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MODELING AND ANALYSIS OF TURNING PROCESS FOR EN18 STEEL USING YATE'S ALGORITHM

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Abstract The work has been taken up with a view to bring out the benefits in developing a model for flank wear prediction in terms of speed, feed, depth of cut and machining time for turning process. Experiments were conducted as per the full factorial experimental design. Using Yate's algorithm and Analysis of variance technique the final model for the flank wear in terms of the parameters was developed. The final model can be used accurately to predict the flank wear in future production thus reducing cost of experimentation and time.

Keywords: Yate's Algorithm, ANOVA, Mathematical model, Metal Cutting

PRELUDE

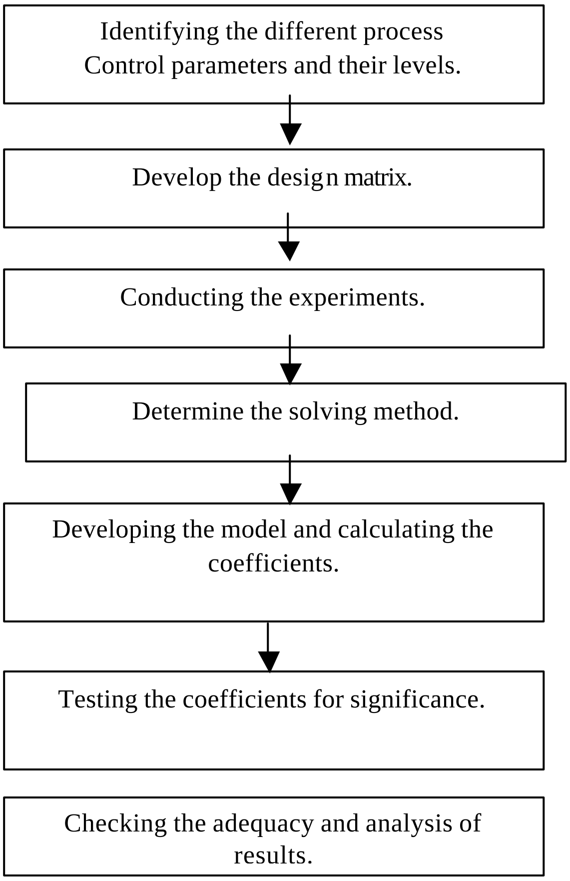
In the current production scenario most of the components produced around the world as on date, are produced after undergoing machining operation. In any machining operation, the metal is removed from the work piece in the form of chips. Under usual cutting condition, wear due to interaction between the chip and the tool face and between the work and tool is the main process by which a cutting tool fails. After the tool has been in use for sometime, wear land and crater appear in the tool, which affects the quantity and quality of production.

The main objective of this project is to present the factors that are responsible for the formation of flank wear. An experiment was conducted, and based on the results obtained the different machining parameters like speed, feed, depth of cut and machining time in real time are optimized by considering the constraint, tool wear through mathematical concept.

The main objective of the project is to develop a model for machining operation by the application of Yate's algorithm and Analysis of variance technique.

METHODOLOGY ADOPTED

The methodology used in this paper is an attempt to formalize and structure a procedure in which the conceptual design is done based on experimental work. later steps are an iterative cycle of mathematical modeling and analysis. The project cycle is shown in the flow chart.



In lathe operations, the machining operation parameters, which are controlling the production rate, quality of product and tool life, are mainly feed, depth of cut and speed.

In this work the work material considered for the observation is EN18 steel. The tool material is Coated Carbide. The machine used for the turning operation is all geared SONA lathe. During the course of operation, using the available mechanism had set the cutting parameters.

The machining operations were carried out number of times to get the feasible accuracy with different set of cutting parameters. The specification of work material, tool material and cutting conditions are given in **Table 1**. The flank wear formed on the tool surface after Radical Tool Makers Microscope has measured each operation.

Table-1: Specifications of work material, tool material and equipments.

Machine tool: 'SONA' All geared lathe
Cutting tool: SNMG 12 04 08-5(ISO Designation) [P20] tg-widadur coated carbides.
Tool material composition: Wc-Tic-Tac-Co
Tool geometry: -6°, -6°, 6°, 6°, 15°, 75°, 0.8mm
Insert shape: "S" – square, thickness-4.76mm
Size: - 12.7x12.7, hole dia-5.15mm
Work material: Alloy steel (EN18)
Work material composition: Carbon 0.35%, Chromium 12% Manganese-0.5686%, Silicon-0.3191 Sulphur 0.0225% Phosphorous 0.4% Ferrous-balance.
Cutting speed: 100,150,200,250 m/min
Feed: 0.1,0.2,0.315,0.4 mm/rev
Depth of cut: 0.5,1,1.5 mm
Environment: Dry
Microscope: Radical toolmaker's microscope.

DESIGN OF EXPERIMENTS

An experiment is a series of trials or tests, which produces quantifiable outcomes. The experiment may be random or deterministic. The merit of this experimental scheme is that the cost of experimentation is much reduced as compared to one factor at a time type experiment.

SELECTION OF FACTORS AND LEVELS

In machining process, the four factors which has considerable effect on the flank wear are:

1. Cutting Speed (V)
2. Feed (F)
3. Depth of Cut (D)
4. Machining Time (T)

Cutting Speed

It is the travel of a point on the cutting edge relative to the surface of the cut in unit time in the process of accomplishing the primary cutting motion. The levels chosen for cutting speed ranges form 100 m/min to 250 m/min.

Feed

The feed is the amount of advancement per revolution of job parallel to the surface being machined. Feed is expressed either as the distance moved by the tool in one minute. The levels chosen for feed ranges from 0.1 mm/rev to 0.4 mm/rev.

Depth Of Cut

It is the thickness of the layer of metal reserved in one cut or passes measured in a direction perpendicular to the machined surface. The depth of cut is always perpendicular to the direction of feed motion. The levels chosen for depth of cut ranges from 0.5 mm to 1.5 mm.

Machining Time

It is the time taken to perform a machining operation by giving the cutting speed, feed and depth of cut. The levels chosen for machining time ranges from 4.94 min to 75.01 min.

The notations, units and their levels chosen are summarized in Table.2

Table-2: Control Parameters and their Levels

S. No.	Parameter	Unit	Levels			
			Original		Coded	
			Low	High	Low	High
1.	Cutting Speed (V)	m/min	100	250	-1	+1
2.	Feed (F)	mm/rev	0.1	0.4	-1	+1
3.	Depth of Cut (D)	mm	0.5	1.5	-1	+1
4.	Machining Time (T)	mm	4.94	75.01	-1	+1

The intermediate levels can be calculated by using the following expression.

$$\mathbf{X_i = 2[2X - (X_{max} - X_{min})] / [X_{max} - X_{min}]}$$

Where X_{max} – Upper level of the parameter

X_{min} – Lower level of the parameter

X_i - Required coded values of the parameter of any values from X_{min} to X_{max}.

EXPERIMENTAL DESIGN

The experimental design considered in this section is used to evaluate the effects of four different factors, where each factor is set at two different levels. All possible combinations of levels are included so there are 2^n (where n refers to the no. of factors (i.e.) $2^4 = 16$ trials in the experiment.

DESIGN MATRIX AND CORRESPONDING OUTPUT RESPONSE

The design matrix chosen and their corresponding output response are given in Table 3.

Table-3: design matrix and corresponding output response

Std. Order	V (X_1)	F (X_2)	D (X_3)	T (X_4)	Flank Wear V_0 mm
1.	-1	-1	-1	-1	0.04
2.	+1	-1	-1	-1	0.05
3.	-1	+1	-1	-1	0.06
4.	+1	+1	-1	-1	0.07
5.	-1	-1	+1	-1	0.10
6.	+1	-1	+1	-1	0.11
7.	-1	+1	+1	-1	0.12
8.	+1	+1	+1	-1	0.16
9.	-1	-1	-1	+1	0.17
10.	+1	-1	-1	+1	0.19
11.	-1	+1	-1	+1	0.19
12.	+1	+1	-1	+1	0.20
13.	-1	-1	+1	+1	0.21
14.	+1	-1	+1	+1	0.21
15.	-1	+1	+1	+1	0.24
16.	+1	+1	+1	+1	0.29

YATES ALGORITHM TO CALCULATE THE SUM OF SQUARES

The column2 of Yate's algorithm table contains the corresponding output response for each run.

These averages are now considered in successive pairs. The first four entries in column 3 are obtained by adding the pairs together. The second four entries in column 3 are obtained by subtracting the top number from the bottom number of each pairs. In the same way column 3 is obtained from column 2, the column 4 is obtained from column 3 and so on...

Table : Yate's Algorithm Table

Sl. No. (1)	Flank Wear V_6 (mm) (2)	(3)	(4)	(5)	(6)	Identification (I) (7)	Sum Of Squares (S) (8)
1. 2.	0.04 0.05	0.09 0.13	0.22 0.49	0.71 1.70	2.41 0.15	I V	0.3630 1.40×10^{-3}
3. 4.	0.06 0.07	0.21 0.28	0.75 0.95	0.07 0.08	0.25 0.07	F VF	3.90×10^{-3} 3.06×10^{-4}
5. 6.	0.10 0.11	0.36 0.39	0.02 0.05	0.11 0.14	0.47 0.05	D VD	0.0138 1.5625×10^{-4}
7. 8.	0.12 0.16	0.42 0.53	0.03 0.05	0.03 0.04	0.11 0.09	FD VFD	7562×10^{-4} 5.062×10^{-4}
9. 10.	0.17 0.19	0.01 0.01	0.04 0.07	0.27 0.20	0.99 0.01	T VT	0.06125 6.25×10^{-6}
11. 12.	0.19 0.20	0.01 0.04	0.03 0.11	0.03 0.02	0.03 0.01	FT VFT	5.625×10^{-5} 6.25×10^{-5}
13. 14.	0.21 0.21	0.02 0.01	0.00 0.03	0.03 0.08	-0.07 -0.01	DT VDT	3.0625×10^{-4} 6.25×10^{-6}
15. 16.	0.24 0.29	0.00 0.05	-0.01 0.05	0.03 0.06	0.05 0.03	FDT VFDT	1.5625×10^{-4} 5.625×10^{-5}

MODEL SELECTED

The model selected will be as a function of V, F, D and T.

$$\text{Flank Wear } (V_b) = f(V, F, D, T)$$

$$V_b = t_0 + t_1 (V) + t_2 (F) + t_3 (D) + t_4 (T) + t_5 (VF) + t6(VD) + t_7 (VT) + t_8 (FD) + t_9 (FT) + t_{10}(DT) + t_{11} (VFD) + t_{12} (VFT) + t_{13} (VDT) + t_{14} (FDT) + t_{15} (VFDT) \quad (1)$$

Where t_o - average of flank wear value.

$t_1, t_2 \ldots t_{15}$ -co-efficient that depends on main effects and interaction effects.

However all the 15 coefficients may not be having significant effect on flank wear or output. To find the significant coefficients, ANOVA technique has been used.

ANOVA TABLE (To find the Significant Factors)

In the ANOVA table the effects and their identification are listed in Column 1. Their sum of squares is listed in Column 2. The degrees of freedom for the corresponding effects are listed and for the error enter the number of estimators which is 5 in our case. Then calculate the mean square value for each factor by dividing the sum of squares by degree of freedom and finally calculate F values as ratios of mean square values.

Table : Anova Table

Sauce of Variation	**Sum of Squares**	**d.o.f.**	**Mean Square**	**Mean Square** **F = ———** **Error**	**F_{theo} (1,5)**
Main Effects					
V	1.4×10^{-3}	1	1.4×10^{-3}	9.57	6.61
F	3.9×10^{-3}	1	3.9×10^{-3}	26.66	6.61
D	0.0138	1	0.0138	94.36	6.61
T	0.06125	1	0.06125	418.83	6.61
Two Factor					
VF	3.06×10^{-4}	1	3.06×10^{-4}	2.09	6.61
VD	1.5625×10^{-4}	1	1.5625×10^{4}	1.068	6.61
FD	7.562×10^{-4}	1	7.562×10^{4}	5.17	6.61
VT	6.25×10^{-6}	1	6.25×10^{-6}	0.042	6.61
FT	5.625×10^{-5}	1	5.625×10^{5}	0.3846	6.61
DT	3.0625×10^{-4}	1	3.0625×10^{4}	2.094	6.61
Error	0.0007312	5	1.4624×10^{4}		
Total	82.66×10^{-3}	15			

DEVELOPMENT OF FINAL MATHEMATICAL MODEL OF FLANK WEAR WIDTH

Based on the equation [1] the final mathematical model was determined by the above analysis and is given below

$$V_b = 0.150625 + 0.15\,(V) + 0.15\,(F) + 0.47\,(D) + 0.99(T) \qquad (2)$$

TESTING THE CO-EFFICIENTS FOR SIGNIFICANCE

The value of the regression co-efficient gives an idea as to what extent the control variables affect the response with which they are associated, without sacrificing much of the accuracy to void cumbersome mathematical model. To achieve this the students t-test is used. Here the results are within the confidence limit and are adequate. Hence the validity of the model has been proved.

RESULTS AND DISCUSISON

The optimization results of the objective function, i.e., width of flank wear against speed, feed, depth of cut and hardness is plotted.

The plots of **Fig.1** show a linear relationship between flank wear and speed with respect to Feed.

The plots of **Fig.2** show linear relationships between flank wear and feed with respect to Speed.

The plots of **Fig.3** show the relationship between Depth of Cut and Flank wear with respect to Speed.

The plots of **Fig.4** show the relationship between Machining Time and Flank wear with respect to Speed.

The plots of **Fig.5** show the relationship between Cutting Speed and Flank wear with respect to Feed. The continuous line represents the experimental value and the dotted line represents the prognostic value and we can see the closeness between the two.

The plots of **Fig.6** show the relationship between Machining Time and Flank wear with respect to Speed. The continuous line represents the experimental value and the dotted line represents the prognostic value.

The plots of **Fig.7** show the relationship between Feed and Flank wear with respect to Speed. The continuous line represents the experimental value and the dotted line represents the prognostic value.

The plots of **Fig.8** show the relationship between Depth of Cut and Flank wear with respect to Speed. The continuous line represents the experimental value and the dotted line represents the prognostic value.

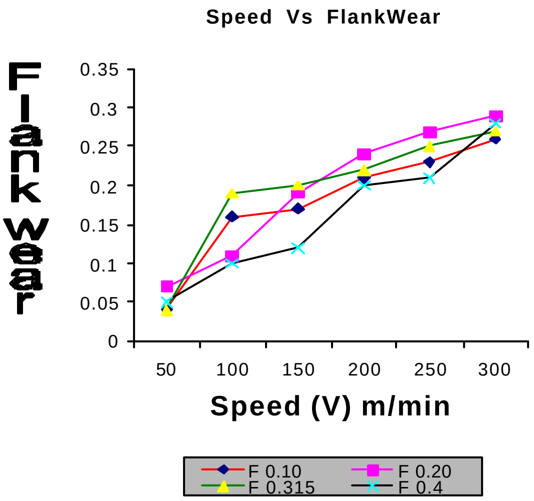


Fig.1 Speed Vs Flank Wear

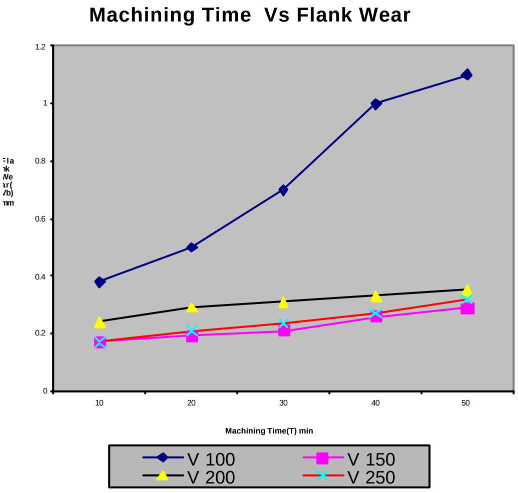


Fig. 4 Machining Time Vs Flank Wear

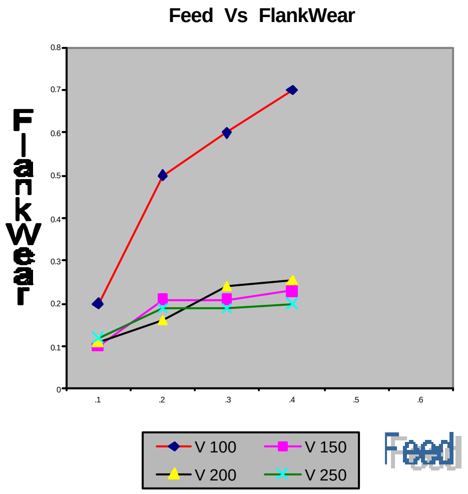


Fig. 2 Feed Vs FlankWear

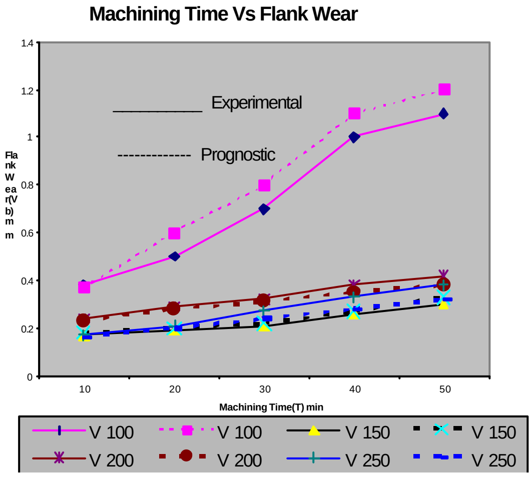
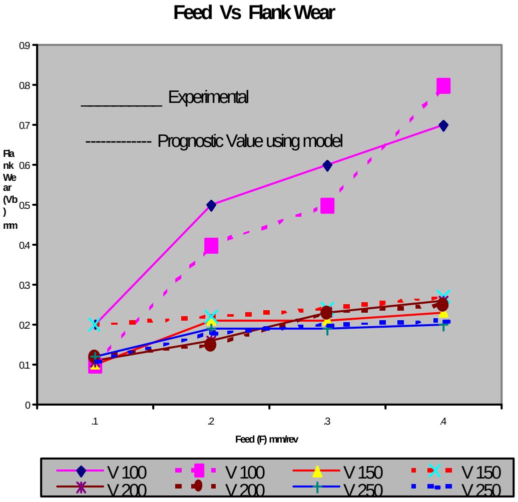


Fig. 5 Machining Time Vs Flank Wear



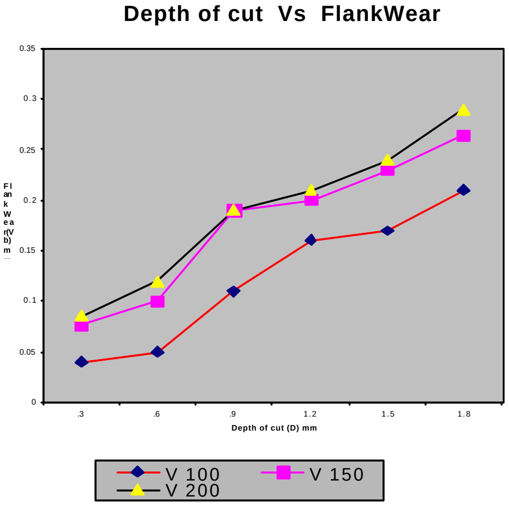


Fig. 3 Depth of Cut Vs Flank Wear

Fig. 6 Feed Vs Flank Wear

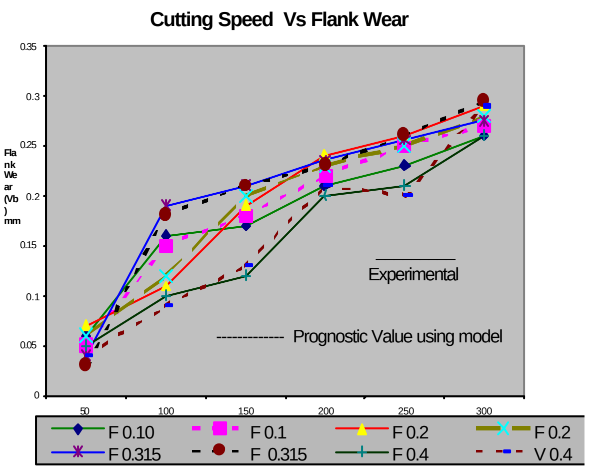


Fig.7: Cutting Speed Vs Flank Wear

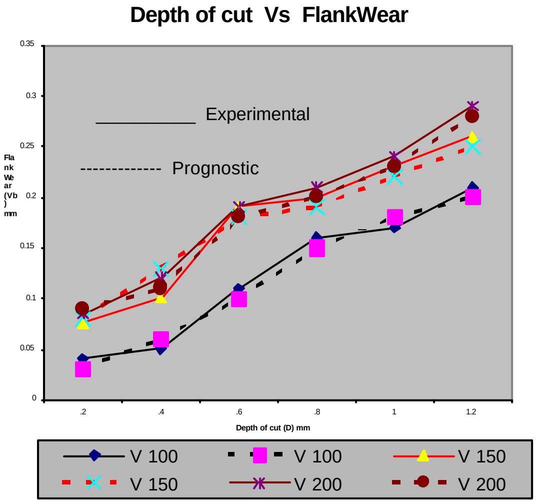


Fig.8: Depth of Cut Vs Flank Wear

CONCLUSION

(1) Using experimental design, a model was developed to estimate the width of flank wear. For a given constant feed rate and hardness, the increase in cutting speed, increase the flank wear.

(2) The factors namely speed, feed, depth of cut and hardness effect the width of flank wears significantly.

The final model developed is $V_b = 0.150625 + 0.15 (V) + 0.15 (F) + 0.47 (D) + 0.99 (T)$ --------[2]

(3) The model can be used accurately to predict the flank wear in future production thus reducing cost of experimentation and time.

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