Investigation of Effect of Process Parameters on Different Performance Parameters for Aluminum Alloy on CNC– Review

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***Abstract*—Aluminum alloy has a wide variety of applications in different industries. Aluminum is the most famous for the lighter weight, strength/weight ratio, recyclability, corrosion resistance, ease of joining, easy of casting, durability, ductility, conductivity, surface finish and formability. The Challenge of modern machining industries is to manufacture the low cost and produce high quality product in shorter period of time. It is necessary to change and improve existing technology and develop product with reasonable price. So, it is necessary to control the process parameters in any manufacturing practices. The typical process parameters for the CNC lathe machines are speed, feed, depth of cut, tool geometry, wet cutting, dry cutting, tool material, work material, etc. which affect desired output like material removal rate, surface roughness, power consumption, tool wear, vibration etc. Selection of the process parameters are also very important to achieve the desired performance characteristics. If selection of process parameters are not proper, will lead to poor quality and productivity. ANOVA approach helps to determine whether selection of process parameters are appropriate or not. Optimization of machining parameters are also required to determine for given responding characteristics to obtain optimal result.**

***Index Terms*— Aluminum alloy, CNC TC, MRR, Optimization, Review, Surface roughness**

I. Introduction

Now days every manufacturing industries try to improve their quality and fulfill the customer requirement. In any machines there are many process parameters which affect the responding/performance characteristics. So, proper selection of process parameters of the each performance characteristic is important. If selection of process parameters are not proper, then the machine will not run under optimal condition, hence surface quality will be poor, higher time consumption, tool life decreases etc. In the CNC turning center there are many process parameter like cutting parameters, Cutting tool parameters, Work piece material and environment parameter etc. which affects on responding characteristics like surface roughness, material removal rate, power consumption, vibration, geometric tolerance, tool wear, etc. So, selection of proper process parameter is utmost important for any responding characteristic.

Aluminum is the most famous for the lighter weight, strength/weight ratio, recyclability, corrosion resistance, ease of joining, easy of casting, durability, ductility, conductivity, surface finish and formability. In manufacturing industries there are wide varieties of aluminum alloy used [14]. The main alloying metals are copper, zinc, magnesium, manganese, silicon and the levels of these other metals are in the range of a few percent by weight [14]. In automotive and aerospace industries, aluminum alloys are used widely. Aluminum alloys are also used in architectural panels and spandrels, marine components, engine blocks, gear case, lawnmower decks, high stress applications, trusses, bridges, cranes, transport applications, ore skips, beer barrels, milk churns, cylinder head etc. [8]

The different methods are used for optimization of the process parameters such as Taguchi method, ANOVA approach, Swan optimization, Response surface methodology, fuzzy logic, genetic algorithm etc. But, Taguchi and ANOVA approach are widely used. The ANOVA approach help to identify which parameters is significant for given responding parameters. Taghuchi approach help to determine optimal condition with lesser number of experiments. The Taguchi Method is a multi-stage process for optimize process named as [18]:

- Systems Design/Concept Design
- Parameter Design
- Tolerance Design

Taghuchi method uses a special design of orthogonal arrays to study entire parameter space with lesser number of experiments. He suggested three single to nose ratio for given static problem which have been chosen according to responding characteristics. These are [8]:

1. Smaller the better
2. Larger the better

3. Nominal the best

II. Selection of Process Parameters

In order to identify the process parameters that affect on performance characteristics like surface roughness, material removal rate, 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 1 represents the cause and effect diagram for the given quality characteristics for the given turned parts. The main process parameters for turned parts are

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

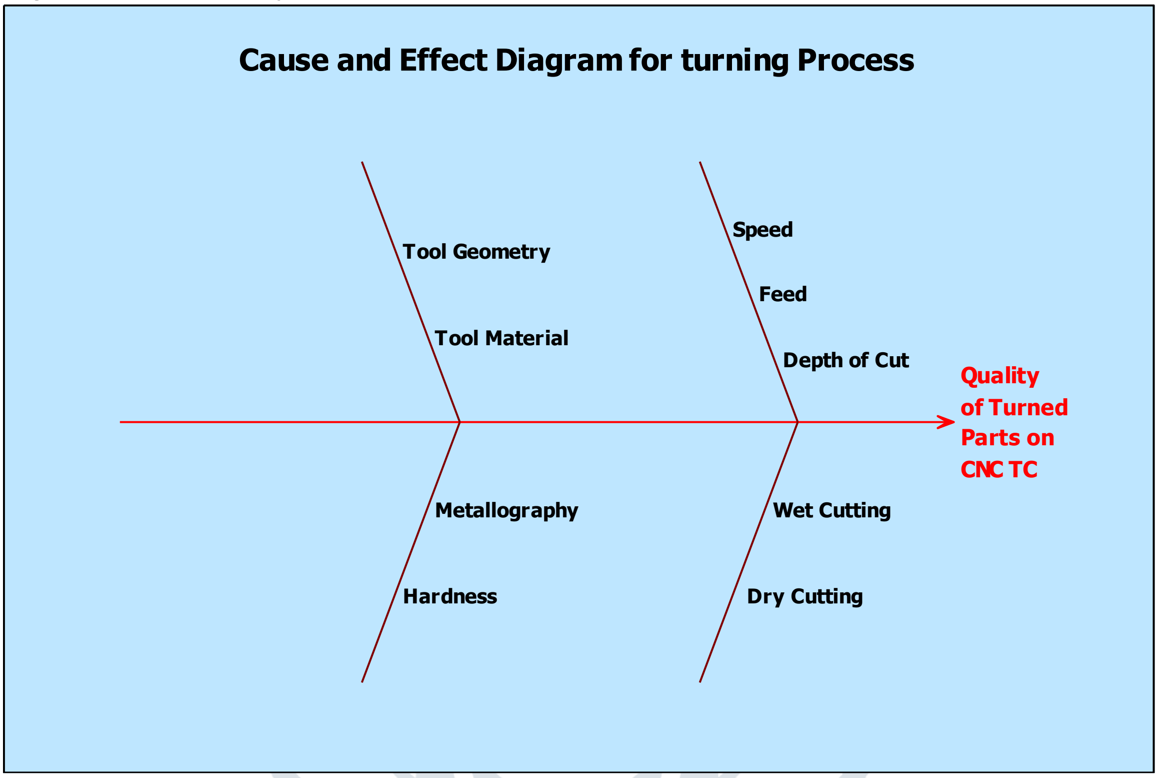

Figure 1 Cause and effect diagram for required quality parts to turned

3. Literature Review

.Y. Mustafa & T. Ali [1] had conducted experiments on aluminum alloy work piece to analyze geometric tolerance and surface roughness by turning. The effect of the length and diameter of working piece, depth of cut and feed were also investigated. They used Taguchi and ANOVA approach to analyze the data. They found from the experiments: (i) The minimum surface roughness value was 0.831 µm, (ii) The minimum cutting force was 94 N, (iii) The minimum workpiece cylindricity error was 0.019 mm. They also concluded from these number of experiments that : (1)cylindrical error the workpiece length and feed are the most significant factor, (ii) Surface roughness, the feed and work piece diameter are the most significant parameters & (iii) for force the most significant parameters are DOC and feed.

Ali Abdallah et. al. [2] had optimized cutting parameters for the surface roughness in CNC turning machining with aluminum alloy 6061 material. They had applied 'response surface methodology' on the most effective process parameters, namely, feed, cutting speed, and depth of cut, and optimized considering the surface roughness and material removal rate for turning process. Based on the results of surface roughness it was analyzed that feed rate affects both MRR and surface roughness. The effect of cutting speed in the cutting process is more significant on surface roughness than on MRR. Higher the cutting speed results in better surface roughness, and this finding can be explained along with other significant parameters. The depth of cut also influences both MRR and surface roughness in the cutting process.

Biswajit Das et. al. [3] 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.

Dr. M. Naga Phani Sastry et. al. [4] have tried to investigate parameters which are most significant for the material removal rate and surface roughness. They used Response Surface Methodology (RSM) for this study. They applied methodology on most effective process parameters i.e. feed, cutting speed and depth of cut while machining aluminum alloy and resin as the two types of work pieces using HSS cutting tool. They analyzed the data set, using statistical tool DESIGN EXPERT-8 Software and reduce the manipulation. They found following results

- The minimum surface roughness value was 1.18 µm for Aluminium alloy and 2.295 µm for resin.
- The maximum metal removal rate was found to be 1377.83 mm^3/min for Aluminium alloy and 182.899 mm^3/min for resin.

Durai Matinsuresh Babu et. al. [5] have tried to find out the effects of process parameters such as speed, feed and depth of cut on power consumption in high tare CNC machines. They observed during experiments that (1) the feed rate and the depth of cut are greatly influencing the energy consumption in CNC machines. (2) Increasing the cutting speed by 50%, decreases tool life by 80% and operating at lower cutting speed (20-40m/min) tends to cause chattering. Thus, tool life is shortened. Hence the optimum cutting speed is 200-275 m/min in case of CNC turning.

Gaurav Vohra et. al. [6] have optimized the boring parameters for aluminium material on CNC turning centre such as speed, feed rate and depth of cut, to achieve the highest possible material removal rate and at the same time minimum surface roughness by using the Taguchi method. They found that for the material removal rate the speed and depth of cut are the most significant parameters and for surface roughness speed and feed are the most significant parameters.

H. M. Somashekara et. al. [7] 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 modelling techniques to generate models including Genetic Algorithm, Response Surface Methodology. They also used Taguchi Technique to optimize the process parameters and ANOVA analysis were 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.

Madhav Murthy et. al. [9] have studied the effect of various cutting parameters on the surface finish of Al 6061 aluminium alloy. L_{16} orthogonal array was selected for conducting turning experiments on Al6061 T6 using CNC LT-16 turner with carbide tipped tool and the cutting parameters selected were feed, spindle speed, depth of cut and tool nose radius. The L16 array used 4 factors at 2 levels each and the experiments were conducted. The results obtained were analyzed using ANOVA and the regression equation for predicting the surface roughness. They found that the feed is the most significant in influencing the surface roughness while the remaining three factors considered are not significant.

Md. Tayab Ali et. al. [10] have optimized the cutting parameters like spindle speed, feed rate, and depth of cut for minimization of Surface Roughness and maximization of material Removal Rate (MRR) in CNC turning of Aluminum Alloy (AA6063-T6) using carbide insert tool in dry condition. They have taken L_9 orthogonal Array (OA) for the study and Minitab- 17 statistical software was used to analyze the data. They found that the most significant parameters for surface roughness are feed rate, spindle speed and least significant factor is depth of cut. For MRR, the depth of cut and the spindle speed is the most significant parameters and least significant factor is feed rate.

Mohan Singh et. al. [11] have presented a fractional factorial experimentation approach to studying the impact of turning parameters on surface roughness on aluminum material. They used regression analysis for evaluation of parameters of surface roughness. They analyzed the results using Excel or MINITAB15. They found that the depth of cut does not impact the surface roughness in the studied range, which could be used to improve productivity. They also found that

- Feeds, nose radius, work material and speeds, the tool point angle has a significant impact on the observed material surface roughness.
- Cutting speed, feed rate, and nose radius have a major impact on surface roughness. Smoother surfaces will be produced when machined with a higher cutting speed, smaller feed rate and nose radius.
- The interactions of the cutting speed, nose radius, and feed rate also have a more significant impact on surface roughness than the individuals.

N. Radhika et. al. [12] have focused on the design of a new hybrid composite as well as to analyse 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 an increase in the surface roughness of hybrid composites ith increases feed and depth of cut, but the surface roughness decreases with increase in cutting speed.

N.Prabhakar et. al. [13] have studied the influence of machining parameters on surface roughness and material removal rate is examined by using ANN & ANOVA techniques. The experiments have been conducted on Aluminum alloy AL 6253 using CNC turner with carbide tip tool and experimental results were analyzed by using ANOVA and the regression equation for predicting the surface roughness and MRR. The ANOVA and ANN results revealed that feed rate and depth of cut are the most significant influencing factors on the material removal rate and surface finish.

Narayana B. Doddapattar et. al. [14] have worked to carry out experimental investigations to optimize machinability of commercial Al – 7050 (Aluminium) and to obtain optimum process parameters. They used Taguchi's orthogonal array based on design of experiments for optimization of process parameters of CNC. They concluded that there are several options through which the surface roughness can be obtained that is through cutting speed, feed rate, depth of cut, and nose radius. They observed that MRR in CNC turning process is greatly influenced by depth of cut.

Ranganath M S et. al. [15] have investigated the parameters affecting the surface roughness produced during the turning process for the material aluminium 6061 using CNC lathe. They used Taguchi and ANOVA approach to analyze the experimental results. They found that the feed and speed are the most influential process parameters on surface roughness.

Ravindra Thamma [16] has predicted and developed various models for the optimum turning parameters for required surface roughness for an aluminium 6061 work pieces. He concluded that

- Cutting speed, feed rate, and nose radius have a major impact on surface roughness. Smoother surfaces will be produced when machined with a higher cutting speed, smaller feed rate, and nose radius.
- Depth of cut has a significant impact on surface roughness only in an interaction.
- The interactions of the cutting speed, nose radius, and feed rate also have a more significant impact on surface roughness than the individuals.

Rishu Gupta et. al. [17] worked on findings of an experimental investigation effects of cutting speed, feed rate, depth of cut and nose radius on material removal rate and surface roughness in CNC turning of Alloy 6061 material. The conclusion revealed that the feed rate and nose radius were the most influential factors on the surface roughness and Material Removal Rate (MRR) in CNC turning process which is greatly influenced by depth of cut followed by cutting speed.

S.V. Alagarsamy et. al. [19] have conducted experiment by turn aluminium Alloy 7075 using TNMG 115 100 tungsten carbide insert at three levels (Speed, feed & DOC) of cutting parameters and analyzed by employing Taguchi technique and respond surface methodology. Taguchi method and Response surface methodology were applied for analyzing to get a minimum surface roughness and maximum material removal rate for turning process of Aluminum Alloy 7075 using CNC machine via considering three influencing input parameters- Speed, Feed and Depth of Cut. They found that the input parameter feed has most influencing to the quality characteristics of surface roughness and depth of cut being most affecting parameter for MRR.

Senthil Kumar et. al. [20] have studied to find the optimum machining parameter of CNC turning centre on Al-HMMC for low value of surface roughness and high Material Removal Rate (MRR). Signal to Noise ratio (S/N) and Analysis of Variance (ANOVA) were used to analyze the effect of cutting parameters on surface roughness and MRR. They found out that the feed rate is the most significant parameter, cutting speed is the second significant parameter and the depth of cut is the third significant parameter on surface roughness and for material removal rate the feed rate is the most significant parameter, cutting speed is the next significant parameter and the depth of cut is the third significant parameter.

Vipindas M P et. al. [21] worked on findings of an experimental investigation of effects of speed, feed and depth of cut on surface roughness during turning of Al 6061 material using Coated carbide inserts. They found that : 1. The lowest surface roughness (Ra) of 0.33 μm was achieved corresponding to: feed: 0.1 mm/rev, Speed: 1000 rpm and depth of cut: 0.4mm. and 2. The most significant parameter in influencing the quality of machined surfaces was feed.

Table 1. Summary of Review Papers

Sr. No.	Year	Author's Name	Material	Input Parameter	Output parameter	Most Significant	
1	2011	A.Y. Mustafa & T. Ali	Al 2017	Length	Cylindrical Error	Length	Feed
				Diameter	Surface Roughness	Feed	Diameter
				Depth of Cut			
				Feed	Force	DOC	Feed

Sr. No.	Year	Author's Name	Material	Input Parameter	Output parameter	Most Significant	
2	2014	Ali Abdallah, Bhuvenesh Rajamony & Abdulnasser Embark	Al-6061	Speed	Surface Roughness	Feed	Speed
				Feed			
				Depth of cut			
3	2013	Biswajit Das, R. N. Rai & S. C. Saha	AL-5CU ALLOY	Speed	Surface Roughness	Feed	-
				Feed			
				Depth of cut			
4	2012	Dr. M. Naga Phani Sastry, K. Devaki Devi & Dr, K. Madhava Reddy	Aluminium alloy	Speed	Surface Roughness	Feed	-
				Feed			
				Depth of cut	MRR	Feed	DOC
				Material			
5	2012	Durai Matinsuresh Babu, Mouleeswaran & Jothiprakash Vishnu	aluminum 6063	Speed	Power	Feed	DOC
				Feed			
				Depth of cut			
6	2013	Gaurav Vohra, Palwinder Singh & Harsimran Singh Sodhi	Aluminium	Speed	Surface Roughness	Speed	Feed
				Feed			
				Depth of cut	MRR	Speed	Feed
7	2012	H.M. Somashekara & Dr. N. Lakshmana Swamy	Al 6051 -T6 Alloy	Speed	Surface Roughness	Speed	Feed
				Feed			
				Depth of cut			
8	2014	Madhav Murthy, K.Mallikharjuna Babu & R.Suresh Kumar	Aluminum 6061	Speed	Surface Roughness	Feed	-
				Feed			
				Depth of cut			
				Nose radius			
9	2014	Md. Tayab Ali & Dr. Thuleswar Nath	AA6063	Speed	Surface Roughness	Feed	Speed
				Feed			
				Depth of cut	MRR	DOC	Speed
10	2010	Mohan Singh, Dharampal Deepak, Manoj Kumar Singla, Manish Goyal & Vikas Chawla	Aluminium	Speed	Surface Roughness	Feed	Nose Radius
				Feed			
				Depth of cut			
				Tool			
				Material			
11	2013	N. Radhika, R. Subramaniam & S. Babudeva senapathi	Al-Si10Mg alloy	Speed	Surface Roughness	Feed	Speed
				Feed			
				Depth of cut	Surface Temprature	Feed	Speed
12	2014	N.Prabhakar, B. Sreenivasulu & U.Nagaraju	AL 6253	Speed	Surface Roughness	Feed	DOC
				Feed			
				Depth of cut			
13	2013	Narayana B. D. & Chetana S. B.	Al 7050	Speed	Surface Roughness	Speed	-
				Feed		Feed	
				Depth of cut		DOC	
14	2013	Ranganath M S, Vipin & R. S. Mishra	Aluminium 6061	Speed	surface roughness	Feed	DOC
				Feed			
				Depth of cut			

Sr. No.	Year	Author's Name	Material	Input Parameter	Output parameter	Most Significant	
15	2008	Ravindra Thamma	Aluminium 6061	speed	Surface Roughness	Speed, Feed & Nose Radius	-
				Feed			
				Depth of cut			
				Nose radius			
16	2014	Rishu Gupta & Ashutosh Diwedi	Al 6061	Speed	Surface Roughness	Feed	Nose Radius
				Feed			
				Depth of cut	MRR	DOC	Speed
				Nose radius			
17	2015	S.V.Alagarsamy & N.Rajakumar	Aluminium Alloy 7075	Speed	Surface Roughness	Feed	Speed
				Feed			
				Depth of cut	MRR	Speed	Feed
18	2014	Senthil Kumar. M.P & Rajendran. I	Al-HMMC	Speed	Surface Roughness	Feed	Speed
				Feed			
				Depth of cut			
19	2013	Vipindas M P & Dr. Govindan P.	Al 6061	Speed	Surface Roughness	Feed	
				Feed			
				Depth of cut			

4. Conclusion

The input parameters used in 19 research papers are as under

- The speed has been used in 18 research papers.
- The feed has been used in 19 research papers.
- The depth of cut has been used in 19 research papers.
- The nose radius has been used in 3 research papers.

The performance parameters found in 19 research papers are as under

- The surface roughness has been found in 17 research papers.
- The material removal rate has been found in 5 research papers.
- The power consumption has been found in 1 research papers.

From above stated 19 research papers I came to conclusion that

- For surface roughness, the most significant parameters are feed, speed and nose radius and least significant parameter is DOC.
- For MRR, the most significant parameters are DOC, feed and speed and least significant parameter is nose radius.

5. Comment

- The performance characteristics like power consumption, geometric tolerance, vibration acceleration are very important parameters and are highly required to be considered to optimize process parameters, looking to the wide range of application.
- The speed, feed, depth of cut and nose radius are the prime and vital input parameters required to achieve desired quality characteristics, besides the secondary input parameters such as wet cutting, dry cutting, work piece length, work piece length, tool material, machine condition, etc. can be also considered and used to achieve optimum possible quality characteristics.
- The multifunctional optimization must be considered when the output have multiple quality characteristics.

6. Reference

[1] A.Y. Mustafa and T. Ali, "Determination and optimization of the effect of cutting parameters and workpiece length on the geometric tolerances and surface roughness in turning operation", International Journal of the Physical Sciences Vol. 6(5), 4 March, 2011, pp. 1074-1084.

[2] Ali Abdallah, Bhuvenesh Rajamony, and Abdulnasser Embark, “Optimization of cutting parameters for surface roughness in CNC turning machining with aluminum alloy 6061 material”, IOSR Journal of Engineering, Vol. 04, Issue 10, October 2014, pp. 01-10.
[3] Biswajit Das, R. N. Rai & S. C. Saha, “Analysis Of Surface Roughness On Machining Of Al-5cu Alloy In CNC Lathe Machine”, International Journal of Research in Engineering and Technology, Volume: 02 Issue: 09, Sep-2013, pp. 296-299.
[4] Dr. M. Naga Phani Sastry, K. Devaki Devi, Dr, K. Madhava Reddy, “Analysis and Optimization of Machining Process Parameters Using Design of Experiments”, Industrial Engineering Letters, Vol 2, No.9, 2012, pp. 23-32.
[5] Durai Matinsuresh BABU, Mouleeswaran Senthil Kumar and Jothiprakash Vishnuu, “Optimization Of Cutting Parameters For CNC Turned Parts Using Taguchi’s Technique”, Internation journal of engineering, Fascicule 3, 2012, pp. 493-496.
[6] Gaurav Vohra, Palwinder Singh and Harsimran Singh Sodhi, “Analysis and Optimization of Boring Process Parameters By Using Taguchi Method”, International Journal of Computer Science and Communication Engineering, 2013, pp. 232-237.
[7] H.M.Somashekara and Dr. N. Lakshmana Swamy, “Optimizing Surface Roughness In Turning Operation Using Taguchi Technique and ANOVA”, International Journal of Engineering Science and Technology, Vol. 4 No.05 May 2012, pp. 1967-1973.
[8] John Gilbert Kaufman, Elwin L. Rooy, “Aluminum Alloys Castings: Properties, Processes and Applications”, ASM International, First printing, December, 2004.
[9] Madhav Murthy, K.Mallikharjuna Babu and R.Suresh Kumar, “Optimization of Machinability Parameters of Al6061 using Taguchi Technique”, International Journal of Current Engineering and Technology, Issue-3, April 2013, pp. 63-66.
[10] Md. Tayab Ali and Dr. Thuleswar Nath, “Cutting Parameters Optimization for Turning AA6063-T6 Alloy by Using Taguchi Method”, International Journal of Research in Mechanical Engineering & Technology, Vol. 4, Issue 2, May - October 2014, pp. 82-86.
[11] Mohan Singh, Dharmpal Deepak , Manoj Kumar Singla, Manish Goyal and Vikas Chawla, “An Experimental Estimate Mathematical Model Of Surface Roughness For Turning Parameters On CNC Lathe Machine”, National Conference on Advancements and Futuristic Trends in Mechanical and Materials Engineering, February 19-20, 2010, pp. 336-343.
[12] N. Radhika, R. Subramaniam and S. Babudeva senapathi, “Machining parameter optimisation of an aluminium hybrid metal matrix composite by statistical modelling”, Industrial Lubrication and Tribology, 65/6 (2013), pp. 425–435.
[13] N.Prabhakar, B. Sreenivasulu & U.Nagaraju, “Application of ANOVA and ANN Technique for Optimize Of CNC Machining Parameters”, International Journal Of Innovations In Engineering Research And Technology, Volume 1, Issue 1 Nov-2014, pp. 1-12.
[14] Narayana B. Doddapattar and Chetana S. Batakurki, “Optimization Of Cutting Parameters For Turning Aluminum Alloys Using Taguchi Method”, International Journal of Engineering Research & Technology, Vol. 2 Issue 7, July – 2013, pp. 1399-1407.
[15] Ranganath M S, Vipin and R. S. Mishra, “Optimization of Process Parameters in Turning Operation of Aluminium (6061) with Cemented Carbide Inserts Using Taguchi Method and ANOVA”, International Journal of Advance Research and Innovation, Volume 1, Issue 1, 2013, pp. 13-21.
[16] Ravindra Thamma, “Comparison Between Multiple Regression Models to Study Effect of Turning Parameters on the Surface Roughness”, Proceedings of The 2008 IAJC-IJME International Conference, 2008.
[17] Rishu Gupta, Ashutosh Diwedi, “Optimization of Surface Finish and Material Removal Rate with Different Insert Nose Radius for Turning Operation on CNC Turning Center”, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 6, June 2014, pp. 13540-13547.
[18] Ross Philip J, “Taguchi techniques for quality engineering” (McGraw-Hill book company, New York), 1996
[19] S.V.Alagarsamy and N.Rajakumar, “Analysis of Influence of Turning Process Parameters on MRR & Surface Roughness Of AA7075 Using Taguchi’s Method and RSM”, International Journal of Applied Research and Studies, Volume 3, Issue 4, Apr-2014, pp. 1-8.
[20] Senthil Kumar. M.P. and Rajendran, “Optimization of CNC Turning Parameters on Aluminum 7015 Hybrid Metal Matrix Composite Using Taguchi Robust Design”, International Journal of Engineering and Technology, Vol. 6, No 4, Aug-Sep 2014, pp. 1675-1682.
[21] Vipindas M P and Dr. Govindan P, “Taguchi-Based Optimization of Surface Roughness in CNC Turning Operation”, International Journal of Latest Trends in Engineering and Technology, Vol. 2 Issue 4 July 2013, pp. 454-463.