Optimization of Process Parameters of Turning Using Various Tool Geometry of Inserts based on Taguchi Method: A Review

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Abstract
The modern machining industry industries are mainly focused on the achievement of high quality products, in terms of dimensional accuracy, surface roughness, high production rate, less wear on the cutting tool. The influence of cutting parameters in the turning process mainly affects the surface roughness and Metal Removal Rate (MRR). The important cutting parameters in turning process are cutting speed, feed rate, depth of cut affects the surface roughness of finished product and Metal Removal Rate (MRR). Some of the researcher worked on optimization of process parameters for EN8 steel using different cutting tools. This paper reviews the work on optimization of cutting parameters of turning process using Taguchi method. A specially designed orthogonal array of is used to find out the effect of cutting parameters through the small number of experiments. Taguchi method is one of the powerful optimization tool. ANOVA (Analysis of variance) is used to find out which input parameter significantly affects the performance characteristics.

Keywords
Turning Process, Surface Roughness, MRR, Taguchi Method, ANOVA.

I. Introduction

Turning is a machining process, which is used to obtain the desired dimension of metal. It is a process in which a cutting tool, typically a non-rotary tool bit, a helical tool path by moving more or less linearly while the work piece rotates. In a traditional form of lathe turning can be done manually, which requires continues supervision by the operator. The turning process are typically carried out on a lathe, considered to be the oldest machine tool and can be of different types such as taper turning, straight turning, straight turning, external grooving or profiling. These types of turning processes can produce various shapes of materials such as straight, curved, conical or grooved work piece. Turning uses single point cutting tool. Every group of work piece materials has an optimum set of tools angles which have been developed through the years. In competition industry, each manufacturing company wants to manufacture low cost and high quality products in optimum time to fulfill customer demand.

A. There are Several Parameters that Affect the Processes

The input process parameters are:

1. Cutting Speed

It is the speed of the work piece surface relative to edge of the cutting tool during turning. The cutting speed is measured in millimeter per second.

2. Feed Rate

Feed rate is the speed of the cutting tool movement relative to the work piece surface as the tool makes the cut. It is measured in millimeter per revolution.

3. Depth of Cut

It is the depth of the tool along the radius of the work piece as it makes the cut in turning operation.

The output process parameters which are taken into account for evolutions of process capability of turning operations are:

1. Metal Removal Rate (MRR)

The MRR is the amount of material removed from the work piece per unit time. The MRR can be calculated from the weight difference before and after machining.

2. Surface Roughness

Surface roughness is the irregularities which are inherent in the production process. In turned component low surface roughness is very important as it can reduce or even completely eliminate further machining. Surface roughness is quantified by the deviations in the direction of normal vectors of a real surface from its ideal form. If these deviations are large then the surface is rough and if these are small then the surface is smooth.

3. Tool Wear Rate

It is the gradual failure of cutting tools due to regular operation. The optimization of cutting parameters is very important in orders to produce the high quality product in less time with minimum manufacturing cost. In order to obtain the high metal removal rate and good surface finish optimization of process parameters in turning operation is needed. In actual practice the optimum cutting parameters are to be recognized first. There are several techniques which are used for process optimization. These are:

- Evolutionary optimization
- Genetic algorithm
- Hybrid genetic simulated annealing algorithm
- Taguchi Optimization method.
- Particle swarm optimization

II. Literature Review

A literature review of recently published research work on turning operation on different stainless steel was carried out to understand the research issues involved and is presented here:

Shivam Goyal et al. [1] studied the optimization of MRR and surface roughness in turning operation using Taguchi method. The experiments were conducted by taking as feed rate, depth of cut & spindle speed as process parameters and got the optimized values of MRR & surface roughness. The turning operation is conducted on AISI 1020 mild steel using WNMG carbide inserts with nose radius of 0.8mm. An L9 orthogonal array, signal to noise ratio are employed to study the performance characteristics. They

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concluded that on increasing depth of cut and feed the combined S/N ratio increases while the combined S/N ratio decreases with increase in speed. The cutting speed is most significantly influencing parameter on surface roughness followed by feed. For MRR depth of cut is most significant parameter followed by cutting speed.

Ankit dogra, Sunil Kumar et al. [2] did the optimization of turning process parameters for EN-8 steel cylindrical rods using Taguchi method. The experimental design was formed based on Taguchi method. An orthogonal array L9 and ANNOVA are applied to find out the best turning conditions. Coated tool inserts are used for machining. They observed that spindle speed is the most significant parameter followed by depth of cut. For to reduce tool tip wear speed is the most significant factor.

Hardeep Singh, Rajesh Khanna et al. [3] carried a turning test for to find out the effect of cutting parameters on MRR and surface roughness in turning EN-8 steel using CNMG inserts. They used Taguchi methods for optimization of cutting parameters. They observed that spindle speed & depth of cut is the most significant parameters while feed rate has a least significant parameter. After conducting test they analyzed that the feed rate has variable effect on surface roughness. They analyzed experimental results using ANOVA.

N. Ramesh, N. Tejeswara Rao et al. [4] tried for optimization of MRR & surface roughness for turning of AA6061 using Taguchi method and Particle swarm optimization technique. They made the optimization using particle swarm optimization (PSO) approach for maximized MRR and minimized surface roughness. They produced a predictive equations for determining MRR and surface roughness with a given set of parameters in CNC turning. They showed that PSO technique can be applied for different predicted Ra values that are modeled by using various conventional approaches and non-conventional approaches.

Rajguru J & Arunachalam N. [5] did the study of performance of coated tool in dry turning of super duplex stainless steel. Their performance were evaluated in terms of tool wear, cutting force, cutting temperature and surface integrity. They measured cutting force with the use of Kistler piezoelectric dynamometer, infrared camera FLIR T250 was used to measure dynamic cutting temperature at tool work piece interface. They used four different coating materials.

J. Chandrasekhar et al. [6] used Taguchi method for optimization of cutting parameters for turning AISI 316 Stainless steel with diamond cutting tool. Did the experiment with four cutting parameters feed, speed, depth of cut and cutting fluids. Design of experiment is done using Taguchi method. For experimentation L9 orthogonal array is selected. Minitab statistical software is used for the analysis of experimental work which gives signal to noise ratio. The average of S/N ratio is calculated. The Minitab software given the equation of surface roughness for work piece material. Then surface roughness is calculated. They observed that cutting speed has the most significant parameter followed by cutting fluid.

M. Kaladhar, Chi. Srinivas Rao et al. [7] determined the optimum process parameter during turning of AISI 304 austenitic stainless steel using Taguchi method. Turned the AISI 304 austenitic stainless steel work pieces on CNC lathe using physical vapor deposition coated cermet inserts with nose radius 0.4mm and 0.8mm They observed that, 1) Feed plays an important role in minimization of surface roughness and maximization of metal removal rate. 2) For metal removal rate, depth of cut is dominant parameter followed by the feed 3) nose radius plays an important role in minimization of surface roughness.

S. Hasan et al. [8] focused on checking the machinability of hard martensitic stainless steel & hard alloy steel using CBN, PCBN cutting tools by turning process. Did the turning test using high precision N. C. Harrison 450 lathe under dry turning on AISI 440 C and SCM 440 alloy steel. They used cutting speed, feed & depth of cut as process parameters. Machinability of both materials and tools are evaluated in terms of roughness, flank wear, cutting force and specific cutting pressure. They concluded that Surface roughness of the stainless steel in terms of value was low at high cutting velocity with low feed rate. Turning stainless steel by using CBN tool produced low value than alloy steel. The roughness by PCBN tool was more than CBN tool. Flank wear formation was high by using CBN tool than PCBN tool. By using PCBN tool low flank wear formed at high cutting velocity with high feed rate.

N. Kiran Rao et al. [9] have made analysis on the optimization of machining parameters in turning of AISI 202 austenitic stainless steel using CVD coated cemented carbide tools. During the experiment, process parameters such as speed, feed, depth of cut and nose radius are used to check their effect on the surface roughness of the work piece. The experiments are conducted using full factorial design in the Design of Experiments (DOE) on Computer Numerical Controlled (CNC) lathe machine. From the analysis, they observed that the feed is the most significant factor that influences the surface roughness followed by nose radius.

Dr. C. J. Rao et al. [10] did the research on effect of cutting parameters on cutting force and surface finish in turning operation using AISI 1050 steel as a work material and ceramic tool. Observed that the feed rate has significant influence on both the cutting force and surface roughness. Cutting Speed has no significant influence on the cutting force as well as the surface roughness. Depth of cut has significant effect on cutting force, but has an insignificant effect on surface roughness. The interaction of feed and depth of cut and the interaction of all the three cutting parameters have significant influence on cutting force, whereas, none of the interaction effects are having significant influence on the surface roughness produced.

Atul P. Kulkarni et al. [11] studied the effect of machining parameter on cutting force, cutting temperature and surface finish during turning of AISI 304 stainless steel using CAE system deposited AlCrN/TiAlN coated carbide insert. They focused on green machining, environmentally friendly manufacturing which is ecologically desirable and cost effective. CAE technique is used for depositing AlCrN/TiAlN coating. The effect of machining parameters on the cutting force, surface finish and cutting temperature were investigated during the experimentation. They observed that, as feed increases, the radial force increases so the surface roughness increases. The tool-chip interface temperature increases with increase in cutting speed. They developed the regression models for different parameters and the obtained results are compared with experimental results.

Tugrul Ozel et al. [12] studied surface finishing and tool flank wear in finish turning of AISI D2 steel using ceramic wiper design insert. They developed both multiple linear regression models and neural network models. Neural network based predictions of tool flank wear and surface roughness are carried out and compared with non-training experimental data. They performed hard turning experiment on using high rigidly CNC lathe with 18 KW spindle power. They concluded that neural models are very effective for prediction of tool wear and surface roughness. They also concluded that good surface finish can be achieved with multi radii wiper tools at higher feed rates.

Alaattin Kacal et al. [13] obtained the experimental results of high speed hard turning of hardened AISI S1 cold worked tool steel using ceramic and CBN cutting tools. On the basis of surface roughness, tool wear and machining force the performance of ceramic and CBN cutting tools are evaluated. The experiments of AISI S1 materials are carried out and obtained results from experiments were evaluated graphically by using ANOVA. During the experiment, speed, feed, depth of cut and tool types are used as process parameters. Analysis of variance (ANOVA) was used for observing the most influencing cutting parameter. They observed that CBN tool has better performance than that of the ceramic tool.

B. Singarvel et al. [14] did the multi objective optimization in turning using Taguchi based utility concept coupled with principal component analysis. They applied this method for simultaneously minimization of cutting force, surface roughness and maximization of metal removal rate. They used CVD and PVD coated carbide tools for turning on EN25 steel. They suggested that the Taguchi utility concept coupled with PCA is found to be a very simple method used for simultaneous minimization of cutting force, surface roughness and maximization of metal removal rate. Coated tool is the most significant parameter followed by speed.

D. Philip selvaraj et al. [15] studied the influence of cutting parameters on the surface roughness of AISI 304 austenitic stainless steel during dry turning. They used cutting speed, feed & depth of cut as a process parameters. They did the experimentation on medium duty kirloskar Turn master-35 lathe machine using tool holder with specification PSBNR 2525M12. An orthogonal array and ANOVA are employed to investigate the cutting characteristics of AISI 304 austenitic stainless steel using TiCN and TiC coated tungsten carbide tool. They observed the cutting speed, feed rate are the major affecting cutting parameters and depth of cut is the minor affecting parameter on surface roughness. They used Taguchi orthogonal array, signal to noise ratio and ANOVA used for cutting parameters optimization.

K. Palani kumar et al. [16] did the experimental investigation and surface analysis on hard turning of AISI D2 steel using coated carbide insert. The cutting parameters considered for experimentation as feed, speed & depth of cut. They observed that gradual increase of feed rate and depth of cut increases the surface roughness in machining of AISI D2 steel by coated carbide insert. From figure they concluded that the surface roughness reduces with increase gradually increase of cutting speed. From graph they noticed that the surface roughness parameter values are more at high feed rate.

Michel coret et al. [17] studied the surface integrity in finish turning of 15-5PH stainless steel using standard carbide coated insert. After machining surface samples have been coated in resin. In this paper the metallurgical model is implemented in numerical model for the prediction of surface integrity after turning. He concluded that thermal kinetic doesn't allow a significant austenite formation even if the maximal reached temperature is clearly higher than the austenization start temperature.

Suhas Rewatkar et al. [18] have made an attempt on to review the optimization of cutting parameters of surface roughness in facing process using Taguchi method. A specially designed orthogonal array of Taguchi method is used to investigate the effect of cutting parameters through the small number of experiments. ANOVA is used to find out which input parameters largely affect the performance characteristics. They observed that most of the researcher have taken the controllable parameters as spindle speed, depth of cut and feed rate. The output process parameters as surface roughness, tool wear rate, cutting force and metal removal rate.

Table 1: Summary of Review Papers

S. No.	Author	W/P Material	Inserts/Tools Used	Input Parameters	Output Parameters	Most Significant
1	Shivam Goyal Et Al.	Aisi 1016 Mild Steel	Wnmg	Speed, Feed, Doc	Mrr, Surface Roughness	Speed
2	Ankit Dogra Et Al.	En-8	Coated Tool	Speed, Feed, Doc	Tool Wear Rate	Speed
3	Hardeep Singh Et Al.	En-8	Cnmg	Speed, Feed, Doc	Mrr, Surface Roughness	Speed, Doc
4	N. Ramesh Et Al.	Aa 6061	Carbide Tool	Speed, Feed, Doc	Mrr, Surface Roughness	Speed, Feed
5	Rajguru J. Et Al.	Super Duplex Steel	MuLti-Layer Coated Cutting Tools	Four Different Coatings On Tools	Tool Wear, Cutting Force, Cutting Temperature, Surface Integrity	[Mt-Ticn]-Al_2o_3 Coating Tool
6	J. Chandrasekhar Et Al.	Aisi 316 Stainless Steel	Tnmg	Speed, Feed, Doc , Three Cutting Fluids	Surface Roughness	Cutting Speed, Cutting Fluids

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7	M. Kaladhar Et Al.	Aisi 304 Stainless Steel	Pvd Coated Cermet Insert	Cutting Speed, Feed Rate, Nose Radius	Mrr, Surface Roughness	Feed Rate
8	S. Hasan Et Al.	Aisi 440c, Scm 440 Alloy Steels	Cbn, Pcbn Tool	CuTting Speed, Feed, Doc	Roughness, Tool Wear, Cutting Force	Cbn Tool
9	K. Narayana Rao Et Al.	Aisi 202 Stainless Steel	Cvd Coated Cemented Carbide Tool	Cutting Speed, Feed Rate, Nose Radius	Surface Roughness	Feed Rate, Nose Radius
10	Dr. C. J. Rao Et Al.	Aisi 1050 Steel	Ceramic Tool	Cutting Speed, Feed Rate, Doc	Surface Roughness, Cutting Force	Feed Rate
11	Atul P. Kulkarni Et Al.	Aisi 304 Stainless Steel	Coated Carbide Inserts	Cutting Speed, Feed Rate, Doc	Cutting Force, Cutting Temperature	Cutting SpeEd, Feed Rate
12	Tugrul Ozel Et Al.	Aisi D2 Steel	Coated Wiper Insert	Cutting Speed, Feed Rate, Doc	Surface Finish, Tool Flank Wear	Feed Rate
13	Alaattin Kacal Et Al.	Aisi S1 Steel	Ceramic And Cbn Tool	Cutting Speed, Doc, Tool Type	Surface Roughness, Tool Flank Wear	Cbn Tool
14	B. Singarvel Et Al.	En25 Steel	Cvd And Pvd Coated Carbide Tools	Cutting Speed, Feed Rate, Doc, Coated Tool	Surface Roughness, Cutting Force, Mrr	Cutting Speed, Coated Tool
15	D. Philip Selvaraj Et Al.	Aisi 304 Stainless Steel	Tic And Ticn Coated Carbide Tool	Cutting Speed, Feed Rate, Doc	Surface Roughness	Cutting Speed, Feed Rate

III. Conclusion

This paper attempts to provide review on research papers of optimization of process parameters of turning operation. It was observed that most of the researchers have taken the controllable parameters as spindle speed, depth of cut, feed and cutting speed while keeping the other parameters like tool signature, coating thickness of cutting tool, nose radius apart from the research. The common output factor are surface roughness, rate (TWR), Material Removal Rate (MRR) tool wear and cutting force. The result from this literature review is the surface roughness is highly dependent on cutting speed and feed rate while performing the operation while the least significant parameter is DOC.

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