DEVELOPMENT OF A PROCESS PARAMETER PREDICTION MODEL BASED ON SURFACE ROUGHNESS IN 3-D MILLING

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Signature of the supervisor: Date: 11th August 2025

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ABSTRACT

One of the main industries that uses CNC milling is the injection mould manufacturing industry. Deep cavities are commonly found in injection mould manufacturing, and one of the essential quality requirements is surface roughness. Since the deeper cavities are common, higher tool overhangs are essential. They present a significant problem because tool deflection and vibration are higher with the long tool overhangs, which can result in deteriorated surface finishes. Despite this, conventional surface roughness models frequently understate the impact of tool overhang. By methodically examining how tool overhang affects surface roughness and utilizing predictive modeling techniques to predict and regulate machining results, this study addresses the research gap.

This study examines the optimal control of cutting parameters to achieve the desired surface finish levels. In injection mould manufacturing, long tool overhangs are essential to machine deeper cavities while maintaining surface quality, which justifies the necessity of the research. A thorough literature review was conducted to determine the critical cutting parameters affecting surface roughness in 3D CNC milling. According to the previous studies, the cutting speed and the feed rate can be optimized. Determine the relationship between surface roughness and variables such as inclined angle, tool overhang, spindle speed, and feed rate was the main goal of this study

To refine the final experiment plan and to investigate the effects of feed rate and spindle speed on surface roughness, a pilot experiment was carried out. A total of 48 experiments were carried out, and the same cutting parameters were maintained to isolate their effects on the results. Artificial Neural Network using MATLAB and Linear Regression using IBM SPSS were used to analyze the data and predict the surface roughness values. According to the results of the data analysis, surface roughness is mostly influenced by feed rate, tool overhang, spindle speed and inclined angle according to the order. Another set of experiments were experiments were used to compare and validate two predicted values. Although both methods were successful, the comparison results showed Artificial Neural Network results outperformed the results of the Linear Regression model in terms of the accuracy. The Linear Regression model displayed deviations from 2% to 18% when compared to the measured surface roughness values and the Artificial Neural Network predicted values had deviations

ranging from 0.03% to 5.7%. The results of the study laid a strong foundation for parameters in CNC milling to produce the required surface finishes, especially in intricate machining situations like injection mould production.

In practical manufacturing scenarios, the surface roughness prediction model has no usability since the output of the model is the surface finish. To address the issue, process parameter prediction model was implemented using same Artificial Neural Network algorithm and the training data, in that model, desired surface roughness, inclined angle and tool overhang were inputs and recommended feed rate and spindle speed were the outputs, so a CNC programmer can optimize the process planning more accurately and precisely aligning predictive modeling with real-world machining requirements.

Keywords: Tool Overhang, Surface Roughness, CNC Milling, Prediction Modeling, Artificial Neural Network, Linear Regression

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LIST OF ABBREVIATIONS

Abbreviation	Description
ANN	Artificial Neural Network
LR	Linear Regression
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
MSE	Mean Squared Error

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