



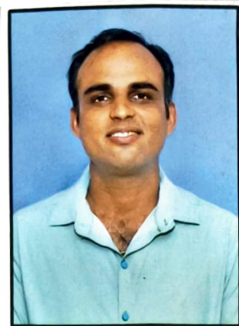
GUJARAT TECHNOLOGICAL UNIVERSITY

(Established by Government of Gujarat under Gujarat Act No. : 20 of 2007)

ગુજરાત ટેકનોલોજીકલ યુનિવર્સિટી
(ગુજરાત સરકારના ગુજરાત અધિનિયમ ક્રમાંક : ૨૦/૨૦૦૭ દ્વારા સ્થાપિત)

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Abstract of the Thesis



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Discipline/Branch: Mechanical

Title of the Thesis: Data-Driven Defect Prediction and Process Optimization
for Quality Improvement of Investment Casting process Using Machine
Learning Approaches.

Abstract

Investment Casting (IC) is a near-net-shape casting process and defect prediction in IC is inherently challenging due to number of interrelated process variables influencing the final casting quality across multiple manufacturing stages. Numerical simulation techniques have demonstrated good predictive capability, they generally rely on predefined assumptions and input parameters that may not fully represent the variability encountered in actual manufacturing environments. Consequently, there is a need for data-driven approaches capable of learning from historical production data and adapting to real manufacturing conditions. Machine Learning (ML) provides such a framework by modelling complex relationships among process variables and enabling reliable prediction of casting defects.

Supervised Machine Learning (ML) models, namely K-Nearest Neighbour (K-NN), Support Vector Machine (SVM), Logistic Regression (LR), Gradient Boosting (GB), and Random

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Engineering" ❖ "Best Engineering Institution 2019" ❖ "Outstanding University in West India 2019"

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Forest (RF), were developed and evaluated to predict ceramic inclusion and shrinkage

defects. K-fold cross-validation and Grid Search were employed for model validation and hyperparameter optimization, respectively, while model performance was assessed using accuracy, precision, recall, and F1-score. The RF model achieved an accuracy of 97.59%, precision of 97.51%, recall of 100%, and an F1-score of 98.79% for ceramic inclusion prediction, and an accuracy of 96.38%, precision of 96.07%, recall of 100%, and an F1-score of 98.00% for shrinkage prediction, indicating superior prediction of ceramic inclusion defects.

To reduce defect occurrence, four optimization techniques, namely Conservative Q-Learning (CQL), K-Nearest Neighbour (K-NN), Bayesian Optimization (BO), and Function Based Clustering (FBC), were implemented to recommend optimal values of the controllable process parameters, Pouring Temperature (PT) and Pouring Time (PTe). Finally, a closed-loop intelligent process optimization framework was developed by integrating the developed RF model for defect prediction with suggestion by optimization techniques.

This PhD Thesis would be useful for researchers and investment casting industries in developing data-driven approaches for defect prediction and adaptive process optimization, thereby supporting improved casting quality, reduced material waste and production costs, and sustainable manufacturing.

List of Publications : 1) Sahitya, S. K., Valaki, J. B., Sutaria, M., & Sapramer, H. R. (2025). Comparative study of supervised machine learning-driven defect prediction in investment casting process. *International Journal on Interactive Design and Manufacturing*. <https://doi.org/10.1007/s12008-025-02459-4>

2) Sahitya, S. K., Valaki, J. B., Sutaria, M., & Sapramer, H. R. (2025). Review of Computational Approaches used for Investment Casting Process. In *Journal of Information Systems Engineering and Management* (Vol. 10, Issue 44s, pp. 930–952). <https://doi.org/10.52783/jisem.v10i44s.8691>

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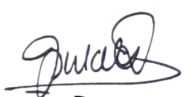
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