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Experimental Investigation for Tool Life by Optimizing Machining and Geometric Parameters of CNC End Mill Tool

Nilesh S. Pohokar [1], **Lalit B. Bhuyar**[2]
[1,2]Mechanical Engineering Department, Prof. Ram Meghe Institute of Technology and Research, Badnera , Amravati
nilesh. pohokar@gmail.com,lbbhuyar@gmail.com

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***Abstract* - CNC end milling is a unique adaption of the conventional milling process which uses an end mill tool for the machining process. During the End milling process, the material is removed by the end mill cutter. The effects of machining parameters of end milling process like spindle speed, depth of cut and feed rate and geometric parameter rake angle of a 14 mm diameter HSS end mill tool have been investigated on a AISI 1025 MS plate work material for pocket milling operation to reveal their impact on tool life using Taguchi Methodology. Experimental plan is performed by a Standard Orthogonal Array three times. The results of analysis of variance (ANOVA) indicate that the proposed mathematical model can be adequately describing the performance within the limit of factors being studied. The optimal set of process parameters has also been predicted to maximize the tool life.**

***Keywords*— CNC end milling, Taguchi method, ANOVA, Tool life**

I. INTRODUCTION

In present time the technology of CNC vertical milling machine has been improved significantly to meet the advance requirements in various manufacturing fields, especially in the precision metal cutting industry. This experiment gives the effect of different machining parameters (spindle speed, feed, and depth of cut) and one geometric parameter rake angle of end mill tool on tool life. The demand for high quality and fully automated production focus attention on the surface condition of the product, surface finish of the machined surface is most important due to its effect on product appearance, function, and reliability. For these reasons it is important to maintain consistent tolerances and surface finish. Among several CNC industrial machining processes, milling is a fundamental machining operation. End milling is the most common metal removal operation encountered. It is widely used in a variety of manufacturing industries. The quality of the surface plays a very important role in the performance of milling as a good-quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. The surface generated during milling is affected by different factors such as vibration, spindle run–out, temperature, tool geometry, feed, cross-feed, tool path and other parameters. During finish milling, the depth of cut is small. Technological parameter range plays a very important role on surface roughness. In end milling, use of high cutting speed, low feed rate and low depth of cut are recommended to obtained better surface finish for the specific test range in a specified material. Cutting feed is the most dominated factor for surface finish. The most important interactions, that effect surface roughness of machined surfaces, are between the cutting feed and depth of cut, and between cutting feed and spindle speed. Surface Roughness is affected negatively if the applied force is increased. With the more precise demands of modern engineering products, the control of surface texture together with dimensional accuracy has become more important. This experimental investigation outlines the Taguchi optimization methodology, which is applied trice to optimize tool life in end milling operation. The experiment is conducted on a AISI 1025 MS plate the processing of the job is done by High Speed Steel (HSS) end-mill tool of 14 mm diameter under rough milling conditions. The machining parameters evaluated are spindle speed, feed rate, depth of cut and only one geometric parameter is taken into consideration tool rake angle. The experiments are conducted by using Taguchi L9 orthogonal array as suggested by Taguchi and this method is applying trice. Signal-to-Noise (S/N) ratio and Analysis of Variance (ANOVA) is employed to analyse the effect of milling parameters on tool life.

II. LITERATURE REVIEW

Optimization, in its broadest sense, can be applied to solve any engineering problem. Some typical applications from manufacturing area indicate the wide scope of the subject [1],

1. Selection of machining conditions in metal-cutting processes for minimum production cost
2. Design of material handling equipment, such as conveyors, trucks, and cranes, for minimum cost
3. Optimal production planning, controlling, and scheduling
4. Optimum design of chemical processing equipment and plants
5. Planning of maintenance and replacement of equipment to reduce operating costs
6. Allocation of resources or services among several activities to maximize the benefit
7. Controlling the waiting and idle times and queueing in production lines to reduce the costs
8. Planning the best strategy to obtain maximum profit in the presence of a competitor.

Genichi Taguchi is a Japanese engineer who has been active in the improvement of Japan's industrial products and processes since the late 1940s. He has developed both the philosophy and methodology for process or product quality improvement that depends heavily on statistical concepts and tools, especially statistically designed experiments. Many Japanese firms have achieved great success by applying his methods. Barker [2] reported that since 1983, after Taguchi's association with the top companies and institutes in USA (AT & T Bell Laboratories, Xerox, Lawrence Institute of Technology (LIT), Ford Motor Company etc.), his methods have been called a radical approach to quality, experimental design and engineering.

L. Eriksson et. al. [3] pointed out that the key element for achieving high quality and low cost is parameter design & optimization. Through parameter design, levels of product and process factors are determined, such that the product's functional characteristics are optimized and the effect of noise factors is minimized.

H. Singh et. al. [4] applied Taguchi's technique for optimizing surface finish, tool wear, cutting force and power consumed in turning operations for machining En24 steel with titanium carbide-coated tungsten carbide inserts. The success of many applications has demonstrated the power of Taguchi's overall approach. It is also worth mentioning that many of the specific statistical techniques he has proposed for implementing robust parameter design have generated a great deal of controversy. However, most commentators agree that Taguchi's loss function concept represents a solid contribution. Furthermore, there is general agreement that off-line experiments during the product or process design stage are of great value and the methodology is based on solid engineering principles. Reducing quality loss by designing the products and processes to be insensitive to variations in noise variables is a novel concept to statisticians and quality engineers.

Gupta et. al. [5] investigated the application of Taguchi method with logical fuzzy reasoning for multiple output optimization of high speed CNC turning of AISI P-20 tool steel using TiN coated tungsten carbide coatings. The machining parameters (cutting speed, feed rate, depth of cut, nose radius and cutting environment) are optimized with considerations of the multiple performance measures (surface roughness, tool life, cutting force and power consumption). Taguchi's concepts of orthogonal arrays, signal to noise (S/N) ratio, ANOVA have been fuzzified to optimize the high speed CNC turning process parameters through a single comprehensive output measure (COM).

They investigated the following results related to combination of parameters multi-response problem and response and multi-response optimization analysis

(1) The factor/level combination S3F2D2N3E3 for surface roughness,S1F1D1N2E3 for the tool life, S1F1D1N2E3 for power consumption and S2F1D1N2E3 for cutting force are the recommended optimum parameters, for high speed CNC turning when all four responses are considered independently.

(2) In the multi-response problem, all the four responses tool life, power consumption, cutting force and surface roughness were simultaneously considered, and S2F1D1N2E3 was the recommended optimum condition as per the hybrid Taguchi-fuzzy approach.

(3) It can be concluded that middle level of cutting speed (160 m/min) and nose radius (0.8 mm) and lower level of feed (0.1 mm/rev) and depth of cut (0.2 mm) yield the optimal result. Cryogenic environment is the most favorable condition out of three cutting environments.

(4) Both single response and multi-response optimization analysis proved that cryogenic machining environment E3 is favorable in increasing tool life and reducing surface roughness, cutting force and power consumption compared to wet (conventional coolant ILO cut 154 Indian Oil recommended for CNC machine) and dry machining.

They also presented the use of fuzzy logics to the Taguchi method in optimization of the high speed CNC turning with multiple performance characteristics. A fuzzy reasoning of the multiple performance characteristics has been performed by the fuzzy logic unit. As a result, four performance characteristics namely surface roughness, tool life, cutting force and power consumption can be improved. It can be concluded that the optimization methodology developed in this study is useful in improving multiple performance characteristics in high speed CNC turning.

A. Cicek & T. Kivak [6] investigated the application of Taguchi method for Surface roughness and roundness error in drilling of AISI 316 stainless steel. In his study, the effects of deep drilling parameters on surface roughness and roundness error were investigated in drilling of AISI 316 austenitic stainless steel with M35 HSS twist drills. In addition, optimal control factors for the whole quality were determined by using Taguchi technique. Two cutting tools, cutting speeds and feed rates were considered as control factors, and L8 (23) orthogonal array was determined for experimental trials. Multiple regression analysis was employed to derive the predictive equations of the surface roughness and roundness error achieved via experimental design. Minimum surface roughness and roundness error were obtained with treated drills at 14 m/min cutting speed and 0.08 mm/rev feed rate. Confirmation experiments showed that Taguchi method precisely optimized the drilling parameters in drilling of stainless steel.

Moshat S. & Datta S. [7] investigated the Optimization of CNC end milling process parameters using PCA-based Taguchi method. To optimize aforesaid quality attributes in a manner that these multi-criterions could be fulfilled simultaneously up to the expected level. This invites a multi-objective optimization problem which has been solved by PCA based Taguchi method. To meet the basic assumption of Taguchi method; in his work, individual response correlations have been eliminated first by means of Principal Component Analysis (PCA). Correlated responses have been transformed into uncorrelated or independent quality indices called principal components. Finally Taguchi method has been adapted to solve this optimization problem. The aforesaid methodology has been found fruitful in the cases where simultaneous optimization of huge number of responses is required.

III.MATERIAL & METHOD

Experiment is divided into three main phases. These three phases are the planning phase (design of experiments, experimental data consideration and machine, machine tool and work material used) the conducting phase (experimentation), the analysis phase (ANOVA). Following are the planning phase input parameter and there levels

A. Design of Experiments

Experiments are designed with the help of using Taguchi L9 orthogonal array. The software used for DOE (Design of experiment) is Minitab15.

TABLE I PROCESS PARAMETERS AND THERE LEVELS

Factors	**Parameters**	**Level 1**	**Level 2**	**Level 3**
A	Spindle Speed in RPM	600	800	1000
B	Feed in mm/min	50	100	150
C	Axial depth of Cut in mm	0.1	0.2	0.3
D	Rake Angle in Degree	10	15	20

As per Taguchi experimental design philosophy a set of three levels assigned to each parameter has two degrees of freedom (DOF). Here we have four parameters with three levels. This gives a total of 8 DOF for four parameters selected in this work. The nearest three level orthogonal array available satisfying the criterion of selecting the OA is L9 having 8 DOF [8].

TABLE II TAGUCHI'S L9 STANDARD ORTHOGONAL ARRAY

Expt. No	**1**	**2**	**3**	**4**	**Response (Raw Data)**				**S/N Ratio (dB)**
	V	**Fr**	**dp**	**Γ**	**R1**	**R2**	**R3**	**R4**	
1	1	1	1	1	$Y1_1$	$Y1_2$	$Y1_3$	$Y1_4$	S/N_1
2	1	2	2	2	$Y2_1$	$Y2_2$	$Y2_3$	$Y2_4$	S/N_2
3	1	3	3	3	$Y3_1$	$Y3_2$	$Y3_3$	$Y3_4$	S/N_3
4	2	1	2	3	$Y4_1$	$Y4_2$	$Y4_3$	$Y4_4$	S/N_4
5	2	2	3	1	$Y5_1$	$Y5_2$	$Y5_3$	$Y5_4$	S/N_5
6	2	3	1	2	$Y6_1$	$Y6_2$	$Y6_3$	$Y6_4$	S/N_6
7	3	1	3	2	$Y7_1$	$Y7_2$	$Y7_3$	$Y7_4$	S/N_7
8	3	2	1	3	$Y8_1$	$Y8_2$	$Y8_3$	$Y8_4$	S/N_8
9	3	3	2	1	$Y9_1$	$Y9_2$	$Y9_3$	$Y9_4$	S/N_9

R1, R2, R3, R4 represent response values for three repetitions of each trial. The 1's, 2's, 3's and 4's represent levels 1, 2, 3 and 4 of the variables, which appear at the top of the column. Yij are the measured values of the quality characteristic (response). The responses of the experimentation was measured in four terms namely flank wear, face wear, surface roughness and tool life

In order to study the significance of the process variables towards flank wear, face wear and surface roughness analysis of variance (ANOVA) was performed for lower is the better term. And for tool life higher is better term are used.

Lower is better $$(S/N)_{LB} = -10\ \mathrm{Log}\ \frac{1}{R}\left[\sum_{j=1}^{R} y^2{}_j\right]$$

Higher is better $$(S/N)_{HB} = -10\ \mathrm{Log}\ \frac{1}{R}\left[\sum_{j=1}^{R} \frac{1}{y^2{}_j}\right]$$

Where, Yj = value of the characteristic in an observation j
R = number of repetitions in a trial

B. Experimental data Consideration

All the experiments are carried out in Indo German Tool Room Aurangabad and testing of tools are carried out in NABL accredited Mikronix calibration Centre Chikhalthana MIDC, Aurangabad. Due to the limitation of infrastructure facilities for making the desired angles, decision are made only one geometric parameter tool radial rake angle is modified. The tools are purchase and modified from Raja Tools Aurangabad. The workpiece material is purchase and cut into number of equal dimensions pieces by Design steel private limited Waluj M.I.D.C. Aurangabad. In this work only one geometric parameter is modified and other parameters such as helix angle, end cutting edge concavity angle, axial and radial relief angle are kept constant. This modified radial rake angle is supplied by the supplier and marked as per the requirement and tested in the laboratory with the help of video measuring machine. Also the three machining parameters spindle speed, feed and axial depth of cut are considered for the optimization and other parameters such as machine power environment and redial depth of cut kept constant. The CNC machine is utilized to make control and accurate measurement of these parameters on the screen of display monitor. All the ranges of value of selected parameters are taken as per hand book recommendations.

C. *Machine, Machine tool and work material*

The experiments were carried out on 3-axis on Surya VF30CNC VS this CNC machine is a quality product of Bharat Fritz Werner Ltd. Bangalore. The HSS M2 grade four flute end mill tool was chosen for the experiments as it is most widely used in the industries because of its superior performance characteristics like good red-hardness and retains its cutting edge longer than other general purpose high speed steels. The table III shows the chemical composition of the tool material. The AISI 1025 (122 X 100 X 10 mm) MS plates are used for the experimentation the chemical composition are shown in table IV.

Figure 1a. 3-axis Surya VF30CNC VS CNC machine

Figure 1b. . HSS M2 grade four flute end mill tool

Figure 1.c. AISI 1025 M.S. Plate

Figure1 (a,b,c). Machine, Machine tool and Work Material used in the Experimentation

TABLE III CHEMICAL COMPOSITION OF HSS M2 GRADE TOOL

Element	W %	Cr %	V %	C %	Mo %
Composition	6	4	2	0.8	9.5

TABLE IV CHEMICAL COMPOSITION OF WORK MATERIAL

C %	Mn %	P %	S %	Density	Hardness	Tensile Strength
0.26	0.4	0.03	0.04	8.41 kg/m^3	115 BHN	750 Mpa

D. *Tool wear and tool life criteria*

The maximum acceptable flank wear for end milling is 0.5 mm stated by W. R. Devries [9]. This criterion is tested by doing the preliminary experimentation and the result obtained for the work and tool material was 0.25 mm is the uniform wear stage. So it is acceptable for all the experiments. The tool life criteria were based on the desired flank wear of 0.25mm is accepted.

IV. OBSERVATION RECORDED

As per hand book recommendation the parameters are first selected. The units of these values are converted as per the input system of CNC program. In this work the Taguchi method applied trice to find the optimal parameters. The observations are divided into three sets

1. First set: Parameters selected as per range given in handbook
2. Second set: Parameters selected just above and below the optimal parameters obtained in first set
3. Final set: Final parameters selected just above and below the optimal parameters obtained in second set

A. Observation of first experiment set

In the first set of experimentation the parameters range are selected as per handbook values. The Table I shows the factors and levels selected for experimentation. For each combination of parameter three trials are conducted.

TABLE V
OBSERVATION RECORDED IN THE SECOND EXPERIMENTATION SET

Ex. No.	Cutting speed in rpm	Feed rate in mm/min	Depth of cut in mm	Rake angle in degree	Flank wear in mm	Face wear in mm	Surface roughness in µm	T_L minute
1	600	50	0.1	10	0.213	0.241	4.21	178
					0.221	0.242	4.26	176
					0.212	0.245	4.24	177
2	600	100	0.2	15	0.228	0.250	4.34	165
					0.219	0.249	4.32	167
					0.230	0.243	4.37	169
3	600	150	0.3	20	0.198	0.248	3.57	174
					0.211	0.245	3.49	175
					0.213	0.248	3.66	176
4	800	50	0.2	20	0.192	0.250	4.87	179
					0.193	0.249	4.84	178
					0.195	0.251	4.65	177
5	800	100	0.3	10	0.178	0.221	4.76	183
					0.181	0.213	4.72	182
					0.179	0.223	4.71	182
6	800	150	0.1	15	0.216	0.248	3.16	179
					0.221	0.249	3.20	178
					0.218	0.251	3.18	178
7	1000	50	0.3	15	0.253	0.259	4.34	163
					0.251	0.258	4.38	164
					0.249	0.261	4.36	163
8	1000	100	0.1	20	0.261	0.259	3.33	171
					0.259	0.262	3.48	173
					0.258	0.260	3.51	172
9	1000	150	0.2	10	0.254	0.261	3.59	173
					0.251	0.265	3.37	174
					0.249	0.262	3.34	175

B. Observation of second experimentation set :

In the second set of experimentation the parameters range are selected as per optimized values obtained from the first set of experimentation. The Table VI shows the factors and levels selected for experimentation.

TABLE VI PROCESS PARAMETERS SELECTED IN SECOND SET

Factors	Parameters	Level 1	Level 2	Level 3
A	Spindle Speed in RPM	790	800	810
B	Feed in mm/min	95	100	105
C	Axial depth of Cut in mm	0.2	0.25	0.3
D	Rake Angle in Degree	9	10	11

Again the L9 orthogonal array is selected which is discussed earlier, for each parametric combination three trials are conducted to achieve a better accuracy for observation. Table VII shows the observations recorded for flank wear, face wear and surface finish for every trial the readings are noted. The average values of flank wear, face wear surface roughness and tool life are taken in each trial.

TABLE VII OBSERVATION RECORDED IN THE SECOND EXPERIMENTATION SET

Ex. No.	Cutting speed in rpm	Feed rate in mm/min	Depth of cut in mm	Rake angle in degree	Flank wear in mm	Face wear in mm	Surface roughness in µm	T_L minute
1	790	95	0.2	9	0.190	0.22	3.56	181
					0.191	0.21	3.54	180
					0.192	0.22	3.55	183
2	790	100	0.25	10	0.177	0.22	3.31	184
					0.178	0.23	3.32	182
					0.176	0.21	3.31	183
3	790	105	0.3	11	0.178	0.22	3.35	180
					0.177	0.23	3.34	179
					0.178	0.21	3.35	181
4	800	95	0.25	11	0.181	0.25	3.45	178
					0.182	0.25	3.44	179
					0.183	0.26	3.45	180
5	800	100	0.3	9	0.185	0.27	3.49	177
					0.184	0.28	3.49	176
					0.185	0.29	3.48	178
6	800	105	0.2	10	0.192	0.28	3.78	178
					0.194	0.29	3.76	179
					0.195	0.29	3.75	177
7	810	95	0.3	10	0.198	0.29	3.76	176
					0.199	0.28	3.75	175
					0.201	0.27	3.76	178
8	810	100	0.2	11	0.210	0.28	3.23	176
					0.221	0.27	3.24	177
					0.212	0.29	3.25	176
9	810	105	0.25	9	0.219	0.26	3.45	175
					0.225	0.25	3.46	174
					0.226	0.26	3.47	173

C. Observation of Final Experimentation set:

In the final set of experimentation the parameters range are selected as per optimized values obtained from the second set of experimentation. The Table VIII shows the factors and levels selected for experimentation.

TABLE VIII PROCESS PARAMETERS SELECTED IN FINAL SET

Factors	Parameters	Level 1	Level 2	Level 3
A	Spindle Speed in RPM	785	790	795
B	Feed in mm/min	98	100	102
C	Axial depth of Cut in mm	0.24	0.25	0.26
D	Rake Angle in Degree	9	10	11

Again the L9 orthogonal array is selected which is discussed earlier, for each parametric combination three trials are conducted to achieve a better accuracy for observation. Table IX shows the observations recorded for flank wear, face wear and surface finish for every trial the readings are noted. The average values of flank wear, face wear surface roughness and tool life are taken in each trial.

On the basic of optimal results obtained in the second and final set of experimentation the mathematical model and the ANOVA response of flank wear, face wear, surface roughness and tool life are discuss in the results and analysis. The mathematical model is prepared by considering both sets parameters combination results. The observation suggested that the slight difference in the variation of parameters and there levels whereas the final experimentation set are prepared for micro level observations. These observations imply the vital role for finding the response characterises of tool wear and surface roughness by knowing the exact significant parameter which has to be again optimized to the greater extent.

TABLE IX OBSERVATIONS RECORDED IN THE FINAL EXPERIMENTATION SET

Ex. No.	**Cutting speed in rpm**	**Feed rate in mm/min**	**Depth of cut in mm**	**Rake angle in degree**	**Flank wear in mm**	**Face wear in mm**	**Surface roughness In µm**	**T_L minute**
1	785	98	0.24	9	0.181	0.22	3.37	183
					0.182	0.21	3.35	182
					0.183	0.22	3.36	184
2	785	100	0.25	10	0.177	0.22	3.34	182
					0.178	0.23	3.35	183
					0.176	0.21	3.34	184
3	785	102	0.26	11	0.178	0.22	3.35	181
					0.177	0.23	3.34	180
					0.178	0.21	3.35	182
4	790	98	0.25	11	0.180	0.23	3.31	179
					0.181	0.23	3.32	180
					0.179	0.22	3.34	181
5	790	100	0.26	9	0.179	0.24	3.32	182
					0.178	0.24	3.31	181
					0.175	0.23	3.32	183
6	790	102	0.24	10	0.176	0.22	3.45	184
					0.177	0.21	3.46	183
					0.178	0.22	3.47	184
7	795	98	0.25	10	0.175	0.22	3.23	179
					0.176	0.21	3.33	179
					0.178	0.22	3.34	180
8	795	100	0.24	11	0.170	0.23	3.29	179
					0.171	0.21	3.30	179
					0.172	0.22	3.28	178
9	795	102	0.25	9	0.182	0.24	3.24	179
					0.181	0.23	3.25	179
					0.183	0.22	3.24	178

V. TOOL LIFE MODEL

The relationship between the independent variables of milling parameters (cutting speed, feed rate, depth of cut and rake angle) and machining response of tool life can be represented by the following mathematical model.

$$T_L = C\left(V^1 F_r^{\,a} d_p^{\,b} \gamma^{c}\right)\varepsilon$$

where T_L is tool life in minutes, V, fr, dp and γ are the cutting speed (rpm), feed rate (mm/min) depth of cut (mm) rake angle in degree respectively. C, l, a, b,c are constants and ε is a random error. Equation 3.1 can be written in the following logarithmic form: $\ln T = \ln C + l \ln V + a \ln F_r + b \ln d_p + c \ln \gamma + \ln \acute{\varepsilon}$

In micros Q1 software, equation of predicted tool life can be rewritten in the following form:

$$\text{TP10 (predicted tool life)} = \text{constant} + \beta 1V + \beta\, 2\, f_r + \beta\, 3d_p + \beta\, 4\, \gamma$$

Instead of just an intercept and slope, the multiple linear regression equation contains a constant (analogous to intercept) and four coefficients (β1-β4), one for each of the three independent variables. These coefficients are called partial regression coefficients. Before using the micros Q1 software, one needs to assume that the relationship between the dependent and independent variables is linear and that for each combination of values of the independent variables, the distribution of the dependent variable is normal with a constant variance. If the independent variables are not linearly related to the dependent variable, in order to estimate the coefficients, one has to transform the data. The mathematical equation of tool life can be written as follows

$$T_L = 433.691 - 0.31\,[v] - 0.065[Fr] - 10.684[dp] + 0.167[\gamma]$$

Where, V- cutting speed in rpm
Fr- feed rate in m/min
dp- depth of cut in mm and
γ-rake angle in degree

VI. RESULT AND DISCUSSION

A. *Effect on flank wear*

It was found that cutting speed and depth of are less significant process parameters for flank wear. Non significant parameters were pooled and the pooled versions of ANOVA of the S/N data and the raw data for flank wear are given in Tables X. From this table, it is clear that feed rate and rake angle significantly affect the variation in the flank wear values.

TABLE X RESPONSE FOR FLANK WEAR

Level	V	Fr	Dp	γ
1	14.95	14.92	15.06	14.87
2	14.99	15.13	14.95	15.15
3	15.07	14.95	15.02	15.08
Delta	0.12	0.21	0.11	0.22
Rank	3	1	4	2

Figure 2 show that the flanks wear decreases with the increase in the cutting speed. For a speed of 785 rpm, feed rate of 98 mm/min, depth of cut 0.24 mm and at rake angle of 9^0 lowest flank wear is registered. Figure also indicates that flank wear increases with rise in feed rate but suddenly it is decreases. Increase in rake angle is seen with larger flank wear is observed. This is because the chip formation is continuous. Further, increases in flank wear after 10^0.

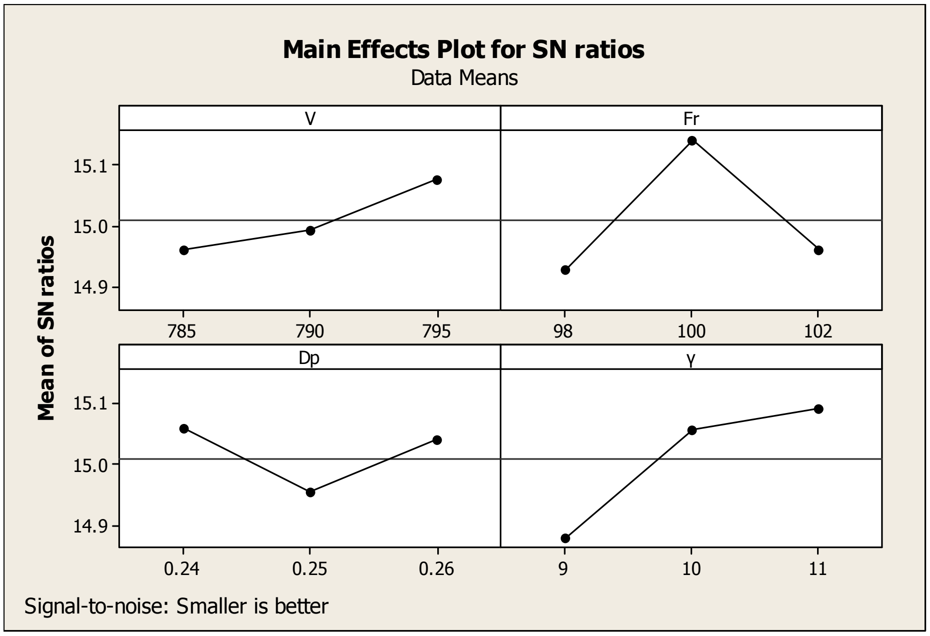

Figure 2. Main effect plot for S/N ratios for flank wear

B. Effect of face wear

Similarly from Table XI it is clear that the cutting speed and the depth of cut are more significant parameter for face wear. The cutting speed and rake angle in comparison of S/N ratio are less significant.

TABLE XI RESPONSE FOR FACE WEAR

Level	V	Fr	dp	γ
1	13.15	12.08	11.65	11.97
2	11.28	11.76	12.30	11.65
3	11.27	11.87	11.76	12.08
Delta	1.88	0.33	0.64	0.43
Rank	1	4	2	3

Figures 3 the face wears decreases increases at 785 rpm and is constant at 790 rpm between 795 rpm cutting speed. For a speed of 785 m/min, feed rate of 98 mm/min, depth of cut of 0.26 mm and rake angle of 11^0 highest face wear is registered. This is because the chip formation is continuous. Further, decrease in face wear 10^0. Cutting parameters like cutting speed and depth of cut results in to higher S/N ratio which ultimately increase face wear.

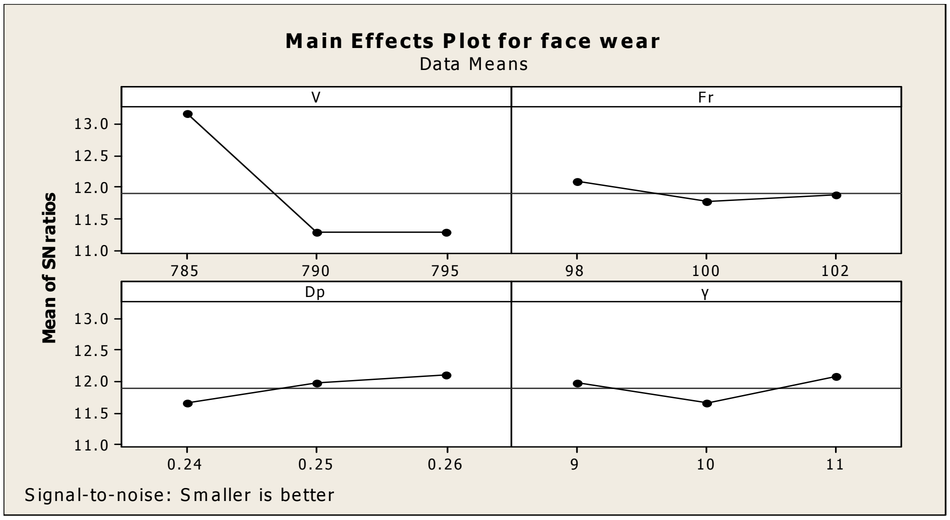

Figure3. Main effect plot for S/N ratios for face wear

C. Effect on surface roughness

Similarly from Table XII it is clear that the rake angle and the depth of cut are more significant parameter for surface roughness. The cutting speed and feed rate in comparison of S/N ratio are less significant.

TABLE XII RESPONSE FOR SURFACE ROUGHNESS

Level	V	Fr	dp	γ
1	-10.50	-10.44	-10.36	-10.57
2	-10.36	-10.41	-10.52	-10.36
3	-10.50	-10.50	-10.45	-10.42
Delta	0.15	0.08	0.15	0.22
Rank	3	4	2	1

Figure 4 show the surface roughness increases at 790 rpm in the cutting speed, 100 mm/min feed rate, 0.24 mm depth of cut and 10^0 rake angle. For a speed of 785 rpm, 102 mm/min, depth of cut of 0.25 mm and rake angle of 9^0 lesser surface roughness is registered.

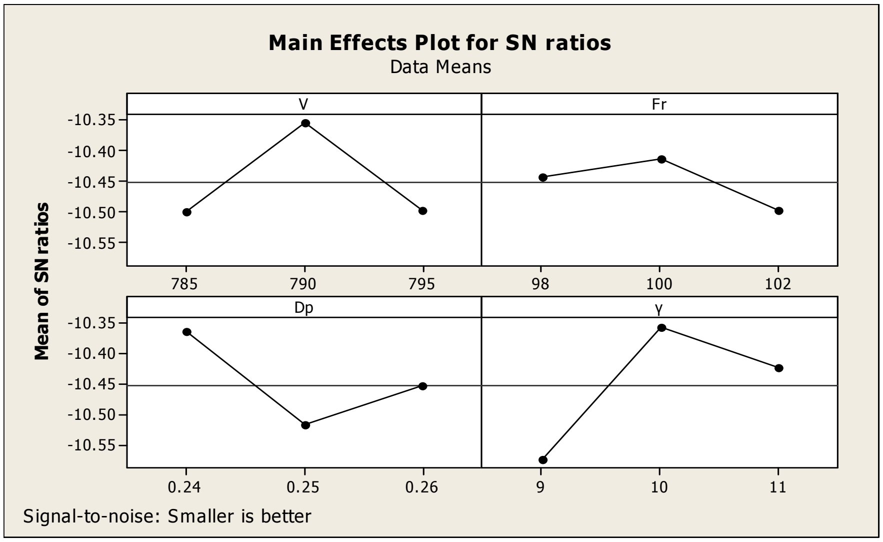

Figure 4.Main effect for S/N ratio on surface roughness

D. Effect on tool life

Similarly, from Table XIII it is clear that the cutting speed and the rake angle are more significant parameter for tool life. The depth of cut and feed rate in comparison of S/N ratio are less significant.

TABLE XIII RESPONSE FOR TOOL LIFE

Level	V	Fr	Dp	γ
1	45.22	45.14	45.19	45.16
2	45.20	45.16	45.12	45.20
3	45.05	45.16	45.18	45.10
Delta	0.17	0.02	0.07	0.10
Rank	1	4	3	2

Figure 5 show that the tool life increases with the decrease in the cutting speed. For a speed of 785 rpm, feed rate of 100 mm/min, depth of cut 0.24 mm and at rake angle of 10^0 highest tool life is registered. Figure also indicates that tool life increases with rise in feed rate. Increase in rake angle is seen with larger tool life is observed but suddenly it is decreases.

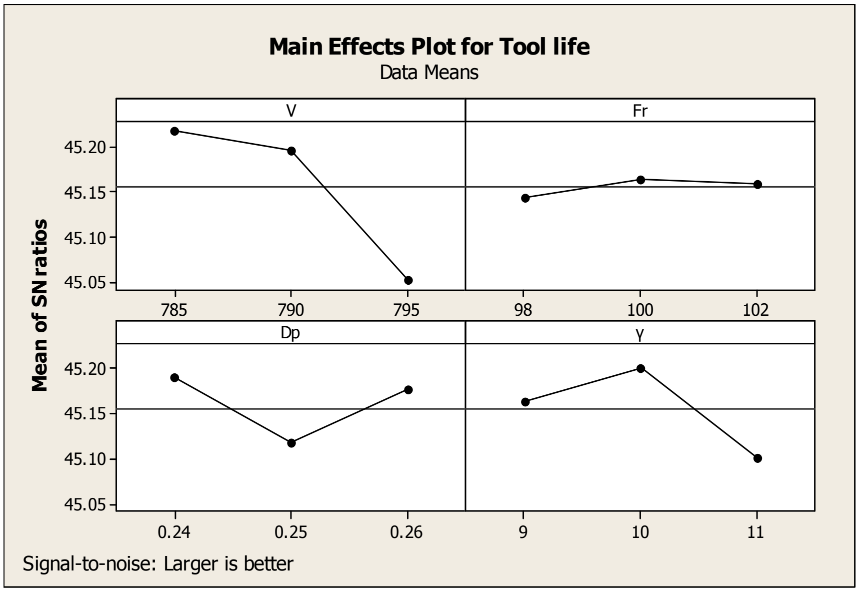

Figure5. Main effect for S/N on tool life

E. Mathematical model for tool life

Using the tool life model equation the tool life is calculated for finding the regression coefficient it is observed that the value of R square is 0.91. The model accuracy was estimated to be 91 %. Figure 6 shows a relationship between observed tool life and calculated tool life.

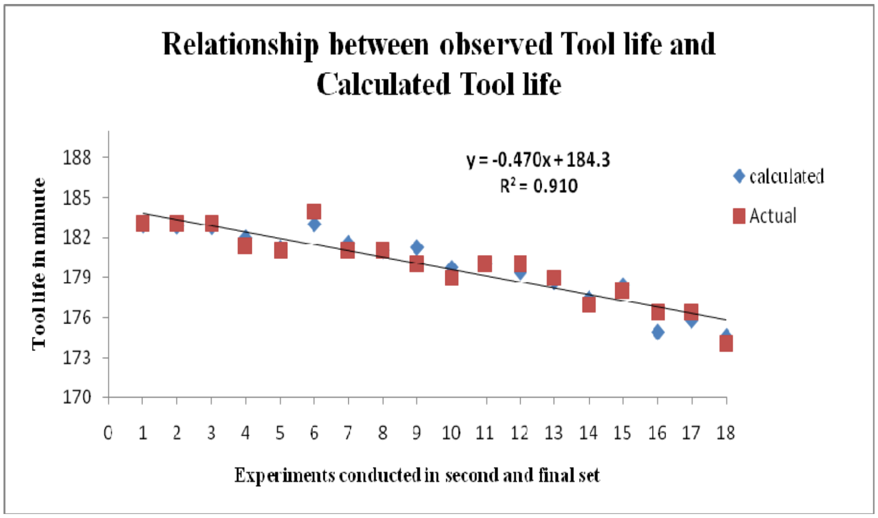

Figure 6 relationship between observed tool life and caluclated tool life

F. Optimum values of parameters

The optimum values of parameters found out from ANOVA response methodology and experimentation are as follows.

- Optimum Value for Cutting Speed- 790 rpm
- Optimum Value for Feed Rate-100 mm/min
- Optimum Value for Depth of Cut-0.24 mm
- Optimum Value for Rake Angle-10^0

VII. CONCLUSIONS

1. The geometric and machining parameters are studied in order to optimize tool life to the greater extent. As per the handbook recommendation the parameters cause the tool wear which is directly proportional to tool life is studied and modified for better results. By understanding the concepts of establishing the values of geometric and machining parameters, the suitable optimization procedures for a wide variety of problem in the area of design and manufacturing was develop and implemented. The optimized values of geometric and machining parameters directly used in the manufacturing industry.
2. Based on the results of experimentation it can be concluded that there is considerable improvement in the tool life.
3. Taguchi method is adopted for finding the significant factors influencing the output S/N and ANOVA
    - Significant parameters for controlling the flank wear are feed rate and rake angle.
    - Significant parameters for controlling the face wear are cutting speed and rake angle
    - Significant parameters for controlling the surface roughness value are rake angle and depth of cut.
    - Significant parameters for controlling the tool life are cutting speed and rake angle.

   From the above it is cleared that the rake angle has most significant parameter was obtained from the micro level observation. The variation in the cutting speed, feed rate and depth of cut are also important as the machining parameters for the tool life.
4. The methodology is verified by optimization method and the experimental readings can directly impart the procedure accuracy.
5. Finally it is concluded that optimization of geometric and machining parameters made more effective by selecting an appropriate values of geometric and machining parameter affecting factor it viz. flank wear, face wear, surface roughness. Also a simplified mathematical equation of tool life can predict tool life at accuracy of 91 %.

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