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Current Emerging Trends in Optimization of Cutting Parameters in CNC Turning: A Review

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Abstract

The task of machining industries is chiefly concentrated on achieving high quality, in term of part/component surface finish, accuracy, increase the product life and high production rate with a more eco-friendly impact. It is necessary to change and upgrade existing technology and develop product which are fairly priced. Hence, it is necessary control the process parameter in any machining. The typical governable machining parameters for the CNC lathe machines are speed, feed, depth of cut which affect desired output like surface roughness, Metal Removal rate etc. These parameters can be optimized for certain response parameters by optimization techniques like Taguchi, Response surface methodology (RSM) etc. This paper presents a review on emerging trends in optimization of process parameters in CNC Turning.

1. Introduction

Turning is frequently used operation for metal cutting. In this operation, a single point cutting tool is fed into the workpiece which is rotating about its axis, cutting unwanted material and desired part is created. Turning can be done on internal as well as external surfaces in order to produce an axially symmetrical part. As shown in figure 1 Turning operation is a form of material removal or machining process used to create parts by cutting unwanted material from the workpiece. Turning process involves lathe, workpiece or job, cutting tool and fixtures. In this process, the workpiece is fixed with help of fixture, which is in turn attached to the lathe machine. A single point cutting tool is used which is secured inside the machine and is fed into the workpiece rotating at high speeds thus producing desired product by cutting away extra material in form of small chips.

Surface texture is concerned with the geometric irregularities. The quality of a surface is an important factor in estimating the productivity of machine tool and machined parts. The surface roughness of machined parts has a significant effect on some functional attributes of parts such as wearing, contact causing surface friction, ability of distributing, light reflection, and also holding a lubricant, load bearing capacity, coating and resisting fatigue. In manufacturing industries, manufacturers are observant on the quality and Productivity of the product. Surface Roughness is quantified by vertical deviations of a real surface from an ideal surface. If these deviations are large then the surface is rough and if they are small then surface is smooth. There are many factors which affect the surface roughness i.e. cutting conditions, tool variables and work piece variables. Cutting conditions include speed, feed and depth of cut and also tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. and work piece variable include hardness of material and mechanical properties. It is very difficult to take all the parameters that control the surface roughness for a particular process. In a turning operation, it is very difficult to select the cutting parameters to achieve the high surface finish. The very intention of Taguchi Parameter Design is to boost the performance of a naturally variable production process by modifying the controlled factors. Factors that affect the surface roughness the most are found out to be feed, cutting speed and depth of cut.

Feed rate - It is the relative velocity at which the cutter is advanced along the workpiece, measured in mm per revolution

Cutting speed- Cutting Speed is defined as the rate that the material moves past the cutting edge of the tool, irrespective of the machining operation used. It is measured in surface feet per minute.

Spindle speed – Spindle speed is the speed in revolutions per minute of the spindle and the work piece. The spindle speed is basically the cutting speed divided by the circumference of the work piece where thw cut is to be made. That means for maintaining a constant cutting speed, spindle speed must vary based on the diameter of the cut.

Depth of cut - The thickness of workpiece removed while being machined is known as depth of cut. A lower feed rate will be required in case of a large depth of cut , otherwise it will reduce the tool life due to high load on tool.

Nose Radius - Nose Radius makes the finish of the cut smoother by overlapping the previous cut and eliminating

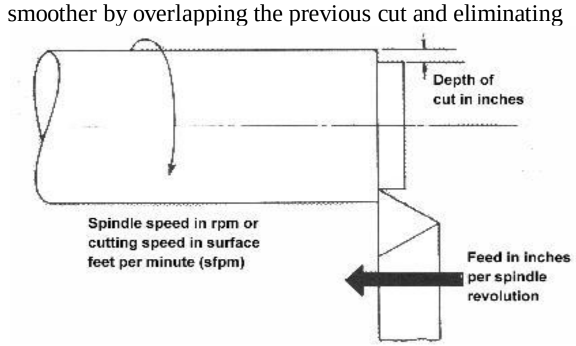

Fig: 1 Turning Process

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the peaks and valleys that a pointed tool produces. Nose radius also strengthens the tip, as a sharp point is quite fragile.

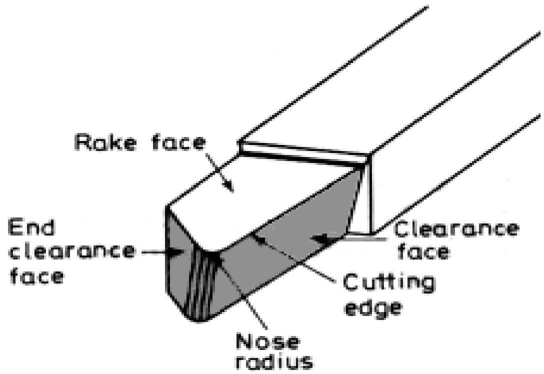

Fig: 2. Tool Geometry

2. Conventional Optimization Techniques

Conventionally, the machine operator selects the cutting conditions. It is very difficult to obtain optimum value in this case so experience of operators has a major role to play. Feed rate, depth of cut and cutting speed are major parameters of the process of turning. Quality of turned parts is determined by setting of these parameters. Taylor's tool life equation and other experimental and analytical approaches are used to investigate the optimization of machining parameters.

3. Modern Optimization Techniques

3.1 Genetic Algorithm (GA)

These are the algorithms that depend on mechanics of natural genetics and natural selection, which are likely to locate optimum value. Due to this feature GA goes through solution space starting not from a single point instead from a group of points. In optimization of machining parameters the cutting conditions are encoded by binary encoding to apply GA. The basic mechanisms in GA, such as mutation and crossover are performed by chromosomes which are formed by the combining set of genes. Crossover is the operation to generate new offspring by exchanging some part of two chromosomes, which is important to rapidly explore the whole search space. After crossover, mutation is applied to the new chromosomes to provide a small randomness. The cutting conditions encoded were decoded from the chromosomes to evaluate each chromosome which is used to predict machining performance measures. Selection of next generation and optimization process is performed by fitness or objective function. Values of objective functions are compared to obtain optimum results of cutting condition after a number of iterations. To operate efficiently appropriate parameters of GA are required apart from weighting factors and constraints. To provide optimum cutting conditions set of machining performance constraints and GA parameters along with relevant objective functions are imposed on GA optimization methodology.

3.1.1 Implementation of GA

The variables are encoded as chromosome strings assigned in a row as n-bit binary numbers. Penalties are given for implementing constraints in GA, to individuals out of constraint. Zero fitness will be assigned to an out of constraint individual. Because, Zero fitness individuals cannot become parents as fitness value is used in the selection of individuals. The possibility of being parents is greater for a large fitness value.

3.2 Taguchi Technique

Genichi Taguchi was a Japanese engineer who developed the philosophy and the methodology for quality improvement of process or product which depends mostly on statistical concepts and tools. Taguchi methods involves the parameter design, quality loss function, tolerance design, design of experiments using orthogonal arrays, on-line quality control, and methodology applied for evaluating measuring systems. There are two separate aspects of the Taguchi methods: the tactics of Taguchi and the strategy of Taguchi. Taguchi tactics is basically the collection of specific techniques and methods used by Taguchi, whereas Taguchi strategy is the conceptual structure or framework for planning a process or product design experiment. Taguchi addresses off-line (design and engineering) as well as on-line (manufacturing) quality. This fundamentally differentiates TM. Taguchi's ideas can be distilled into two fundamental concepts: 1) High system-quality levels can be achieved economically by designing quality into the product. 2) Deviations from targets must be defined as quality losses, not conformance to arbitrary specifications. Quality is measure of deviation of the functional characteristic from its final value. Uncontrolled variables (noises) can result in loss of quality because they cause such deviations. Effect of noises can be reduced by this method. The main element for achieving high quality and low cost is parameter design through which levels of process and product factors are determined resulting in minimization of effect of noise factors and optimization of the product's functional characteristics.

3.3 Fuzzy Logic

Fuzzy logic captures human decision making, commonsense reasoning and some aspects of human cognition. The limitations of classic logical systems can be overcome. This logic reduces vagueness in the constraints and coefficients. New way opens up by modelling of fuzzy logic to optimize tool selection and cutting conditions

3.3.1 Methodology

This logic involves a fuzzification-defuzzification module and a fuzzy interference engine. Governing rules in linguistic form, are formed on the basis of experimental observations, such as if machining time is high and cutting force is high, then tool wear is high. Inference on output grade and membership value can be drawn on the basis of each rule. Final decision can be drawn by combining inferences obtained from various rules. True value can be obtained by defuzzification of the membership values obtained using various techniques.

3.4 Grey Relational Method

In the Grey relational analysis (GRA) the quality characteristics are normalized first, between the ranges zero to one. Then to represent the relation between the actual and the desired experimental data the Grey Relational Coefficient (GRC) which is based on normalized experimental data is calculated. After this by averaging the GRC corresponding to selected responses overall Grey Relational Grade (GRG) is determined. This calculated GRG is then used for overall performance characteristic of the multiple response process. This approach, thus changes the multiple response process optimization problem into a problem of optimization of single response. The highest GRG results from the evaluation of optimal parametric combination.

3.5 Response Surface Method

A simple way for estimating a first-degree polynomial model is to utilize a fractional factorial design or a factorial experiment. This is enough to determine which variables have an impact on the desired response variables. Once it is verified that only important explanatory variables are left, and then a design such as a central composite design can be used to estimate a second-degree polynomial model. However, the second-degree model can be used to minimize, maximize, or attain a specific target for.

4. Literature Review

Upinder Kumar Yadav et. al. [1] by the help of Taguchi method have optimized the machining parameters for surface roughness in CNC Turning. They used Medium Carbon Steel (AISI 1045) of Ø: 28 mm, length: 17 mm for the turning experiments in their study. There are a variety of applications of AISI 1045 in vehicle component parts & machine building industry. In high speed turning of medium carbon steel in dry conditions surface roughness is the main quality function. In their study, they inspected the effect and optimization of machining parameters on surface roughness .They used an L-27 orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance (ANOVA) in their study. Experiments are done on STALLION-100 HS CNC lathe and they used three levels of machining parameters. They concluded that feed rate is the most significant factor affecting surface roughness is feed rate followed by depth of cut and cutting speed is the least significant factor. Harisk Kumar et. al. [2] conducted experiments using CNC lathe machine under dry condition on MS 1010 by HSS tool. Speed, feed and DOC were taken as the input parameters and surface roughness as output parameter for analysis. The data was analysed using Taguchi methodology and ANOVA. They found that for speed to be the most significant parameter for surface roughness and DOC the least significant parameter for MS 1010. M. Kaladhar et.al.[3] optimized machining parameters such as cutting speed, depth of cut, feed and nose radius in turning of AISI 202 austenitic stainless steel with the help of CVD coated cemented carbide tools and their effect on the surface roughness (Ra) was explored. Full factorial design was used for conducting the experiment on CNC lathe. Further, for analyzing the effect of process parameters and their synergy during machining the analysis of variance (ANOVA) was taken into account. It was observed from the analysis that the most significant factor influencing the surface roughness is feed followed by nose radius. Generation of prediction model for surface roughness was also attempted and validation experiments were carried out to confirm the predicted values. M. Kaladhar et. al. [4] conducted experiments for turning AISI 304 austenitic stainless steel. They used Physical Vapour Deposition (PVD) coated inserts at four levels (Speed, feed, DOC and nose radius) of cutting parameters. They utilised Taguchi and ANOVA approach. They took L16 mixed array for analysing the data .They took MRR and surface roughness as responding parameters found that the most significant parameter for surface roughness is feed followed by nose radius and for MRR the most significant parameter is DOC and followed by feed. They predicted the optimal range of Ra and material removal rate at 95% confidence level and also developed the regression model for surface roughness.

M. Kaladhar et. al. [5] have used AISI 304 austenitic stainless steel for their experiments and used Chemical Vapour Deposition (CVD) coated cemented carbide Duratomic cutting insert at four levels (Speed, feed, DOC and nose radius) of cutting parameters and employed Taguchi technique for determining the optimal levels of process parameters and ANOVA approach to determine which process parameters are most significant. They utilised L16 mixed array for the analyzing the data and cutting speed comes out to be the most significance variable superseded by nose radius for surface roughness. In case of MRR, the most significant one is the depth of cut followed by the feed. M. Nalbant et. al. [6] have studied the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools by taking into account the signal-to-noise ratio, orthogonal array, and annova. Three parameters namely nose radius, depth of cut and feed rate were taken for optimizing the surface roughness. L9 orthogonal array was used by them for the study. They found the percent of contributions of feed rate, insert radius and D.O.C. for surface roughness to be 48.54, 46.95 and 3.39, respectively. Ilhan Asilturk et. al. [7] investigated the effects of process parameters like depth of cut, feed and cutting speed on Surface roughness (Ra and Rz) in turning of AISI 4140 with coated carbide cutting tools. They used L9 orthogonal array of the Taguchi method for the optimization of surface roughness and used nine experimental runs. It's been seen that the feed rate has the most effect on Ra and Rz. A model is developed that can be used in order to determine the optimum cutting parameters for minimum surface roughness in the metal machining industries. Aman Aggarwal et. al. [8] suggested that there are a number of parameters like depth of cut, feed rate, cutting speed, nose radius and cutting environment which effects in power consumption in CNC turning of AISI P-20 tool steel. They used L27 orthogonal array and face cantered central composite design conducting the experiments and utilised Design of experiment techniques, response surface methodology (RSM) and Taguchi's technique in analyzing the data. The cryogenic environment emerges to be the most significant factor in minimizing power consumption followed by depth of cut and cutting speed as shown by the 3D surface plots of RSM as well as by Taguchi's technique.

Anand S. Shivade et al. [9] carried out experiments for single response optimisation for turning based on L9 orthogonal design of Taguchi's method. The experiments were conducted on EN8 Steel. The optimisation of surface roughness and tool tip temperature by single point carbide cutting tool using Taguchi parameter design was the main investigation and optimum combination for both surface roughness and tool tip temperature were found out. For analyzing the effect of process parameters during turning operation ANOVA (Analysis of Variance) was used. M. Kaladhar et. al. [10] worked to find an experimental investigation of effects of speed, feed, depth of cut, and nose radius on surface roughness (Ra) and material removal rate (MRR) during turning of AISI 202 austenitic stainless steel with a CVD coated cemented carbide tool. Taguchi's L8 orthogonal array (OA) served as a tool of experimental planning. They found that the most significant parameter for surface roughness is feed followed by nose radius and for MRR it is DOC followed by cutting speed. JitendraVermaet. al. [11] have experimented on ASTM A242 type-1 ALLOY steel of 250 mm long with 50 mm diameter of material using a CNC lathe machine. Taguchi and ANOVA approach were used to analyze the data. They concluded that speed with 57.47% contribution is the most significant factor affecting surface roughness and followed by feed with 23.46% contribution. Cutting speed was shown as the least significant factor affecting surface roughness. H. K. Dave et. al. [12] studied the effects of various machining parameters like inserts, work materials, speed, feed and DOC on different materials like EN-8 and EN-31 in CNC turning process using TiN coated cutting tools. They investigated the effects of the selected as machining parameters on surface roughness and MRR by using Taguchi L8 orthogonal array and ANOVA and showed that the depth of cut play significant role in producing higher MRR and insert has significant role to play for producing lower surface roughness. N.E. Edwin Paul et. al. [13] conducted experiments based on L9 orthogonal array on EN8 material using CNC Lathe. EN8 has high surface hardness and thus it is used for making gudgeon pins, gears etc. For the purpose of analyzing the data signal to noise ratio and ANOVA was the tool. The results showed that feed has greater influence on the surface roughness followed by the cutting speed. They proved that the determined optimal combination of machining parameters satisfy the real requirements of machining operations in the facing of EN8 materials. Hari Singh et. al. [14] experimented to get an optimal value of feed force by optimizing setting of turning process parameters (cutting speed, feed rate and depth of cut) in machining EN24 steel with TiC-coated tungsten carbide inserts. EN24 is medium-carbon low-alloy steel which has its applications in the manufacturing of automobile and machine tool parts. L27 orthogonal array was used in the experiments. They found that the percent contributions of cutting parameters in affecting the variation of feed force and showed that depth of cut(55•15 %) and feed rate (23•33 %) are significantly larger as compared to the contribution of the cutting speed (2•63 %).

Jakhale Prashant et. al. [15] have checked the effect of cutting parameters (cutting speed, feed rate, depth of cut) and insert geometry(CNMG and DNMG type insert) on surface roughness in the high turning of alloy steel (280 BHN). The experiments have been conducted using L9 orthogonal array and by using the statistical methods of signal-to-noise (S/N) ratio the optimum cutting condition was determined whereas the significance of cutting parameters and insert type on surface roughness were evaluated by the analysis of variance (ANOVA). They found DOC to be the most significant parameter which affects the surface finish followed by cutting speed and feed rate is the least significant parameters. Krishankant et. al. [16] experimented for the optimization of turning process by the effects of three turning parameters i.e. Spindle speed, Feed rate and Depth of cut. They applied Taguchi Methods for the experimentation to optimize the Material Removal Rate. They used bars of diameter 44mm and length 60mm. They designed Taguchi orthogonal array with the help of software Minitab 15 with three levels of turning parameters. Signal-to-noise ratio was used for studying the response variation which results in minimization of quality characteristic variation due to uncontrollable parameter.

They found out that a greater S/N ratio corresponds to a better performance regardless of the category of the performance characteristics and thus the level with greatest value is the optimal level of the machining parameters. Durai Matinsuresh Babu et. al. [17] experimented to obtain results for selecting appropriate cutting parameters which ensure less consumption of power in high tare CNC machines. Experiments were conducted with cutting speed, feed rate and depth of cut as process parameters on a CNC lathe with an extruded aluminium shaft using Taguchi's technique.L9 orthogonal array is used for conducting the experiments and data was analyzed by S/N ratio. It was observed from the study that the feed rate and the depth of cut are the factors which have a great influence on the energy consumption in high tare CNC machines. Srinivas Athreya et.al. [18] used Taguchi Method for optimizing the process parameters and improving the quality of components manufactured. They employed the orthogonal arra, signal to noise ratio and the analysis of variance in studying the performance characteristics on facing operation. Speed, feed and depth of cut were the three factors considered. The results of the experiments were compared with the results of the full factorial method. It's been illustrated that Taguchi's Method of parameter design provides a simple, systematic, and efficient methodology for optimizing the process parameters and yields similar results in lesser number of experimentation than that of full factorial analysis.Upinder Kumar et.al. [19] Investigated the optimization of two response parameters namely, Surface Roughness and Material Removal Rate , by three machining parameters which are cutting speed ,feed rate and depth of cut in high speed turning of AISI 1045 in dry conditions. Individual optimization is achieved by using Taguchi's L'9 orthogonal array and analysis of variance (ANOVA). Grey Relational Analysis approach is used for the simultaneous optimization. It is shown that the Grey relational based Taguchi method enhances the performance characteristics of the turning operations and the optimization of the complicated multiple performance characteristics of the processes can be greatly simplified by using this method. Yacov Sahijpaul et al. [20] anlysed the effect of feed, depth of cut, cutting fluid concentration , two cutting fluids having different base oils and cutting speed on surface roughness of AISI 1040 steel in turning operation. They used cutting design method, design of experiments, leverage plots, variance analysis and desirability profiling with the help of JMP software for the purpose of optimizing surface roughness in wet CNC turning. Feed rate was revealed to be the most important significant parameter effecting surface roughness and that the two different cutting fluids does not significantly effect the surface roughness was also found out. Vikas B. Magdum et.al.[21] used EN8 steel in their experiments to study for optimization and evaluation of machining parameters for turning on Lathe machine. They estimated optimum performance characteristics and the use of tool materials and process parameters for machining forces were investigated for selected parameter range. A methodology for optimization of cutting forces and machining parameters was also developed.

T. I. Ogedengbe et.al.[22] studied the significance of careful selection of optimum complexity for lathe produced jobs and further determined the effects of varying job parameters on release time of jobs. The parameters which are the salient factors on which the release time of jobs is subjected to include complexity of job, material and length of job, and depth of cut. Linear, exponential, polynomial, logarithmic, and power regression were used to examine correlation and it was observed that job complexity, depth of cut, and length of job have comparative effects on the release time of jobs produced on lathe machine. Ashish Yadav et. al.[23] have investigated the relation between different machining parameters like spindle speed, feed and depth of cut and the change in hardness caused by these parameters on the material surface during the turning operation of EN8 metal with coated carbide as the tool material. Taguchi method was utilized for planning the experiments whereas Rockwell scale was used to measure the hardness after turning. The obtained experimental data has been analyzed with the help of signal-to-noise (S/N) ratio and also the calculation of percentage contribution of various process parameters affecting hardness was carried out. . Mihir Patel et al. [24] experimented on CNC turning center and turned E250 B0 steel material with CVD (Chemical Vapour Deposition) coated inserts of cemented carbides. Process parameters choosen were speed, feed, depth of cut and nose radius, and their effect on boring operation were investigated. L16 orthogonal array with an applied noise factor was utilized for the purpose of determining optimum parameters and for the purpose of analysing Excel and Minitab 16.0 software were utilized. Speed , nose radius and feed were concluded to be the most significant parameters. Regression analysis helped in the accomplishment of mathematical modelling and for predicating surface roughness.

N. Ganesh et al. [25] conducted experiments on EN 8 steel using cemented carbide tool. They focused to find optimum cutting parameters such as Spindle Speed, Feed and Depth of cut to improve performance on machining time and surface roughness. There work also focuses on CNC turning for varying Spindle speed, feed and depth of cut. Their experiment was designed to for Second Order linear model using Response Surface Method (CCD). The optimization was carried out using Genetic Algorithm (GA). They predicted that GA is best modeling as it learns the best fit of even linear models. Mittal P. Brahmbhatt et al. [26] by the help of Taguchi Method have optimized the cutting parameters for surface roughness in CNC Turning. They used Hardened Steels for the turning experiments in their study. The effect of cutting parameters on surface roughness, tool wear and cutting force were analyzed. It was found in the study that for surface roughness and cutting force, feed rate is the most significant factor and for tool wear, cutting speed is most significant factor. Also found that Taguchi method provided simple, systematic and efficient methodology for optimization for turning operation. Madhav Murthy et al. [27] investigated the effect of various cutting parameters which were feed, spindle speed, depth of cut and tool nose radius on surface finish of A16061 aluminium alloy. They selected L16 orthogonal array which was based on Taguchi method of design of experiments for conducting their experiments on the material on CNC Lt-16 turner using carbide tipped tool. ANOVA was used for analysing the results and for predicting the surface roughness the regression equation was developed. The conclusion given by them was that the most important factor in influencing the suface roughness is feed and the other factors are not that significant.

Taquiuddin quazi et al. [28] optimized surface roughness of mild steel , EN-8 and EN-31 in turning utilizing Taguchi methods with parameters being cutting speed (200, 250, and 300 m/min) , feed rate (0.08, 0.12 and 0.15 mm/rev), depth of cut (0.5 mm) whereas tool grades being TN60, TN0500 and TT8020. Standard L9 orthogonal array was used to carry out the experiments. The results emerged out were that in comparison with full factorial design the Taguchi method is more suitable for solving the stated problem by minimum trials.

Table: 1. Summary of Review Papers

S. No.	Year	Author's Name	Material	Input Parameter	Output Parameter	Method	Most Significant
1.	2012	Upinder Kumar Yadav et al	Med. Carbon steel AISI 1045	Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Feed ,Speed
2.	2013	Harish Kumar et al	MS 1010	Speed Feed DOC	Surface Roughness	Taguchi and ANOVA	Speed, Feed
3.	2010	M. Kaladhar et al	AISI 202 Austenitic Stainless Steel 300 series 200 Series	Speed, Feed, DOC Nose Radius	Surface Roughness	Full Factorial ANOVA	Feed, Nose Radius

4.	2012	M. Kaladhar et al	AISI 304 Austenitic Stainless Steel	Speed, Feed, DOC, Nose Radius	Surface Roughness	Taguchi and ANOVA	Feed, Nose Radius
5.	2012	Jitendra Verma et al	ASTM A242 Type-1 Alloy Steel	Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Speed, Feed
6.	2007	M. Nalbant et al	AISI 1030 Steel bar	Nose Radius, DOC, Feed	Surface Roughness	Taguchi and ANOVA	Nose, Radius Feed
7.	2011	Ilhan Asilturk et al	AISI 4140 (51 HRC)	Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Feed DOC
8.	2008	Aman Agrawal et al	AISI P-20 tool Steel	Speed, Feed, DOC, Env., Nose Radius	Power Consumption in different conditions	Taguchi and RSM	Envi. Speed
9.	2014	Anand S. Shivade et al	EN 8 Steel	Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Speed, DOC
10.	2011	M. Kaladhar et al	AISI 202 Austenitic Stainless Steel	Speed, Feed, DOC, Nose Radius	Surface Roughness	Taguchi and ANOVA	Feed Nose Radius
					MRR		DOC Speed
11.	2012	M. Kaladhar et al	AISI 304 Austenitic Stainless Steel	Speed, Feed, DOC, Nose Radius	Surface Roughness	Taguchi and ANOVA	Speed Nose Radius
					MRR		DOC Feed
12.	2012	H. K. Dave et al	EN -8, EN-31	Tool, Work Material, Speed, DOC, Feed	Surface Roughness	Taguchi and ANOVA	Tool DOC
					MRR		DOC Tool
13.	2013	N. E. Edwin Paul et al	EN8 Steel	Speed Feed DOC	Surface Roughness	Taguchi and ANOVA	Speed Feed
14.	2006	Hari Singh et al	EN24 steel	Speed, Feed, DOC	Force	Taguchi and ANOVA	DOC ,Feed
15.	2013	Jakhale Prashant et al	High Alloy Steel (280 BHN)	Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	DOC, Speed
16.	2012	Krishankant et. al	EN24 steel	Speed, Feed rate, DOC.	MRR	Taguchi	347 RPM 0.458 mm/rev. 1.1 mm
17.	2012	Durai Matinsuresh Babu et. al.	Aluminium	Speed, Feed, DOC	Power consumed (energy)	Taguchi and ANOVA	Feed,DOC

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18.	2012	Srinivas Athreya et.al.	Mild Steel	Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Speed , DOC
19.	2013	Upinder Kumar et.al.	Medium Carbon Steel AISI 1045	Speed, Feed, DOC	Surface Roughness MRR	Taguchi , ANOVA and Grey Relationa l ,	V-188m/min F-0.1 mm/rev, D-1.5 mm
20.	2013	Yacov Sahijpaul et al	AISI 1040	Cutting Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Feed, Cutting Speed
21.	2013	Vikas B. Magdum et.al	EN8 steel	Tool shape and Material Speed, Feed, DOC	Cutting Forces	Taguchi	A2-Carbide, B2-384m/min, C1-05mm, D1-0.065mm/rev
22.	2013	T. I. Ogedengbe et.al	Different Jobs	Complexity of Job, Material, Length, DOC	Release Time of Jobs	Regression Analysis	Job complexity, DOC
23.	2012	Ashish Yadav et. al	EN8	Speed Feed DOC	Hardness	Taguchi and ANOVA	S-1950rpm F-.45mm/rev D-1mm
24.	2014	Mihir Patel et al	E 250 BO	Speed, Feed, DOC, Nose Radius	Surface Roughness	Taguchi and Regression Analysis	Speed, Feed
25.	2014	N. Ganesh et al	EN-8 Steel	Spindle Speed, Feed, DOC	Surface Roughness	RSM and GA	Speed, Feed
26.	2014	Mittal P Brahmbhatt et al	Hardened Steel	Cutting Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Feed, Speed
27.	2014	Madhav Murthy et al	Al6061 aluminum alloy	Speed, Feed , DOC	Surface Roughness	Taguchi and ANOVA	Feed, Speed
28.	2014	Taquiuddin Quazi et al	EN 8 & EN 31	Speed, Feed, DOC	Surface Roughness	Taguchi and ANOVA	Speed, Feed

5. Conclusion

A review of literature shows that various traditional machining optimization theories have been successfully applied in the past for optimizing the various machining process variables. Fuzzy logic, genetic algorithm and Taguchi technique are the latest optimization techniques that are for optimal selection of process variables in the area of machining. In the recent optimization technique Taguchi methods is latest design techniques widely used in industries for making the product/process insensitive.To any uncontrollable factors such as environmental variables. Taguchi approach has potential. The further review reveals that very less work is done on En-8 Steel which has a wide range of applications in making gudgeon pins, shafts, Gears, Keys etc. Thus, the Review on optimization of cutting parameters for different response parameters has been presented.

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