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Model Optimization of cutting conditions of CNC face-milling operations using DNN and Pareto Method

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***Abstract* - The manufacturing sector has seen notable expansion as a result of the increased demand for elevated quality of goods and computer numerical control (CNC) equipment, allowing developers to generate such elevated quality and high-complexity items at greater speeds. Milling is an useful methodology that is frequently used in manufacturing and involves the manufacturing including both basic and complicated configurations. The depth of cut necessary for the machining processes, as well as the level of surface quality, can be determined by modelling the mechanical and topological layout of a mill cutters. The study's major focus is to enhance the tool-workpiece interface behaviour.**

***Index Terms* - CNC, Milling, Machining, Optimization.**

I.INTRODUCTION

Milling is a machine-based technique wherein the cutters spin to eliminate material from the work piece in the orientation of the cutting axis. Cutting tools can be used to conduct a wide range of operations and processes, from little to huge things. Milling machines are indeed referred to as multi-tasking machines (MTMs), as they are multi-purpose devices that can cut and twist substances. The milling machine is equipped with a blade that aids in the deformation of the material from the work piece's face. The substance is eliminated out from milling process once it has completely cooled. In the milling process, many various cutting instruments are employed. End mills are milling cutters with unique cutting surfaces on their end faces that allow these to be drilled into the workpiece material. For peripheral milling, they also have expanded cutter areas on both sides. At the terminal edges of the milling cutters are little cutters. The cutters are composed of strong, long-lasting substances that cause minimal friction.

Whatever substance that passes throughout the milling device's cutting zone is sliced at periodic times. Consistent spikes can be found on the edge cutters. The spacing among the spikes is determined by the injection pressure, cutter radius, and number of cutting surfaces. Important differences in the height of the surfaces might be the cause of this.

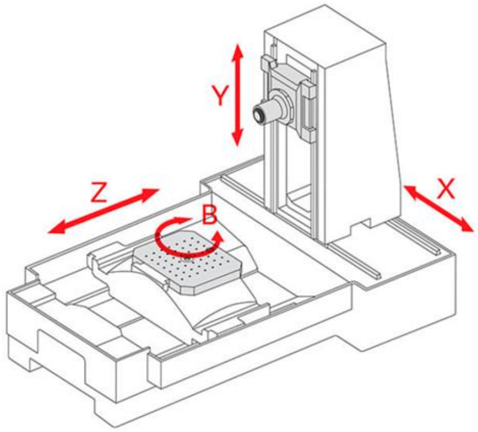

Fig. 1. CNC Milling Machine

In the last six years, the machined sector has grown significantly, and by 2025, it is expected to be worth $100 billion. This is related to the increased market for high quality items and computer numerical control (CNC) equipment, which allow makers to create such high-quality, elevated complicated products at greater speeds. The surface finish remains fixed as the tool rotates during the milling operation. The rotating tool with several cutting blades works over the work item to create a plane or flat edge in this milling operation. Milling equipment can be hard, covered, or non - coated, and then they can also contain tool extensions all along edge of the tool. Milling operations have long been used in the industrial industry to eliminate material from work - piece and produce a variety of dimensions, forms, and characteristics. High efficiency and production, face milling is among the most popular mill techniques. In order to deal with this, the cutters is positioned on a spindle that spins perpendicular to the workpiece's weld zone, and material is eliminated across a route parallel to the subsurface. Face milling is extensively utilised in a variety of industries, including machines and machine tool manufacturing, vehicle manufacturing, and so on. Surface roughness was among the most quality related factors in determining whether machineries will operate reliably and can be integrated easily, and this is one of the key control factors in face milling

Based on how far the workpiece gets sliced, milling functions can be classed as face or peripheral. These require removing material from the surface with a spinning cutting equipment called a milling cutter. The milling cutter pushes on the workpiece's top as it spins, thereby chipping away a few of the substance in that region.

Face milling and peripheral milling both use a revolving milling to eliminate material from a workpiece in similar way. Yet, the manner wherein they carry out this function differs.

II. LITERATURE REVIEW

Fountas et al. [1] used a genetic optimization technique the trajectories of 3-axis surface machining tool routes available to commercialized computer-aided manufacturing techniques.

Daniyan et al. [2] proposed simulation models for estimating the magnitude of temperatures and surface quality throughout titanium alloy processing using Response Surface Methodology (RSM) and Artificial Neural Network (ANN) approaches (Ti6Al4V). The forecasting of mean temperature was done using an Artificial Neural Network (ANN).

Abbas et al. [3] provided a technique for maximizing the cutting variable in CNC face-milling procedures that combined an artificial neural network (ANN) with the Edge worth-Pareto technique. The settings are tweaked to increase surface roughness and minimum unit-volume material elimination rates, lowering manufacturing costs while increasing precision.

Abbas et al. [4] developed a novel Edge worth–Pareto evaluation of a surface roughness (Ra) artificial neural network (ANN) for forecasting within one element in CNC moving throughout minimum machining duration (Tm) and at primary operating costs (C) in magnesium alloys. In the Matlab software framework, an ANN is created to forecast Ra, Tm, and C as a function of cut and feed rate, vc, depth of cut, ap, and feeding per rotation, fr.

Abbas et al. [5] explored the role of cutting rate V, feeding rate f, and cut depth t on solid steel twisting. Recent science on machined high-strength steel is limited. Due to the increasing price of this substance, we must seek out the best turning circumstances in order to achieve the desired surface roughness while reducing unit volume machining time. As a consequence of this research, an artificial neural network based on the multilayer perceptron was created in Matlab that accurately simulates the rough quality of the workpiece's surface inside the number of experimental cutting conditions, cutting depth, and feed rate values with a 2.14 percent respectively.

The objective in the work is to optimize the cutting parameter in CNC face-milling operations for different application in production industries. To learn the impact of dimensionless parameters on surface roughness and hardness of material. To design a mathematical modelling for optimization of multiple parameters such as feed fate, cutting speed, and depth of cut while determining the surface roughness. To design more robust multi-objective optimization techniques that can handle uncertainties and improves efficiency of machining.

In CNC milling machines, there really are two main spindle configurations. The spindle axis, often known as the z-axis, is usually oriented in vertical CNC machines. The spindle rotates in this direction in a c-column setup, while the table that supports the workpiece swings in both x and y horizontal orientations. Vertical milling machines are ideal for high-volume, fast-paced applications such as coverings and clamps, which are machined from one side.

The spindle z-axis in horizontal CNC machines is horizontal and runs parallel to the machine's length. The spindle moves horizontally in the x-axis and vertically in the y-axis. The workpiece is held by the pallet and fixtures, which move in the z-axis while rotating in the b-axis. Horizontal machining has a number of advantages, including the right to access processing from all four sides, the ability to complete numerous operations on the same fixture, the ability to mill more complex products, and improved chip removal.

III. METHODOLOGY

The objective of this work is to compare the predicting capability of deep neural network and regression analysis for surface roughness generated by different cutting conditions of spindle speed (rpm), feed rate (mm/min), and depth of cut (mm).In this work, analysis of experimental data from Face Milling of grade-H steel will be conducted using different DNN models and the results will be compared to the experimental results to select the model with the highest accuracy. The results from the best DNN model will then be compared to the results from a regression mathematical model. Using DNN models, the study of the milling of high tensile strength materials for a positive effect and negative effect of milling parameters on surface roughness would be established.

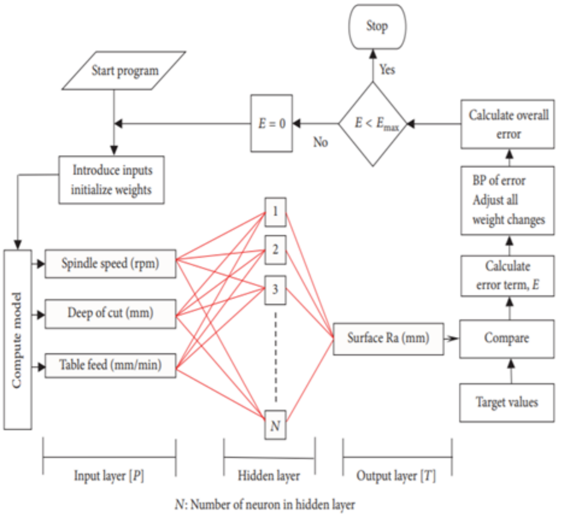

Fig. 2. Deep Neural network to predict of the surface Roughness

In this work, deep learning algorithm is proposed for prediction and optimization, which provided better results than the previous algorithms.

So in this work, the issue related with less convergence time and better surface roughness is resolved and for that following objective functions are considered:

- Maximum value of surface roughness based on CNC parameters.
- Control independent parameters.

The linear equation which relates the surface roughness with four optimizing parameters is given in equation below:

$R_a=f(x_1)+f(x_2)+f(x_3)+f(x_4)$

Where, Ra = surface roughness in µm,

x_1 =*speed in m/min*

x_2 =*feed-in µm /rev*

x_3 =*depth of cut in mm*

x_4 =*steps of speed.*

IV. RESULT AND DISCUSSION

The simulation result analysis is performed on MATLAB platform. Below table shows the prediction result.

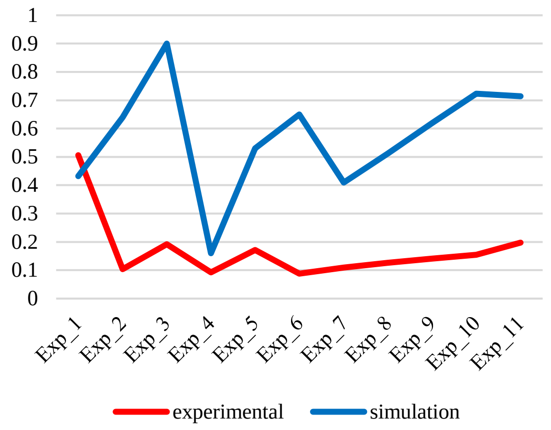

Fig. 3. Surface roughness of grade-H steel

The simulation result analysis shows the experimental and simulation result of estimation of surface roughness of grade-H steel [3].

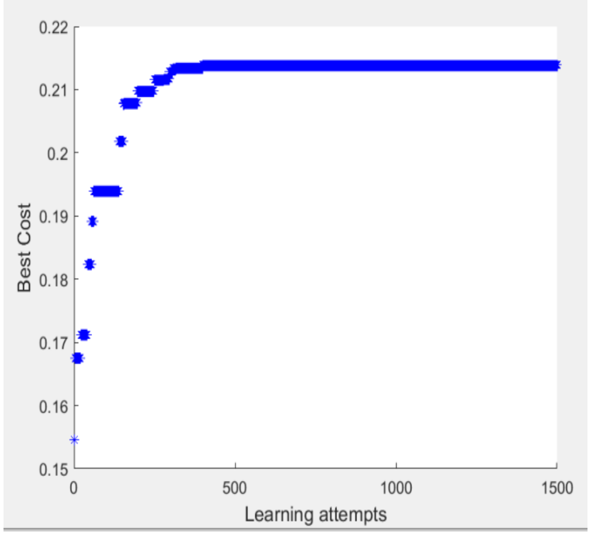

Fig. 4. Learning Optimization

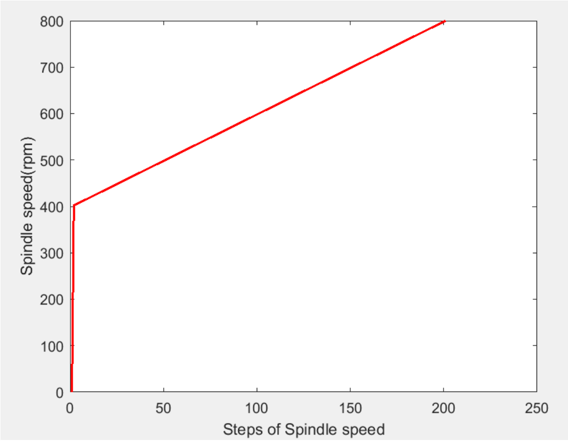

Fig. 5. Spindle speed Prediction

The simulation result analysis is performed for variable depth cut and fixed spindle speed and feed rate.

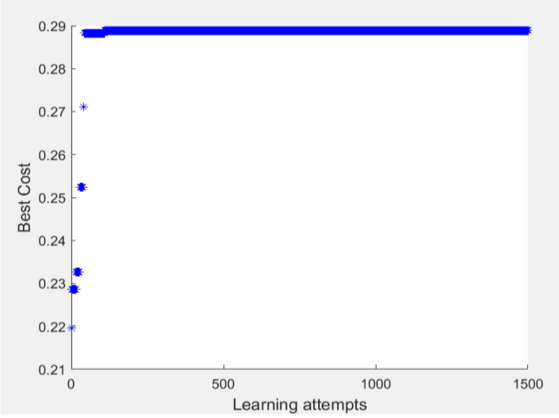

Fig. 6 Pareto Convergence for variable depth cut

The simulation result analysis is performed for variable depth cut and fixed spindle speed and feed rate.

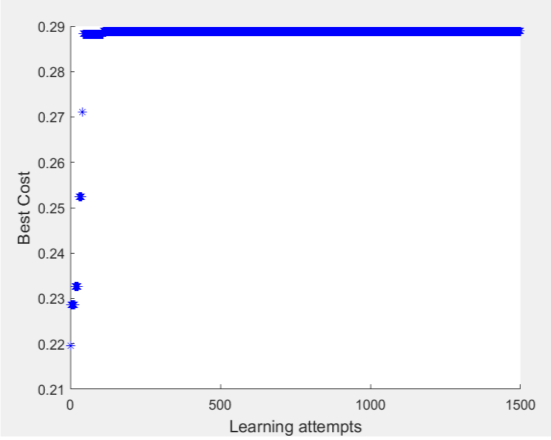

Fig. 7. Pareto Convergence for Variable Depth Cut

The simulation result analysis is performed for variable spindle speed and fixed depth cut and feed rate.

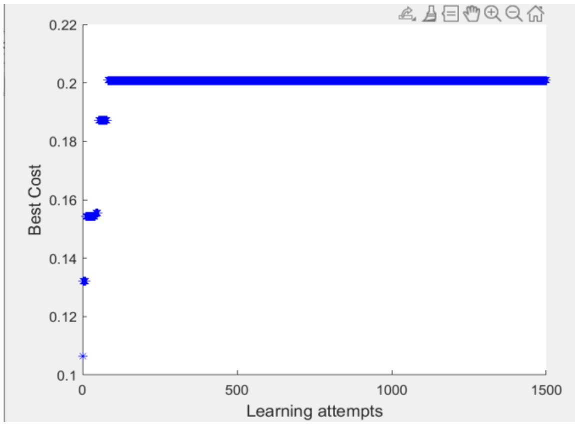

Fig 8. Pareto Convergence for variable spindle speed

The simulation result analysis is performed for variable feed rate and fixed depth cut and spindle speed.

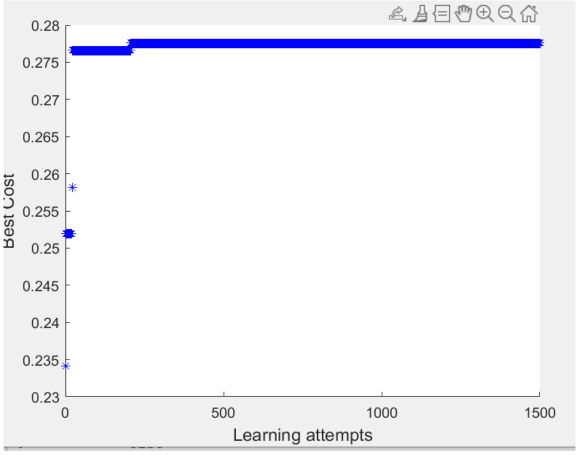

Fig. 9. Pareto Convergence for variable feed rate

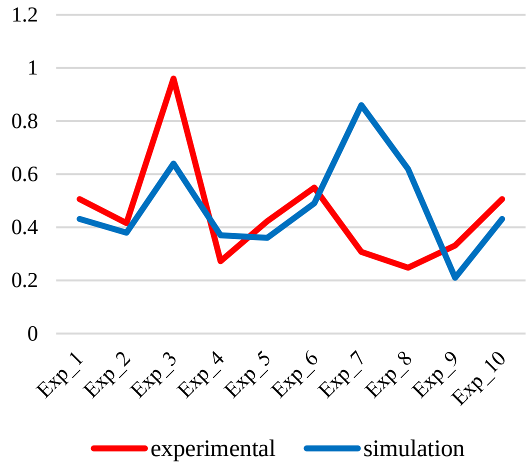

Fig. 10. Surface roughness of SIMOLD 2083Alloy

The simulation result analysis shows the experimental and simulation result of estimation of surface roughness of SIMOLD 2083Alloy [9].

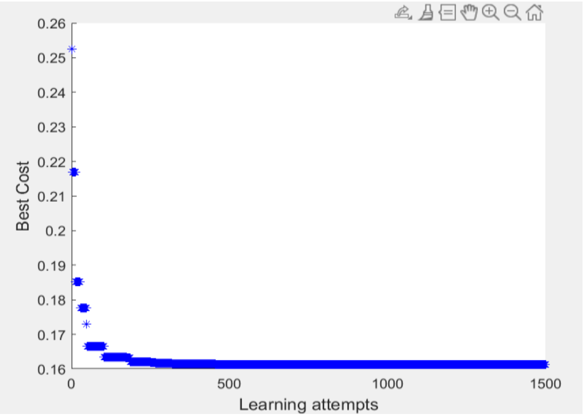

Fig. 11. Learning Optimization of SIMOLD 2083Alloy

V. CONCLUSION

The milling operation is a versatile operation often employed during production, which requires machining of both simple and complex geometries. The integration of advance technologies such as DNN would leads to development of models that can predict and optimize the surface of high strength materials. The result analysis shows the prediction result of surface roughness and optimization of objective functions.

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