Techniques and Tools Used in Optimization of Response Variables in CNC Lathe Turning of Aluminium 7075 Alloy: A Review

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Abstract: Turning at high speeds has emerged as a key manufacturing technology in machining of different metals and alloys. Turning at high speed is performed on the order of five to ten times the conventional cutting speed. It is advantageous in many ways like reduction in cutting forces and temperature, low power consumption, improvement in surface finish, high MRR, better dimensional accuracy and better part quality [1, 2]. In order to achieve the quality output, it is necessary to optimize the process parameters (like speed, feed, depth of cut, nose radius) during the high speed machining of alloy. The study applies Taguchi's design of experiment methodology and grey relational analysis to optimize the process parameters in turning aluminum alloy AA7075-T6 material, a high strength aluminum alloy used for aerospace application using coated carbide insert under dry environment condition and having four type insert nose radius such as 0.2, 0.4, 0.8, 1.2 mm. Experiment have been carried out based on L16 standard orthogonal array design with four process parameters namely cutting speed, feed rate , Depth of cut and nose radius for surface roughness and Material removal rate

Keywords - Turning, CNC lathe, Optimization, Taguchi , Grey

I. INTRODUCTION

The increase of consumer needs for better quality metal cutting related products in terms of more precise tolerance and better surface finish has driven the metal cutting industry to continuously improve quality control of the metal cutting processes. Surface Roughness quality is an important requirement of the finished work pieces in the machining operations. this parameter is of great importance in automotive, aerospace, die and mould manufacturing application.[3]. at the same time , higher material removal rate (mrr) is desired by the industries to cope up with mass production without sacrificing product quality in short span of time. higher mrr is achieved by optimizing the process parameters like cutting speed, feed and depth of cut.

A The Turning operation

Turning is the process of removing metal from outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to specify dimension, and to produce a smooth finish on the metal. Turning is the machining operation that produces cylindrical parts. [6]. In turning operation a high precision single point cutting tool is held rigidly at a tool post and is fed past a rotating work piece in a direction parallel to the axis of the rotation of the work piece at a constant rate, and unwanted material is removed which gives rise to a cylindrical or more complex profile [7, 8]. This operation is carried out in a lathe machine either manually under an operator's supervision, or by controlling program.

II.ADJIUSTABLE CUTTING PARAMETERS IN TURNING

A. Cutting speed:

Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply that product of the rotating speed times the circumference of the work piece before the cut is the stated. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same therefore rotating speed is taken as the optimization parameter in the present study [10, 16].

B. Feed:

Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power- fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (Of the spindle). or mm/rev [10, 16].

$$F_m = f.\ N \qquad \text{mm/min.} \qquad (1)$$

Here Fm is the feed in mm/minute, f is the feed in mm/rev and N is the spindle speed in RPM. [10]

C. Depth of cut

Depth of cut is practically self explanatory. It is the thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is important to note though that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work [10, 16].

$$D-d = 2 \times DOC \quad \text{in mm} \qquad (2)$$

Here D and d represent initial and final diameter (in mm) of the job respectively

D. Nose Radius

It is the rounded tip on the cutting edge of a single point tool. A zero degree nose radius creates a sharp point of the cutting tool. its value normally varies from 0.2mm to 1.2mm, depending upon several factors like depth of cut, amount of feed, type of cutting, type of tool (solid or with insert) etc. in the present study we have taken cemented carbide tools of standard nose radius of 0.2mm, 0.4mm, 0.8mm and 1.2 mm [10,16].

E. Levels of Input parameters and their levels in the Study

Input Parameters	**Symb.**	**Unit**	**L 1**	**L2**	**L3**	**L4**
Speed	V	rpm	300	400	500	600
Feed rate	F	mm/min	20	30	40	50
Depth of cut	D	mm	0.2	0.4	0.6	0.8
Nose radius	N	mm	0.2	0.4	0.8	1.2

III. RESPONSE VARIABLES IN TURNING PROCESS

A Material Removal Rate (MRR)

The material removal rate (MRR) is the volume of material removed per unit time is expressed in mm^3/min. In turning operation, for each revolution of the work piece, a ring-shaped layer of material is removed, whose cross- sectional area is product of the distance the tool travels in one revolution (feed) and depth of cut [10 , 16].

$$MRR = \frac{\text{Initial weight} - \text{Final weight}}{\text{Density} \times \text{Time}} \quad mm^3/min \qquad (3)$$

Where initial and final weight are measured in grams using digital weighing machine and density of AL 7075 is taken as 6.81g/cm^3 and time taken for turning is calculated using stop watch.

B. Surface Roughness (Ra)

Roughness is measure of the texture of a surface. It is quantified by the vertical deviation of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth surface. Roughness plays an important role in determining how a real object will interact with its environment. Rough surface usually wear more quickly and have higher friction coefficients than smooth surface [7, 8].

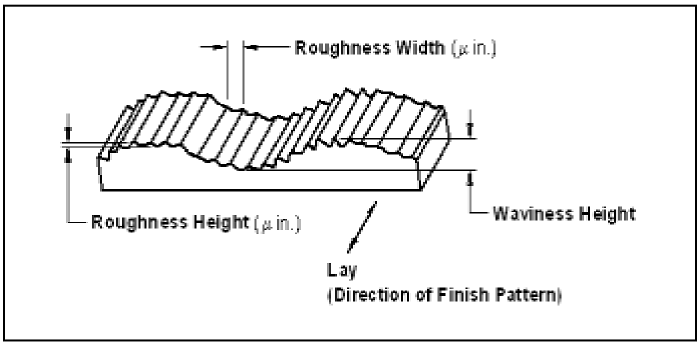

Figure 2: Surface Roughness Pattern

It was measured directly by using SJ-201 tester in the present study

Figure 3: Shows SJ-201 Surface Roughness tester

C .Response Variables in the Present Study

S. No.	Response Variables	Abbreviation	Unit
1.	Material Removal Rate	MRR	mm^3/min
2.	Surface Roughness	Ra	µm

IV. LITERATURE SURVEY FOR THE PRESENT STUDY

The present literature review represents the previous work done by the researchers in the same field of machining especially turning operation and influence of various parameters such as speed, feed, depth of cut and insert nose radius on Material removal rate and Surface roughness and then the study of this previous work is utilized in analysis of research gap and problem formulation for the present experiment, it also helps in conducting the experimental procedure and the application of Multi-objective optimization technique.

H.M. Somashekara et. al. [2012**]-** Used process parameters like speed, feed and depth of cut to optimize the value of surface roughness while machining AL 6351-T6 alloy with uncoated Carbide inserts. They have used several statistical modeling techniques to generate models including Genetic Algorithm, Response Surface methodology. They also used Taguchi to optimize the process parameters and ANOVA analysis was also performed to obtain significant factors influencing Surface roughness. They concluded that-
• Speed has a greater influence on the surface roughness followed by feed.
• Depth of Cut had least influence on surface roughness.
• The error occurred during the validation experiment was less than 2.0% between equation and actual value [19].

Biswajit Das et. al. [2013]- have studied surface roughness on turning operation using CNC lathe. The process parameters used in the experiment were cutting speed, depth of cut and feed rate. Other parameters such as tool nose radius, work piece length, work piece diameter, and work piece material were taken as constant. They concluded that the feed rate is a dominant parameter and feed rate makes dramatic changes in the surface finish of the machined surface [20].

N. Radhika et.al. (2013)- have focused on the design of new hybrid composite as well as to analyses the optimum turning conditions to minimize the surface roughness and work piece surface temperature, thereby increasing the productivity. Experiments were conducted based on the Taguchi parameter design by varying the feed (0.1, 0.15 and 0.2 mm/rev), cutting speed (200,250 and 300 m/min) and depth of cut (0.5, 1.0 and 1.5 mm). They found that there is increases in the surface roughness of hybrid composites increase feed and depth of cut, but the surface roughness decrease with increase in cutting speed [21].

Mohan Singh et. al. [2013]- have presented a factorial experimentation approach to study the impact of turning parameters on surface roughness aluminium material. They used regression analysis for evaluation of parameters of surface roughness. They analyzed the result using Excel and MINITAB 15 software. They found that depth of cut does not impact the surface roughness in the studied range, which could be used to improve productivity. They also found that feed rate, nose radius, work material, speed and tool point angle has a significant impact on the material surface roughness [22].

Vipindas M P et. al. [2013]- worked on finding of an experimental investigation of effect of speed, feed and depth of cut on surface roughness during turning of AL 6061 material using coated carbide inserts. They found that the minimum surface roughness of 0.33 micron was achieved corresponding to feed 0.1mm/rev, speed 1000 rpm and depth of cut 0.4 mm the most significant factor influencing the quality of machined surface was feed [23].

Gaurav Vohraet et al. [2013]- have optimized the boring parameters for aluminum material on CNC turning center such as speed, feed rate and depth of cut to achieve the maximum MRR the speed and depth of cut are the most significant parameters and for surface roughness speed and feed are the most significant parameters [24].

N. Prabhakaret et al. [2014]- studied the influence of machining parameter on MRR and surface roughness by using Taguchi and ANOVA analysis technique. The experiments have been conducted on AL 6253 using CNC machine with carbide tool tip and experimental results were analyzed by using ANOVA and regression equation for predicting MRR and surface roughness. The ANOVA results revealed that feed rate and depth of cut are the most influencing factors on MRR and surface roughness [25].

Rishu Gupta and Ashutosh Diwedi [2014]- in their experimentation the effect of nose radius was considered along with the other input parameters such as speed, feed and depth of cut upon the MRR and surface roughness of Aluminum 6061 alloy, it was found that nose radius and feed rate were the most influential factors on the surface roughness and material removal rate followed by depth of cut and cutting speed when observed under single optimization and depth of cut followed by the nose radius were most influential when observed under multi objective optimization

S J Raykar et al. [2015]- perform CNC turning of aluminum 7075 alloy using coated and uncoated cemented carbide tool under dry and wet conditions considering speed, feed and depth of cut as input parameters and MRR, surface roughness, cycle time and power as output parameters optimization of input parameters is done by using Multi-objective Taguchi method using grey relational analysis, it was found that high speed turning of aluminum 7075 can be done at 200m/min speed, 0.1 mm/rev feed and 0.5 mm depth of cut with coated carbide insert under dry condition to get the optimum combination of output parameters [4]

B. Ramareddy and Gopal Varavatte [2015]- AL-7075 alloy was used for experimentation purpose and considering speed feed and depth of cut as input parameters and MRR and surface roughness as output parameters Taguchi method was used and SN ratios and ANOVA are employed to study the performance of CNC turning, for MRR larger the better criterion was considered and for surface roughness smaller the better criterion was considered Taguchi reduces the number of experiments to be performed and considered as an effective tool for optimization of various machining parameters, it was observed that depth of cut was the most influencing factor than feed rate and speed for surface roughness and material removal rate both [26]

S.V. Alagarsamy et al. [2015]-AL7075 Alloy was turned using TNMG 115100 tungsten carbide insert at three levels (speed, feed and depth of cut) as input parameters and analyzed by employing Taguchi method and response surface methodology to obtain minimum surface roughness and maximum material removal rate using CNC machine it was found that depth of cut was the most influencing factor for surface roughness [27]

Devendra Singh et al. [2016]- Investigation of the effect of nose radius and other input parameters such as speed feed and depth of cut on surface roughness and MRR were studied and Analyzed. DOE were conducted for the analysis of the influence of the turning parameters on the surface roughness by using Response Surface Methodology and then followed by optimization of the results using ANOVA to minimize Surface Roughness. The nose radius was identified as the most significant parameter. The value Surface roughness decreases with the increase in nose radius [28].

A. Gaps in Literature Review

After analyzing the previous research work, it was observed that a lot of work had been done on machining of different aluminum alloys before but effect of nose radius along with other input parameters as a control parameter on the response variables such as MRR and surface finish has not been done before for the alloy used in the present study. So the attempt to fill this research gap has been done in this present study by using Multi-objective optimization technique to get best combination of control parameters for optimum set of response variables (MRR and surface roughness) simultaneously.

B .Objectives of Present study

In present study an attempt is made to fill the research gap analyzed based on the previous work literature review by conducting experimentation as well as using optimization techniques such as Taguchi and grey relational analysis the objective of the present study is to optimize control parameters for maximizing MRR and minimizing surface roughness under single objective optimization and the present work also covers the optimization of process parameters to get a best possible combination of response variables (MRR and surface roughness) at the same time under multi objective optimization.

V. OPTIMIZATION TECHNIQUES AND TOOLS USED

Techniques and Methodology used in the study

In the present study optimization of process parameters is done for MRR and Surface Roughness for maximizing MRR and minimizing Surface Roughness using Taguchi technique then in further sections optimization of process parameters to get a best possible combination of MRR and surface roughness simultaneously is done by using Taguchi and grey relational analysis under Multi objective optimization , the details of both the process is discussed in the sections below:-

A. Taguchi method

Taguchi method is designed by Dr. Geinchi Taguchi, a Japanese quality management consultant. It is an efficient tool to design high quality manufacturing system. The advantage of this design method is reduction in experimental time and to find out significant factor. Taguchi method eliminates large number of experiment runs to be performed and provides solution within the range provided by orthogonal array designed. Taguchi considered three steps in process and product development: system design, parameter design and tolerance design. In the present study L_{16} array was designed by using Taguchi technique [3, 15].

B. Multi objective optimization technique

As two response parameters are considered to be optimized simultaneously so we have adopted a multi objective optimization technique. In present experimental work we are taking grey and Taguchi for optimization of process parameters and then based on its grade it is finally optimized by Taguchi technique [9].

C. Grey Relational technique

Grey relational technique is a method to convert two or more quality parameters in to single quality parameter so that multi objective can be converted in to a single objective quality parameter and optimization technique like Taguchi used for single objective optimization can be utilized. This is done by obtaining grey relational grade from grey relational analysis. It is characterized by less data and multifactor analysis, where these two characteristics can overcome the disadvantage of statistical regression analysis. Grey relational grade is used as a performance characteristic in this single objective optimization technique [4].

Steps in grey relational technique:-

- Normalization of S/N ratios
- Determination Deviation Sequence
- Determination of Grey Relational Coefficient
- Determination of Grey Relational Grade (GRG)
- Providing Rank according to GRG

E. ANOVA and its Significance

ANOVA is a statistical decision-making tool used to detect any differences in the average performance of the group of items tested. ANOVA helps to test the significance of all major factors and their interactions by making a comparison of the mean square against an estimate of the experimental errors at specific confidence levels (95%**).** ANOVA investigates the design parameters and indicate parameters that are significantly affecting the output parameters. In the analysis the sum of squares and variance are calculated. An F-test value at 95 % confidence level helps to decide the significant factors affecting the process. Larger F- value shows that the variation of process parameters makes a big change on the performance. ANOVA helps in testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels [18].

F. S/N Graph

On analyzing the Taguchi design of experiment for the collected data using Minitab software, S/N graphs for MRR and surface roughness can be plotted. Irrespective of the criterion of maximizing or minimizing the response variable, highest value of the mean S/N ratio is always considered in their optimization.

V. CONCLUSIONS

- Taguchi Analysis is very effective technique for optimization of machining parameters involved
- Grey Relational Analysis is very effective technique for optimization of machining processes which involves multiple responses
- Confirmation test revealed good agreement between predicted and experimental values of the MRR and surface roughness at optimum combination of the input parameters under single objective optimization.
- Confirmation test revealed good agreement between predicted and experimental values of the GRG at optimum combination of the input parameters under multi objective optimization.

VI. REFERENCES

[1] Singh, Devendra , Chadha Vimanyu and Singari Ranga , May 2016 ,"Effect of Nose Radius on Surface Roughness during CNC turning using Response Surface Methodology", *International Journal of Recent advances in Mechanical Engineering (IJMECH),* Vol.5, No.2
[2] Feng, C.X. and Wang X, 2002, "Development of Empirical models for Surface Roughness Prediction in Finish Turning", *International Journal of Advanced Manufacturing Technology*; Vol. 20, pp.348-356.
[3] Aggarwal Aman, Singh Hari, Kumar Pradeep and Singh Manmohan, 2008 "Optimizing Power Consumption for CNC Turned Parts using Response Surface Methodology and Taguchi's technique - A comparative analysis", *Elsevier Journal, Journal ofmaterials processing technology*, pp. 373–384
[4] S.J. Raykara, D.M. D'Addona, A.M. Manea, "Multi-objective optimization of high speed turning of Al 7075 using grey relational analysis",9th CIRP Conference on Intelligent Computation in Manufacturing Engineering, Procedia CIRP 33 (2015) 293 – 298
[5] Rusdi Nura, D.Kurniawan, M.Y.Noordinb, S.Izman, "Optimizing power consumption for sustainable dry turning of treated aluminum alloy", 2nd International Materials, Industrial, and Manufacturing Engineering Conference, MIMEC2015, 4-6 February 2015, Bali Indonesia, Procedia Manufacturing 2 (2015) 558 – 562
[6] Azizah Mohamad, Azlan Mohd. Zain, Nor Bahiah Hj. Ahmad, Noordin Mohd Yusof and Farhad Najarian, " Roundness Error Study in Deep Hole Drilling of Cold Mold Steel 718", Indian Journal of Science andTechnology,Vol10(13), April 2017
[7] Lambert, B.K.; Determination of metal removal rate with surface finish restriction. Carbide and tool Journal, May – June : 16-19, 1983.
[8] Ho SY , Lee KC, Chen SS, Ho SJ; Accurate Modeling prediction of surface roughness by computer vision in turning operation using an adaptive neuro- fuzzy inference system. Int J Mach Tools Manuf, 2002; 42:1441-1446.
[9] Malakooti B. and Raman V.; An Interactive Multi –Objective artificial neural network approach for machine setup optimization, Journal of Intelligent Manufacturing, 2000, Vol. 111, pp 41-50.
[10] Rasch and Roistadas; Series of finish turning tests under variation of parameters : Material quality ., Tool quality , Tool nose radius , feed speed and cutting time. Journal of material processing technology, 1971, Vol-132, 203-214.
[11] Tian-Syung Lan and Ming-Yung Wang; Competitive parameter optimization of multi-quality CNC turning; The International Journal of Advanced Manufacturing Technology; April 2009, Volume 41, Issue 7-8, pp 820-826
[12] Feng, C.X. and Wang X, Development of empirical models for surface roughness prediction in finis turning. International Journal of Advanced Manufacturing Technology; 2002, Vol. 20, pp.348-356.
[13] Lambert, B.K.; Determination of metal removal rate with surface finish restriction. Carbide and tool Journal, May – June : 16-19, 1983.
[14] Ho SY , Lee KC, Chen SS, Ho SJ; Accurate Modeling prediction of surface roughness by computer vision in turning operation using an adaptive neuro-fuzzy inference system. Int J Mach Tools Manuf, 2002; 42:1441-1446.
[15] Malakooti B. and Raman V.; An Interactive Multi –Objective artificial neural network approach for machine setup optimization, Journal of Intelligent Manufacturing, 2000, Vol. 111, pp 41-50.
[16] Rasch and Roistadas; Series of finish turning tests under variation of parameters : Material quality ., Tool quality , Tool nose radius , feed speed and cutting time. Journal of material processing technology, 1971, Vol-132, 203-214.
[17] Tian-Syung Lan and Ming-Yung Wang; Competitive parameter optimization of multi-quality CNC turning; The International Journal of Advanced Manufacturing Technology; April 2009, Volume 41, Issue 7-8, pp 820-826
[18] T. K Durga Bhavani , G. S .V Seshu Kumar, Prof. K Satyanarayana, I. Ajit Kumar,Optimization of Material Removal Rate and Surface Roughness in Turning of Aluminum, Copper and Gunmetal Materials using RSM
[19] SomashekaraH, Swamy M. N. lakhshmana,2012, "Optimizing surface roughness in turning operation usingtaguchi technique and ANOVA, *International Journal of Engineering Science and Technology* ,IJEST, VOL-4, PP-1967-1973
[20] Biswajit Das, Susmita Roy, R.N. Rai and S.C. Saha, 2012, "Studies on Effect of Cutting Parameters on Surface Roughness of Al-Cu-Tic MMCs: An Artificial Neural Network Approach", *Procedia Computer Science* 45, 745-752.
[21] N. Radhika**,** Subramanian Rand Sajith A, 2013, "Analysis of chip formation in machining aluminiumhybrid composites",*Journal of Scientific,* Research vol. 2(1). pp.009-015
[22] Mohan Singh, Dharmpal Deepak , Manoj Kumar Singla,ManishGoyal and Vikas Chawla, "An Experimental Estimate Mathematical Model Of Surface Roughness For Turning Parameters On CNC Lathe Machine", National Conference onAdvancements and Futuristic Trends in Mechanical and Materials Engineering, February 19-20, 2010, pp. 336-343 .
[23]Vipindas M P and Dr. Govindan P, July 2013, "Taguchi-Based Optimization of Surface Roughness in CNC Turning Operation", *International Journal of Latest Trends in Engineering and Technology*, Vol. 2 Issue 4 , pp. 454-463.
[24] GauravVohra, Palwinder Singh and Harsimran Singh Sodhi, 2013, "Analysis and Optimization of Boring Process Parameters By Using Taguchi Method", International Journal of Computer Science and Communication Engineering, pp. 232-237.
[25] N.Prabhakar, B. Sreenivasulu and U.Nagaraju, Nov-2014, "Application ofANOVA and ANN Technique for Optimize Of CNCMachining Parameters", *International Journal Of Innovations In Engineering Research And Technology*, Volume 1, Issue 1pp. 1-12.
[26] Ramareddy B., VaravatteGopal,2015, "optimization of process parameters in CNC turning of aluminum alloy 7075 by Taguchi method using regression analysis",*Proceeding of NCRIET-2015 & Indian J.Sci.Res.* 12(1)203-208
[27] Alagarsamy.S.V, Raveendran.P, Arockia Vincent Sagayaraj.S and Tamil Vendan.S, ,Jan-2016 "Optimization Of Machining Parameters For Turning Of Aluminium Alloy 7075 Using Taguchi Method",*International Research Journal of Engineering and Technology,* Volume: 03, Pp.316-322
[28] Singh, Devendra; ChadhaVimanyu and SingariRanga , May 2016 ,"Effect of Nose Radius on Surface Roughness during CNC turning using Response Surface Methodology",*International Journal of Recent advances in Mechanical Engineering (IJMECH),* Vol.5, No.2