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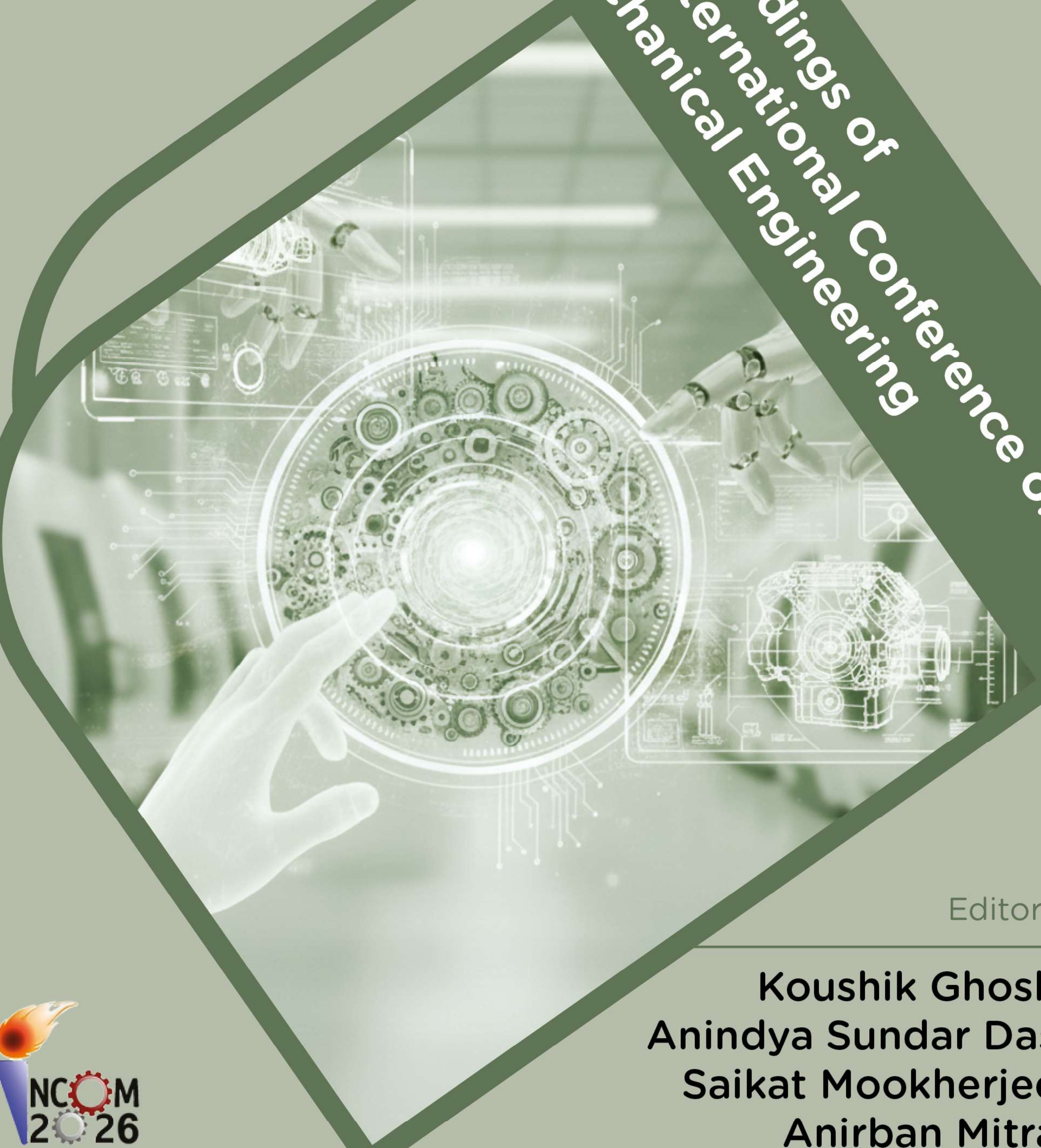

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Koushik Ghosh
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MACHINE LEARNING-BASED OPTIMIZATION OF WIRE EDM PARAMETERS FOR INCONEL-718: A COMPARATIVE STUDY

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ABSTRACT

Wire Electrical Discharge Machining (WEDM) enables precise machining of hard-to-cut nickel-based alloys such as Inconel-718. This study systematically evaluates four machine learning (ML) models - Random Forest, Support Vector Regression, Artificial Neural Networks, and Ridge Regression-using experimental data to predict Material Removal Rate (MRR) and Surface Roughness (R_a). Thirty-one experiments varying peak current (1–5A), pulse-on (30–70µs), pulse-off (2–10µs), and gap voltage (30–70V) were performed. Ridge Regression yielded the highest predictive accuracy for MRR (R^2=0.893, MAPE=4.29%), while Random Forest provided the best results for R_a (R^2=0.456, MAPE=3.78%). Feature importance analysis confirmed peak current and pulse-on time as the most influencing parameters for the responses. The integrated machine learning framework enables up to a 25% improvement in efficiency compared to trial-and-error tuning.

Keywords: *Wire EDM, Inconel-718, Machine Learning, Process Optimization*

NOMENCLATURE

K	Thermal Conductivity (W/m-K)
H	Hardness (HB)
MRR	Material Removal Rate (mm^3/ min)
ρ	Density (g/cm^3)
α	Co-Efficient of thermal expansion (µm/m.ºC)
I_P	Peak current (A)
R_a	Surface Roughness (µm)
T_m	Melting point (ºC)
T_{on}	Pulse-on-time (µ sec)
T_{off}	Pulse-off-time (µ sec)
V_g	Gap voltage (Volts)

1. INTRODUCTION

Wire Electrical Discharge Machining (WEDM) has emerged as a pivotal non-traditional machining technique, particularly effective for processing hard-to-machine materials such as Inconel-718 [1]. This nickel-based superalloy is widely used in aerospace, power generation, and high-performance engineering applications due to its superior mechanical strength, thermal resistance, and corrosion resilience. However, its exceptional hardness and poor thermal conductivity present formidable challenges for conventional machining techniques, which are often constrained by excessive tool wear, surface degradation, and limited material removal rates. WEDM offers a promising alternative by utilizing a thin, continuously traveling wire electrode that generates a series of rapid electrical discharges between the wire and the workpiece submerged in a dielectric fluid. These discharges lead to localized melting and vaporization of material, enabling precision machining with minimal mechanical stresses and high dimensional accuracy. The process is largely unaffected by the hardness of the workpiece, making it especially suitable for superalloys like Inconel-718 [4]. Despite these advantages, the efficiency and surface quality of the WEDM process are highly sensitive to a range of controllable process parameters such as peak current, pulse-on time, pulse-off time, and gap voltage. These parameters interact in complex, nonlinear ways, influencing key performance metrics like Material Removal Rate (MRR) and Surface Roughness (Ra). Traditional parameter tuning relies on extensive operator experience and trial-and-error experimentation, which is often time-consuming, resource-intensive, and suboptimal. In response to these challenges, machine learning (ML) techniques have gained traction as data-driven tools capable of modelling intricate parameter-output relationships. ML algorithms can learn from historical data, identify patterns, and predict process outcomes under new settings, thereby enabling rapid, intelligent optimization of WEDM parameters. Ramakrishnan et al. [1] investigated the impact of pulse-on time, time delay, wire feed speed, and ignition current on MRR and surface roughness of Inconel 718, optimized using ANN models. Newtown et al. [2]