Final Year Design Project Showcase
Batch-2022
Year 2026

Department: Metallurgical Engineering Programme: Metallurgical Engineering	
1	**Project Title** Optimization of Heat Treatment Process Parameters of Dies Material (H-13) Via Machine Learning
2	**Project Idea** The project aims to develop a machine learning-based framework for predicting and optimizing the hardness of AISI H13 hot-work tool steel using industrial heat treatment data. Instead of relying on conventional trial-and-error methods, machine learning models analyze the relationship between heat treatment parameters and hardness to recommend optimal processing conditions, improving productivity, consistency, and decision-making in industrial heat treatment.
3	**Process** ➢ Collected industrial heat treatment data from Karachi Tools, Dies and Moulds Centre (KTDMC). ➢ Preprocessed and cleaned the dataset. ➢ Trained multiple machine learning models including Linear Regression, Ridge Regression, Random Forest, and XGBoost. ➢ Evaluated model performance using R^2, MAE, and RMSE. ➢ Selected the best-performing model for hardness prediction. ➢ Developed a Streamlit-based graphical user interface (GUI) for industrial users to predict hardness from heat treatment parameters.
4	**Outcome** A machine learning-based framework was successfully developed for predicting the hardness of AISI H13 tool steel using industrial heat treatment data collected from KTDMC. Four machine learning models (Linear Regression, Ridge Regression, Random Forest, and XGBoost) were developed and evaluated using R^2, MAE, and RMSE. Random Forest achieved the highest predictive accuracy (R^2 = 0.5838), followed by XGBoost (R^2 = 0.5738), while Ridge Regression (R^2 = 0.5360) and Linear Regression (R^2 = 0.4890) exhibited comparatively lower predictive performance**.** The best-performing Random Forest model was integrated into a Streamlit-based graphical user interface, enabling real-time hardness prediction and supporting data-driven industrial decision-making.
5	**Evidence (Theoretical Basis)** This project presents a machine learning-based framework for predicting and optimizing the hardness of AISI H13 tool steel using industrial heat treatment data. Heat treatment parameters influence martensitic transformation and carbide precipitation, which govern the hardness evolution of H13 steel. Four machine learning models (Linear Regression,

	Ridge Regression, Random Forest, and XGBoost) were developed and evaluated to model these complex relationships**.** Random Forest achieved the highest predictive accuracy and was selected as the final deployment model**.** The developed framework predicts hardness, identifies optimized heat treatment parameter combinations, reduces trial-and-error experimentation, improves process consistency, minimizes defects and energy consumption, and enhances manufacturing efficiency. The optimized Random Forest model was deployed through a Streamlit-based application to support real-time industrial decision-making.
6	**Competitive Advantage or Unique Selling Proposition**
a	**Attainment of any SDG** The proposed machine learning framework supports climate action by reducing unnecessary heat treatment trials, furnace operating time, and energy consumption. Optimized process parameters improve manufacturing efficiency, helping industries lower greenhouse gas emissions and promote more sustainable heat treatment practices.
b	**Any Environmental Aspect** The proposed machine learning framework minimizes unnecessary heat treatment trials, reducing furnace operating time, energy consumption, and material wastage. This leads to lower carbon emissions, improved resource efficiency, and promotes sustainable manufacturing practices in the heat treatment industry.
c	**Cost Reduction of Existing Product** The proposed machine learning framework reduces the overall cost of the existing heat treatment process by minimizing trial-and-error experimentation, energy consumption, material wastage, and production time. Optimized process parameters improve process efficiency, reduce defects, and lower manufacturing costs while maintaining the desired hardness.
d	**Process Improvement which Leads to Superior Product or Cost Reduction, Efficiency Improvement of the Whole Process** The current industrial heat treatment process for H13 tool steel largely depends on trial-and-error methods and operator experience to achieve the desired hardness. This results in inconsistent hardness, higher defect rates, increased energy consumption, longer processing time, and additional manufacturing costs. The proposed machine learning framework predicts hardness and recommends optimized heat treatment parameters before production, reducing unnecessary trials and improving process consistency. This leads to lower production costs, improved product quality, higher energy efficiency, and enhanced overall manufacturing productivity.
e	**Expanding of Market share** The proposed machine learning framework enhances the competitiveness of heat treatment industries by enabling faster, more accurate, and data-driven process optimization. Its adoption can improve product quality, reduce production costs, and help manufacturers

	attract more customers in the tool, die, and automotive sectors, ultimately expanding their market share.	
7	**Target Market** (Industries, Groups, Individuals, Families, Students, etc) Please provide some detail about the end-user of the product, process, or service The proposed system is intended for: ➢ Heat treatment industries ➢ Tool and die manufacturing companies ➢ Automotive component manufacturers ➢ Steel processing industries ➢ Foundries ➢ Metallurgical engineers ➢ Quality control engineers ➢ Manufacturing engineers ➢ Research organizations working on advanced materials and Industry 4.0 applications	
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10	**Supervisor Name** (along with email address)	Dr. Shafaq Asrar (Supervisor) shafaqasrar043@gmail.com Dr. Aqeel Ahmed Shah (Co-supervisor) aqeelshah@cloud.neduet.edu.pk
11	**Video (If any)**	NA

Pictures (to be pasted below

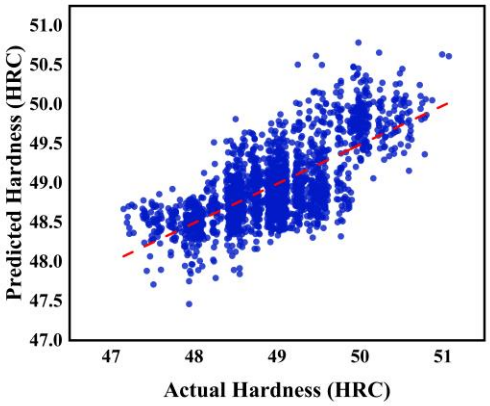

Figure 1: Parity Plot obtained by Linear Regression

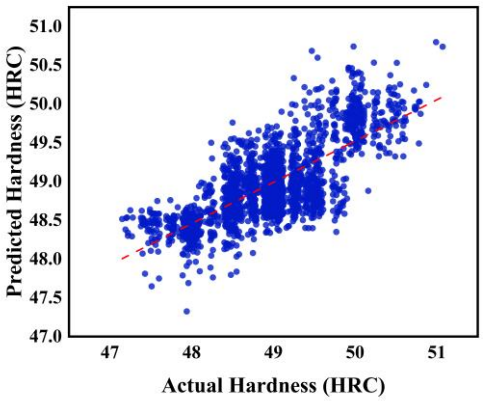

Figure 2: Parity Plot obtained by Ridge Regression

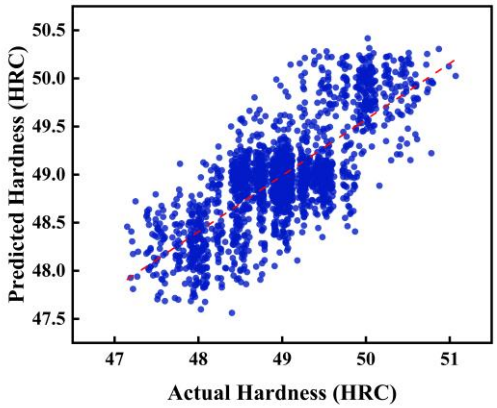

Figure 3: Parity Plot obtained by XGBoost

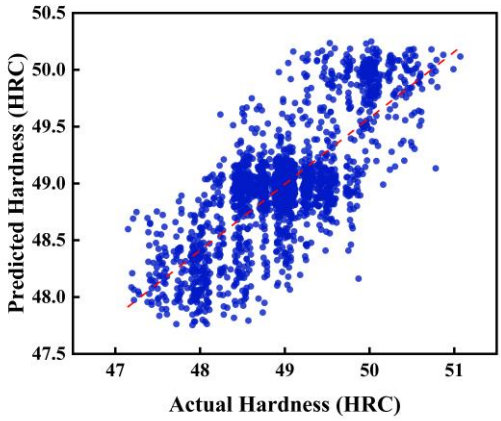

Figure 4: Parity Plot obtained by Random Forest