Optimization of machining characteristics using CNC Lathe: A Critical review

Mayank Juneja[1], Nikhil Juneja[2], Anmol Bhatia[3*]

[1&2]Scholars, Department of Mechanical Engineering, The NorthCap University, Gurugram, India

[3]Assistant Professor, Department of Mechanical Engineering, The NorthCap University, Gurugram
*Corresponding Author E-mail: *anmolbhatia@ncuindia.edu*

Abstract: To sustain, survive and overcome the fierce competition in the modern manufacturing industries, there is a requirement of production of high-quality goods and services at the most economical cost with high production rate. Turning is one of the most commonly used manufacturing industries and to achieve high cutting performance, minimizing other costs and to improve quality, selection of optimal cutting parameters becomes a very important task. This paper reviews various optimization techniques that are implemented to determine the optimal cutting parameters of different materials machined under different cutting environment.

Keywords: Turning, Cutting parameters, optimization techniques and Material Removal Rate.

I. INTRODUCTION

Computer Numerical Control is the most commonly used machine in the manufacturing sector. As the name suggests, it dictates the movement of tools and machinery with the help of pre-programmed computer software. Powered by the stepper and servo motors, which provide highly accurate movements, it has become possible to produce complex shapes with high precision which was previously constrained while using manually operated machines. Not only that, it also contributes to increasing the productivity, versatility and decreasing the overall cost and manpower. There are several parameters associated with the CNC Machine. The following are listed below:

- Cutting speed is characterized as the speed at which the work moves w.r.t. tool.
- Feed rate is characterized as the as the distance the tool travels during one revolution of the part.
- Depth of cut is characterized as the thickness of the layer of metal evacuated in one slice perpendicular to the direction of feed motion.

Streamlining of process parameters is done to have incredible control over quality, efficiency and cost parts of the procedure. A portion of the improvement systems are recorded underneath:

Taguchi

Taguchi Method is a capable quality apparatus used to make a vigorous outline that includes a factual way to deal with improve the process parameters keeping in mind the end goal to accomplish the coveted quality highlights of segments that are being produced which are additionally obtuse to the commotion factors introduce in the earth. Taguchi technique utilizes the philosophy of orthogonal cluster as opposed to utilizing the full factorial strategy which restricts the no. of trials while covering the whole parameter space sparing both time and cost. The impediment of Taguchi

technique is that it centers around outlining of the quality as opposed to enhancing quality. Taguchi strategy gives a precise and proficient philosophy for the plan advancement of the cutting parameters with far less impact than would be required for most enhancement procedures [1]. The S/N proportion is utilized to register the quality attributes and analyze the alluring worth (flag) and unfortunate esteem (commotion). There are three characterizations of execution qualities, i.e., the-bring down the-better, the-higher-the-better and the-ostensible the-better. The mean S/N esteem for each level is ascertained and ideal levels are along these lines chose. To discover generally critical influencing parameter, Analysis of Variance (ANOVA) is utilized. It is done by isolating the aggregate changeability of the multi-reaction S/N proportions, which is estimated by the entirety of squared deviations from the aggregate mean of multi-reaction S/N proportion, into commitments by every one of process parameters and mistake. [12,13]

Grey Relation Analysis

This Technique was Developed by J. Deng, Gray Relation Analysis is actualized to change over multi-target enhancement into a solitary target improvement process and comprehend it adequately. The information should be preprocessed. Various quality attributes are converted into one incorporated esteem, known as Gray Relation Grade (GRG). It is figured by first normalizing the information in the range about 0 and 1, and afterward discovering the Gray Relation Coefficient (GRC) utilizing an arrangement of conditions. Higher the GRG, higher the optimality of that level. ANOVA is then performed to discover the altogether influencing parameters. [9,10].

Response Surface Methodology

Response Surface Methodology is used to develop a relationship between the one or more than one response and independent parameters. The main reason for its applicability in various fields is that it is inexpensive, saves time and easy to solve as compared to different traditional methods used for optimization. Estimation of the regression coefficient is done by least squares method. A response surface quadratic model is developed for finding the optimum values. The results are demonstrated using 3D surface graphs or counter maps. The effectiveness and confidence level of the obtained results can be checked using ANOVA [5,7].

II. LITERATURE REVIEW

W. H. Yang et al. (1998) [1] portrays the ideal cutting parameters for turning task of S45C steel bars utilizing tungsten carbide slicing instruments to build apparatus life and limit the surface harshness. The test format configuration depended on Taguchi's L9 Orthogonal Array method and Analysis of Variance (ANOVA) was performed to recognize the impact of the cutting parameters on the reaction factors. Ideal benefits of cutting parameters were resolved and the change of parameters from the underlying removing parameters was observed to be 250%.

Ilhan Asiltürk et al. (2011) [2] thought about cutting rate, encourage rate and profundity of cut as cutting parameters in machining AISI 4140 review steel on CNC Lathe. They utilized Taguchi orthogonal exhibit of L9. A reaction table was shaped to locate the ideal cutting parameters took after by ANOVA. It was watched that the control parameter having most elevated impact on surface harshness is encourage rate, and better surface unpleasantness esteems were gotten at higher nourish rates.

V. S. Thangarasu et al. (2012) [3] tested to enhance the surface unpleasantness and material expulsion rate (MRR) while machining of AISI 304 stainless steel utilizing Taguchi based Response

Surface Methodology (RSM). The control factors in their examination were discovered to be shaft speed, nourish rate, profundity of slice and embed write through measurable investigation of reaction factors. L27 Orthogonal Array and Response Surface Methodology (RSM) was utilized to compute the ideal estimations of parameters and it was discovered that the usage of ideal cutting parameters yielded a change of 11.83% in efficiency.

Anil Gupta et al. (2011) [4] utilized Taguchi strategy with the consistent fluffy thinking for Multi-Output Optimization (MOO) of fast CNC turning of AISI P-20 instrument steel. The test design expressed five controllable variables that are, cutting velocity, bolster, profundity of cut, nose range and cutting condition parameters for advancement of hardware life, cutting power, control utilization and surface harshness. L27 Orthogonal Array was utilized to locate the ideal blend of variables and levels. A solitary reaction called thorough yield measure (COM) was acquired by processing the four associated reactions utilizing the fuzzy rationale unit (FLU).

Süleyman Neşeli et al. (2011) [5] contemplated the impact of hardware geometry at first glance complete while turning of AISI 1040 steel utilizing Al_2O_3 covered embed apparatuses. Taguchi technique and Multiple Response Methodology (RSM) was utilized to build up a connection between surface unpleasantness and machining parameters. The outcomes are communicated in counter guide or 3D arrangement. Instrument nose span was discovered to be the most overwhelming component influencing the surface harshness. A quadratic model was produced which can be utilized for deciding the surface harshness while machining.

Taguchi Technique for getting an ideal estimation of Material Removal Rate (MRR) while machining of SAE 1020 was connected by Sayak Mukherjee et al. (2014) [6]. The procedure parameters embraced for streamlining were cutting velocity, encourage rate and profundity of cut. Every parameter was assigned 5 levels and, in this manner, an orthogonal exhibit of L25 was shaped to finish up the same. ANOVA strategy was utilized for discovering the most persuasive factor influencing the MRR under scrutiny. F-proportion or fluctuation proportion was ascertained, and it was discovered that profundity of cut was the most noteworthy factor of the 3 expressed parameters.

Ilhan Asiltürk et al. (2012) [7] meant to acquire the ideal cutting parameters for R_a and R_z esteems utilizing multi-protest enhancement by means of Taguchi technique-based reaction surface investigation for turning AISI 304 austenitic stainless steel, machined under dry conditions utilizing IC 3028 review carbide embeds. The relapse coefficient is figured utilizing slightest square issues in the reaction surface procedure. The quadratic reaction surface model was created utilizing focal composite outline to get the connection between cutting conditions and harshness parameters R_a and R_z and in this manner can be utilized to anticipate surface unpleasantness at various control parameters.

D. Philip Selvaraj et al. (2010) [8] attempted to enhance the cutting parameters amid turning of AISI 304 review steel utilizing TiC and TiCN covered tungsten carbide cutting apparatus. Taguchi system and ANOVA were utilized to distinguish the ideal cutting parameters and locate the most critical one. The recognized cutting parameters were cutting pace, profundity of cut and bolster. Affirmation tests were done to check the outcome acquired by Taguchi streamlining method.

R. Vinayagamoorthy et al. (2014) [9] embraced Gray Analysis for multi-yield advancement of execution parameters while turning of Ti-6Al-4V. 3 levels each for 4 machining parameters, that are encourage rate, profundity of cut, cutting pace and nose span, are chosen which brought about picking of L27 Orthogonal Array to plan the analysis design. The trial comes about acquired for the surface harshness, device wear, chip morphology and cutting powers were standardized trailed by

figuring of dim connection coefficient. Reaction table was shaped to discover most huge influencing parameters. ANOVA, that is, Sum of squared deviation from the aggregate mean of the dark connection review was computed to discover the commitments of every parameter.

Shreeymoy Kumar Nayak et al. (2014) [10] researched the impact on execution parameters, for example, MRR, surface unpleasantness and cutting power by fluctuating the machining parameters being cutting pace, nourish and profundity of cut while turning of AISI 304 stainless steel under dry conditions utilizing ISO review P30 review uncoated carbide embed. Multi-yield advancement was done utilizing Gray Relation Analysis which included normalizing the information and computing Gray Relation Coefficient shape the standardized information. ANOVA was performed by ascertaining the Gray Relation Grade for various factors and levels indicating velocity and bolster rate to be the most noteworthy parameters. There was a critical change in execution parameters demonstrating the expansion in MRR by 12.5% while cutting power and surface harshness was diminished by 32.62% and 38.79% individually.

Surendra Kumar Saini et al. (2014) [11] completed the multi-target improvement for streamlining the two clashing execution parameters that is surface unpleasantness and material expulsion rate by choosing the ideal CNC turning parameters (sustain, speed and profundity of cut) while turning of Aluminum 8011 compound utilizing uncoated carbide device. Flag to clamor proportion for reaction factors was computed from the L27 orthogonal exhibit including 3 levels. This information was then plotted to clarify the effect of the information parameters on surface harshness and material evacuation rate. The fluffy thinking was then connected to get a solitary target reaction called thorough yield measure by utilizing surface harshness and MRR as fluffy fresh contribution to do multi-target enhancement. Nourish rate was discovered to be the most prevailing component of the three chose parameters.

M. Nalbant et al. (2007) [12] contemplated the impact of cutting parameters on surface harshness in turning procedure of AISI 1030 steel bars. Orthogonal cluster, motion to-commotion proportion, and ANOVA were utilized to recognize and dissect the ideal parameters which were embed range, profundity of cut and bolster rate. Since there were 3 levels each, orthogonal cluster of request L9 was framed. The F-test, named after Fisher, found the commitment of each cutting parameters on surface unpleasantness. The affirmation tests were done to check the outcomes and the change of surface harshness while utilizing the ideal removing parameters was observed to be 3.35 times.

C. Y. Nian et al. (1999) [13] endeavored to enhance the turning activities considering numerous execution qualities with the assistance of Taguchi strategy. Multi-reaction S/N proportion was acquired by figuring the aggregate misfortune work which included doling out weight elements to execution qualities that are apparatus life, surface harshness and cutting power and duplicating them with their standardized misfortune work took after by the summation of these qualities. Turning improvement was done on S45C steel bars machined utilizing P-10 tungsten carbide. ANOVA was then executed to discover the most representing process parameters. The tentatively acquired upgraded process parameters were the confirmed and contrasted and the anticipated level of process parameters.

Ersan Aslan et al. (2007) [14] utilized the Taguchi approach on hard turning of AISI 4140 steel under dry conditions machined utilizing alumina-based fired apparatuses to limit the surface harshness and flank wear which were chosen as the execution parameters in this investigation. L27 orthogonal exhibit including 3 levels and 3 machining parameters was utilized trailed by ANOVA to examine the impact of cutting rate, sustain rate, and profundity of cut on surface unpleasantness and flank wear. F esteems and P esteems were ascertained with a specific end goal to decide the factual

commitment of the machining parameters on execution measures. It was watched that cutting rate contributed around 30.62% of the aggregate variety for the instrument wear took after by profundity of cut with a commitment of around 18.32%. Surface harshness was for the most part affected by cutting rate nourish rate communications and encourage rate– hub profundity collaboration. A powerful arrangement by simply setting the encourage rate to 0.05, without controlling the other 2 factors, brought about bringing down the surface unpleasantness. Different direct relapses drew a connection amongst elements and execution parameters to decide the qualities for any on-screen character levels.

J. Paulo Davim (2001) [15] introduced optimal cutting conditions in turning of free machining steel, AISI 12L13, utilizing TPUN 1660308 P10 established carbide embeds. Taguchi and ANOVA systems were done to first outline the investigation design and after that to discover the impact on add up to difference of results. Surface harshness parameters, number juggling normal unpleasantness, Ra, and most extreme crest to-valley stature, Rt, were investigated and assessed utilizing profilometers. Removing speed was observed to be the most predominant factor influencing the surface unpleasantness. The goal, finding the connection amongst's cutting and execution parameters, was accomplished by utilizing numerous straight relapses, after which affirmation tests were done.

Ashok Kumar Sahoo et al. (2012) [16] analyzed, anticipated and improved the procedure parameters for dry turning AISI 1040 steel utilizing carbide covered embed utilizing Taguchi philosophy, Regression investigation and Gray connection examination. A L9 orthogonal cluster including 3 levels was outlined trailed by computing S/N proportion for surface harshness and material evacuation rate and this information was utilized for their parametric streamlining by figuring the mean S/N proportion from the reaction tables. MINITAB programming was utilized to build up the scientific models by playing out the relapse investigation utilizing the trial information took after by contrasting the genuine and anticipated qualities with decide the ampleness of the model. Multi-yield enhancement of the surface harshness and material evacuation rate was expert utilizing dark connection investigation by computing the mean dim social review for each level.

Table 1: Summary of literature review

S. No.	*Author(s)*	*Input Parameters*	*Response Parameters*	*Methodology*
1	W. H. Yang et al.	Cutting Speed, Feed Rate and Depth of Cut	Tool Life and Surface Roughness	Taguchi, ANOVA
2	Ilhan Asiltürk et al.	Cutting Speed, Feed Rate and Depth of Cut	Surface Roughness	Taguchi, ANOVA
3	V. S. Thangarasu et al.	Spindle Speed, Feed Rate and Depth of Cut	Surface Roughness and Material Removal Rate	Taguchi, RSM
4	Anil Gupta et al.	Cutting Speed, Feed Rate, Depth of Cut, Nose Radius and Environment	Surface Roughness, Tool Life, Power Consumption and Cutting Force	Taguchi, Fuzzy Logic, ANOVA
5	Süleyman Neşeli et al.	Tool Geometry (Nose Radius, Approach Angle and Rake Angle)	Surface Finish	Taguchi, ANOVA, RSM, Multiple Regression Analysis

Table 1 Continue…

6	Sayak Mukherjee et al.	Cutting Speed, Feed Rate and Depth of Cut	Material Removal Rate	Taguchi, ANOVA
7	Ilhan Asiltürk et al.	Cutting Speed, Feed Rate and Depth of Cut	Surface Roughness	Taguchi, ANOVA, RSM, Multiple Regression Analysis
8	D. Philip Selvaraj et al.	Cutting Speed, Feed Rate and Depth of Cut	Surface Roughness	Taguchi, ANOVA
9	R. Vinayagamoorthy et al.	Feed Rate, Depth of Cut, Cutting Speed and Nose Radius	Cutting Temperature and Surface Roughness	Taguchi, Grey Relation Analysis, ANOVA
10	Shreeymoy Kumar Nayak et al.	Cutting Velocity, Feed Rate and Depth of Cut	Surface Roughness, Cutting Force and Material Removal Rate	Taguchi, Grey Relation Analysis, ANOVA
11	Surendra Kumar Saini et al.	Spindle Speed, Feed Rate and Depth of Cut	Material Removal Rate and Surface Roughness	Taguchi, Fuzzy Logic
12	M. Nalbant et al.	Insert Radius, Depth of Cut and Feed Rate	Surface Roughness	Taguchi, ANOVA
13	C. Y. Nian et al.	Cutting Speed, Feed Rate and Depth of Cut	Tool Life, Cutting Force and Surface Roughness	Taguchi, ANOVA
14	Ersan Aslan et al.	Cutting Speed, Feed Rate and Depth of Cut	Flank Wear and Surface Roughness	Taguchi, ANOVA, Multiple Regression Analysis
15	J. Paulo Davim	Feed, Cutting Velocity, and Depth of Cut	Surface Finish	Taguchi, ANOVA, Multiple Regression Analysis
16	Ashok Kumar Sahoo et al.	Cutting Speed, Feed and Depth of Cut	Surface Roughness and Material Removal Rate	Taguchi, Grey Relation Analysis, ANOVA, Multiple Regression Analysis

III. CONCLUSION

In this paper, the application of various optimization techniques has been discussed involving both single objective optimization and multi-objective optimization of performance parameters of turning operation done on various grades of steel and aluminum on CNC lathe by computing and determining the optimum levels of the control parameters. Taguchi and ANOVA techniques were used for single objective optimization while RSM, grey analysis and fuzzy logic were used for multi-objective optimization.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities

REFERENCES

[1]. Yang W. H., Tarng Y. S. (1998), 'Design optimization of cutting parameters for turning operations based on the Taguchi method', Journal of Materials Processing Technology, Volume 84, pp.122-129.

[2]. Asiltürk Ilhan, Akkuş Harun (2011), 'Determining the effect of cutting parameters on surface roughness in hard turning using the Taguchi method', Measurement, Volume 44, pp.1697-1704.
[3]. Thangarasu V. S., Devaraj G., Sivasubramanian R. (2012), 'High Speed CNC Machining of AISI 304 Stainless Steel', International Journal Of Engineering Science and Technology, Volume 4, pp.66-77.
[4]. Gupta Anil, Singh Hari, Aggarwal Aman (2011), 'Taguchi-fuzzy multi output optimization (MOO) in high speed CNC turning of AISI P-20 tool steel', Expert system with Applications, Volume 38, pp.6822-6828.
[5]. Neşeli Süleyman, Yaldiz Süleyman, Türkeş Erol (2011), 'Optimization of tool geometry parameters for turning operations based on the response surface methodology', Measurement, Volume 44, pp.580-587.
[6]. Mukherjee Sayak, Kamal Anurag, Kumar Kaushik (2014), 'Optimization of Material Removal Rate During Turning of SAE 1020 Material in CNC Lathe using Taguchi Technique', Procedia Engineering, Volume 97, pp.29-35.
[7]. Asiltürk Ilhan, Neşeli Süleyman (2012), 'Multi response optimization of CNC turning parameters via Taguchi method-based response surface analysis', Measurement, Volume 45, pp.785-794.
[8]. Selvaraj D.Philip, Chandramohan P.(2010), 'Optimization of surface roughness of AISI 304 Austenitic Stainless Steel In Dry Turning Operation Using Taguchi Design Method', Journal Of Engineering Science and Technology, Volume 5, pp.293-301.
[9]. Vinayagamoorthy R., Anthony Xavior M. (2014), 'Parametric Optimization on Multi-Objective Precision Turning Using Grey Relation Analysis', Procedia Engineering, Volume 97, pp.299-307.
[10]. Kumar Nayak Shreeymoy, Kumar Patro Jatin, Dewangan Shailesh, Gangopadhyay Soumya (2014), 'Multi-Output Optimization of Machining Parameters During Dry Turning of AISI 304 Austenitic Stainless Steel Using Grey Relation Analysis', Procedia Materials Science, Volume 6, pp.701-708.
[11]. Kumar Saini Surendra, Kumar Pradhan Sharad (2014), 'Optimization of Multi-Objective Response during CNC Turning using Taguchi-Fuzzy Application', Procedia Engineering, Volume 97, pp.141-149.
[12]. Nalbant M., Gökkaya H, Sur G. (2007), 'Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning', Materials and Design, Volume 28, pp.1379-1385.
[13]. Nian C. Y., Yang W. H., Tarng Y. S. (1999), 'Optimization of turning operations with multiple performance characteristics', Journal of Material Processing Technology, Volume 95, pp.90-96.
[14]. Aslan Ersan, Camuşcu Necip, Birgören Burak (2007), 'Design optimization of cutting parameters when turning hardened AISI 4140 steel (63 HRC) with AL2O3 + TiCN mixed ceramic tool mixed ceramic tool', Materials and Design, Volume 28, pp.1618-1622.
[15]. Davim J. Paulo (2001), 'A note on the determination of optimal cutting conditions for surface finish obtained in turning using design of experiments', Journal of Materials Processing Technology, Volume 116, pp.305-308.
[16]. Kumar Sahoo Ashok, Nanda Baral Achyuta, Kumar Rout Arun, Routra B. C. (2012), 'Multi-objective Optimization and Predictive Modeling of Surface roughness and Material removal rate in Turning using Grey relation and Regression Analysis', Procedia Engineering, Volume 38, pp.1606-1627,
[17]. Singh P., Channi A.S. (2015), "Multi Response Optimization of Machining Responses in Turning Process of AISI D2 Tool Steel using WPM Approach", International Journal of Advanced Engineering Research and Applications, 1(5), pp. 221-227.

This volume is dedicated to Late Sh. Ram Singh Phanden, father of Dr. Rakesh Kumar Phanden.

