International Journal of Scientific & Engineering Research Volume 8, Issue 8, August-2017
ISSN 2229-5518

Parameter Optimization on Surface Roughness and Cutting Temperature in Hard Part Turning of AISI-1060 Steel Using RSM and GA

Nandini Bhowmik, Md. Habibor Rahman

Abstract:

A difficult-to-cut material like hardened steel is used predominantly in the automotive and bearing industries due to its exceptional corrosion and thermal resistance and high shear strength. This paper represents the study and development of a regression model to predict surface roughness and cutting temperature using SNMG insert for hard turning of AISI-1060 medium carbon steel for both dry and wet condition. Two methodologies are compared by GA (Genetic Algorithm) and RSM (Response Surface Methodology) for their modeling abilities, prediction and optimization. A mathematical model has been developed for relating surface roughness and temperature to process parameters (cutting speed, feed rate, depth of cut). The second order response surface methodology was employed to create a mathematical model and the adequacy of the model was verified using ANOVA where surface roughness and temperature are considered as objective function where constraints are limited for feed rate, cutting speed, depth of cut, hardness.

Keywords: Finish Hard Turning, Surface Roughness, Cutting Temperature, Response Surface Methodology, Genetic Algorithm

1. Introduction

Manufacturers generally attempt to produce a product within the shortest possible time keeping the cost of the product at a minimum level without affecting the quality of the product as well. Now a day it is a challenging part to turning hard steel for industrial and production sectors where surface finish plays a vital role for quality characteristics which influences production cost. As, environmental regulations are being emerged and imposed, the manufacturers are put to re-fabricate their manufacturing processes and reduce or eliminate harmful chemicals, dusts and effluents associated with machining that can deteriorate the environment. Hardened steel is one such material that has been used extensively, particularly in the automotive industry for components such as bearings, gears, shafts, and cams. Hard machining is attracting more and more attention as an alternative to grinding in finish machining some hardened steels.

Hard turning is most often performed on post-heat treated parts with surface hardness ranging from 45HRC to 68HRC or even higher, which provides surface roughness, dimensional and shape tolerances similar to those achieved in grinding. Hard turning provide benefits like high flexibility and the ability to cut complex geometries with a single machine setup which are the main technological advantages of hard turning over the grinding process. This gives it an inherent advantage over grinding, which requires specific knowledge and experience that not all machinists possess. Hard turning allows for the finishing of radius and free-curved surfaces. Grinding processes require a custom-dressed wheel, which is time consuming to produce, or highly customized grinding machines that can be expensive.

Metal can be removed much fas`ter in hard turning operations, and high speed turning is possible with SNMG, CBN and also ceramic cutting tools. This high cutting temperature not only reduces dimensional accuracy and tool life but also adulterates the surface integrity of the product. Vestnik [1] deals with flank wear, cutting force and surface roughness value which were measured throughout the tool life by DNMG 150608 and compared in dry and wet condition and substantial reduction in tool wear, which enhanced the tool life where elevated tool temperatures have negative impact on tool life. T. Tamizharasan et al. [2] describes the various characteristics in terms of component quality, tool life, tool wear, and effects of individual parameters on tool life and material removal, and economics of operation. Then the newer solution is, a hard turning operation, is performed on a lathe. The chip-tool interface temperature plays a vital role in the thermal distortion and dimensional accuracy the machined part and in the tool life as well. It also weakens the surface integrity of the product by inducing

residual stresses in the surface and subsurface micro-cracks in addition to rapid oxidation and corrosion. When tool wear reaches a certain value, increasing cutting force, vibration and cutting temperature, it causes deteriorated surface integrity and dimension error greater than tolerance [3].
There are many parameters used to evaluate surface finish in turning is found to be influenced such as cutting speed, feed rate, depth of cut, material characteristics, tool geometry, built-up edge, cutting fluid, etc. the process parameters highly affect the machining process efficiencies in terms of tool wear, cutting temperature, cutting forces, surface integrity etc. Optimization of cutting parameters in turning which will ultimately minimize the cutting force requires a model in terms of those parameters. Those objectives are often conflicting and incomparable like- the increase of rate of feeding brings about the growth of the production rate but also increases the cost of the operation due to excessive tool wear and decreases the surface quality because of greater roughness[4]. Sardiñas et al. [5] proposed a multi-objective optimization technique, based on genetic algorithm to optimize the cutting parameters in turning processes: cutting depth, feed and speed. The proposed model used micro-genetic algorithm in order to obtain the non-dominated points and build the Pareto front graph. Xie and Guo [6] combine genetic algorithms (GAs) with a pass enumerating method in selecting the cutting parameters that will minimize the unit production cost (UC) in multi-pass turnings. Sahoo [7] used Response Surface Methodology (RSM) to develop a predictive model of surface roughness in terms of machining parameters in turning based on experimental results and then used Genetic algorithm (GA) to optimize the machining parameter that results minimum surface roughness. Srikanth and Kamala [8] proposed a real coded genetic algorithm (RCGA) and its advantages over the existing approach of binary coded genetic algorithm. Savadamuthu et al. [9] proposed an optimal fuzzy control scheme designed by the Taguchi-genetic method in optimizing cutting parameters in turning. Various methodologies and practices are being used for the prediction of surface roughness like classical experimental design, Taguchi method and Artificial Intelligence of soft computing techniques [10, 11]

2. Experimental conditions:

2.1 Work Piece Material:

The material used in this project was medium carbon steel of 22 HRC with approximately 0.51% carbon content. After hardening the hardness distribution within the sample is shown below where hardness value fluctuates from 53 to 58 HRC. Hardness values were measured on the C scale of Rockwell Hardness tester. The average value has been obtained as 56±2 HRC. The hardness of the sample before heat treatment was 22 HRC and after heat treatment it became around 56±2 HRC.

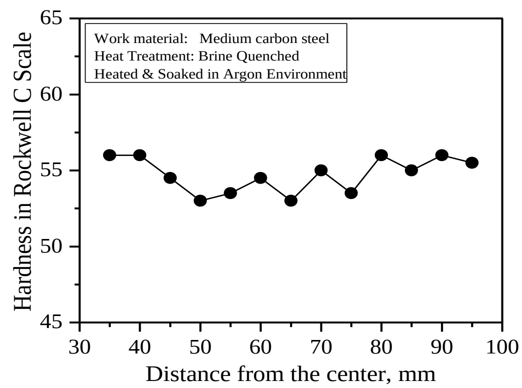

Fig.1 Hardness distribution

The machining was carried out on lathe, which has a 3.5 kW main spindle power and a maximum spindle speed of 1600 rpm. The final arrangement made and used has been shown in Fig. 2

Fig. 2 Photographic view of experimental set-up

The table below shows the chemical composition of AISI-1060 medium carbon steel

TABLE 1

CHEMICAL COMPOSITION FOR AISI-1060 STEEL

ELEMENT	CONTENT (%)
IRON, FE	98.35-98.85
MANGANESE, MN	0.60-0.90
CARBON, C	0.55-0.660
SULFUR, S	≤ 0.050

2.2 Cutting Tool

SNMG TN 4000, Widia inserts for turning medium carbon steel was used which has coating material TiCN, WC, Co and the following tool geometry:

Fig. 3 cutting tool SNMG TN 4000, Widia carbide insert

- Back rake angel:-6°
- Side rake angel:-6°
- Principal cutting edge angel:6°
- Side cutting edge angel: 6°
- End Clearance angel: 15°
- Side clearance angel :75°
- Nose radius: 0.8 mm.

3. EXPERIMENTAL SETUP:

The experimental setup involves the selection of suitable levels for the machining parameters i.e. cutting speed, feed rate and depth of cut. Selection parameters were made as listed in table: 2 based on the machine tool, cutting tool and work piece capability.

Table 2

Experimental setup at three levels parameters

No.	Cutting parameters	Unit	Low level	Middle level	High level
1	Cutting Speed	rpm	108	136	216
2	Feed Rate	mm/rev	0.09	0.10	0.12
3	Depth of cut	mm	0.5	1.0	1.5
4	Hardness	µm	50	54	58

Data Collection:

For any kind of analysis data collection plays a significant role as it decides the progression of the analysis to the best or worst. A proper and suitable data helps to find a better result and solution from the analysis. In this paper data collection (chip-tool interface temperature) has been completed for both dry and wet condition and surface roughness in done by wet condition. Table 3 and 4 present the results of the chip-tool interface temperature for both dry and wet condition and average surface roughness for various combinations of cutting speed (S0), feed rate (f) and depth of cut (d). The value of cutting temperatures (θ) change for variation of tool configuration, cutting speeds and feeds as well as machining environment. The cutting temperature if not controlled properly, cutting tools undergo severe flank wear and notch wear, lose sharpness of the cutting edge by either wearing or become blunt by welded built-up edge and weaken the product quality. Cutting temperature is increased with the increase in process parameter as well as with the increase in hardness and strength of the work material. It can be seen from table 3 that lowest temperatures produce in for wet condition and for feed rate 0.12 mm/rev and cutting speed 34 m/min the best value of chip-tool temperature (θ) obtained was 625oC.

On the other side, from table 4 surface roughness are obtained from various combination of cutting speed (S0), feed rate (f) and depth of cut (d) and hardness. The best average value of surface roughness 0.40 µm obtained from the cutting speed 68 m/min, feed rate 0.09 mm/rev hardness 54 and depth of cut 1.5mm. Here lower surface roughness found from lower feed rate. Mohammed T. Hayajneh et al performed a set of experiments on aluminium samples to study the effects of machining parameters on the surface roughness in the end milling process. The study developed a better understanding of the effects of spindle speed, cutting feed rate and depth of cut on the surface roughness. The study showed that the cutting feed is the most dominant factor of those studied [14] where the results showed that the cutting speed has no significant effect on cutting forces and surface roughness. Feed rate is the rate at which the tool advances along its cutting path and the surface roughness increased with increased feed rate [15].

TABLE 3

CHIP-TOOL INTERFACE TEMPERATURE FOR BOTH DRY AND WET CONDITION

Dry Condition		
Feed Rate	Cutting Speed	Temperature, θ
0.09	108	737
	136	750
	216	763
0.10	108	725
	136	745
	216	758
0.12	108	700
	136	712
	216	720
Wet Condition		
Feed Rate	Cutting Speed	Temperature, θ
0.09	108	662
	136	687
	216	712
0.10	108	650
	136	675
	216	673
0.12	108	625
	136	650
	216	655

TABLE 4

EXPERIMENTAL DATA OBTAINED FROM THE HARD TURNING TRIALS (SURFACE ROUGHNESS)

Experiment No.	Environment Wet condition				
	Feed Rate	Cutting Speed	Hardnes s	Depth of cut	Surface Roughness
1	0.09	108	50	0.5	0.92
2		136	50	1.0	0.83
3		216	50	1.5	0.81
4		108	54	0.5	0.72
5		136	54	1.0	0.59
6		216	54	1.5	0.40
7		108	58	0.5	2.05
8		136	58	1.0	1.89
9		216	58	1.5	1.03
10	0.10	108	50	0.5	0.94
11		136	50	1.0	0.89
12		216	50	1.5	0.67
13		108	54	0.5	1.20
14		136	54	1.0	0.97
15		216	54	1.5	0.85
16		108	58	0.5	1.93
17		136	58	1.0	1.78
18		216	58	1.5	1.05
19	0.12	108	50	0.5	1.05
20		136	50	1.0	0.98
21		216	50	1.5	0.87
22		108	54	0.5	1.15
23		136	54	1.0	1.02
24		216	54	1.5	0.97
25		108	58	0.5	2.02
26		136	58	1.0	1.95
27		216	58	1.5	1.78

4. METHODOLOGY

4.1Response Surface Method

Response Surface Methodology (RSM) is useful for the modeling and analysis of programs in which a response of interest is influenced by several variables and the objective is to optimize this response. It uses various statistical, graphical and mathematical techniques to develop, improve and optimize a process and also use for modeling and analysis of problems if our response variables in influenced by several independent variables. RSM used in different fields of real life like industries, agriculture, electronics, medical field and many other like this where we need to get optimum response. The mathematical model commonly used for the machining response Y is represented as

Y= f (d, N, f) + ϵ

Where d, N, f are depth of cut, spindle speed and feed rate respectively and ϵ is the error which is normally distributed about the observed machining response Y.

Let,

$$\eta = E(y) = f(x_1, x_2)$$

The surface represent by η is called response surface.

Approximate the true relationship between y and the independent variables by the lower-order polynomial model. When the experimenter is relative closed to the optimum, the second-order model is used to approximate the response.

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon$$

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j} \beta_{ij} x_i x_j + \varepsilon$$

Here, xi's are process variable such as cutting speed, feed rate, depth of cut respectively, and by linear multiple regression analysis β's are regression coefficients can be calculated. Table 5 and 6 determines that all the parameters such as cutting speed, feed rate, and depth of cut are having significant influence on Surface roughness and chip-tool interface temperature. Here the adequacy of the regression model is evaluated using ANOVA and R2 values of surface roughness is 0.5243 and cutting temperature is 0.9647 which is greater than 0.8. This model is very much suitable to navigate the design space. And fig: 4 and 5 shows the surface plots for surface roughness and temperature.

TABLE 5

ANALYSIS OF VARIANCE (ANOVA FOR QUADRATIC MODEL OF SURFACE ROUGHNESS):

Source	DF	Adj Sum of Squares	Adj Mean Square	F value	P value
Model	14	3.44249	0.24589	1.26	0.326
Linear	4	1.60228	0.40057	2.05	0.135
Cutting Speed (A)	1	0.13054	0.13054	0.67	0.426
Feed Rate (B)	1	0.00120	0.00120	0.01	0.938
Depth of Cut (C)	1	0.24200	0.24200	1.24	0.282
Hardness (D)	1	1.22854	1.22854	6.29	0.023
Square	4	0.83822	0.20955	1.07	0.402
A*A	1	0.66490	0.66490	3.41	0.084
B*B	1	0.00645	0.00645	0.03	0.858
C*C	1	0.00287	0.00287	0.01	0.905
D*D	1	0.17169	0.17169	0.88	0.362
2-Way Interaction	6	1.00199	0.16700	0.86	0.547
A*B	1	0.02176	0.02176	0.11	0.743
A*C	1	0.00601	0.00601	0.03	0.863
A*D	1	0.20931	0.20931	1.07	0.316
B*C	1	0.40006	0.40006	2.05	0.172
B*D	1	0.35106	0.35106	1.80	0.199
C*D	1	0.01381	0.01381	0.07	0.794
Error	16	3.12367	0.19523		
Lack-of-Fit	10	1.60192	0.16019	0.63	0.752
Pure Error	6	1.52174	0.25362		
Total	30	6.56615			

Model Summary:

S	R-squared	R-squared (adj)	R-squared (pred)
0.441848	52.43%	10.80%	0.00%

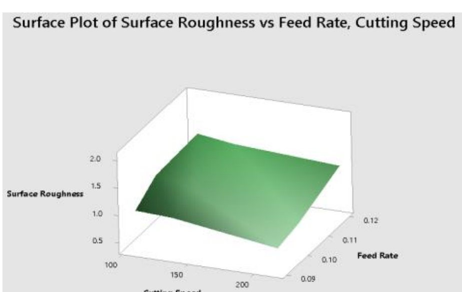

Fig. 4 Surface Plot for surface roughness with respect to cutting parameters

Figure 4 shows the plots for three dimensional surface with respect to cutting parameters such as cutting speed and feed rate. It is seen from the above figure that surface roughness increases with the decrease of cutting speed and the increase of feed rate. Here the total process is vice-versa. On the other hand, Figure 4 shows the plots for three dimensional temperature for same cutting parameters. Here it is shown that, temperature increases with the increase of cutting speed and feed rate.

Table 6

ANALYSIS OF VARIANCE FOR TEMPERATURE (ANOVA FOR QUADRATIC MODEL OF TEMPERATURE):

Source	DF	Seq Sum of square	Adj Sum of Squares	Adj Mean Square	F value	P value
Regression	6	4837.03	4837.03	806.17	9.10	0.102
Linear	3	4672.35	3882.92	1294.31	14.61	0.065
Cutting Speed	1	1419.33	134.32	134.32	1.52	0.343
Feed Rate	1	2781.46	2167.06	2167.06	24.46	0.039
Depth of cut	1	471.56	476.78	476.78	5.38	0.146
Square	1	80.10	80.10	80.10	0.90	0.442
Feed Rate*Feed Rate	1	80.10	80.10	80.10	0.90	0.442
Interaction	2	84.59	84.59	42.29	0.48	0.677
Cutting Speed*Feed Rate	1	79.07	21.15	21.15	0.24	0.673
Feed Rate*DOC	1	5.52	5.52	5.52	0.06	0.826
Residual Error	2	177.19	177.19	88.60		
Total	8	5014.22				

Model Summary

S	R-squared	R-squared (adj)	R-squared (pred)
9.41250	96.47%	85.86%	0.00%

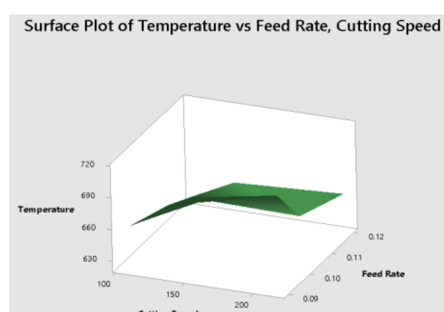

Fig. 5 Surface Plot for temperature with respect to cutting parameters

International Journal of Scientific & Engineering Research Volume 8, Issue 8, August-2017
ISSN 2229-5518

Here the roughness is determined from the average of roughness values measured over the circumference of the turned surface.

4.2 Genetic Algorithm

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. Many people, biologists included, are astonished that life at the level of complexity that we observe could have evolved in the relatively short time suggested by the fossil record. The idea with GA is to use this power of evolution to solve optimization problems. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution; especially those follow the principles first laid down by Charles Darwin of "survival of the fittest". Genetic algorithms (GAs) begin with a set of solutions represented by chromosomes, called population. Solutions from one population are taken and used to form a new population, which is motivated by the possibility that the new population will be better than the old one. Further, solutions are selected according to their fitness to form new solutions, that is, offspring's. The above process is repeated until some condition is satisfied. Algorithmically, the basic genetic algorithm (GAs) [12] is outlined as below.

Step i [Start] Generate random population of chromosomes, that is, suitable solutions for the problem.

Step ii [Fitness] Evaluate the fitness of each chromosome in the population.

Step iii [New population] Create a new population by repeating following steps until the new population is complete

Genetic Algorithms (GA) are search algorithms based on the mechanics of natural selection and natural genetics [13]. GA then iteratively creates new populations from the old by ranking the strings and interbreeding the fittest to create new, and conceivably better, populations of strings which are (hopefully) closer to the optimum solution to the problem at hand. The GA maintains a population of n chromosomes (solutions) with associated fitness values. Parents are selected to mate, on the basis of their fitness, producing offspring via a reproductive plan. Consequently highly fit solutions are given more opportunities to reproduce, so that offspring inherit characteristics from each parent. As parents mate and produce offspring, room must be made for the new arrivals since the population is kept at a static size. In this way it is hoped that over successive generations better solutions will thrive while the least fit solutions die out.

New generations of solutions are produced containing, on average, better genes than a typical solution in a previous generation. Each successive generation will contain more good `partial solutions' than previous generations. Eventually, once the population has converged and is not producing offspring noticeably different from those in previous generations, the algorithm itself is said to have converged to a set of solutions to the problem at hand. The GA approach is depicted in Figure: 6.

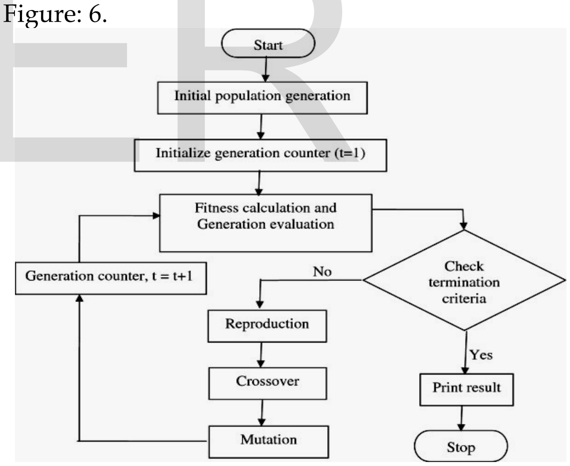

Fig. 6 Genetic algorithm approaches for optimization of cutting parameters

5. Formulated Model of Cutting Force and Validation

From the analysis of the results using MINITAB-16 it is found that the value of surface roughness is increased when the feed rate varied from 0.09mm/rev to 0.10mm/rev. Again when cutting speed increased from the value of 108 rpm to 216 rpm the value surface roughness increased that means the surface finish is increased. As the depth of cut increased from 0.5mm to 1.5mm, surface roughness is increased but when cutting fluid VG-68 is used then surface roughness decreased that mean surface finish is increased.

In the Present work, the average cutting temperature was measured for the 0.5mm depth of cut under all the machining conditions undertaken by simple but reliable tool-work thermocouple technique with proper calibration. The evaluated role of coolant on average chip-tool interface temperature in turning hardened medium carbon steel by SMNG insert at different Vc-So combinations in compare to dry condition and wet condition have been shown in Fig.7. Cutting temperature is increased with the increase in process parameter as well as with the increase in hardness and strength of the work material.

Second order response surface quadratic models were fitted using MINITAB-16 for all the response variable Ra (surface roughness) and chip-tool interface temperature. Here Equation 1 and 2 shows the best fitted regression model for surface roughness and temperature. From MATLAB R2014a it is found that minimum temperature occur when the cutting speed rate is 216 rpm, feed rate is 0.12 mm/rev and depth of cut is 0.5 mm and minimum surface roughness found when cutting speed rate is 108 rpm, feed rate is 0.12 mm/rev and depth of cut is 0.5 mm.

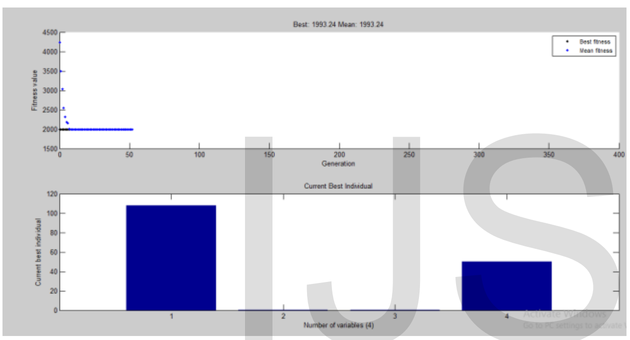

Fig. 7 Graphic presentation of the simulation process using GA

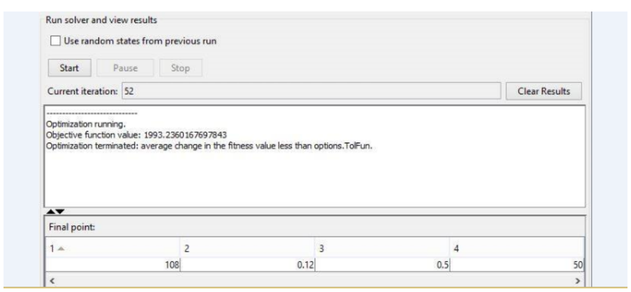

Fig. 8 Final result window

6. Cutting Parameter Optimization Using GA

In this present study, an effort has been made to determine the optimum values of cutting parameters to obtain the best possible surface quality within the specific test range. An effective optimization method, genetic algorithm (GA) is

Surface Roughness = 0.957 + 0.0737 Cutting Speed + 0.0071 Feed Rate - 0.1004 Depth of cut + 0.2263 Hardness + 0.1525 Cutting Speed * Cutting Speed - 0.0150 Feed Rate * Feed Rate - 0.0100 Depth of cut*Depth of cut + 0.0775 Hardness * Hardness - 0.037 Cutting Speed*Feed Rate + 0.019 Cutting Speed*Depth of Cut+ 0.114 Cutting Speed*Hardness - 0.158 Feed Rate*Depth of Cut - 0.148 Feed Rate*Hardness - 0.029 Depth of Cut*Hardness (1)

Temperature, T= 1043.55 + 1.38839*Cutting Speed-7233.68*Feed Rate+7.00893*Depth of Cut+32222.2*Feed rate * Feed Rate-32.5893*Cutting Speed*Feed Rate+586.607*Feed Rate*Depth of Cut (2)

developed to solve the optimization problem for this study. GA toolbox of MATLAB was utilized to optimize the cutting force model found in equation (1).

During parameters selection, four parameters are considered means crossover fraction and function, mutation function and fraction as most sensitive and different combinations of this four parameters are tried to determine the optimum values with a view to minimizing the objective function for different value of cutting speed and feed rate [16]. Figure: 7 depict the graphic presentation of the simulation process with GA. In the present study, population size 200, mutation rate 0.6, crossover rate 0.8 and number of generations 600 are judiciously taken. From figure 8, we found the optimized value of cutting speed 108 rpm, feed rate 0.12 mm/rev, depth of cut 0.5 mm where the hardness of AISI-1060 medium carbon steel will be 50 µm. optimal results were obtained after 54 iteration. A lower bound [108 0.09 0.5 50] and an upper bound [216 0.12 1.5 58] was used for four variables respectively cutting speed, feed rate, depth of cut and hardness.

7. CONCLUSION

In the present investigation, GA approach was used for predicting surface roughness during hard turning of AISI-1060 medium carbon steel with minimal cutting fluid application. RSM is applied successfully in analyzing effect of process parameters on different surface roughness parameters. The following conclusions are made:

The optimal combination of process parameters to obtain optimized surface finish though Genetic Algorithm technique for machining hardened steel are cutting speed of 108 rpm, the feed rate of 0.12 mm/rev and the depth of cut 0.5 mm.
It is well recommended that smaller feed rate and higher cutting speed (spindle speed) can help to produce higher quality of surface.
Second order surface roughness prediction model has been found to represent the hard turning process very well.

REFERENCE:

[1] Vestnik. S., "An Experimental Investigation on Effect of Cutting Fluids inTurning with Coated Carbides Tool", Journal of Mechanical Engineering 56/3, 2010

[2] T. Tamizharasan, T. Selvaraj, A. NoorulHaq, "Analysis of tool wear and surface finish in hard turning", The International Journal of Advanced Manufacturing Technology, April 2006, Volume 28, Issue 7-8, pp 671-679

[3] C, Felho., J. Kundrak, "Investigation of Theoretical and Real Surface Roughness in Face Milling of 42CrMo04 Steel"

[4] Tanveer Hosssain Bhuiyan, Imtiaz Ahmed, 'OPTIMIZATION OF CUTTING PARAMETERS IN TURNING PROCESS', Journal of Process Engineering, Volume 2, No.2

[5] Sardiñas, R. Q., Santana, M. R. and Brindis, E. A., (2006), "Genetic algorithm-based multi-objective optimization of cutting parameters in turning processes", Engineering Applications of Artificial Intelligence, Vol. 19, No. 2, pp. 127-133

[6] Xie, S. and Guo, Y., (2011), "Intelligent Selection of Machining Parameters in Multi-pass Turnings Using a GA-based Approach", Journal of Computational Information Systems, Vol. 7, No. 5, pp. 1714-1721.

[7] Sahoo, P., (2011), "Optimization of turning parameters for surface roughness using RSM and GA", Advances in Production Engineering and Management, Vol. 6, No. 3, pp. 197-208.

[8] Srikanth, T. and Kamala, V., (2008), "A real coded genetc algorithm for optimization of cutting parameters in turning", International journal of computer science and network security, Vol. 8, No. 6, pp. 189-193.

[9] Savadamuthu, L., Muthu, S. and Vivekanandan, P., (2012), "Optimization of Cutting Parameters for Turning Process using Genetic Algorithm", European Journal of Scientific Research, Vol. 69, No. 1, pp. 64-71.

[10] N. Qehaja, H. Zeqiri, A. Salihu, H. Osmani, F. Zeqiri, Machinability of Matals, Methods, and Practical Application, Annals of DAAAM & Proceedings 2012, The 23RD World Symposium, 24-27th October 2012, University of Zadar, Croatia, URL: http:\\www.daaam.com, Vienna University of Technology, Karlsplatz 13/311, A-1040 Wien, Austria, Europe.

[11] A. Salihu, H. Zeqiri, A. Bunjaku, N. Qehaja, F. Zeqiri, Research of Surface Roughness Average of Steel C45 During Turning, Anals of DAAAM for 2010 & Procedings of the 21st International DAAAM symposium, Volume 21, PP. 0185÷0186, ISBN 978-3-901509-73-5. No 1. ISSN 1726-9679. Vienna University of Technology, Karlsplatz 13/311, A-1040 Wien, Austria, Europe..Chu-Kuei Tu and Tseng-Hsien Lin. "Applying Genetic Algorithms On Fuzzy Logic System For Underwater Acoustic

[12] Chu-Kuei Tu and Tseng-Hsien Lin. "Applying Genetic Algorithms On Fuzzy Logic System For Underwater Acoustic Signal Recognition, Proceedings of the 2000 International Symposium on Underwater Technology, pp. 405-410.

[13] D. Goldberg "Genetic Algorithms in Search, Optimiza- tion, and Machine Learning," Machine Learning, Vol. 3, No. 2-3, 1988, pp. 95-99.

[14] Mohammed T. Hayajneh, Montasser S. Tahat, Joachim Bluhm, " a study of the effect of machine parameters on the surface roughness in End milling process"- Volume 1, Number 1, ISSN 1995-6665,2007

[15] N. Satheesh Kumar, Ajay Shetty, Ashay Shetty, Ananth K, Harsha Shetty, "Effect of spindle speed and feed rate on surface roughness of Carbon Steels in CNC turning", Procedia Engineering 38 (2012) 691 – 697

[16] Kaya, I., and Engin, O. (2007), 'A new approach to define sample size at attributes control chart in multistage processes: An application in engine piston manufacturing process", journal of Materials Processing Technology, Vol.183, No. 1, pp.38-48