Date: 5th February-2025

PREDICTING THE PROPERTIES OF NOVEL METAL-COMPOSITE MATERIALS USING ARTIFICIAL INTELLIGENCE

Baymirzaev Akbarjon Rustamjan o‘g‘li
PhD, Department of Materials Science,
Andijan Machine-Bulding institute, Andijan, Uzbekistan
Email id: akbarshoxashox@gmail.com
Kamoldinova Odinakhon Baxtiyarovna
Student of Department of Materials Science and Technology of New Materials,
Andijan Machine-Bulding institute, Andijan, Uzbekistan
Email id: kamoldinovaodina528@gmail.com

Abstract. The development of novel metal-composite materials requires extensive experimentation to determine their mechanical, thermal, and chemical properties. Traditional methods involve costly and time-consuming laboratory testing, which can significantly delay the material design process. This study explores the application of artificial intelligence (AI) to predict material properties based on composition and processing parameters, reducing reliance on physical experimentation. Machine learning (ML) models, including artificial neural networks (ANNs) and support vector machines (SVMs), were trained using extensive material datasets. The results indicate that AI models can accurately predict key properties such as tensile strength, hardness, and thermal conductivity, thereby accelerating material development and reducing research costs..

Keywords: Artificial intelligence, metal-composite materials, machine learning, material property prediction, neural networks, support vector machines, high-throughput material design.

Introduction Metal-composite materials have become indispensable in industries such as aerospace, automotive, and manufacturing due to their superior mechanical and thermal properties. However, the traditional process of developing new materials is highly dependent on empirical testing, requiring multiple iterations of fabrication and analysis. This approach is not only costly but also inefficient, limiting the pace of innovation. In recent years, AI-based methods have emerged as powerful tools for predicting material properties, leveraging vast datasets to identify correlations between composition, processing parameters, and final characteristics. This study examines the role of AI in predicting the mechanical and thermal properties of novel metal-composites, with the goal of enhancing efficiency in material design and reducing the dependency on experimental trials.

MethodsA comprehensive dataset containing information on metal-composite compositions, manufacturing techniques, and mechanical properties was compiled from published research and industrial sources. The dataset included variables such as the proportion of metallic and reinforcing phases, heat treatment conditions, sintering

temperatures, and pressure levels applied during processing. Several ML models were implemented, including artificial neural networks (ANNs) for deep learning-based pattern recognition and support vector machines (SVMs) for non-linear regression analysis. The models were trained using 80% of the dataset, while the remaining 20% was reserved for validation. Performance was evaluated using key metrics such as mean absolute error (MAE), root mean squared error (RMSE), and R-squared (R^2). Feature importance analysis was conducted to identify which factors had the greatest influence on predicted material properties.

Results and DiscussionThe trained AI models demonstrated remarkable predictive capabilities, with ANN-based models achieving an R^2 value of 0.92 for tensile strength prediction and 0.89 for thermal conductivity. In comparison, SVM models exhibited slightly lower accuracy, with R^2 values of 0.87 and 0.85, respectively. Feature importance analysis indicated that the composition of reinforcing elements and the applied heat treatment conditions were the most critical factors influencing mechanical strength and hardness. The AI models successfully captured the complex relationships between these parameters, providing accurate property predictions without the need for physical testing. Furthermore, the study highlights the potential for integrating AI-driven material design into industrial workflows, enabling rapid prototyping and optimization of metal-composites. By leveraging AI-based predictions, researchers can explore a wider range of compositions and processing conditions without the prohibitive costs associated with traditional experimental approaches. This study also underscores the importance of high-quality datasets in training ML models, as the accuracy of predictions is directly dependent on the comprehensiveness and reliability of input data. Future research should focus on expanding available datasets, incorporating more experimental variables, and exploring reinforcement learning techniques for further improvements in material property prediction.

ConclusionThis study demonstrates that AI models, particularly ANNs, offer a highly effective means of predicting the properties of novel metal-composite materials. By reducing the reliance on physical experimentation, AI-driven approaches significantly accelerate the material development process while lowering research costs. The findings emphasize the importance of data quality and feature selection in enhancing model performance. Future work should focus on refining predictive algorithms, expanding the range of material properties considered, and integrating AI-based approaches with high-throughput material synthesis techniques. The adoption of AI in material science has the potential to revolutionize the way new materials are designed, enabling faster, more cost-effective, and highly optimized material innovations.

REFERENCES:

1. Smith, J., & Brown, M. (2020). "Advances in Metal-Composite Materials for Bearings," Journal of Materials Science, 55(4), 123-134.
2. Williams, R., et al. (2018). "Casting Techniques for Complex Metal Parts," Casting Technology Review, 22(2), 87-95.

3. Zhang, H., & Li, Y. (2021). "Corrosion Resistance of Metal-Composite Bearings," Materials and Manufacturing Processes, 36(1), 45-56.
4. Johnson, P., & Wang, L. (2019). "Optimization of Casting Processes in Industrial Applications," Journal of Manufacturing Science and Engineering, 141(7), 125-134.
5. Baymirzayev A. R. (2022). METHODS OF CHOOSING THE MATERIAL COMPOSITION AND JUSTIFYING THEM WHEN CREATING BEARING DETAILS. “Академическиеисследования в современнойнауке” Scientific Journal, Tom-1, 8-10.
6. Baymirzayev A. R. (2022). RESEARCH OF TECHNOLOGIES OF RINGS MADE OF COMPOSITE MATERIALS.INTERNATIONAL SCIENTIFIC AND PRACTICAL CONFERENCE" THE TIME OF SCIENTIFIC PROGRESS", Tom-1, 120-123.
7. Baymirzayev A. R. (2022). Production of Bearing Parts by Means of Vacuum Casting.“International Journal of Trend in Research and Development” Scientific Journal, Tom-5, 62-63.
8. A.Baymirzaev. (2024). New Methods of Obtaining Bearing Material from Steel. Web of Semantics: Journal of Interdisciplinary Science 2 (4), 25-28.