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Optimization of Turning Process Parameters Using Genetic Algorithm for Enhanced Machining Performance

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Abstract - Optimization of machining parameters plays a crucial role in achieving higher productivity and superior product quality in today's competitive manufacturing environment. This study focuses on the multi-objective optimization of the turning process for C45 medium carbon steel, targeting the simultaneous reduction of surface roughness (Ra) and enhancement of material removal rate (MRR) using Genetic Algorithms (GA). Cutting speed, feed rate, and depth of cut were selected as the primary process parameters. A total of eighteen experiments were conducted using Taguchi's L18 ($3^3 \cdot 2^1$) orthogonal array, and the collected data was further analyzed and modeled using the Response Surface Methodology (RSM). The influence and significance of each machining parameter on the overall performance characteristics were also examined through RSM. Genetic Algorithms were then employed to determine the optimal combination of parameters. The optimized results were validated through confirmation experiments, demonstrating strong agreement with the predicted values and confirming the effectiveness of the proposed approach.

1.INTRODUCTION

Machining is a material-removal process used to modify the size, shape, and surface of a workpiece with high dimensional accuracy and good surface finish. Despite benefits, it involves material waste and is time, energy, and labor intensive. Turning is a machining process in which a rotating workpiece is cut by a linear-moving tool, typically on a lathe or CNC turning center. Rough turning removes excess material quickly using high feed and large depth of cut. Finish turning uses higher speed, low feed, and shallow depth of cut to produce a smooth, accurate surface.

2. Aim of the Study

The main aim of this study is to identify the optimal cutting parameters and determine the most influential factors affecting C45 steel during CNC turning. Response Surface Methodology (RSM) is employed to analyze the effect of each parameter on the response variables and to develop predictive models. Fuzzy goal programming is then applied to convert the multi-objective optimization problem into a single objective form. Finally, a Genetic Algorithm (GA) is used to obtain the optimal response values and corresponding optimal machining parameters.

3. Surface Response Technique

Response Surface Methodology (RSM) is a statistical technique used to develop mathematical models and optimize responses influenced by multiple input variables through well-planned experiments. It was originally created for physical experiments but is now widely used for numerical simulations, where errors arise from numerical noise rather than measurement. RSM helps approximate complex problems with smooth functions, reducing computational cost and improving optimization efficiency, especially in applications involving methods like FEM or CFD.

Genetic Algorithms

Genetic Algorithms (GAs) are adaptive search techniques inspired by natural selection and genetics. They use evolutionary principles to find optimal solutions by improving candidate solutions over generations. Unlike conventional AI, GAs are more robust, handle noise well, and efficiently search large, complex, or multi-modal spaces. In a GA, each generation contains a population of individuals (chromosome-like strings), each representing a potential solution. Through selection, crossover, and mutation, fitter individuals produce better offspring, leading the population toward improved solutions over successive generations.

Methology

Reducing production cost and achieving good product quality requires optimizing cutting parameters. In turning, Material Removal Rate (MRR) directly affects productivity, while Surface Roughness (Ra) determines surface quality and component performance. Both depend on factors like cutting speed, feed, depth of cut, and tool nose radius. Collecting response data by varying one factor at a time is time-consuming, so Design of Experiments (DOE) is used to study multiple factors efficiently and draw meaningful conclusions.

Table -1: CNC Turning Process Parameters and Levels

Parameter	Level 1	Level 2	Level 3
Spindle Speed (RPM)	2500	3000	3500
Feed (mm/rev)	0.10	0.15	0.20
Depth of Cut (mm)	0.4	0.8	1.2

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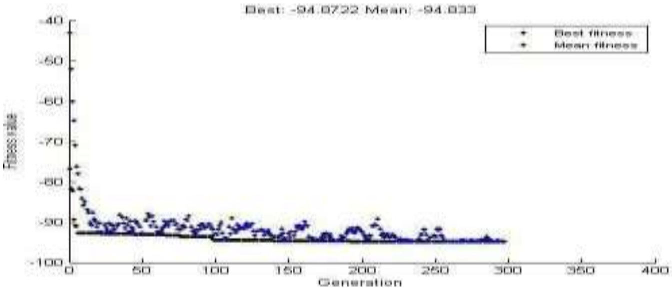
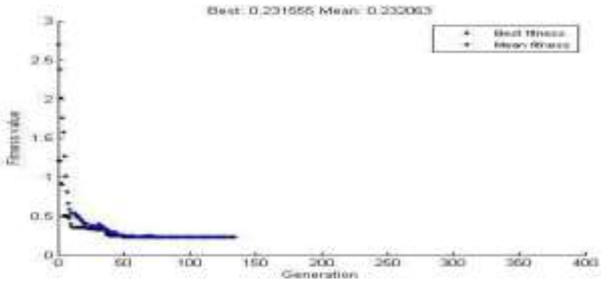
Parameter	Level 1	Level 2	Level 3
Nose Radius (mm)	0.4	0.8	—

OPTIMIZATION OF PARAMETERS





Nose radius	Spindle speed	feed	depth of cut	Ra
0.8	1900	0.1	0.1	0.2315

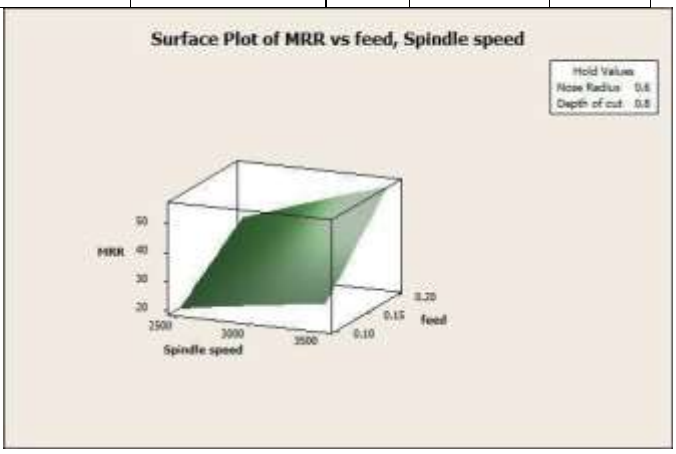
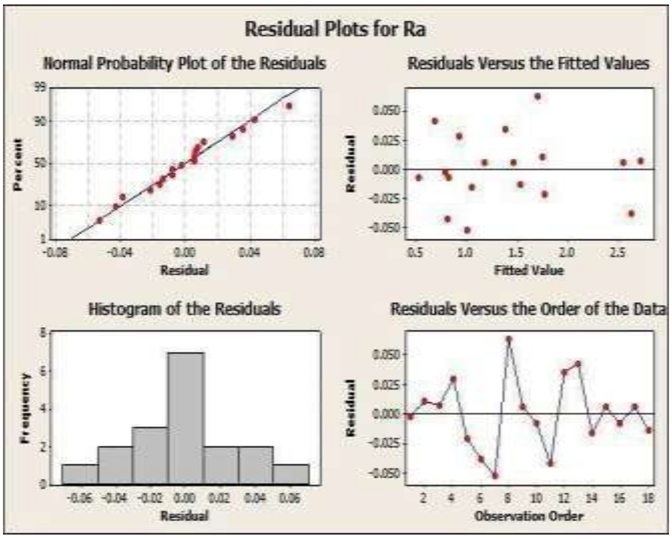


Fig -:**Surface plot of MRR vs spindle speed and feed**

Analysis of MRR

Term	Coef	SE Coef	T	P
Constant	22.969	8.579	2.677	0.055
A	6.045	4.977	1.215	0.291
B	-0.005	0.0051	-0.982	0.382
C	-279.4	37.617	-7.427	0.002
D	-34.35	3.9442	-8.708	0.001
B*B	0	0	-1.29	0.267
C*C	-70.82	87.563	-0.809	0.464
D*D	-1.107	1.3682	-0.809	0.464
A*B	-0.002	0.0013	-1.791	0.148
A*C	30.945	16.547	1.87	0.135
A*D	-3.868	2.0684	-1.87	0.135
B*C	0.093	0.0067	13.894	0
B*D	0.013	0.0008	15.879	0
C*D	294.78	11.106	26.541	0

Residual plots for Ra



RESULT

1. For Minimum Surface Roughness

Nose radius: 0.8 mm

Spindle speed: 1900 RPM

Feed: 0.1 mm/rev

Depth of cut: 0.1 mm

2. For Maximum MRR

Nose radius: 0.8 mm

Spindle speed: 3500 RPM

Feed: 0.2 mm/rev

Depth of cut: 1.2 mm

3. For Combined Ra & MRR:

Nose radius: 0.8 mm

Spindle speed: 2007 RPM

Feed: 0.1 mm/rev

Depth of cut: 0.49 m

CONCLUSIONS

· Feed has the strongest influence on surface roughness (Ra). Significant interaction effects exist between nose radius–spindle speed and nose radius–feed.Surface roughness increases as nose radius increases.At higher feeds, Ra decreases initially with depth of cut, then increases. MRR rises with spindle speed, feed, and depth of cut, with depth of cut being the most dominant factor.Genetic Algorithm optimization effectively avoids local optima and achieves global optimal solutions.

ACKNOWLEDGEMENT

The heading should be treated as a 3rd level heading and should not be assigned a number.

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