International Journal of Research and Innovation in Engineering Technology
ISSN: 2394 – 4854
Volume: 02 Issue: 12
Pages: 16 – 26

IJRIET

INVESTIGATION OF MACHINING PARAMETERS IN CNC TURNING USING RESPONSE SURFACE METHODOLOGY (RSM)

Azhagu Shankar.S.S[1], Balakrishnan.G[2], Meinathan.S[3], Mayilsamy.P[4]
[1,2,3,4]*Assistant Professor, Department of Mechanical Engg, Shree Venkateshwara Hi-Tech Engineering College, Gobi Tamilnadu, India*
E-mail-ID: [1]azhagushankarss@gmail.com,[2]balakrishnanmech1989@gmail.com, [3]s.meinathan@gmail.com, [4]mayilsvhec@gmail.com

Received 24 June 2016, Revised 20 July 2016, Accepted 22 July 2016
Available online 31 July 2016

Abstract

CNC turning is one among the metal cutting process in which quality of the finished product depends mainly upon the machining parameters such as feed, speed, depth of cut, type of coolant used, types of inserts used etc. Similarly the work piece material plays an important role in the metal cutting process. This study involves in identifying the optimized parameters in CNC turning of Aluminium and Stainless Steel. To identify and measure the formation of burrs samples are examined under scanning electron microscope (SEM).The optimization techniques used in this study are Response surface methodology, and Genetic algorithm. These optimization techniques are very helpful in identifying the optimized control factors with high level of accuracy. Brass and Copper (Non Ferrous) materials are taken for this investigation.

Keywords: Design of Experiments, Turning, Scanning Electron Microscope, Response surface methodology, Genetic algorithm.

1. INTRODUCTION

The recent advancements in the manufacturing process like metal forming, rolling, extrusion, milling, drilling, and turning have made the manufacturing products very competitive in the global market. In each manufacturing process the cost of the product plays an important role. The cost is the outcome of raw material cost, transportation cost, loading and unloading cost, machining cost and shipping cost. Even though all the above costs decide the total cost of the product, the method of production plays an important role in the production cost. Now a days the computer numerical machining process (CNC) plays an important role in controlling the parameters and avoids the human interventions. In the manufacturing of cylindrical shafts the CNC turning machine products precise components than the components produced by even turret lathe or capstan lathe. Not only accurate components the production time also reduced drastically. The productivity increase and hence profit increase. Even though the advantages of CNC turning, the burrs are major problems which are analyzed by some researchers. It recognized that burr occur if the plastically deformed material left on the work piece after machining. Burrs are produced in every edge and junction of faces which produce undesirable edge geometry and future trouble after machining. The existence of burrs hinders assembly of parts. The breaking-off of burrs causes malfunctioning and thus shortens its life time, jeopardizes worker safety. Traditional approach to obtain components of burr free edges is to machine the part first and later remove burrs by a deburring process. However, all the deburring operations are time and money consuming processes. The original deburring operation depends on manual work which leads to a long, labor intensive and costly process with this mind, the best solution is to prevent and minimize the formation of burrs in the machining operation. Surface roughness plays an important role as it influences the fatigue strength, wear rate, coefficient of friction, and corrosion resistance of the machined components. In actual practice, there are many factors which affect the surface roughness, i.e. tool variables, work piece variables and cutting conditions. Tool variables include tool material, noise radius, rake angle, cutting edge geometry, tool vibration, tool point angle etc. Work piece variables include material, hardness and other mechanical properties. Cutting conditions include speed, feed, and depth of cut. In hard turning process, the cutting inserts are always provided with negative chamfer angle in order to increase the edge strength of the cutting tools. This negative chamfer angle acts as a negative rake angle to the insert. The total effective rake then becomes the sum of the negative rake angle provided by the chamfer angle of the inserts and the negative rake angle provided by the tool holder to the cutting inserts.

2. EXPERIMENTAL WORK

2.1 Process parameters

The experiments were carried out on a CNC lathe. The Brass rod & Copper of initial dimensions 20.5 mm diameter and 100 mm length was turned using tungsten carbide &Cemented Carbide tools .The final dimensions obtained from Brass and Copper are 5 mm length and 5 mm diameter . The speed, feed and depth of cut were set same throughout the experiments to investigate the minimum burr formation among the tool & work piece combinations.

Feed Rate: The maximum allowable feed has a pronounced effect on both the optimum spindle speed and production rate. Feed changes have a more significant impact on tool life than the depth of cut changes. The system energy requirement reduces with feed, since the optimum speed becomes lower. Therefore, the largest possible feed consistent with the allowable machine power and surface finish is desirable, in order for a machine to be fully used. It is often possible to obtain much higher metal removal rates without reducing tool life by increasing the feed and decreasing the speed. In general, the maximum feed in a roughing operation is limited by the force that the cutting tool, machine tool, work piece and fixture are able to withstand. The maximum feed in a finishing operation is limited by the surface finish requirement and can often be predicted to a certain degree, based on the surface finish ad tool nose radius.

Cutting Speed: Cutting speed is a vital component of the tool life equation. When compared with depth of cut and feed, the cutting speed has only a secondary effect on chip breaking, when it varies in the conventional speed range. There are certain combinations of speed, feed and depth of cut which are preferred for easy chip removal which are mainly dependent on the type of tool and work piece material.

The base material used in the present work is LM6 which is an aluminum-silicon alloy containing 11 to 13% of silicon. The details of the LM6 chemical composition. In order to obtain different composition, B4C particles of 30microns size were added to the aluminum matrix in the proportion of 2.5%, 5% and 7.5% by weight.

In this study an attempt is made to establish the input-output relationship of electro chemical machining (ECM) of aluminium metal matrix composites. It is important to note that selection of the range of operating parameters is an important consideration. A pilot study has been conducted to determine the appropriate working range of the parameters.

2.2 Design of Experiments (DOE)

The DOE procedure consists of the following four steps.

Planning: Definition of the problem and the objective and development of an experimental plan.

Screening: Reduction of the number of variables by identifying the key variables that affect the product quality.

Optimization: Determination of the optimal valves for various experimental factors.

Verification: Performing a follow-up experiment at the predicted best processing conditions to confirm the optimization results.

Experiments were conducted on a computer numerical control (CNC) vertical machining center and L_{27} orthogonal array was chosen for the experiments. The work piece material of diameter 20.4 mm was turned to diameter 5mm and length 5mm for keeping in scanning electron microscope for the circumference magnification process to know better results and to identify the burr height and pyrometer is used to identify the surface roughness value (Ra).

Parameters	Unit	Levels		
		-1	0	1
Speed	rpm	100	1750	4000
Feed	mm/min	0.01	0.06	0.1
Depth of cut	mm	0.1	0.3	0.5

Table: 1 Machining parameter levels

2.3 DOE Experiments Runs for Brass using Box-Behnken Design

Run	Speed (rpm)	Feed (mm/min)	Depth of Cut	Roughness (microns)	Burr Height (microns)	Machining Time (sec)
1	100	0.01	0.3	0.372	0.00503	74
2	2050	0.06	0.3	0.236	0.00342	69
3	2050	0.06	0.3	0.236	0.00342	69
4	2050	0.01	0.3	0.238	0.00322	74
5	2050	0.06	0.5	0.236	0.00342	69
6	4000	0.10	0.3	0.230	0.00311	74
7	2050	0.06	0.3	0.236	0.00342	69
8	2050	0.06	0.3	0.236	0.00342	69
9	4000	0.01	0.3	0.229	0.00458	50
10	2050	0.06	0.3	0.236	0.00342	69
11	2050	0.06	0.3	0.236	0.00342	69
12	2050	0.06	0.3	0.236	0.00342	69
13	2050	0.06	0.3	0.236	0.00342	69
14	2050	0.06	0.3	0.236	0.00342	69
15	2050	0.01	0.1	0.238	0.00322	74
16	100	0.10	0.3	0.369	0.00710	52
17	2050	0.10	0.5	0.231	0.00453	51
18	2050	0.06	0.3	0.236	0.00342	69
19	2050	0.06	0.3	0.236	0.00342	69
20	4000	0.06	0.5	0.228	0.00422	56

Table: 2 Box-Behnken Design Experiment Runs and Results

2.4 DOE Experiments Runs for Copper using Box-Behnken Design

Run	Speed (rpm)	Feed (mm/min)	Depth of Cut (mm)	Surface Roughness (microns)	Burr Height (microns)	Machining Time (sec)
1	100	0.01	0.3	0.361	0.00656	55
2	2050	0.06	0.3	0.228	0.00374	61
3	2050	0.06	0.3	0.228	0.00374	61
4	2050	0.01	0.3	0.237	0.00456	53
5	2050	0.06	0.5	0.228	0.00374	61
6	4000	0.10	0.3	0.209	0.00394	53
7	2050	0.06	0.3	0.228	0.00374	61
8	2050	0.06	0.3	0.228	0.00374	61
9	4000	0.01	0.3	0.211	0.00414	51
10	2050	0.06	0.3	0.228	0.00374	61
11	2050	0.06	0.3	0.228	0.00374	61
12	2050	0.06	0.3	0.228	0.00374	61
13	2050	0.06	0.3	0.228	0.00374	61
14	2050	0.06	0.3	0.228	0.00374	61
15	2050	0.01	0.1	0.237	0.00456	52
16	100	0.10	0.3	0.364	0.00728	50
17	2050	0.10	0.5	0.231	0.00462	50
18	2050	0.06	0.3	0.228	0.00374	61
19	2050	0.06	0.3	0.228	0.00374	61
20	4000	0.06	0.5	0.211	0.00414	66

Table: 3 Box-Behnken Design Experiment Runs and Results

3. RESULTS

3.1 Anova

Since there are a large number of variables controlling the process, some mathematical models are required to represent the process. However, these models are to be developed using only the significant parameter influencing the process rather than including all the parameter. In order to achieve this, statistical analysis of the experimental results will have to be processed using the analysis of variance (ANOVA). ANOVA is a computational technique that enables the estimation of the relative contributions of each of the control factors to the overall measured response. In the present work, only the significant parameters will be used to develop mathematical models using response surface methodology (RSM). Regression equation obtained as follows:

Regression Equation for Brass (Depends on Surface Roughness)

Final Equation in Terms of Coded Factors: Surface Roughness = +0.24-0.071*A-2.250E-003*B+7.500E-004*C+1.000E-003*A*B-1.000E-003*A*C-5.000E-004*B*C+0.064*A^2+2.500E-004*B^2-1.250E-003*C^2

Final Equation in Terms of Actual Factors: Surface Roughness = +0.37855-1.04749E-004*Speed-0.070275*Feed+0.030812*Depth of Cut+1.13960E-005*Speed*Feed-2.56410E 006*Speed*Depth of Cut-0.055556*Feed*Depth of Cut+1.67653E-008*Speed^2+0.12346*Feed^2-0.031250*Depth of Cut^2

Where,

A=Speed, B=Feed and C=Depth of Cut

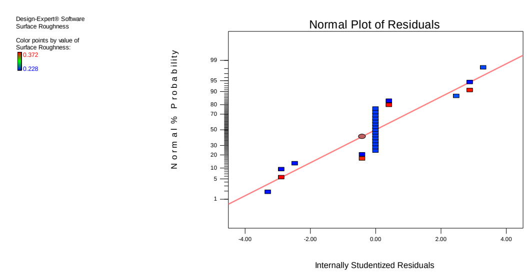

Figure: 1 Normal Plot of Residuals (Surface Roughness)

Regression Equation for Brass (Depends on Burr Height)

ISSN: 2394 – 4854
Pages: 16 – 26

Final Equation in Terms of Coded Factors:

$$\text{Burr Height} = +3.420E\text{-}003-9.675E\text{-}004*A+4.000E\text{-}004*B-1.400E\text{-}004*C-8.850E004*A*B+2.850E\text{-}004*A*C-5.000E\text{-}006*B*C+1.350E\text{-}003*A^{2}+1.850E\text{-}004*B^{2}+2.750E\text{-}004*C^{2}$$

Final Equation in Terms of Actual Factors:

$$\text{Burr Height} = +5.84847E\text{-}003-1.61631E\ 006*\text{Speed}+0.019681*\text{Feed}-6.29252E\text{-}003*\text{Depth of Cut}-1.00855E\text{-}005*\text{Speed}*\text{Feed}+7.30769E\text{-}007*\text{Speed}*\text{Depth of Cut}-5.55556E\text{-}004*\text{Feed}*\text{Depth ofCut}+3.55030E010*\text{Speed}^{2}+0.091358*\text{Feed}^{2}+6.87\ 500E\text{-}003*\text{Depth of Cut}^{2}$$

Where,

A=Speed, B=Feed and C=Depth of Cut

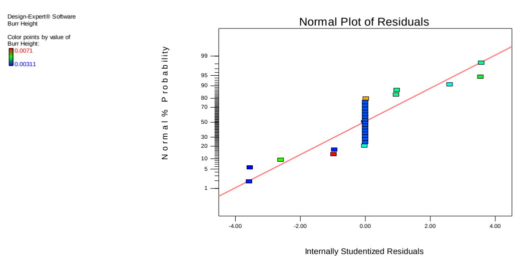

Figure: 2 Normal Plot of Residuals (Burr Height)

Regression Equation for Brass (Depends on Machining Time)

Final Equation in Terms of Coded Factors:

$$\text{Machining Time}=+69.00-2.38*A-5.50*B+1.88*C+11.50*A*B-2.75*A*C+0.000*B*C-4.87*A^{2}-1.62*B^{2}-4.88*C^{2}$$

Final Equation in Terms of Actual Factors:

$$\text{Machining Time} =+67.06229-1.05413E\text{-}003*\text{Speed}-302.61159*\text{Feed}+96.95513*\text{Depth of Cut}+0.13105*\text{Speed}*\text{Feed}-7.05128E\ 003*\text{Speed}*\text{Depth of Cut}-3.94746E\text{-}01*\text{Feed}*\text{Depth of Cut}-1.28205E\text{-}006*\text{Speed}^{2}-802.46914*\text{Feed}^{2}-121.87500*\text{Depth of Cut}^{2}$$

Where,

A=Speed, B=Feed and C=Depth of Cut

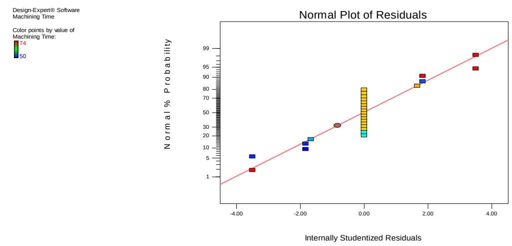

Figure: 3 Normal Plot of Residuals (Machining Time)

Regression Equation for Copper (Depends on Surface Roughness)

Final Equation in Terms of Coded Factors:

$$\text{Surface Roughness} =+0.23-0.075*A-0.015*B+0.014*C-1.250E\text{-}003*A*B-2.500E004*A*C-0.026*B*C+0.041*A^{2}+0.017\ B^{2}+0.015*C^{2}$$

Final Equation in Terms of Actual Factors:

$$\text{Surface Roughness} = +0.35846-8.14305E\text{-}005*\text{Speed}-0.36740*\text{Feed}+7.35577E\text{-}003*\text{Depth of Cut}-1.42450E\text{-}005*\text{Speed}*\text{Feed}-6.41026E\ 007*\text{Speed}*\text{Depth of Cut}-2.91667*\text{Feed}*\text{Depth of Cut}+1.07495E008*\text{Speed}^{2}+8.58025*\text{Feed}^{2}+0.37188*\text{DepthofCut}^{2}$$

Where,

A=Speed, B=Feed and C=Depth of Cut

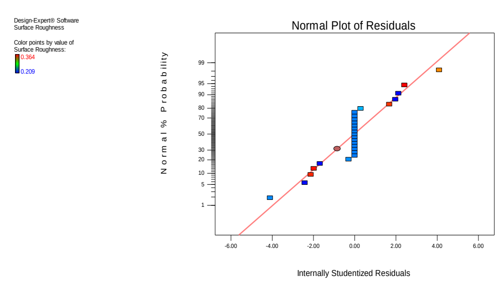

Figure: 4 Normal Plot of Residuals (Surface Roughness)

Regression Equation for Copper (Depends on Burr Height)

Final Equation in Terms of Coded Factors: Burr Height $=+3.740E-003-1.183E-003*A-3.250E-005*B+2.200E-004*C-2.300E-004*A*B+2.400E-004*A*-2.150E-004*B *C+7.725E-004*A^2+9.675E-004*B^2+9.750E-005*C^2$

Final Equation in Terms of Actual Factors: Burr Height $= +6.90005E-003-1.47980E-006*Speed-0.040738*Feed-3.10150E-004*Depth\ of\ Cut-2.62108E-006*Speed*Feed+6.15385E-007*Speed*Depth\ of\ Cut-0.023889*Feed *Depth\ of\ Cut+2.03156E010*Speed^2+0.47778*Feed^2+2.43750E-003*Depth\ of\ Cut^2$

Where,

A=Speed, B=Feed and C=Depth of Cut

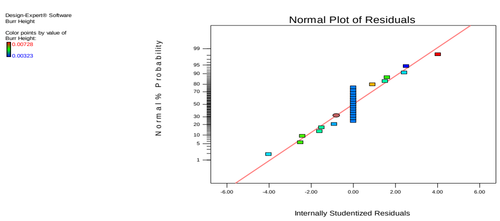

Figure: 5 Normal Plot of Residuals (Burr Height)

Regression Equation for Copper (Depends on Machining Time)

Final Equation in Terms of Coded Factors:

$MachiningTime=+60.60+0.13*A0.87*B+0.25*C+1.75*A*B+0.0005.50*B*C+0.075*A^2 8.43*B^2+4.33*C^2$

Final Equation in Terms of Actual Factors: Machining Time $= +50.55692-1.11363E-003*Speed+580.66002*Feed-30.01389*Depth\ of\ Cut+0.019943*Speed*Feed+5.69345E-018*Speed*Depth\ of\ Cut-611.11111*Feed*Depth\ of\ Cut+1.97239E-008*Speed^2 4160.49383*Feed^2+108.12500*Depth\ of\ Cut^2$

Where,

A=Speed, B=Feed and C=Depth of Cut

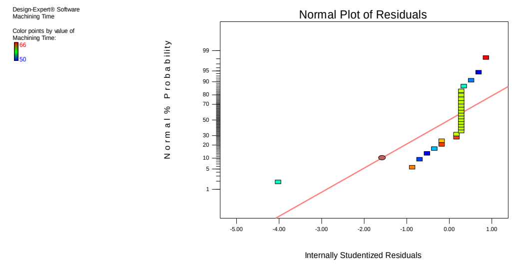

Figure: 6 Normal Plot of Residuals (Machining Time)

3.2 Response surface methodology

Response surface designs are employed in the empirical study of relationship between one or more measured response variables and a number of independent or controllable variables of a process. Response surface designs are employed to investigate and predict the following conditions of a process. RSM methodology is practical, economical and relatively easy for use. They are the effect on a particular response by a given set of input variables over some specified region of interest. The required values of variables to achieve a minimum or maximum response and the mature response surface near this minimal or maximal value. To describe the response surface method by second order polynomials, the factor in the experimental design should have at least three levels.

Surface Roughness for Brass Material

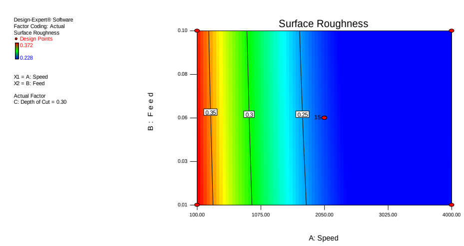

Figure: 7 2D Contour Plot Speed vs Feed (Brass Material)

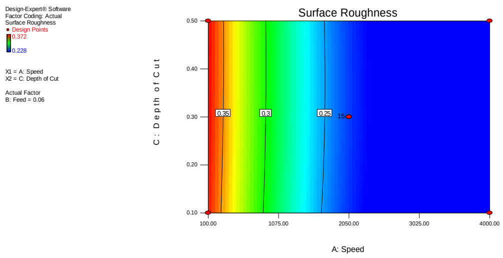

Figure: 8 2D Contour Plot Speed vs Depth of Cut (Brass Material)

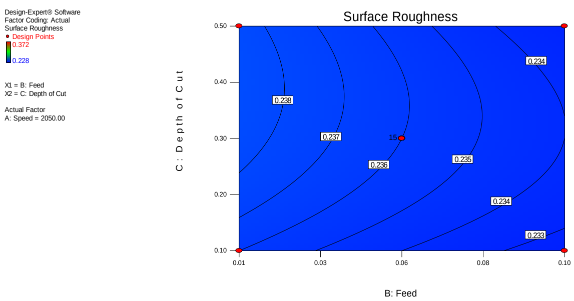

Figure: 9 2D Contour Plot feed vs Depth of Cut (Brass Material)

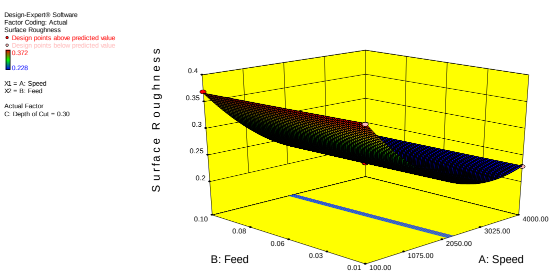

Figure: 10 3D Contour Plot Speed vs Feed (Brass Material)

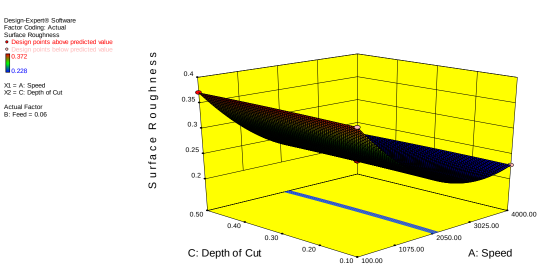

Figure: 11 3D Contour Plot Speed vs Depth of Cut (Brass Material)

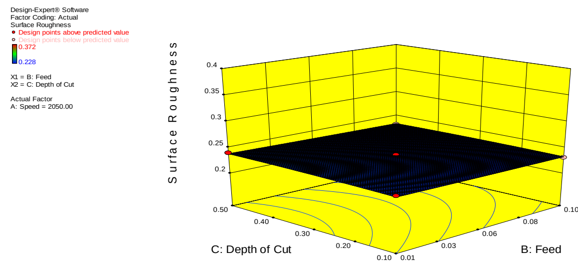

Figure: 12 3D Contour Plot feed vs Depth of Cut (Brass Material)

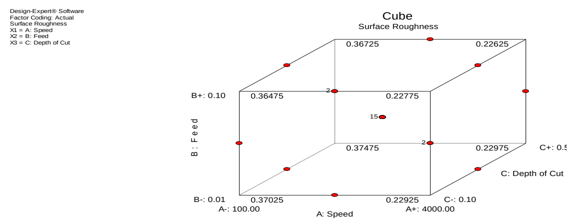

Figure: 13 Cube Plot for Speed, Feed and Depth of Cut

Surface Roughness for Copper Material

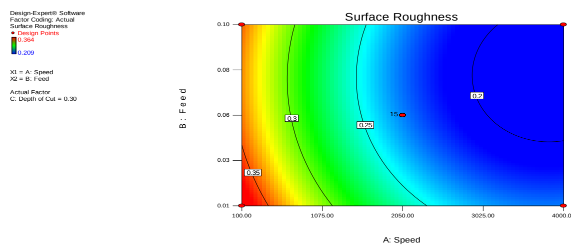

Figure: 14 2D Contour Plot Speed vs Feed (Copper Material)

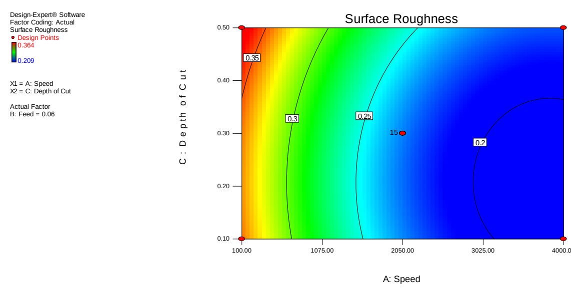

Figure: 15 2D Contour Plot Speed vs Depth of Cut (Copper Material)

 ISSN: 2394 – 4854
Pages: 16 – 26

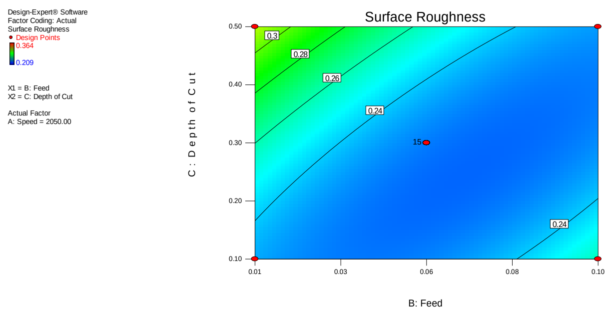

Figure: 16 2D Contour Plot feed vs Depth of Cut (Copper Material)

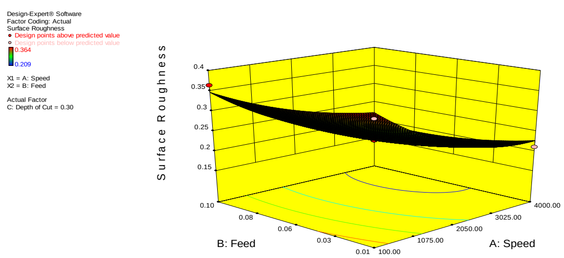

Figure: 17 3D Contour Plot Speed vs Feed (Copper Material)

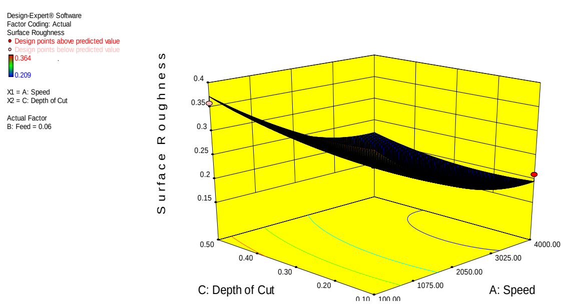

Figure: 18 3D Contour Plot Speed vs Depth of Cut (Copper Material)

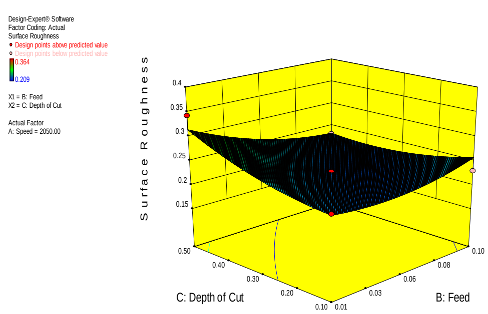

Figure: 19 3D Contour Plot feed vs Depth of Cut (Copper Material)

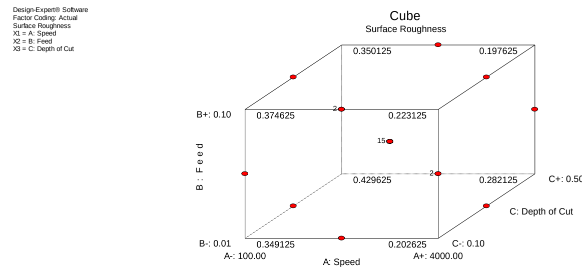

Figure: 20 Cube Plot for Speed, Feed and Depth of Cut

3.3 Genetic Algorthim

Genetic algorithm, are a family of population based search heuristics, inspired by Darwin's principal of "survival of fittest". An implementation of genetic algorithm begins with a population of random solutions called chromosomes, then each chromosome is individually evaluated and reproduction is carried out in such a way that those chromosomes which represent better solution to the target problem are given more chances to "reproduce" than those chromosomes which are poorer solutions. The goodness of a solution is typically defined with respect to the current population. In addition a local search mechanism is proposed for selecting the population to improve performance of GA genetic algorithm in general is a purpose search algorithm suitable for optimization problem due to its processing approach and due to its structure and it is able to return asset of optimal solutions. MATLAB is a high performance language for technical computing which is used to optimize the objective function of different materials in genetic algorithm.

3.4 Program for Genetic Algorithm-Brass Material

3.4.1. Surface Roughness

Function Z= surfaceroughness(x)

Z= + 0.37855 -1.04749^ -004*x(1) -0.070275*x(2) +0.030812*x(3) +1.13960^-005*x(1)*x(2) -2.56410^ -006*x(1)*x(3) -0.055556*x(2)*x(3) +1.67653^-008*x(1)^2 +0.12346*x(2)^2 -0.031250*x(3)^2

3.4.2 Burr Height

Function Z= burrheight(x)

Z= + 5.84847^-003 -1.61631^-006*x(1) +0.019681*x(2) -6.29252^-003*x(3) -1.00855^-005*x(1)*x(2) +7.30769^-007*x(1)*x(3) -5.55556^-004*x(2)*x(3) +3.55030^-010*x(1)^2 +0.091358*x(2)^2 +6.87500^-003*x(3)^2

3.4.3 Machining Time

Function Z= machiningtime(x)

Z= +67.06229 -1.05413^-003*x(1) +302.61159*x(2) +96.95513*x(3) +0.13105*x(1)*x(2) -7.05128^-003*x(1)*x(3) -3.94746^-013*x(2)*x(3) -1.28205^-006*x(1)^2 -802.46914*x(2)^2 -121.87500*x(3)^2

Genetic Algorithm Graph

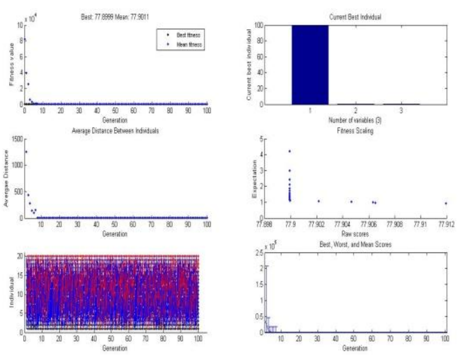

Figure: 21 Plot from Genetic Algorithm (Brass Material)

The detailed study and the optimization procedure have been to study the effect of speed, feed and depth of cut while machining which would help in real practice. The machining parameter ranges were analyzed optimization approaches.

For Brass Material the best ranges obtained by using the genetic algorithm approach are

Cutting Speed- 1433.74 rpm, Cutting Feed- 0.077mm/min, Depth of Cut- 0.1

Optimal Surface Roughness from Genetic Algorithm (GA) is 0.315 microns.

E. Program for Genetic Algorithm-Copper Material

3.4.4 Surface Roughness

Function Z= surfaceroughness(x)

Z= + 0.35846 -8.14305^ -005*x(1) -0.36740*x(2) +7.35577^003*x(3) -1.42450^-005*x(1)*x(2) -6.41026^ -007*x(1)*x(3) -2.91667*x(2)*x(3) +1.07495^-008*x(1)^2 +8.58025*x(2)^2 +0.37188*x(3)^2

3.4.5 Burr Height

Function Z= burrheight(x)

Z= + 6.90005^-003 -1.47980^-006*x(1) -0.040738*x(2) -3.10150^-004*x(3) -2.62108^-006*x(1)*x(2) +6.15385^-007*x(1)*x(3) -0.023889*x(2)*x(3) +2.03156^-010*x(1)^2 +0.47778*x(2)^2 +2.43750^-003*x(3)^2

3.4.6 Machining Time

Function Z= machiningtime(x)

Z= +50.55692 -1.11363^-003*x(1) +580.66002*x(2) -30.01389*x(3) +0.019943*x(1)*x(2) +5.69345^-018*x(1)*x(3) -611.11111*x(2)*x(3) +1.97239^-008*x(1)^2 -4160.49383*x(2)^2 +108.12500*x(3)^2

Genetic Algorithm Graph

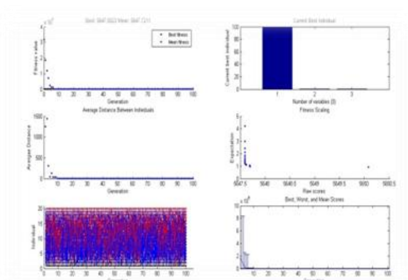

Figure: 22 Plot from Genetic Algorithm (Copper Material)

The detailed study and the optimization procedure have been to study the effect of speed, feed and depth of cut while machining which would help in real practice. The machining parameter ranges were analyzed optimization approaches.

For Brass Material the best ranges obtained by using the genetic algorithm approach are

Cutting Speed- 1567.77 rpm, Cutting Feed- 0.061mm/min, Depth of Cut- 0.1

Optimal Surface Roughness from Genetic Algorithm (GA) is 0.345 microns.

3.5 Analysis and Discussion

The surface quality of the machined parts is the value of surface roughness or the waviness are mainly decided by the three factors speed, feed and depth of cut beyond the levels influenced by the other factors. The surface roughness is mainly a result of three controllable factors and hence it is easier to attain the physical dimensions. A detailed could give the effect of speed, feed, depth of cut, nose radius and other factors on surface roughness. These studies and effects of factors on surface roughness have been evaluated and models are developed to address the requirements of the end operator, who decides the input parameters based on the specified requirements. The goal of this study is to obtain a mathematical model that relates the surface roughness to three machining parameters in turning operation, precisely to the speed, feed and depth of cut. Therefore two approaches have been used such as response surface methodology (RSM) and analysis of variance (ANOVA). The genetic Algorithm approach can be used for the fine tuning of the results obtained to get the optimized solution.

4. CONCLUSION

The current Experiment has Performed to study the effect of Machining parameters on surfacRoughness The following conclusions are drawn from the study:

1. The Surface roughness is mainly affected by feed rate and depth of cut. With the increase in feed rate & depth of cut the surface roughness increases
2. As the cutting speed increases there is slightly increase in Surface Roughness.
3. The optimum value of the surface roughness (Ra) comes out to be 0.315 µm.
4. The parameters taken in the experiments are optimized to obtain the maximum surface roughness possible. The optimum points of cutting parameters for better Quality Surface finish is as :-
   i. Cutting Speed- 1433.74 rpm,
   ii. Cutting Feed- 0.077mm/min,
   iii. Depth of Cut- 0.1

References

[1] T.rajmohan, k.palanikumar, m.kathirvel, optimization of machining parameters in drilling hybrid aluminium metal matrix compositesscience direct trans. Nonferrous met. Soc. China 22(2012) 1286-1297 received 17 october 2011; accepted 26 december (2011).

[2] Krishankant, Taneja Jatin , Bector Mohit , Kumar Rajesh (2012) , "Application of Taguchi Method for Optimizing Turning Process by the effects of Machining parameters", International Journal of Engineering and Advanced Technology, Volume-2, pp. 2249 – 8958.

[3] Lalwani D.I., Mehta N.K. and Jain P.K. (2006) "Experimental investigation of cutting parameters influencing on cutting forces ans surface roughness in finish hard turning of MDN 250 steel" Journal of material processing technology,pp.167-179.

[4] Sharma A.V.N.L., Venkatasubbaiah K.,Raju P.S.N.(2013) "Parametric Analysis and Multi Objective Optimization of Cutting Parameters in Turning Operation of EN353 – With CVD Cutting Tool Using Taguchi Method ,International Journal of Engineering and Innovative Technology ,Volume 2, ISSN: 2277-3754.

[5] Tanikic Dejan and Marinkovic Velibor (2012) "Modelling and Optimization of the Surface Roughness in the Dry Turning of the Cold Rolled Alloyed Steel Using Regression Analysis",J. of the Braz. Soc. of Mech. Sci. & Eng., Vol.34, No. 1 / 41.

[6] Yadav Ashish , Bangar Ajay , Sharma Rajan , Pal Deepak (2012), Optimization of Turning Process Parameters for Their Effect on En 8Material Work piece Hardness by Using Taguchi Parametric OptimizationMethod " ,International Journal of Mechanical and Industrial Engineering (IJMIE), Volume-1, ISSN No. 2231 –6477.

[7] Thamizhmanii S., Saparudin S., Hasan S.(2007), "Analysis of surface roughness by using taguchi method" Achievements in materials and manufacturing engineering, vol.,20,pp. 503-505.

[8] Yang W.H and Tarng Y.S. (1998), "Design optimization of cutting parameters for turning operations based on Taguchi method", Journal of Material Processing Technology, vol. 84,pp.122-129.

[9] http://en.wikipedia.org/wiki/Box Behnken_design, Date: April 18, 2012.

[10] http://www.itl.nist.gov/div898/handbook/pri/section3/pri336.htm,Date:April18, 2012.