Optimization of Cutting Parameters in CNC Machine using Mathematical Algorithm

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Abstract— **Now a day's machining is done through various automated machines. One of the widely used machines is CNC. Even though the automated machines are used, the quality of the work is determined by parameters used. The cutting parameters of the CNC machine determine the productivity, surface finish, machining time and other qualities of the product. This study involves the optimization of those cutting parameters. In order to get optimized CNC parameters for a specific tool-work combination, Harmony Search Algorithm (HSA) is used to compute the best parameters based on the experiments conducted on a CNC Turning center. The three cutting parameters are cutting speed (V), feed (f), and depth of cut (d). The practical constraints have been considered during both practical and experimental approaches. The result reveals that HSA is very well suited in solving parameters selection problems**.

Keywords—CNC turning, Cutting parameters,HSA,Surface Roughness, Machining time, AISI 321

I. Introduction

Computer Numerical Control (CNC) is one of the most commonly used machines. The machining is done by entering the coded information and cutting parameters. Selecting the optimized parameters to attain efficient machining is very difficult. It has been proved that proper selection of parameters decides the productivity rate and the cost of production per component. The implementation of CNC needs high initial investment, so it is must have better usage of the machine to make a profit. The selection of parameters must be within the range which are taken from the cutting tool catalogue or hand books. After getting the range for cutting parameters, the optimization of parameters within the range is done through optimizing techniques. The various optimization techniques available are Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO). In this research work, we have used recently developed algorithms called Harmony search algorithm (HSA) for the optimization problem. Our ultimate aim is minimizing machining time and attaining better surface finish. Here in this work, we fixed surface finish of a product and we tried to reduce the machining time in order to increase the production rate. The three parameters were analyzed in various ways to determine the effect of one over the other two.

II. LITERATURE REVIEW

M.S.Chua, M.Rahman, Y.S.Wang and H.T.Loh [1] developed relations between the tool life, cutting force, power consumption and the cutting conditions using multiple regression analysis through factorial design of experiments. Based on the analysis, it was found that the tool life model is dependent on depth of cut while the Cutting force and power consumption models are dependent on speed, feed and depth of cut. C.Y.Nian, W.H.Yang and Y.S.Tarng [2] employed orthogonal array, multi-response signal-to-noise ratio and ANOVA to study the performance characteristics in turning operations. Experimental results were provided to illustrate the effectiveness in using Taguchi method. The author concluded that the tool life, cutting force and surface roughness could be improved simultaneously using the proposed approach instead of engineering judgment. C.F.Cheung and W.B.Lee [3] established and evaluated a model-based simulation system for analysing the surface roughness in ultra-precision diamond turning. The analysis includes the effects of process parameters, tool geometry and relative vibration between the tool and work piece. It was found that the system can accurately predict the surface roughness under various cutting conditions B.Y.Lee, Y.S.Tarng and H.R.Lii [4] described the use of polynomial network to construct the machining database in turning operation. The relationships between the cutting parameters and the tool life, surface roughness and cutting force were accurately correlated by a self-organizing adaptive modelling technique. Experimental results showed that the machining database has a high accuracy in the prediction of cutting performance in turning operation. J Paulo Davim and C.A.Conceicao Antonio [5] proposed GA to select optimum cutting conditions in turning and drilling aluminium matrix composites. The

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obtained results show that machining was perfectly compatible with the cutting conditions for cutting time of industrial interest and in agreement with the optimal machining parameters. Numerical and experimental models based on GA are a matter of scientific interest and large industrial applications. M.Y.Noordin, V.C.Venkatesh, S Sharif, S Elting and A Abdullah [6] presented the findings of an experimental investigation of the effect of feed rate, Side Cutting Edge Angle (SCEA) and cutting speed on the surface roughness and tangential force in turning steel. ANOVA revealed that feed is the most significant factor influencing the surface roughness followed by SCEA, while cutting speed provided secondary contribution to the tangential force. The quadratic model developed using RSM was reasonably accurate and can be used for prediction of performance measures. Wassilla Bouzid [7] developed empirical models for tool life, surface roughness and cutting force for calculating optimum cutting conditions in tuning to achieve maximum production rate. The coefficients of these models were determined based on the experiments. The author explained the relation of feed to the roughness, which depends on cutting speed and finally concluded that the proposed method was capable of selecting the appropriate conditions. Muthukrishnan and J Paulo Davim [8] studied the surface roughness of composite bars under different cutting conditions. Experimental data were tested with ANOVA and ANN techniques. ANOVA revealed that feed rate has highest influence (51%) on surface roughness followed by depth of cut (30%) and cutting speed (12%). The results of ANN model showed close matching between the model output and the directly measured surface roughness. S Bharathi Raja and N Baskar [9] examined SA, GA, and PSO in three different mathematical models such as single pass turning operation, multi-pass turning operation and grinding operation. The authors found that PSO outperformed the other optimization techniques in all the cases. Bharathi Raja and Baskar [10] adopted PSO for optimize machining parameters to get desired surface roughness in minimum possible machining time. The author's claimed that average deviation and accuracy rate of predicted surface roughness to the actual surface roughness value is found to be 0.05 microns and 85% respectively. The average deviation and accuracy rate of the predicted machining time to the actual machining time is found to be 2 s and 96% respectively. S.Bharathi Raja, C.V.Srinivas Pramod, K.Vamshee Krishna, Arvind Ragunathan and Somalaraju Vinesh [11] implemented Firefly Algorithm (FA) to explore optimum Electric Discharge Machine (EDM) parameters to minimize machining time for the desired surface finish. It is observed that the proposed FA could predict the set objective function considerably close to the experimental values.

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III.PILOT EXPERIMENT

In pilot experiment AISI 321grade material are used to machining in LL-20-T L5 CNC turning centre as shown in fig 1.1. The simple turning operations as shown in fig 1.2 are machine dusing carbide tool.

S.no	Speed(v) (rpm)	Feed(F) (mm/rev)	Depth of cut(D) (mm)
1	600	0.2	0.5
2	750	0.25	1
3	900	0.3	1.5

Table1.1 Machining parameters

Fig 1.1 is CNC machine

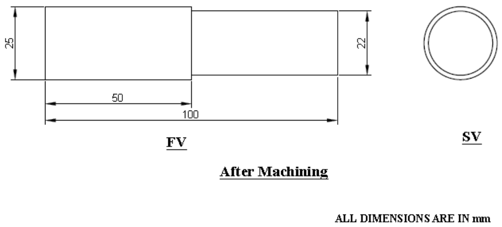

Fig 1.2 is work piece design

. The different values within the range of the machining parameters are chosen and the three different values in the range are mentioned in the table 1.1

Fig 1.3 machining work piece

s.no	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	Machining time(rev)	Surface roughness (µm)
1	600	0.2	0.5	35.33	1.166
2	600	0.2	1	35.23	0.686
3	600	0.2	1.5	36.20	0.579
4	600	0.25	0.5	36.17	0.584
5	600	0.25	1	36.42	0.788
6	600	0.25	1.5	25.89	0.912
7	600	0.3	0.5	36.51	0.591
8	600	0.3	1	24.07	0.732
9	600	0.3	1.5	24.14	0.768
10	750	0.2	0.5	28.75	0.425
11	750	0.2	1	28.82	0.541
12	750	0.2	1.5	28.76	0.549
13	750	0.25	0.5	22.81	0.549
14	750	0.25	1	23.12	1.063
15	750	0.25	1.5	22.85	1.152
16	750	0.3	0.5	18.65	1.457
17	750	0.3	1	20.41	1.794
18	750	0.3	1.5	19.56	1.816
19	900	0.2	0.5	24.36	0.765
20	900	0.2	1	23.59	0.976
21	900	0.2	1.5	23.68	1.138
22	900	0.25	0.5	18.96	2.026
23	900	0.25	1	19.09	2.125
24	900	0.25	1.5	18.65	1.95
25	900	0.3	0.5	15.86	2.982
26	900	0.3	1	15.81	3.059
27	900	0.3	1.5	15.58	2.623

Table 1.1 The machining is done by formulating the design of experiment table by using the full factorial method. The three values from the range as shown in table 1.1 are used to tabulate the design of experiment table. The design of table are shown in table 1.2 and the machining are done as per the machining parameters as shown in the design of experiment table 1.2 The machining are done as per the above machining table and the finished work piece are shown in the fig 1.3. the finished product.

IV.FORMULATION OF EMPIRICAL RELATION

In the **mini tab** software the cutting parameters such as speed, feed and depth of cut as the input parameter and the machining time as the constraint the separate equation are formed. The equations formed are taken as the general format and the any output can be defined by keeping the cutting parameters as the input parameters.

Table1.2 Pilot Experiment Table

Keeping the cutting parameters such as speed, feed, depth of cut as the input parameters and the machining time as the output the equation are formed.

Machining time = 82.0 - 0.0461 v - 82.4 f - 1.34 d

Where
v = speed in mm/sec
f = feed in mm/rev
d= depth of cut in mm

Keeping the cutting parameters such as speed, feed, depth of cut as the input parameters and the surface roughness as the output the equation are formed.

surface roughness = - 4.65 + 0.00416 v + 10.4 f + 0.150 d

Where
v = speed in mm/sec
f = feed in mm/rev
d= depth of cut in mm

V. HARMONY SEARCH ALGORITHM

Firstly proposed by Geem et al. in 2001 , the Harmony Search (HS) method is inspired by the underlying principles of the musicians' improvisation of the harmony. The HS has the distinguishing features of algorithm simplicity and search efficiency. As we know, when musicians compose the harmony, they usually try various possible combinations of the music pitches stored in their memory. This search for the perfect harmony is indeed analogous to the procedure of finding the optimal solutions to engineering problems. The HS method is actually inspired by the working principles of the harmony improvisation . Figure 1 shows the flowchart of the basic HS method, in which there are four principal steps involved.

STEP 1

Initialize the HS Memory (HM). The initial HM consists of a certain number of randomly generated solutions to the optimization problems under consideration. For an *n*-dimension problem, an HM with the size of *N* can be represented as follows:

$$\mathrm{HM} = \begin{bmatrix} x_1^1, x_2^1, \ldots, x_n^1 \\ x_1^2, x_2^2, \ldots, x_n^2 \\ \vdots \\ x_1^{\mathrm{HMS}}, x_2^{\mathrm{HMS}}, \ldots, x_n^{\mathrm{HMS}} \end{bmatrix},$$

where [*x* , *x* ,…, *x*] (*i* = 1,2,…, HMS) is a solution candidate. HMS is typically set to be between 50 and 100.

STEP 2

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Improvise a new solution [*x* ′, *x* ′,…, *x* ′] from the HM. Each component of this solution, *x* ′, is obtained based on the Harmony Memory Considering Rate (HMCR). The HMCR is defined as the probability of selecting a component from the HM members, and 1-HMCR is, therefore, the probability of generating it randomly. If *x* ′ comes from the HM, it is chosen from the *j*th dimension of a random HM member and is further mutated according to the Pitching Adjust Rate (PAR). The PAR determines the probability of a candidate from the HM to be mutated. As we can see, the improvisation of [*x* ′, *x* ′,…, *x* ′] is rather similar to the production of offspring in the Genetic Algorithms (GAs) with the mutation and crossover operations. However, the GA creates new chromosomes using only one (mutation) or two (simple crossover) existing ones, while the generation of new solutions in the HS method makes full use of all the HM members.

STEP 3

Update the HM. The new solution from Step 2 is evaluated. If it yields a better fitness than that of the worst member in the HM, it will replace that one. Otherwise, it is eliminated.

STEP 4

Repeat Step 2 to Step 3 until a preset termination criterion, for example, the maximal number of iterations, is met.

Similar to the GA and swarm intelligence algorithms , the HS method is a random search technique. It does not require any prior domain knowledge, such as the gradient information of the objective functions. However, different from those population-based approaches, it only utilizes a single search memory to evolve. Therefore, the HS method has the distinguishing feature of computational simplicity.

VI. CONFIRMATORY EXPERIMENT

Confirmation Experiment is the process which is conformation of Practical Experimentation value with the Theoretical experimentation values. Which one of the process is best in other wise which one of the processes is closer to the Perfect machining time. The confirmation process is more important to determine the best process .By using the HSA algorithm the degree of accuracy are calculated and are tabulated in the table 1.3. The accuracy are calculated with the aid of the actual machining time and the predictable machining time. By calculating the percentage of accuracy that is closeness to the actual value the best optimization technique is found. The accuracy is calculated by using the formula.

Accuracy = 100 – ((|Actual MT – Predictable MT| / Actual MT) * 100)

Actual Machining Time	Predictable Machining Time	Deviation	Accuracy %
35.33	33.22	2.11	94.02
35.23	27.30	7.93	77.49
36.20	30.33	5.87	83.78
36.17	28.29	7.88	78.21
36.42	27.05	9.37	74.27
25.89	29.33	3.44	86.71
36.51	32.50	4.01	89.01
24.07	19.64	4.43	81.59
24.14	23.30	0.84	96.52
28.75	28.01	0.74	97.42
28.82	26.56	2.26	92.15
28.76	27.45	1.31	95.44
22.81	25.45	2.64	88.42
23.12	22.24	1.12	95.15
22.85	21.20	1.65	92.77
18.65	23.78	5.13	72.54
20.41	19.39	1.02	95.0
19.56	18.24	1.32	93.25
24.36	26.75	2.39	90.18
23.59	22.81	0.78	96.69
23.68	24.47	0.79	96.66
18.96	17.28	1.68	91.13
19.09	20.38	1.29	93.24
18.65	16.68	2.03	89.11
15.86	15.08	0.72	95.46
15.81	14.45	1.36	91.39
15.58	14.30	1.28	91.78

Table 1.3 Confirmation table

VII. RESULT

A graph is plotted between the actual machining time and the predictable machining time. From the graph by using the HSA algorithm the machining time is almost closeness to the accuracy level. The graph is denoted in graph 1.1

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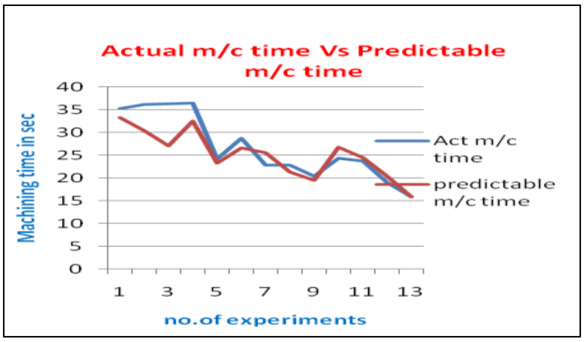
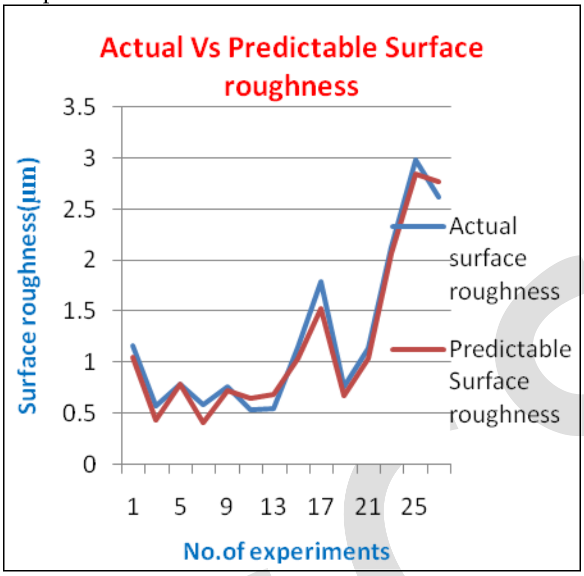
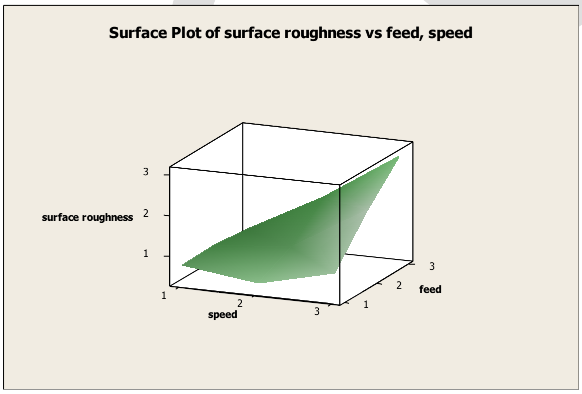


Graph1.1 actual machining time Vs predictable machining time

A graph is plotted between the actual surface roughness and the predictable surface roughness. The graph is denoted in Graph1.2



Graph 1.2 actual machining time Vs predictable machining time



Graph 1.3 surface plot of surface roughness Vs feed, speed

VIII. CONCLUSION

By the pilot experiments are conducted to study the effect of cutting parameters on machining time for a continuous finished profile. Further, predicted machining time based on cutting parameter optimization by hormony search algorithm was verified by experimental results. The followings are the observations evolved from the present work:

1. The effect of feed on machining time was dominating more than cutting speed.
2. hormony search Algorithm could able to predict the machining time for the proposed continuous profile in terms of accuracy as follows: Maximum Finishing Accuracy: 97.42% Minimum Finishing Accuracy : 74.47%
3. hormony Algorithm has proved to be one of the best tools for optimization tool for solving any engineering problems and to select the best values from the given parameters
4. The present method of selection of cutting parameters can very well be replaced by the proposed method of
5. selection of optimized cutting parameters by HSA.
6. Since a real time job profile was undertaken, optimized parameters by HSA have increased the production rate when compared to the parameters utilized before optimization.
7. Time and cost is not a major function in introducing the proposed method of parameters selection.
8. Use of HSA is completely generalized and it can be very well used for solving any engineering problems.

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