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Optimization of Turning Process Parameters by Different Optimization Technique- A Review

Mihir Thakorbhai. Patel[1], Himanshu C. Mevada[2]

[1]*Mechanical Engineering Department, B & B Institute of Technology,*
[2] *Mechanical Engineering Department, B & B Institute of Technology,*

Abstract — *In this paper an attempt is made to review the literature on optimizing the process parameters for different quality parameters in lathe processes by using different analyzed tools like ANOVA, Taguchi, Genetic algorithm, neural network, response surface methodology etc. The latest techniques for optimization include fuzzy logic, scatter search technique, ant colony technique, genetic algorithm, Taguchi technique and response surface methodology which are being applied successfully in industrial applications for optimal selection of process parameters for required quality parameters. Taguchi methods and ANOVA combined approach are widely used for solving the process parameters problems for different quality parameters. Multi optimization is also important to solve multiple objective functions. The selection of process parameters are also important and may vary according to different performance/quality parameters.*

Keywords- *ANOVA, Multi optimization, Optimization, Performance parameters, Process parameters, Quality parameters, Taguchi, Turning.*

I. INTRODUCTION

The main function of lathe is to remove metal from work piece and obtained required kind of shape and size. This is accomplished by holding the work piece securely and rigidly on the machine and then fed the tool against the work and obtained required work surface by removing metal in form of chip. The tool must be harder than the cutting work material.

The main function of lathe is turning. Turning is the removal excess material form the work piece to produce a cone shaped or a cylindrical surface[21]. The various types of turning operations are

- Straight turning
  - Tough turning
  - Finish turning
- Taper turning

In a competitive environment every industries are trying to decrease the cutting cost and increased the quality of machined parts/components. The objective of this research is to study the effect of process parameters like cutting speed, feed, depth of cut, machining time on quality/performance parameter like metal removal rate, power consumption, surface roughness, flank wear, cutting cost etc. In the lathe machine, determining optimum cutting conditions or parameters under the given machining situation is challenging in practice. Conventional way for selecting these conditions such as cutting speed and feed rate has been based upon data from machining handbooks and/or on the experience and knowledge of the part of programmer. As a result, decrease in productivity due to sub optimal use of machining capability this cause high manufacturing cost and low product quality. So, optimization of process parameters for given performance parameters are important. This paper also gives the broad ideas of the various optimization techniques used to optimize the process parameters.

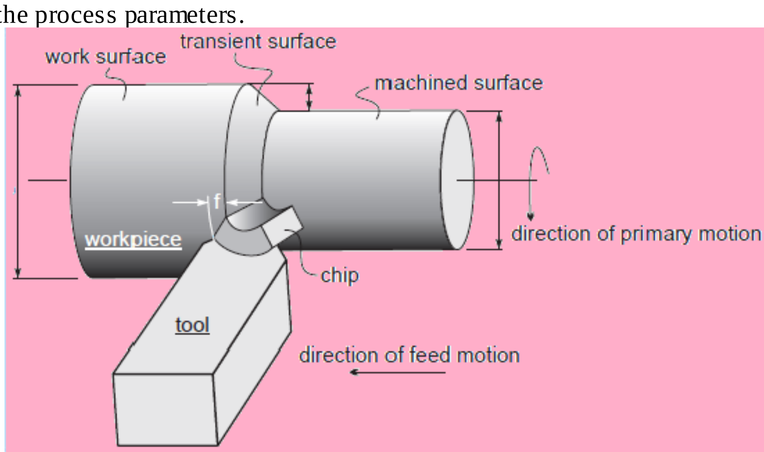

Figure 1 Turning Process

II. WORK PIECE MATERIAL

In manufacturing industries there are wide varieties of work piece are used for different application. The main work materials used in manufacturing industries are Mild steel, Aluminum, Brass, Alloy steel, Cast iron, Ferritic steel, Non ferrite steel etc.

III. TOOL MATERIAL

The selection of tool material depends on types of services to which the tool is subjected. The main tool materials used in manufacturing industries are Carbon steel, Medium alloy steel, High speed steels, Cemented Carbides, Ceramics, Silicon Nitride, Cubic Boron Nitride (CBN), Diamond etc.

IV. FACTOR AFFECTING THE PERFORMANCE PARAMETERS

In order to identify the process parameters that effect on performance characteristics like surface roughness, material removal rate, tool wear, geometric tolerance, power consumption, vibration etc., the fish bone diagram help to identify which process affect the responding characteristics. So, cause and effect diagram/fish bone diagram/Ishikawa diagram helped for selection of process parameters. Here figure 2 represents the cause and effect diagram for the given quality characteristics for the given turned parts. The main process parameters for turned parts are [5]

- Cutting parameters: Speed, Feed, Depth of cut
- Cutting tool parameters: Tool geometry and tool material
- Work piece material: Hardness, Metallography
- Cutting environment: Wet, dry

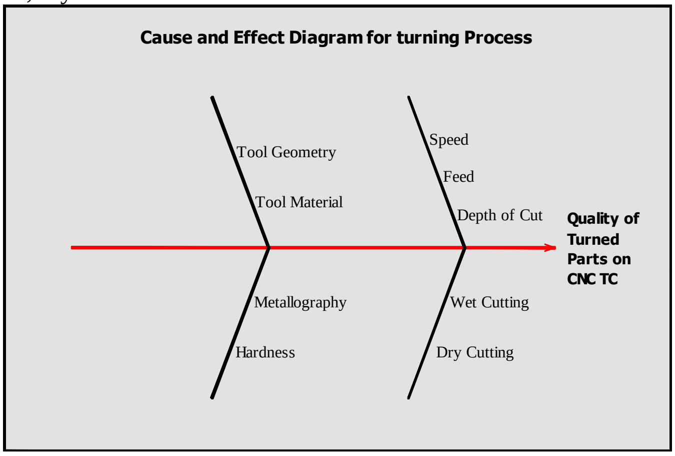

Figure 2 Cause and effect diagram for required quality parts to turned

V. OPTIMIZATION TECHNIQUES

The latest techniques for optimization are fuzzy logic, scatter search technique, ant colony technique, genetic algorithm, Taguchi technique and response surface methodology, artificial neural network, particle swan optimization, grey relation analysis.

A. Genetic Algorithm: Genetic Algorithms (GA) are search algorithms based on the mechanics of natural selection and natural genetics [2]. Specifically, GA simulates the biological processes that allow the consecutive generations in a population to adjust to their environment. The adaptation process is mainly applied through genetic inheritance from parents to children and through survival of the fittest. Therefore, GA is a population-based search methodology [5]. The steps of Genetic algorithm are [22]:

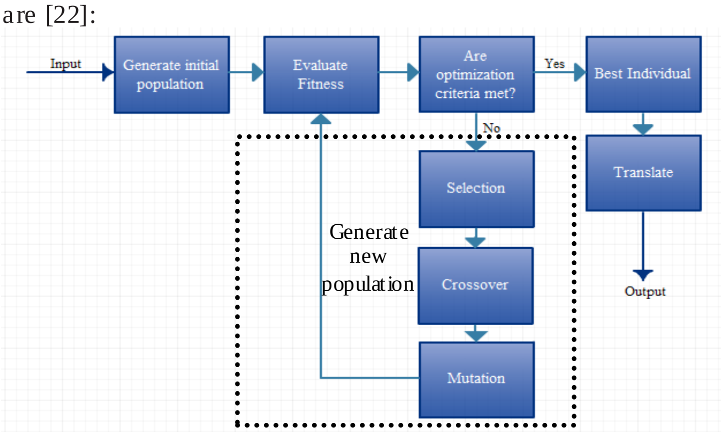

Figure 3 Genetic algorithm

B. Grey Relation Analysis:
The grey relation analysis used to investigate the influence of different machining parameters such as cutting speed, feed, depth of cut, nose radius etc. on different performance measures. The step involved in grey relation analysis described below[17]:
1. Normalizing the experimental results of number of quality parameters all the trials.
2. Performing the Grey relational generating and to calculate the Grey relational coefficient.
3. Calculating the Grey relational grade by averaging the Grey relational coefficient.
4. Selecting the optimal levels of process parameters.
5. Conduct confirmation experiment and verify the optimal process parameters setting.

C. Taguchi Approach: Taguchi suggested that engineering optimization of a process or product should be carried out in a three-step approach i.e., system design, parameter design, and tolerance design. Taguchi method gives a special design of orthogonal arrays to study the entire parameter space with a small number of experiments. Taguchi recommends the use of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is further transformed into a signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristic in the analysis of the S/N ratio, those are, the lower-the-better, the higher-the-better, and the nominal-the-better [13]. The various steps involved in Taguchi methodology are [24]
1. Identify the main function, side effect and failure mode.
2. Identify noise factors and testing conditions for evaluating the loss function.
3. Identify the quality characteristics to be observed and objective function to be optimized
4. Identify the control levels and their factors
5. Design experimental matrix and define the data analysis procedure.
6. Conduct the experimental matrix.
7. Analyse the data, determine optimal levels for control factors and predict performance under these level.
8. Conduct the verification experiments and plan future action.

D. PSO Methodology
PSO technique was introduced by Kennedy and Eberhart to solve continuous optimization problems. The implementation of PSO is very simple and needs only a few lines programming code. It requires uncomplicated mathematical operators; therefore it is computationally economical in terms of both memory requirements and speed[24]. The PSO framework for process parameter optimization is depicted in Figure 4.

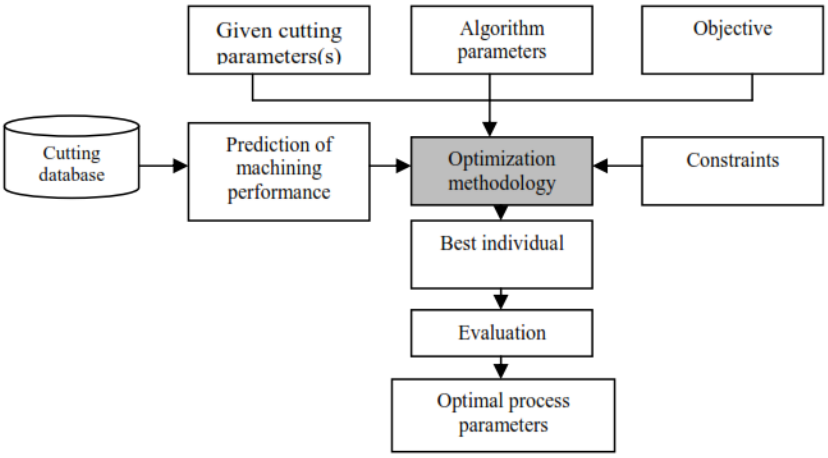

Figure 4 PSO framework for process parameters optimization [24]

E. Response Surface Methodology:
Response Surface Methodology is combination of mathematical and statistical technique [25], used develop the mathematical model for analysis and optimization. By conducting experiment trails and applying the regression analysis, the output responses can be expressed in terms of input machining parameters namely table speed, depth of cut and wheel speed. The major steps in Response Surface Methodology are[26]:
1. Identification of predominate factors which influences on performance parameters.
2. Developing the experimental design matrix, conducting the experiments as per the above design matrix.
3. Developing the mathematical model.
4. Determination of constant coefficients of the developed model.
5. Testing the significance of the coefficients.
6. Adequacy test for the developed model by using analysis of variance (ANNOVA).
7. Analyzing the effect of input machining parameters on output responses.

VI. LITERATURE REVIEW

A. Y. Mustafa And T. Ali were analyzed the data of cutting force, surface roughness, cylindricity and vibration by turning aluminum work piece on Jonford TC35 CNC lathe. Statically method of taguchi was used in this work in order to analyzed results data. They analyzed and investigated the effect of the length and diameter of working piece, cutting depth and feed on required performance parameters. They presented regression model of process parameters and performance parameters.

Abdelouahhab Jabri et al. were optimized two objective functions one was cutting cost and second was tool life. They proposed model deals multi-pass turning processes where the cutting operations are divided into multi-pass rough machining and finish machining. Results obtained from Genetic Algorithms method were presented in Pareto frontier graphic; this technique helps us in decision making process.

Aman Aggrawal et al. were found experimental investigation into the effect of cutting speed, feed rate, depth of cut, nose radius, and cutting environment in CNC turning if AISI P-20 tool steel. Design of experiment technique, Response surface methodology (RSM) and Taguchi's technique used for analyzed the results data. Taguchi's technique as well as response surface methodology reveled that cryogenic environment is the most significant factor followed by cutting speed and depth of cut. They also found that the effects of feed rate and nose radius were found to be insignificant compared to other factors.

Diwarkar Reddy et al. were carried out experiments on Mild steel material in dry cutting condition in a lathe machine and surface roughness was measured using Surface Roughness Tester. They compared of the experimental data and ANN results and conclude that there is no significant difference and ANN was used confidently. They also conclude that ANN was reliable and accurate method for solving the cutting parameter optimization.

Dorianana M. D' Addona at al. optimized based on Genetic algorithm for the determination of the cutting parameters in maching operation. The main advantage of proposed methodology was the capability to perform process optimization, minimum machining time while considering technological and material constrains. The results obtained from the simulation model have presented fast and suitable solution for selection of the machining parameters.

H.Ganesan and G.Mohankumar had presented multi objective optimization technique based on Genetic algorithm to optimize the cutting parameters in CNC TC. They used model Genetic algorithm in order to obtain the non-dominated sorting genetic algorithm (NSGA-2) and built the Pareto front graph.

H.M.Somashekara and Dr. N.Lakshmana Swmy have been investigated effect of process parameters (Cutting speed, Feed and Depth of Cut) on surface Roughness while machining Al 6351-T6 alloy with Uncoated Carbide Insert. They developed model to predict surface Roughness using regression analysis. Taguchi technique and ANOVA analysis were performed to obtain optimal sequence and significant factors influencing on Surface Roughness. They conclude form ANOVA and signal to noise ratio that speed has a greater influence on the surface roughness followed by feed. Depth of Cut had least influence effect on surface roughness.

Ilhan Aslilturk and Harun Akkus have optimized turning parameters for minimize surface roughness (Ra and Rz) using Taguchi method. They concluded that feed rate has the most significant effect on Ra and Rz. They also concluded that two factor interactions of the feed rate-cutting speed and depth of cut-cutting speed appear to be important. They found that surface roughness minimum at 120 m/min for the cutting speed, 0.18 mm/rev for the feed rate and 0.4 mm for the depth of cut.

J. S. Shenthilkumar et al. used Inconel 718 material as work piece which is widely used in aerospace industries. Cutting experiments were conducted as per full factorial design under dry cutting condition. They investigated the effects of process parameter (Cutting speed, feed and Depth of cut) on the quality measure (surface roughness and flank wear) for turning and facing operations. Confirmation test were conducted at an optimal condition to verified result. They studied the percentage error between experimental and predicted result was 8.69 % and 8.49 % in turning and facing process respectively.

Kalyanmoy Deb and Ritapurna Datta used evolutionary multi objective optimization (EMO) algorithm for analyzed results data. They suggested a heuristic –based local search procedure for a computationally faster approach in which the problem –specific heuristic are derived from an innovatization study performed on the EMO solution. In this paper author had dealt with couple of machining process and demonstrated the use of hybrid multi objective optimization algorithm in finding a set of well-converged trade-off compromised solution.

M. Kaladhar et al. have applied Taguchi method to determine the optimum process parameters for turning of AISI 304 austenitic stainless steel on CNC lathe. They conducted test at four levels of cutting speed, feed and depth of cut and two level of nose radius to investigate on the surface roughness and material removal rate (MRR). They used ANOVA to analyze the influence of cutting parameters during machining. The optimal combination of process parameters for minimum surface roughness was obtained at 150 m/min cutting speed, 0.15 mm/rev feed, 0.5 mm depth of cut and 0.8 mm nose radius. The optimal combination of process parameters for maximum surface roughness was obtained at 190 m/min cutting speed, 0.20 mm/rev feed, 2.0 mm depth of cut and 0.4 mm nose radius. They found that depth of cut is most contributing parameter for material removal rate and for surface roughness cutting speed is most contributing parameter.

M. Kaladhar et al. have optimized of machining parameters in turning of AISI 202 austenitic stainless steel using CVD coated cemented carbide tools. They performed full factorial design on Computer Numerical Control (CNC) lathe. ANOVA was used to analyze result data. They concluded that feed is the most significant factor for surface roughness followed by nose radius. They also concluded that good surface finish on AISI 202 steel at higher cutting speed, lower feed rate, lower depth of cut and higher nose radius.

M. Nalbant et al. have used Taguchi method to find an optimal process parameters for surface roughness on Johnford T35 CNC lathe using TiN coated tools. They used L_9 orthogonal array, the signal-to-noise ratio and ANOVA to study the quality characteristic in turning operation. They optimized three process parameters namely insert radius, feed rates and depth of cut with consideration of surface roughness. They conclude that Taguchi's robust orthogonal array design method is suitable to analyze the surface roughness problem and they concluded that use of greater insert radius (1.2 mm), low feed rate (0.15 mm/rev) and low depth of cut (0.5 mm) were recommended to obtain better surface roughness for the specific test range.

Mihir Patel et al. have investigated the effect of machining parameters like spindle speed, feed, depth of cut and nose radius on material removal rate and surface roughness. They used L_8 mixed orthogonal array. ANOVA and signal to noise ratio used for analyzed data. They used Aluminum Alloy – Al 6082 grade material. They concluded that the MRR was mainly affected by spindle speed and depth of cut and for surface roughness the least significant parameter was depth of cut.

Mihir Patel et al. selected E 250 B0 steel material and turned on CNC TC by using CVD coated cemented carbide insert of 0.8 mm and 1.2 mm. They investigated the effect of process parameters on responding quality parameter. They used Excel, Minitab software for analyzed data. They conclude that speed, nose radius, and feed were the most significant parameters for boring operation and its percentage contribution are 74.92, 11.09 & 11.12 respectively. They developed mathematical modeling and prediction of surface roughness by using regression analysis.

N. Zeelan Basha et al. have investigated effect of process parameters (spindle speed, Feed rate and depth of cut) in turning operation. They used Aluminum 6061 material and coated carbide as a tool for performing experiments. They developed Mathematical model using regression technique of Box-Behnken of Response surface methodology (RSM) in design expert 8.0 software and optimization carried out by using genetic algorithm in Matlab 8.0. They used genetic algorithm and determine optimal solution of different cutting conditions.

Shreemoy Kumar Nayak et al. have investigated the influence of different machining parameters such as cutting speed, feed and depth of cut on different performance measured (MRR, Cutting force and Surface roughness) on AISI 304 austenitic stainless steel. They used ISO P30 grade uncoated cemented carbide insert as a tool. They used L_{27} orthogonal array for experiments. They found that the optimal setting for multi objective parameters (MRR, Cutting force and Surface roughness) of machining parameters were Vc=45 m/mm, f=0.1mm/rev, t=1.25mm.

Suileman Abdulkareem et al. have investigated influence of machining parameters (depth of cut, feed rate and spindle speed) on surface roughness during turning of mild steel. They have optimized the machining parameters for effective machining of the work piece by using DOE. They use Box Behnken experimental design method and analyzed the result by ANOVA. They developed mathematical model correlating the influence of machining parameters on the surface roughness Ra during the machining process by using multiple linear regression. They found that the feed rate is to be most important parameter effecting surface roughness.

Upinder Kumar Yadav et al. used Medium Carbon steel AISI 1045 and investigated the effect of machining parameters on surface roughness. They used L_{27} orthogonal array for performing experiments and ANOVA and Taguchi method for analyzed data result. They investigate three levels of machining parameter and experiments were done on STALLION - 100 HS CNC lathe. They conclude that feed rate is the most significant factor affecting surface roughness followed by depth of cut. They also conclude that cutting speed is the least significant factor affecting surface roughness.

Uros Zuperl and et al. was proposed a neural network based approach to complex optimization of cutting parameters. They described multi objective technique of optimization of cutting condition by means of the neural network taking into consideration the technological, economic and organizational limitation. They concluded that neural network approach is more advantageous than interactive approaches. They presented future work of neural networks.

Table 1 Summary of different review papers

Ref. No.	Year of Publication	Author Name	Input Parameters	Quality Parameters	Tool used for Analysed data
1	2011	A. Y. Mustafa and T. Ali	Length, Diameter, Cutting Depth & Feed	Surface Roughness, Vibration accelration & Force	Taguchi
2	2013	Abdelouahhab Jabri, Abdellah El Barkany, Ahmed El Khalfi	Speed, feed & DOC	Operating time, Production cost & Tool wear	Genetic Algorithm
3	2008	Aman Aggarwal, Hari Singh, Pradeep Kumar & Manmohan Singh	Speed, feed & DOC	Power Consumption	Taguchi & RSM
4	2011	Diwakar Reddy.V, Krishnaiah.G, A. Hemanth Kumar and Sushil Kumar Priya	Speed, feed & DOC	Surface Roughness	Neural Networks
5	2013	Doriana M. D' Addona & Roberto Teti	Speed, feed & DOC	Production time & MRR	Genetic Algorithm
6	2013	H. Ganesan & G. Mohankumar	Speed, feed & DOC	Production Cost & Tool wear	Genetic Algorithm
7	2012	H.M.Somashekra & Dr. N. Lakshmana Swamy	Speed, feed & DOC	Surface Roughness	Taguchi & ANOVA
8	2011	Ilhan Asilturk & Harun Akkus	Speed, feed & DOC	Surface Roughness	Taguchi & ANOVA
9	2010	J.S.Senthilkumaar, P.Selvarani & RM.Arunachalam	Speed, feed & DOC	Surface roughness and Flank wear	Taguchi & ANOVA
10	2011	Kalyanmoy Deb and Rituparna Datta	Speed, feed & DOC	Surface Roughness, MRR, Force	Genetic Algorithm
11	2012	M. Kaladhar, K. Venkata Subbaiah & Ch. Srinivasa Rao	Speed, feed, DOC & Nose Radius	MRR, Surface Roughness	Taguchi & ANOVA
12	2010	M. Kaladhar, K. Venkata Subbaiah, Ch. Srinivasa Rao and K. Narayana Rao	Speed, feed, DOC & Nose Radius	Surface Roughness	ANOVA
13	2007	M. Nalbant, H.Gokkaya & G. Sur	Nose radius, DOC & Feed	Surface Roughness	Taguchi & ANOVA
14	2014	Mihir T. Patel & Vivek A. Deshpande	Speed, feed, DOC & Nose Radius	MRR, Surface Roughness	Taguchi & ANOVA
15	2014	Mihir T. Patel & Vivek A. Deshpande	Speed, feed, DOC & Nose Radius	Surface Roughness	Taguchi & ANOVA
16	2013	N.Zeelan Basha, G.Mahesh & N.Muthuprakash	Speed, feed & DOC	Surface Roughness	Genetic Algorithm
17	2014	Shreemoy Kumar Nayak, Jatin Kumar Patro, Shailesh Dewangan & Soumya Gangopadhyay	Speed, feed & DOC	MRR, Cutting Force & Surface Roughness	Grey Relational Analysis

Ref. No.	Year of Publication	Author Name	Input Parameters	Quality Parameters	Tool used for Analysed data
18	2011	Suleiman Abdulkareem, Usman Jibrin Rumah & Apasi Adaokoma	Feed, Cutting Speed and Spindle speed	Surface Roughness	ANOVA & RSM
19	2012	Upinder Kumar Yadav, Deepak Narang, Pankaj Sharma Attri	Speed, feed & DOC	Surface Roughness	Taguchi & ANOVA
20	2000	Uros Zuperl and Franc Cus	Speed, feed & DOC	Production Rate	Neural Networks

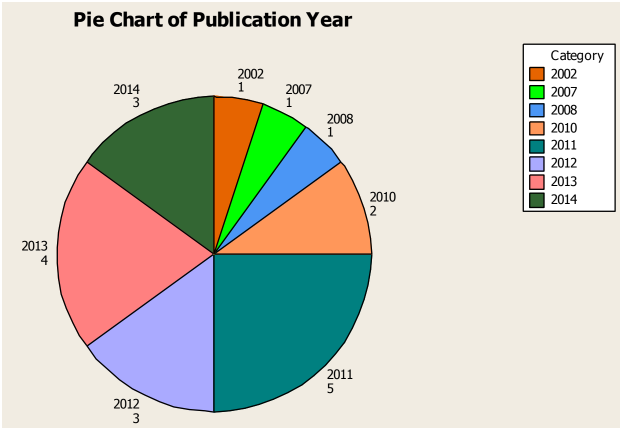

Figure 5 Pie chart of publication year with number of papers

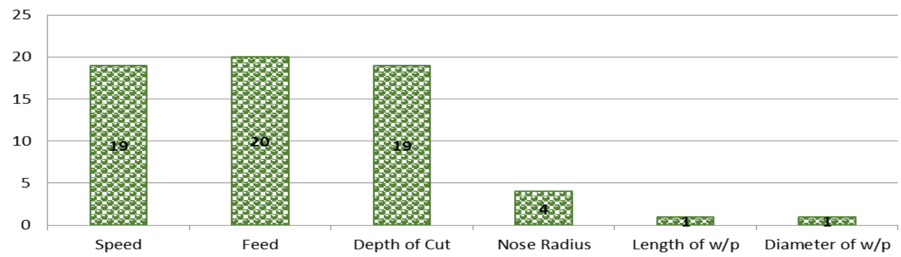

Figure 6 Process Parameters taken in different research paper

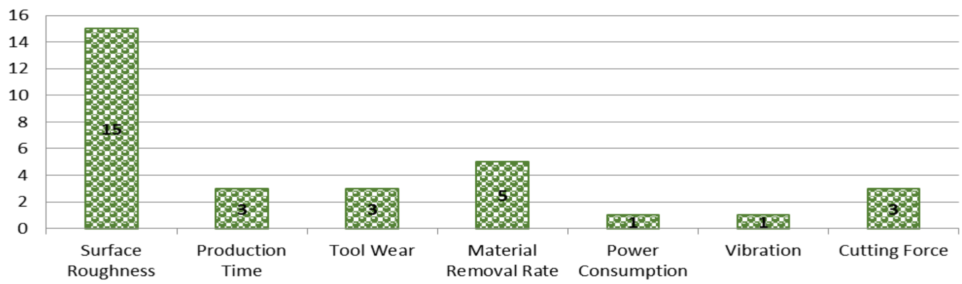

Figure 7 Performance/Quality Parameters taken in different research papers

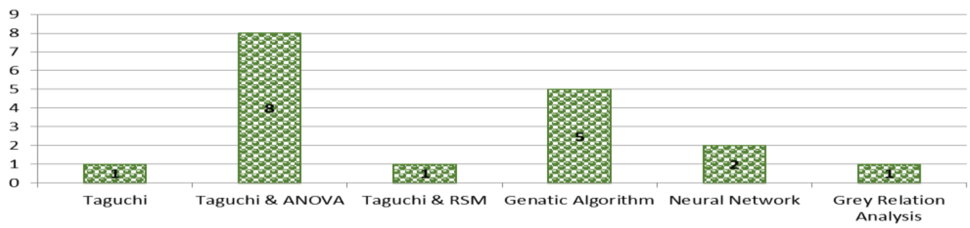

Figure 8 Analysis tool used in the Research Paper

VII. CONCLUSION

From the above research papers we concluded following points

- Most of the research people have taken speed, feed and depth of cut as input parameters. Speed, feed and depth of cut are the important parameters while studying the effects of process parameters on the required performance characteristics.
- Every research people tried to optimize the quality/performance characteristics according to problem taken. All performance characteristics are equally important according to industries problem.
- Taguchi combined with ANOVA are good methodologies to analyze the result data. Taguchi helps to determine optimal sequence and ANOVA technique helps to determine which parameters are most significant and their percentage contribution.
- Grey Relation analysis and Neural network are generally used for multi optimization.

VIII. COMMENT

- Few research people worked on performance characteristics like geometric tolerance, vibration acceleration, cutting force etc. They are also important characteristics while machining on the lathe machine.
- Taguchi and ANOVA combined tools show the good result and used for determining optimization sequence as well to determine which parameters have significant effect on required quality parameters.
- Multi optimization is also important techniques while optimizing more than two quality parameters and few research people worked on that.

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