Paper Title: A generalized machine learning framework for data-driven prediction of relative density in laser powder bed fusion parts

Abdul Khalad[1,2], Kondababu Kadali [1,2], Gururaj Telasang[3], Peng Neo Zhang[4], Wei Xu[2], Viswanath Chinthapenta[1]

[1]Micromechanics Lab, Department of Mechanical and Aerospace Engineering, Indian Institute of Technology, Hyderabad, Sangareddy, Telangana 502284, India

[2]School of Engineering, Deakin University, Victoria 3216, Australia

[3]Centre for Laser Processing of Materials, International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), Hyderabad 500005, India

[4]Institute for Frontier Materials, Deakin University, Waurn Ponds, VIC 3216, Australia

abdulk7297@gmail.com

Abstract

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Attaining high relative density (RD) is of paramount importance for any new alloy system manufactured through the laser powder bed fusion (L-PBF) process. However, the conventional design of experiment (DOE) methods poses a significant challenge due to the large number of process parameters involved. This study explores the data-driven machine-learning (ML) approach to confine the search for the optimized process parameters to the most significant process parameters. The relevant datasets were obtained from existing literature spanning across the last decade on 11 different alloy systems. The collected datasets were divided into 80:20 for training and testing. In this work, a detailed framework is presented to identify the most appropriate ML model to represent the complexities and nonlinearities in the data accurately. Among the employed models, the gradient boosting–particle swarm optimization (GB-PSO) exhibited the highest predictive performance, with mean absolute error (MAE) and coefficient of determination (R2) values of 0.20 and 0.99 for training and 0.73 and 0.95 for testing, respectively. The Shapley additive explanations (SHAP) analysis was utilized to comprehend the global and local significance of material properties and machine process parameters. The reduced experimental design from the data-driven ML framework is used to validate the predictions from the trained hybrid GB-PSO model. Validation for achieving the highest RD is carried out on the Inconel 718 alloy system deposited in-house.

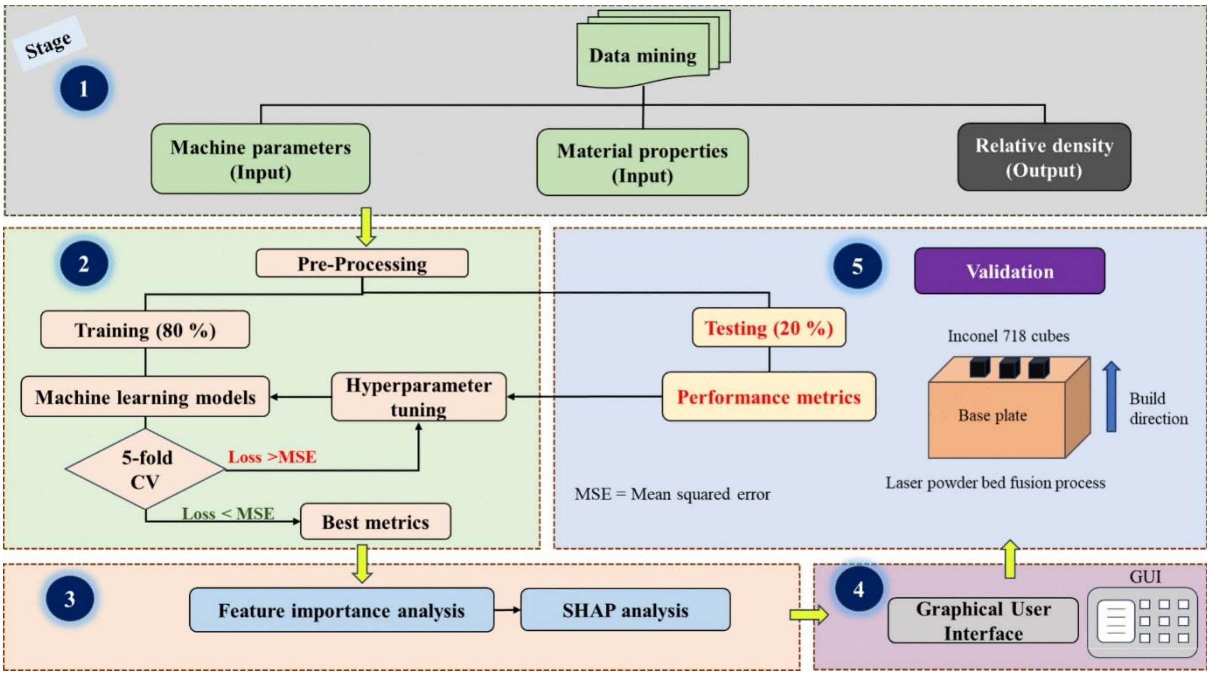

Figure 1: Flow chart of the relative density predictive tool for L-PBF using a machine learning framework