ARTIFICIAL INTELLIGENCE IN LASER BEAM MACHINING

based on *"A review on applications of artificial intelligence in modeling and optimization of laser beam machining"*

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Introduction

- Laser Beam Machining (LBM) : a non-conventional machining process; uses a high-energy laser beam to cut, drill, or engrave materials.
- Laser beam focused on the workpiece: melts or vaporizes the material, creating a narrow kerf or hole.
- LBM parameters like laser power, cutting speed, pulse width, assist gas pressure, etc., having a considerable effect on quality characteristics of workpiece.
- AI models to predict the optimal LBM parameters that will result in the desired quality characteristics of the workpiece.
- AI techniques such as artificial neural networks (ANNs), fuzzy logic (FL), and metaheuristic optimization algorithms are commonly used to develop these models

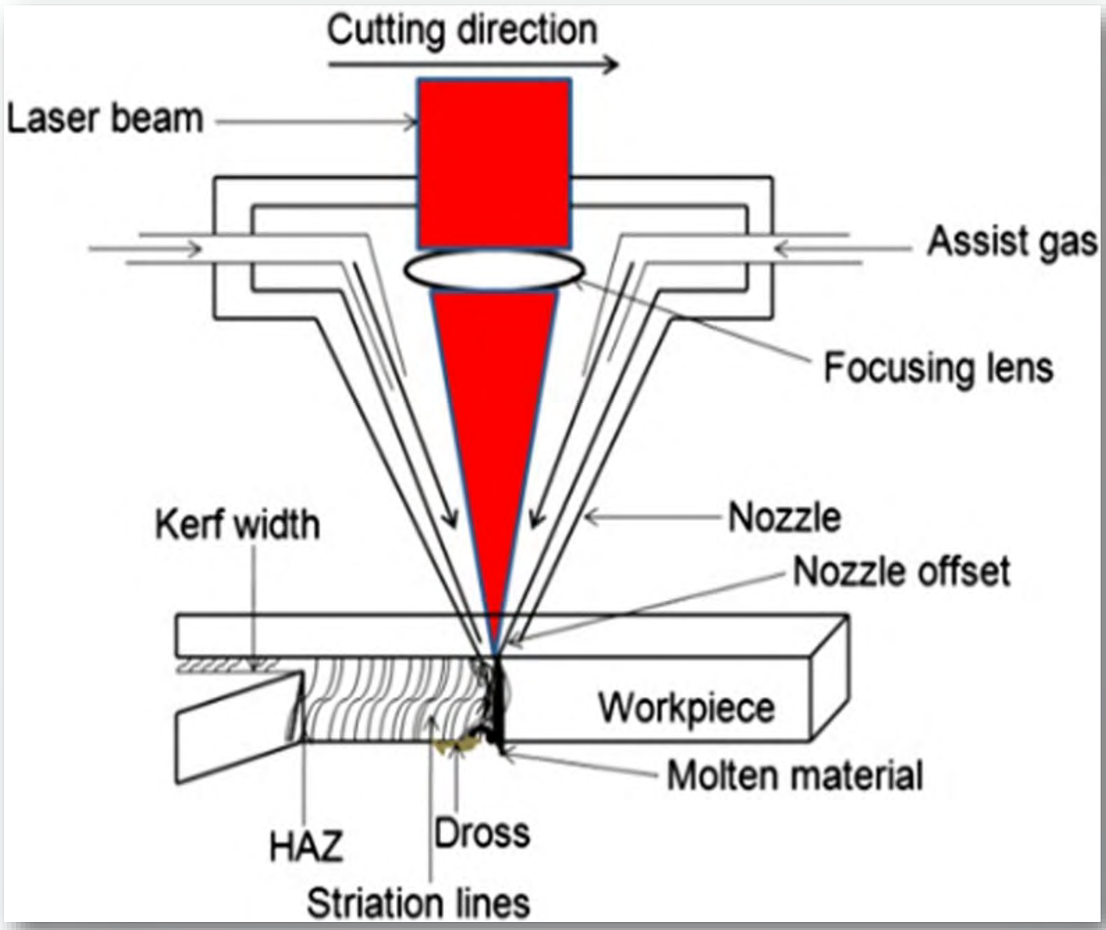

Fig 1: Schematic of laser beam cutting

Approaches and Methods

- LBM quality characteristics: geometry characteristics, metallurgy characteristics, surface roughness, and material removal rate (MRR)
- **Geometry characteristics:** kerf width, kerf deviation
- ✓ Multi-objective optimization, including Genetic Algorithm (GA) and Partial swarm optimization (PSO) was used to obtain the optimal value of different process parameters for improvement of kerf deviation, kerf width and kerf taper in the Nd:YAG laser machining of Inconel-718.
- **Metallurgical characteristics:** for predicting and optimizing metallurgical characteristics such as heat-affected zone (HAZ), hole circularity, and bearing strength in LBM.
- ✓ A multi-objective optimization approach combining ANN and GA was used to optimize the drilling process parameters for a basalt-glass hybrid composite.
- ✓ ANN and GA were used to predict the HAZ extent and bearing strength in CO2 laser drilling of a glass fiber-reinforced plastic composite.

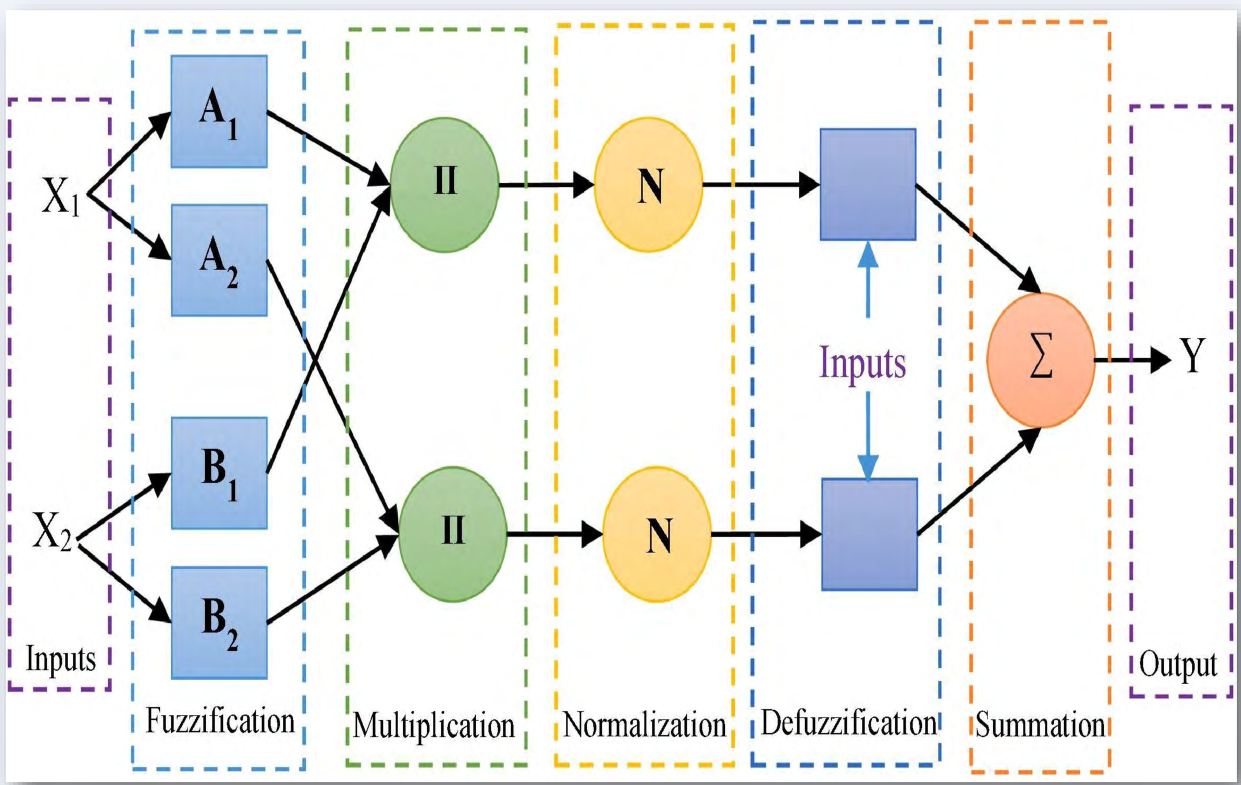

Fig 2: Schematic of an ANFIS.

- **Surface Quality:** surface roughness, surface morphology, and surface integrity in LBM.
- ✓ A GA-based approach was used to optimize the process parameters for laser polishing of a titanium alloy, which resulted in a significant improvement in surface roughness.
- ✓ A PSO-based approach was used to optimize the process parameters for laser surface texturing of a titanium alloy, which resulted in a significant improvement in surface morphology.

- **Material removal rate (MRR):** amount of material removed per time unit
- ✓ Three modeling methods, including RSM, ANN, and ANFIS, were applied for the prediction of MRR and taper in LBM and laser welding.
- ✓ ANFIS provides a more accurate prediction than other methods

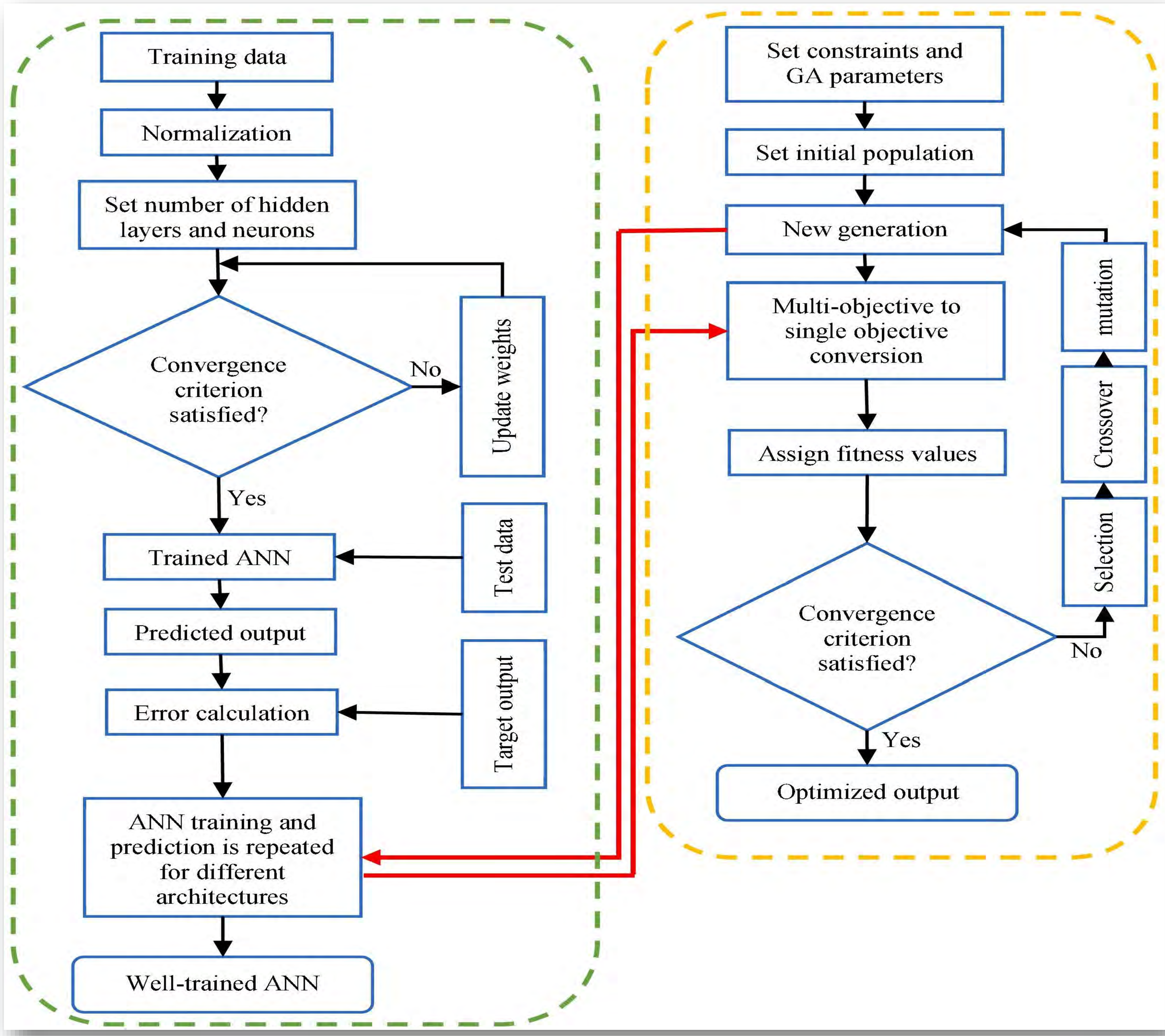

Fig 3: The flowchart of integrated GA and ANN.

Advantages and Limitations of AI for LBM

- ✓ Can be used to develop accurate models that correlate the input parameters of the LBM process with the output quality characteristics of the workpiece.
- ✓ To predict the optimal LBM parameters that will result in the desired quality characteristics of the workpiece.
- ✓ Selection of optimal LBM parameters without the need for a large number of empirical data
- ANNs and FL face problems in choosing the appropriate structure.
- The accuracy of AI models depends on the quality and quantity of the input data.
- May not be able to capture the complex behavior of LBM process in certain cases.
- Needing trial and error to select the best network structure
- The performance of the model is highly related to the inference systems, type of membership function, and the number of rules.

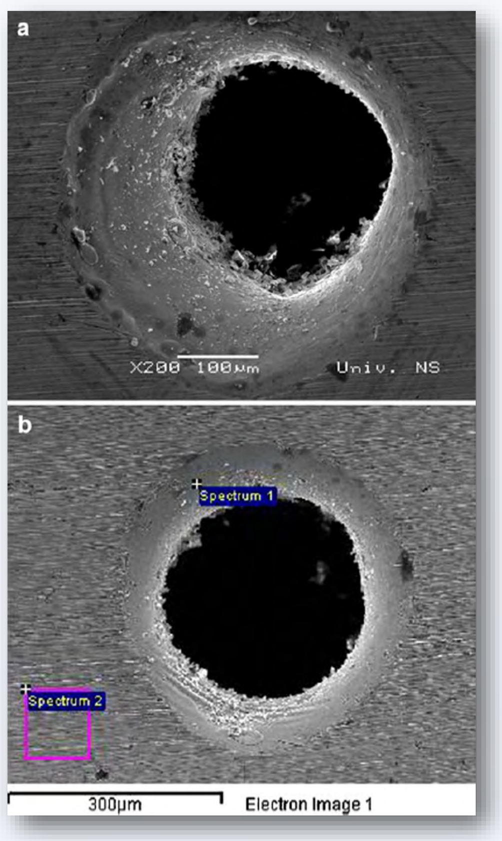

Fig 4: hole drilled with a) initial and b) optimized parameters

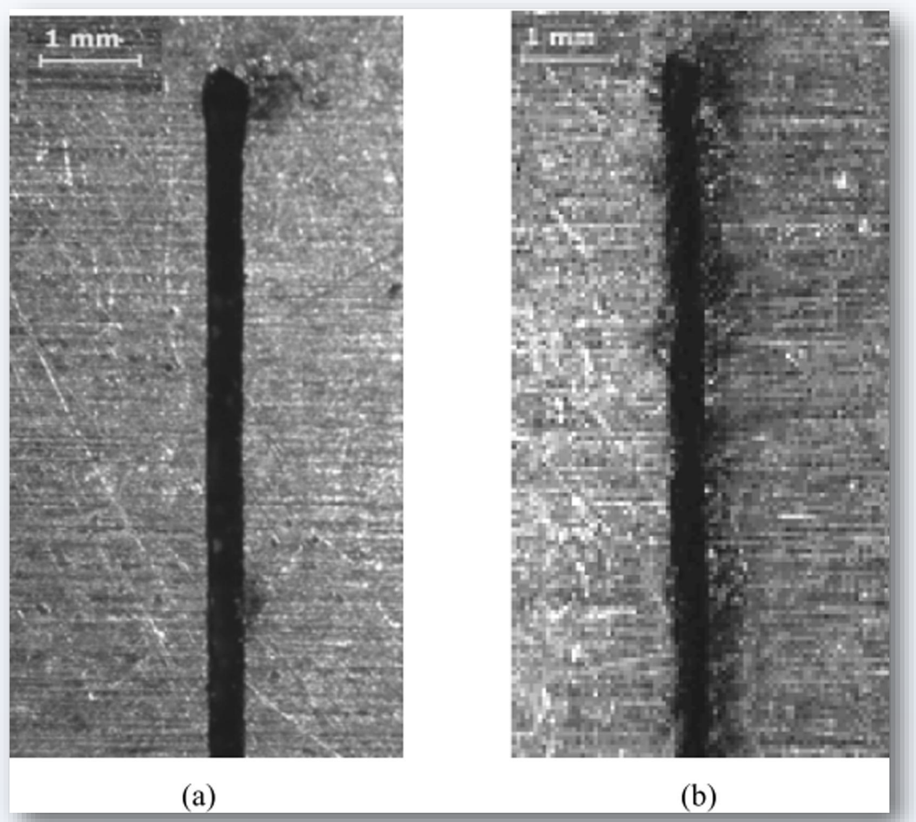

Fig 5: kerf acquired with (a) optimal and (b) initial parameters

Practical implications of AI for LBM

- To obtain a comprehensive model and optimal setting parameters of LBM.
- To achieve high-quality cuts with high efficiency
- AI techniques that are highly adaptable to automation and online monitoring are a prominent necessity in the next generation of LBM systems.

Future directions

- Hybrid AI methods to solve the problems faced by ANNs and FL in choosing the appropriate structure.
- LBM process for specific applications, such as medical device manufacturing and aerospace engineering.
- To develop real-time monitoring and control systems for LBM.
- To optimizing the LBM process for multi-objective optimization problems, such as minimizing surface roughness and maximizing material removal rate simultaneously.

References

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