Application of response surface methodology for predicting flank wear in turning operation

作者：P Thangavel, V Selladurai, and R Shanmugam

報告者：黃家慶

Proc. IMechE Vol. 220 Part B: J. Engineering Manufacture

- Introduction
- Experimental procedure
- Results and discussion
- Conclusions

Introduction

近年來逐漸發展自動化的製程，其最終目標希望由無人控制機來達到自動化的目標。在此最佳的生產模式內，工具磨耗(tool wear)為阻礙進行自動化生產的重要的因子之一，所以工具磨耗(tool wear) 的監控技術是被需要的。

Response surface methodology

- 實驗區域內，以有系統的方式進行實驗得到所需要的反應值。
- 數學模型的建立。
- 在實驗區中，找出反應值的最大值與最小值。
- 透過二維或三維的圖形，可更快速的看出flank wear 製程變數的影響。

Experimental procedure

- Identification of the process parameters
- Finding the limits of the process variables
- Design matrix
- Development of the mathematical model
- Calculation of coefficients of models
- Final mathematical model for flank wear

Identification of the process parameters

- 切割速度(Cutting speed)-------V
- 進刀速度(Feed rate)-------F
- 切割深度(Depth of cut)-------T

Select process parameters and notations

Table 1 Control parameters and their levels

Parameter	Notation	Factor levels		
		1	2	3
Cutting speed (r/min)	V	80	100	125
Feed rate (mm/rev)	F	0.14	0.16	0.18
Depth of cut (mm)	T	0.5	1.0	1.5

Design matrix

Table 2 Central composite design matrix

Specimen no.	Design matrix V (r/min)	F (mm/rev)	T (mm)	Diameter (mm)	Experimental value of force ratio	Experimental value of flank wear, W (mm)	Calculated value of flank wear, W (mm)
01	3	3	3	24.10	0.559	0.557	0.56
02	3	3	1	25.10	0.532	0.534	0.54
03	2	2	2	29	0.449	0.451	0.446
04	2	1	2	29	0.410	0.409	0.404
05	2	2	2	29	0.436	0.437	0.446
06	2	3	2	29	0.507	0.509	0.506
07	3	1	3	24.10	0.502	0.501	0.506
08	1	2	2	34.90	0.410	0.411	0.403
09	3	2	2	24.60	0.518	0.520	0.521
10	1	3	3	34.60	0.460	0.461	0.458
11	2	2	2	29	0.437	0.435	0.446
12	2	2	1	29.5	0.405	0.401	0.382
13	2	2	2	29	0.428	0.427	0.446
14	1	3	1	35.4	0.430	0.431	0.434
15	1	1	3	34.4	0.422	0.423	0.424
16	2	2	2	29	0.451	0.432	0.446
17	3	1	1	25.1	0.409	0.410	0.418
18	2	2	2	29	0.442	0.440	0.446
19	2	2	3	28.5	0.452	0.450	0.462
20	1	1	1	35.4	0.234	0.230	0.236

Development of the mathematical model

The response function representing the wear performance can be expressed as

$$Y = f(V, F, T) + \varepsilon \tag{3}$$

where Y = response or yield.

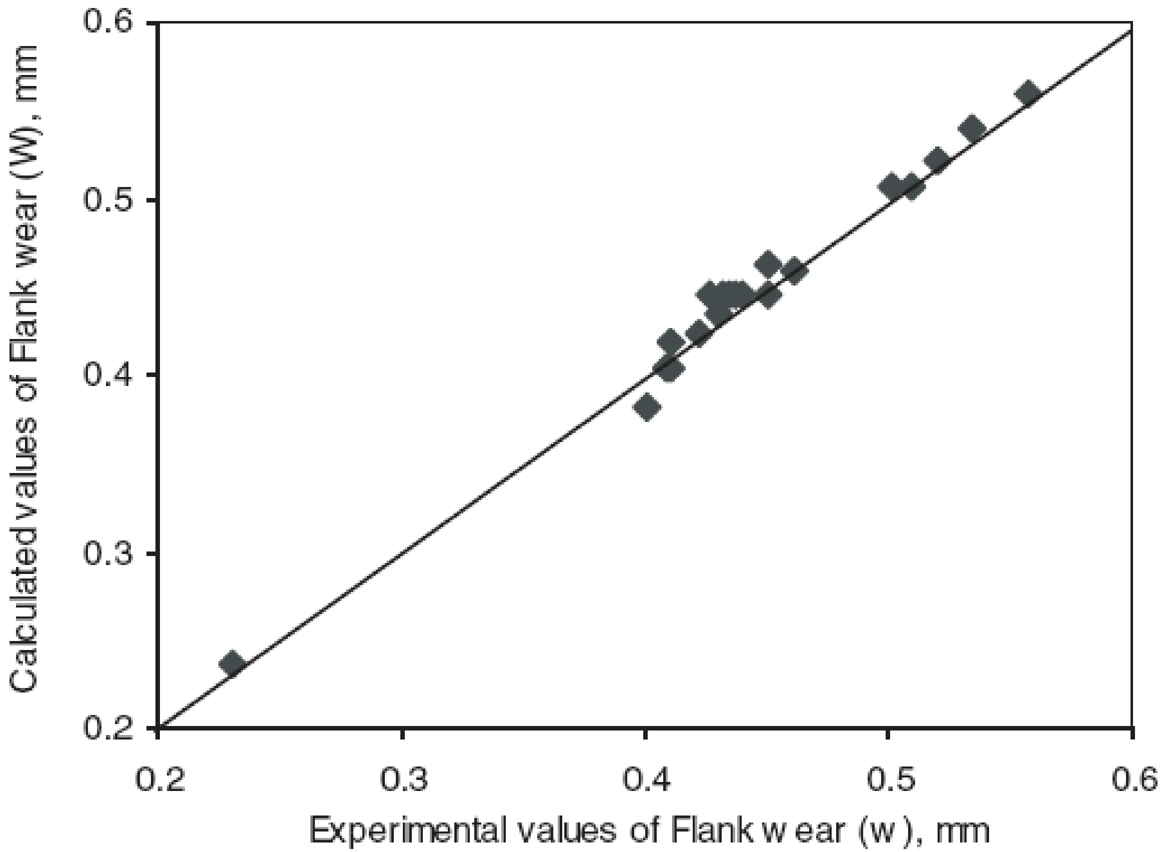
The second-order polynomial (regression) equation used to represent the response surface for K factors is given by

$$Y = b_0 + \sum_{i=1}^{K} b_i X_i + \sum_{i,j=1}^{K} b_{ij} X_i X_j + \sum_{i=1}^{K} b_{ii} X_i^2 \tag{4}$$

Final mathematical model for flank wear

$$
\begin{aligned}
\text{Flank wear, } W(\text{mm}) = {} & -0.142 + 0.083\,V + 0.135\,F \\
& + 0.268\,T + 0.016\,V^2 + 0.009\,F^2 \\
& - 0.024\,T^2 - 0.031\,V\,F - 0.037\,V\,T \\
& - 0.053\,F\,T + 0.012\,V\,F\,T \qquad (6)
\end{aligned}
$$

Results and discussion



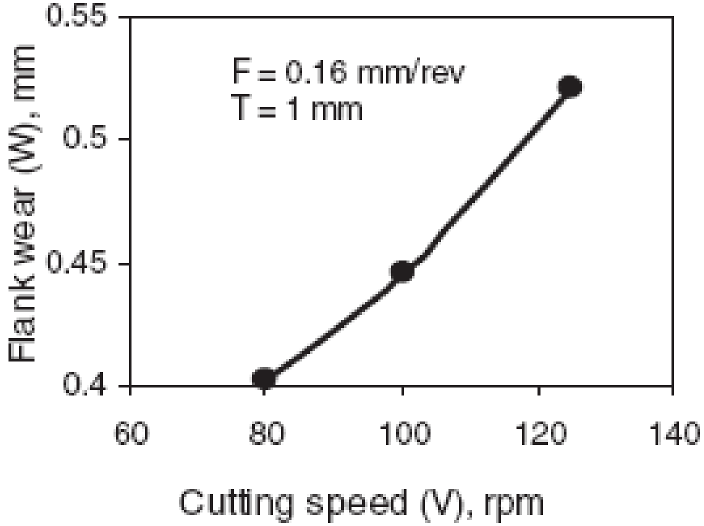


Fig. 3 Direct effects of cutting speed V on flank wear

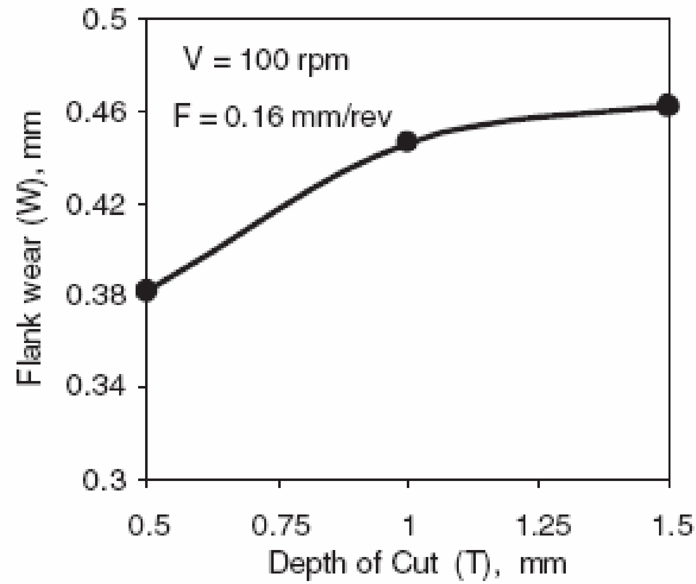


Fig. 5 Direct effects of depth of cut T on flank wear

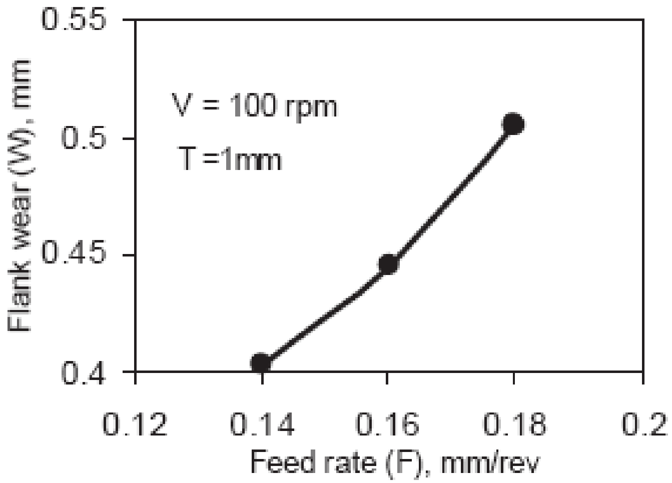


Fig. 4 Direct effects of feed rate F on flank wear

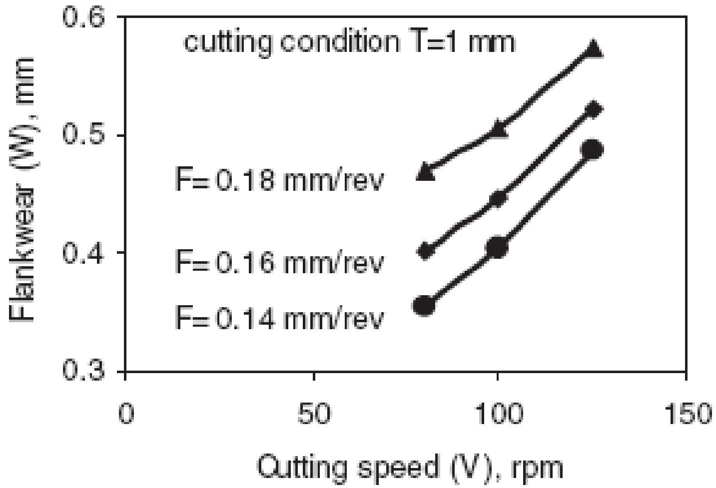


Fig. 6 Interaction effect of cutting speed *V* and feed rat on flank wear

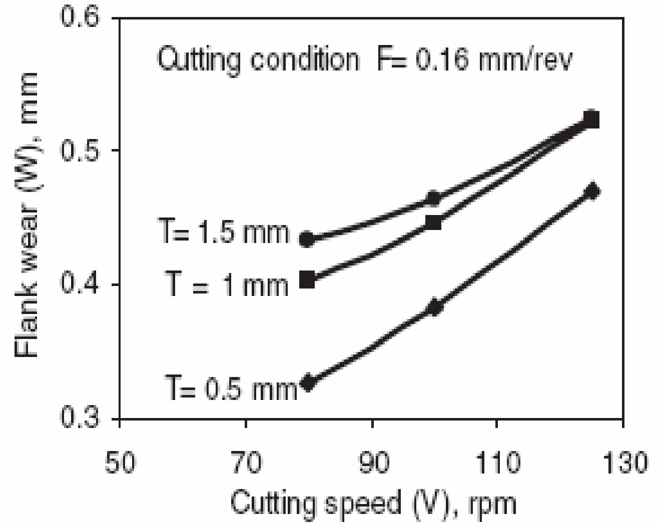


Fig. 7 Interaction effect of cutting speed *V* and depth of cut *T* on flank wear

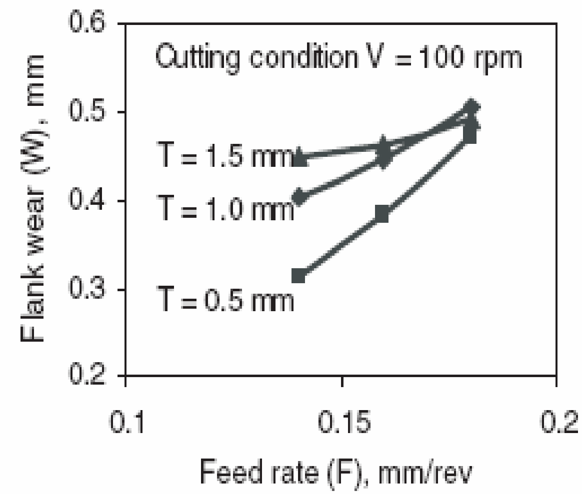


Fig. 8 Interaction effect of feed rate *F* and depth of cut *T* on flank wear

Conclusions

- 在轉動作業中的切割工具，可更簡單的透過三因子三階層的方法，去發展預測flank wear的數學模型。
- 實驗值與預測值的比照，顯示出在此paper中的數學模型，適用於預測flank wear上。
- 切割速度與切割深度的增加，導致flank wear顯注的增加。
- 相同的分析，應該可用在milling、shaping and drilling的製程中。

感想

- 反應曲面法所建構的數學模型，是否可進一步的結合基因演算法，進而尋求出問題的正確解答？

報告完畢

謝謝