how the improved EDM methods might contribute to a more sustainable world. This holistic strategy significantly alters the EDM business by giving engineers and manufacturers access to previously unavailable resources and methods. Furthermore, the emphasis on sustainability is in line with the increasing worldwide demand for eco-friendly production methods.

V. CONCLUSION

A. Critical Evaluation

A critical analysis of the body of literature demonstrates how machine learning and computational math have significantly converged in the realm of EDM optimization. Nonetheless, certain constraints are apparent, such as the absence of established techniques and restricted investigation of multidisciplinary strategies. There is hope for more synergy between these methods and how they can be applied to address the reduction of energy consumption and sustainability components of EDM. A glaring void in the literature at this point calls for more thorough research and standardized procedures in order to fully realize the potential advantages of programming mathematics and neural networks for EDM improvement.

B. Research Recommendation

The study's conclusions highlight the benefits of combining computational mathematics and machine learning methods in improving the performance of electric discharge machining (EDM). In order to improve EDM procedures, it is advised that upcoming studies concentrate on:

Hybrid Models: Examine the creation of mathematical programming languages and combination machine learning models to improve the resilience and precision of EDM parameter optimization methodologies [27].

Real-time Monitoring: Investigate the deployment of systems for real-time monitoring, utilizing machine learning to make dynamic modifications to optimize EDM procedures as they take place.

Case Studies: To illustrate the usefulness of the suggested techniques, carry out in-depth case studies along with empirical validations in business environments [28]. These lines of inquiry can propel the field ahead and lead to more effective and long-lasting EDM methods.

C. Future Work

Subsequent investigations in the domain of EDM optimization utilizing machine learning along with programming mathematics ought to delve into sophisticated algorithms that augment optimizing parameters and model resilience [29]. It is imperative to investigate surveillance systems that are capable of adaptively adjusting machining parameters in response to dynamic conditions. Furthermore, the creation of useful industry regulations for implementation along with the investigation of EDM in conjunction with cutting-edge technologies, like Industry 4.0 along with IoT, can present fresh opportunities for additional improvement [30]. Future research should focus on addressing issues like data security along with processing speed that arise when integrating artificial intelligence models through a manufacturing procedure.

REFERENCES

[1] H. Ma *et al*, "A comprehensive survey on NSGA-II for multi-objective optimization and applications," *The Artificial Intelligence Review,* vol. 56, *(12),* pp. 15217-15270, 2023. Available: https://www.proquest.com/scholarly-journals/comprehensive-survey-on-nsga-ii-multi-objective/docview/2873089625/se-2. DOI: https://doi.org/10.1007/s10462-023-10526-z.

[2] O. Mypati *et al*, "A critical review on applications of artificial intelligence in manufacturing," *The Artificial Intelligence Review, Suppl.1,* vol. 56, pp. 661-768, 2023. Available: https://www.proquest.com/scholarly-journals/critical-review-on-applications-artificial/docview/2879629962/se-2. DOI: https://doi.org/10.1007/s10462-023-10535-y.

[3] O. Licht *et al*, "Extensive literature search on mineral oil hydrocarbons," *EFSA Supporting Publications,* vol. 20, *(2),* 2023. Available: https://www.proquest.com/scholarly-journals/extensive-literature-search-on-mineral-oil/docview/2780327313/se-2. DOI: https://doi.org/10.2903/sp.efsa.2023.EN-7893.

[4] A. K. Ghosh, S. Fattahi and S. Ura, "Towards Developing Big Data Analytics for Machining Decision-Making," *Journal of Manufacturing and Materials Processing,* vol. 7, *(5),* pp. 159, 2023. Available: https://www.proquest.com/scholarly-journals/towards-developing-big-data-analytics-machining/docview/2882579410/se-2. DOI: https://doi.org/10.3390/jmmp7050159.

[5] A. Malyushevskaya *et al*, "Optimizing Energy Efficiency of Dielectric Materials' Electrodischarge Dispersion as One Sustainable Development Green Trend," *Energies,* vol. 16, *(20),* pp. 7098, 2023. Available: https://www.proquest.com/scholarly-journals/optimizing-energy-efficiency-dielectric-materials/docview/2882566188/se-2. DOI: https://doi.org/10.3390/en16207098.

[6] Y. Zhang, S. Wang and G. Ji, "A Comprehensive Survey on Particle Swarm Optimization Algorithm and Its Applications," *Mathematical Problems in Engineering,* vol. 2015, 2015. Available: https://www.proquest.com/scholarly-journals/comprehensive-survey-on-particle-swarm/docview/1722855905/se-2. DOI: https://doi.org/10.1155/2015/931256.

[7] C. F. Ana Carolina and Sanderson César Macêdo Barbalho, "Mechatronics: A Study on Its Scientific Constitution and Association with Innovative Products," *Applied System Innovation,* vol. 6, *(4),* pp. 72, 2023. Available: https://www.proquest.com/scholarly-journals/mechatronics-study-on-scientific-constitution/docview/2856776018/se-2. DOI: https://doi.org/10.3390/asi6040072.

[8] Y. Chen *et al*, "Parameters Optimization of Electrical Discharge Machining Process Using Swarm Intelligence: A Review," *Metals,* vol. 13, *(5),* pp. 839, 2023. Available: https://www.proquest.com/scholarly-journals/parameters-optimization-electrical-

discharge/docview/2819479274/se-2. DOI: https://doi.org/10.3390/met13050839.

[9] I. Podder, T. Fischl and U. Bub, "Artificial Intelligence Applications for MEMS-Based Sensors and Manufacturing Process Optimization," *Telecom*, vol. 4, *(1)*, pp. 165, 2023. Available: https://www.proquest.com/scholarly-journals/artificial-intelligence-applications-mems-based/docview/2791700056/se-2. DOI: https://doi.org/10.3390/telecom4010011.

[10] M. A. Rahman *et al*, "Review of Intelligence for Additive and Subtractive Manufacturing: Current Status and Future Prospects," *Micromachines*, vol. 14, *(3)*, pp. 508, 2023. Available: https://www.proquest.com/scholarly-journals/review-intelligence-additive-subtractive/docview/2791680214/se-2. DOI: https://doi.org/10.3390/mi14030508.

[11] R. P. Parouha and V. Pooja, "An innovative hybrid algorithm for bound-unconstrained optimization problems and applications," *J. Intell. Manuf.*, vol. 33, *(5)*, pp. 1273-1336, 2022. Available: https://www.proquest.com/scholarly-journals/innovative-hybrid-algorithm-bound-unconstrained/docview/2656448016/se-2. DOI: https://doi.org/10.1007/s10845-020-01691-x.

[12] N. M. Alkadi, "Product Design for Energy Reduction in Concurrent Engineering: An Inverted Pyramid Approach." Order No. 3300881, West Virginia University, United States -- West Virginia, 2007.

[13] U. A. Kulkarni, "Generic Cost Estimation Framework for Design and Manufacturing Evaluation." Order No. 3055737, Old Dominion University, United States -- Virginia, 2002.

[14] Y. Luo, "Integration of e -Business Strategy for Multi - Lifecycle Production Systems." Order No. 3077939, New Jersey Institute of Technology, United States -- New Jersey, 2001.

[15] B. Yang *et al*, "Application of Digital Twins and Metaverse in the Field of Fluid Machinery Pumps and Fans: A Review," *Sensors*, vol. 22, *(23)*, pp. 9294, 2022. Available: https://www.proquest.com/scholarly-journals/application-digital-twins-metaverse-field-fluid/docview/2748560092/se-2. DOI: https://doi.org/10.3390/s22239294.

[16] J. Dugar *et al*, "Sustainable Hybrid Manufacturing of AlSi5 Alloy Turbine Blade Prototype by Robotic Direct Energy Layered Deposition and Subsequent Milling: An Alternative to Selective Laser Melting?" *Materials*, vol. 15, *(23)*, pp. 8631, 2022. Available: https://www.proquest.com/scholarly-journals/sustainable-hybrid-manufacturing-alsi5-alloy/docview/2748556571/se-2. DOI: https://doi.org/10.3390/ma15238631.

[17] V. Petrauskiene *et al*, "Color Recurrence Plots for Bearing Fault Diagnosis," *Sensors*, vol. 22, *(22)*, pp. 8870, 2022. Available: https://www.proquest.com/scholarly-journals/color-recurrence-plots-bearing-fault-diagnosis/docview/2739457281/se-2. DOI: https://doi.org/10.3390/s22228870.

[18] J. Li *et al*, "Moth Search: Variants, Hybrids, and Applications," *Mathematics*, vol. 10, *(21)*, pp. 4162, 2022. Available: https://www.proquest.com/scholarly-journals/moth-search-variants-hybrids-applications/docview/2734653933/se-2. DOI: https://doi.org/10.3390/math10214162.

[19] S. Masihi, "Development of Smart Wearable Sensory Systems on Flexible and Fabric Platforms for Health Monitoring Applications." Order No. 29318899, Western Michigan University, United States -- Michigan, 2022.

[20] A. Batwara *et al*, "An Empirical Investigation of Green Product Design and Development Strategies for Eco Industries Using Kano Model and Fuzzy AHP," *Sustainability*, vol. 14, *(14)*, pp. 8735, 2022. Available: https://www.proquest.com/scholarly-journals/empirical-investigation-green-product-design/docview/2694031767/se-2. DOI: https://doi.org/10.3390/su14148735.

[21] B. K. Tripathy *et al*, "Harris Hawk Optimization: A Survey onVariants and Applications," *Computational Intelligence and Neuroscience : CIN*, vol. 2022, 2022. Available: https://www.proquest.com/scholarly-journals/harris-hawk-optimization-survey-onvariants/docview/2687536561/se-2. DOI: https://doi.org/10.1155/2022/2218594.

[22] I. Rahimi *et al*, "Scheduling by NSGA-II: Review and Bibliometric Analysis," *Processes*, vol. 10, *(1)*, pp. 98, 2022. Available: https://www.proquest.com/scholarly-journals/scheduling-nsga-ii-review-bibliometric-analysis/docview/2621346003/se-2. DOI: https://doi.org/10.3390/pr10010098.

[23] A. V. Paul *et al*, "Modeling Energy Demand—A Systematic Literature Review," *Energies*, vol. 14, *(23)*, pp. 7859, 2021. Available: https://www.proquest.com/scholarly-journals/modeling-energy-demand-systematic-literature/docview/2608131653/se-2. DOI: https://doi.org/10.3390/en14237859.

[24] S. K. Mahalingam *et al*, "A Hybrid Approach of ANFIS—Artificial Bee Colony Algorithm for Intelligent Modeling and Optimization of Plasma Arc Cutting on Monel™ 400 Alloy," *Materials*, vol. 14, *(21)*, pp. 6373, 2021. Available: https://www.proquest.com/scholarly-journals/hybrid-approach-anfis-artificial-bee-colony/docview/2596056382/se-2. DOI: https://doi.org/10.3390/ma14216373.

[25] D. Zhang, L. Du and Z. Gao, "Real-Time Parameter Identification for Forging Machine Using Reinforcement Learning," *Processes,* vol. 9, *(10),* pp. 1848, 2021. Available: https://www.proquest.com/scholarly-journals/real-time-parameter-identification-forging/docview/2584507548/se-2. DOI: https://doi.org/10.3390/pr9101848.

[26] D. Leinmüller, A. Misik and M. F. Zaeh, "Renewable On-Site Power Generation for Manufacturing Companies—Technologies, Modeling, and Dimensioning," *Sustainability,* vol. 13, *(7),* pp. 3898, 2021. Available: https://www.proquest.com/scholarly-journals/renewable-on-site-power-generation-manufacturing/docview/2562195101/se-2. DOI: https://doi.org/10.3390/su13073898.

[27] W. C. H. Schoonenberg, "Engineering Systems: Structure, Behavior, and Optimization with Hetero-Functional Graph Theory." Order No. 28322807, Dartmouth College, United States -- New Hampshire, 2021.

[28] V. Gue Ivan Henderson *et al*, "Artificial neural networks for sustainable development: a critical review," *Clean Technologies and Environmental Policy,* vol. 22, *(7),* pp. 1449-1465, 2020. Available: https://www.proquest.com/scholarly-journals/artificial-neural-networks-sustainable/docview/2432261137/se-2. DOI: https://doi.org/10.1007/s10098-020-01883-2.

[29] Z. M. Çınar *et al*, "Machine Learning in Predictive Maintenance towards Sustainable Smart Manufacturing in Industry 4.0," *Sustainability,* vol. 12, *(19),* pp. 8211, 2020. Available: https://www.proquest.com/scholarly-journals/machine-learning-predictive-maintenance-towards/docview/2548846675/se-2. DOI: https://doi.org/10.3390/su12198211.

[30] D. Karaboga and E. Kaya, "Adaptive network based fuzzy inference system (ANFIS) training approaches: a comprehensive survey," *The Artificial Intelligence Review,* vol. 52, *(4),* pp. 2263-2293, 2019. Available: https://www.proquest.com/scholarly-journals/adaptive-network-based-fuzzy-inference-system/docview/1984338087/se-2. DOI: https://doi.org/10.1007/s10462-017-9610-2.