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Optimization of Cutting Parameters in CNC Turning by using Taguchi Method: A Review

Tawseef Abdullah[1], Dr. P. S Rao[2], Zahid Maqsood[3]

[1,3] M.E scholar, Department of Mechanical Engineering, National Institute of Technical Teachers Training and Research, (NITTTR), Chandigarh.

[2] Assistant professor, Department of Mechanical Engineering, National Institute of Technical Teachers Training and Research, (NITTTR), Chandigarh.

Abstract

The growing competition in the modern era for high productivity with high quality surface finish has emerged the need of using high quality machining tool. The influence of cutting parameters in the turning process mainly affects the surface roughness and machining time. The significant performance measures in turning of different materials are mainly cutting speed, feed rate, depth of cut, cutting fluids which affects the surface roughness of the required material. This paper reviews the optimisation of cutting parameters in turning process using Taguchi and Response Surface Methodology (RSM). The performance characteristics were checked by using Analysis of Variance (ANOVA) to find out which input parameter dominates the most during the turning process on CNC lathe. Signal to Noise ratio(S/N) is used to compare the level of desired output parameters.

Key Words: CNC, Optimization, Turning, Taguchi, RSM

1. INTRODUCTION

(i) CNC Turning

Machining is basically a material removal process from the work-piece by using one or more cutting tools to achieve the required dimensions [1,2]. There are different machining processes viz turning, milling, drilling knurling etc [3]. A metal cutting tool is used to remove material from the work-piece through the process of shear deformation using a single point or multi-point cutting tool [4]. Generally, one of the two rotates at high speed causing the shearing of the material in the form of chips for example as seen in Fig.1 a turning operation of lathe the work-piece rotates in a chuck while the tool moves in the dimension in two dimensions is translationally [2].

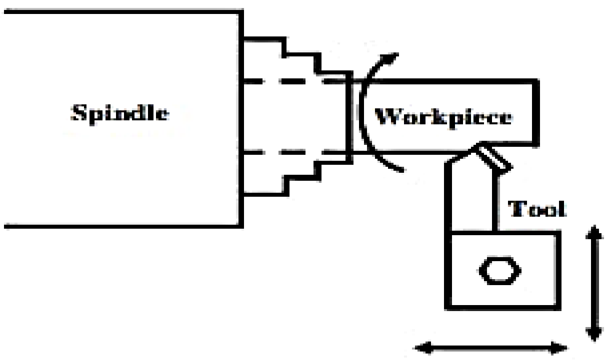

Fig.1 Drive in a metal cutting [2]

The important parameter for all metal cutting processes are cutting speed, feed rate and depth of cut (DOC). The Fig.2 shows important geometry for the turning process.

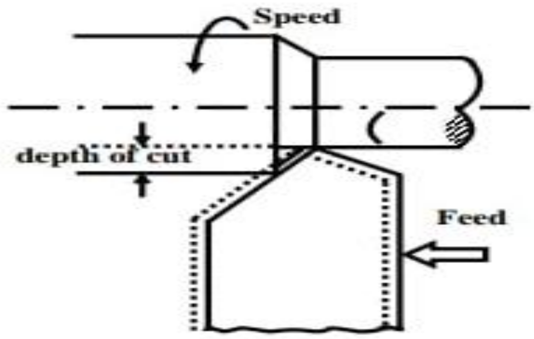

Fig 2 Turning of metal [2]

Modern manufacturing demands extreme dimensional accuracy and surface finish. It is very difficult to achieve this manually, even with expert operators. In cases where it is possible, it takes higher amount of time due to the need for frequent dimensional changes to prevent overcutting. Development of computer numerically controlled (CNC) machines has made possibly the automation of the machining process with flexibility to handle production easily [5].

(ii) Taguchi Design

Genichi Taguchi of Nippon Telephones and Telegraph Company Japan developed a Statistical Method for the production of robust products, proposed several approaches to experimental designs called "Taguchi Methods" based on Orthogonal Array (L_9, , L_{18}, L_{27}, L_{36}) with optimum settings of control parameters [6]. Taguchi's Signal to Noise ratio (S/N) as desired outputs serve as base of objective function for obtaining optimum results [7,8]. The flow chart is shown in fig.3

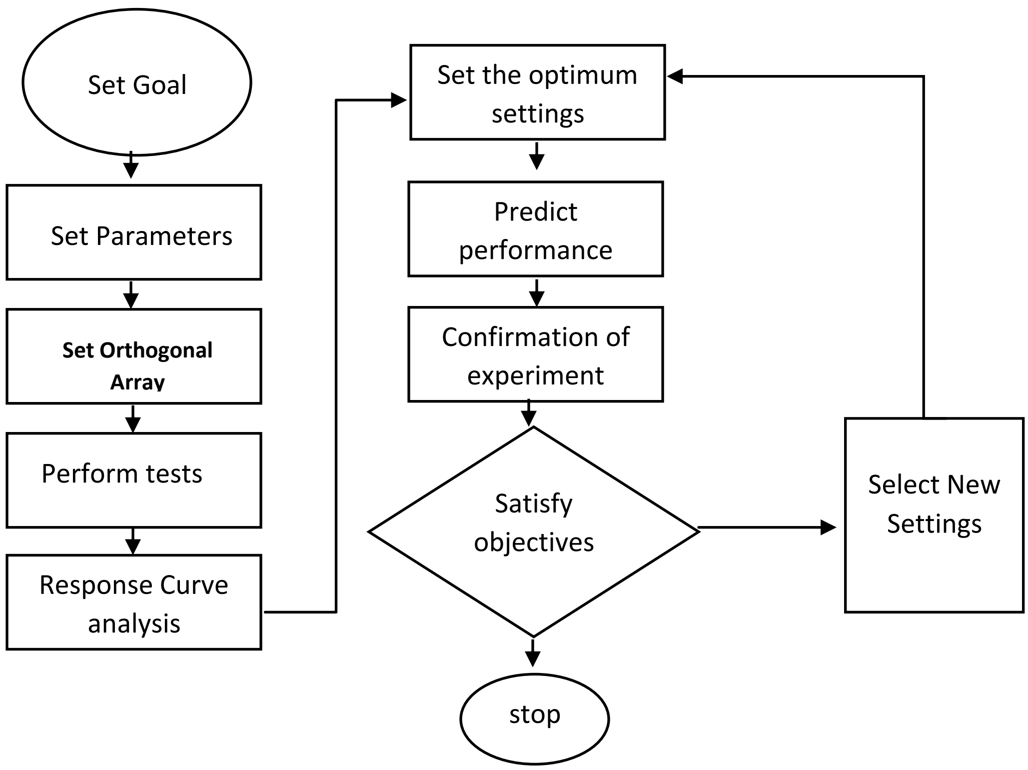

Fig 3 Flow chart of Taguchi method

2. LITERATURE REVIEW

Perumal et al. [9] performed experiments on two materials AISI 304 & AISI 306 Stainless Steel by using Titanium Carbonitride coated tool during CNC Turning and determined the optimum cutting parameters viz cutting speed, feed rate and depth of cut to obtain better Surface Finish by using Taguchi Method & S/N ratio was calculated. It was found that for both types of materials the optimum cutting speed was 1200 RPM, feed rate of 0.1 mm/rev and 0.4 mm depth of cut. It was also observed that surface finish is directly proportional to speed and inversely proportional to feed and depth of cut.

Kuppusamy and Ramalingam [10] studied the optimization of process parameters in CNC turning of Titanium alloy TI-16Al-7Nb with carbide coated tool inserts by using Taguchi analysis. The influence of individual turning parameters was carried by ANOVA. Finally, the desirability function approach is used in the optimisation of multi response surface through RSM. The optimised parameters were feed rate of 0.08 mm/rev., cutting speed 100 m/min, insert angle of 80*, nose radius 0.4 mm, and depth of cut 0.4 mm by using wet conditions.

Basmaci [11] has worked on optimisation of process parameters like feed rate, depth of cut and cooling system in turning of AISI 316L stainless steel using Taguchi method. The Taguchi's L9 orthogonal array is used to formulate the experiment layout. Cutting forces and surface roughness were measured by using Carbide tool material. With the help of Pareto's chart, it was determined that depth of cut and feed rate affect the cutting force is most. The best results with lowest values of cutting force is were obtained by keeping the feed rate 0-1 mm/rev, depth of cut 0-5 mm and dry cooling system.

Chandrasheker et al. [12]: investigated the effect of four control factors viz cutting speed, feed rate, depth of cut and three cutting fluids (Sherol B, Sherol ENF, Straight Cutting Fluid) for optimising surface roughness produced during turning operation of AISI 316 stainless steel based on Taguchi methodology by using L_9 orthogonal array with three levels of control factors. The best condition for cutting speed was observed as 96.6 m/min, feed rate 150 mm/rev. & depth of cut 0.8 mm by using straight cutting oil as a cutting fluid.

Alagarsamy et al. [13] studied optimisation of machining parameters like speed, feed and depth of cut for turning of aluminium alloy 7075 using Taguchi method by using tungsten coated carbide tool for material removal rate (MRR) and machining time. The ANOVA (Analysis of Variance) and Signal to noise ratio (S/N) were employed to study the performance characteristics. It was investigated that speed has significant role in producing higher material removal rate (MRR) and lesser machining time. The best conditions were cutting speed of 1500 m/min, feed rate of 0.20 mm/rev, depth of cut off 0.8 mm for optimising MRR and Machining time. ANOVA for Signal to Noise ratio for MRR indicates that cutting speed has significant contribution of 16.46%, followed by feed rate 24.13% and depth of cut 0.32% in obtaining of optimal material rate (MRR).

Asilturk et al. [14] this study involves modelling of experimental surface roughness of Co28Cr6Mo ASTM F 1537 medical alloy during CNC turning with input parameters as spindle speed, feed rate, depth of cut and tip radius by using Taguchi and RSM Designs. The optimised parameters were found to acquire minimum roughness with spindle speed 318 rpm, feed rate 0.1 mm/rev, depth of cut 0.7 mm and tool tip radius of 0.8 mm under dry conditions. It was observed that for surface roughness tip radius was the dominant factor contributing 38% followed by feed rate of 33%.

Qureshi et al. [15] studied the optimisation of cutting parameters such as cutting speed, feed rate, depth of cut and nose radius for surface roughness in the turning of Steel with coated carbide inserts. The optimal combination were low feed rate and low depth of cut were beneficial for good surface finish.

Eldhose et al**. [16]** studied optimization of the cutting parameters of stainless-steel SS 304 for CNC turning operation by using Taguchi method. They have found that depth of cut is the most effecting factor on material removal rate, on surface roughness is steel and depth of cut, machining time and tool wear were mostly affected by feed and speed.

Sarikaya et al. [17] analysed the effects of the turning parameter viz cutting speed, feed rate, depth of cut cooling conditions on average surface roughness and average maximum height of the profile when turning AISI 1050 Steel by using Design Of Experiments methodology. Tests are designed by Taguchi orthogonal L_{16} Orthogonal array. The results were analysed by using ANOVA, 3D surface graphics and Signal to Noise ratio. Finally, the desirability function approach is used in the optimisation of multi response surface through RSM. Dimensions of the workpiece was diameter 80-220 mm. The chemical composition of this material is 0.43 C, 0.75% Mn, 0.07% Cr, 0.09% Ni, 0.21% Si, 0.29 % Cu and 0.04% S. The cutting tool material used for the machining was TIALN coated Carbide by physical vapour deposition (PVD). It was found that the optimal cutting parameters were cooling conditions of MQL (Minimum Quantity Lubrication) at 120 ml/hr cutting speed of 200 m/min, feed rate of 0.07 mm/rev and depth of cut 1.2 mm. The optimised values of surface roughness 0.77-0.95 micro metre and average maximum height of the profile 7.60 micro metre. ANOVA demonstrates that the feed rate and the cooling condition were significant parameters on the surface roughness. The percentage contribution by feed rate and cooling conditions were 68.68% and 16.8% respectively. Rz is influenced by feed rate of 77.50%.

Makadia and Nanavati [18] studied the effect of main turning parameters like feed rate, nose radius, cutting speed and depth of cut on the surface roughness of AISI 410 Steel with ceramic inserts by using RSM. It was found that the feed rate is the main cutting parameter on the surface roughness followed by nose radius and cutting speed. Depth of cut have no significant effect on surface roughness.

Asilturk et al. [19] presents multi-response optimization of CNC turning parameters wheels cutting speed depth of Cut feed rate via Taguchi method-based response surface analysis. The AISI 304 austenitic stainless-steel workpiece is machined by coated carbide inserts under dry conditions and surface roughness was examined. It was found that feed rate is the significant factor affecting surface roughness which can be minimised when feed rate and depth of cut are set to lowest level by keeping high cutting speed. The optimised cutting parameter for surface roughness were cutting speed of 50 mm/min, feed rate of 0.15 mm/rev. and depth of cut 1.5 mm. Also, the model for surface roughness is obtained using response surface methodology proved by ANOVA. Taguchi and Response Surface Statistical Analysis both indicated that feed rate is the most dominant factor on the surface roughness contributing 85.5% in obtaining optimal performance measures.

Outerio [20] this study presents the effect of cutting process parameters on machining performance and surface integrity of Inconel 718 and Austenitic Steel 316L with both coated and uncoated carbide tools during dry conditions, during turning on modern CNC Lathe with specially designed experimental setup for measuring cutting forces and infrared temperature measurement. It was observed that higher surface residual stresses are generated when machining with the uncoated tool than with the coated one. It was also observed that higher residual stresses were obtained on the transient surface than with the machined surface; for Inconel 718 cutting speed 70 m/min. feed rate 0.2 mm/rev., depth of cut 0.5 mm and for 316L Stainless Steel cutting speed of 125 m/min metre, feed rate of 0.05 mm/rev for Revolution and depth of cut 2.5 mm were measured.

Aggarwal et al. [21] revived the optimisation of multiple quality characteristics like tool life, cutting forces, surface roughness and power consumption in CNC turning of P20 Steel using liquid nitrogen as a coolant. It was determined that highest desirability could be obtained at low level of cutting speed feed and depth of cut and high nose radius.

Kuman Jha et al. [22] used Taguchi method to optimise cutting parameters during dry conditions of aluminium with carbide tipped tool on CNC. By varying spindle speed feed and depth of cut. The output parameter MRR was observed best with cutting speed as the most significant parameter.

Nalbant et al. [23] researched the effect of cutting parameters namely insert radius, feed rate and depth of cut for surface roughness in turning of AISI 1030 Steel bar's during CNC turning by using TiN coated tools by Taguchi design methodology for achieving high accuracy and very low processing time. The experimental results showed that the insert radius 1.2 mm, low feed rate 0.15 mm/rev and depth of cut 0.5 mm are recommended to obtain better surface finish. The percentage contribution of insert radius was 48.54%, feed rate by 46.95% followed by depth of cut 3.39%.

3. CONCLUSIONS:

After going through the literature survey, Researchers have:

- Mostly used Taguchi Method to productively decide the parameter combinations important to minimise surface roughness of the turned surface in CNC.
- Taken the performance parameters such as speed, feed rate, depth of cut and cutting speed into consideration while leaving the other parameters viz tool signature, type of lubricant and nose radius apart from the research.
- Used coated carbide tool materials in to consideration while keeping the other coatings apart. Also the thickness of coating material is not mentioned in most of the Research papers.
- Analysed the common output parameters such as Surface roughness, MRR and cutting forces and it was found that surface roughness is highly dependent on cutting speed and feed rate.

4. FUTURE WORK AND SCOPE

Future work may be extended to analyse the effects of some additional parameters such as the type of lubricant, nose radius, thickness of coating material and tool wear rate.

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