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THE EFFECT OF THE FLANK TOOL WEAR
ON THE MACHINABILITY OF METALS

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ABSTRACT

The results obtained from tool life tests are presented, and a Taylor type tool life equation, taking both cutting speed and feed into consideration, is introduced.

To study the effect of flank wear on the cutting process, different cutting tools having artificial wear land were used to simulate the action of naturally worn tools.

A relationship between the power consumed in cutting and the amount of flank wear present was established, and thus enabling the tool wear to be evaluated during the machining operation.

KEYWORDS

Metal cutting, Machining, Tool life, Tool wear, Cutting force, Power consumption.

INTRODUCTION

Economics of machining depend to a great extent on tool life, which is defined as the useful cutting time before the tool has reached a practical limit of wear. The limit of wear, or the wear criterion, varies according to the requirements of production and constraints involved in the machining operation. In spite of the fact that literature is full of reports concerned with the study of tool wear mechanism, the effect of tool wear on the cutting process, and various methods proposed to evaluate tool life [1 - 19], the wear mechanism is still not fully understood, and the majority of the formulae regarding tool life evaluation are determined empirically.

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It has been the purpose of the present work to evaluate tool life for a particular tool-workpiece combination, and also to construct an empirical formula for the determination of flank wear during machining.

EXPERIMENTAL WORK

Cylindrical bars of steel 37 were turned orthogonally, under dry cutting condition, by means of high speed steel cutting tools having 10 deg. rake angle each.

For the tool life experiments, constant depth of cut of 1.5 mm was used throughout the experiments. The speed range was 25 - 55 m/min, while that for feed was 0.10 - 0.23 mm/rev. Flank wear land was measured, at set intervals of time, using a tool maker's microscope.

For the machining experiments, artificial wear land was produced on the flank face of each tool, and the range used was 0 - 1.2 mm. Series of cutting tests were performed for each value of artificial wear land, varying the cutting speed, feed, and depth of cut. The range used for cutting speed was 5 - 16 m/min, for feed 0.08 - 0.19 mm/rev, and for depth of cut 1.0 - 2.0 mm. Cutting forces were measured by means of an inductive three components force dynamometer and its accessories.

RESULTS AND DISCUSSION

A - Tool Life

Fig. 1 illustrates a typical relationship between flank wear and machining time for different cutting speeds at constant feed. As can be seen, there is an increase in the wear rate at high values of cutting speed, and this is due to the increase in cutting temperature which leads to the increase in adhesive and diffusive wear. Depending upon the wear criterion selected, the tool life at each cutting speed was evaluated. When plotting tool life against cutting speed, for different feed values and at 0.4 mm flank wear criterion, on a double logarithmic scale, Fig. 2, the best fit using least square method gave the following formula,

$$V T^{0.35} = C \quad (1)$$

where V is cutting speed in m/min.
 T is tool life in min.
 C is a constant, function of feed

The value of the tool life exponent agrees with that obtained by Lau et al [19] when machined mild steel tubes with high speed steel tools. They attributed such a high value to the decrease of the cutting speed exponent in its relationship with the mean temperature at the rake face.

Upon plotting the constant (C) against feed on a double



logarithmic scale, Fig. 3, the following expression was obtained,

$$C = K f^{-0.57} \quad (2)$$

where K is a constant, function of wear criterion
 f is feed in mm/rev

From equations (1) and (2),

$$V T^{0.35} f^{0.57} = K \quad (3)$$

The same procedure was adopted for different values of wear criterion, and the formulae obtained were similar to equation (3), except that the constant (K) was found to be a function of the wear criterion used. The relationship between the constant (K) and the wear criterion was found, from Fig. 4, to be,

$$K = 58 w^{0.54} \quad (4)$$

where w is wear criterion in mm.

Thus, the general tool life empirical formula at 1.5 mm depth of cut could be constructed as follows,

$$T = 11 \times 10^4 V^{-2.86} f^{-1.63} w^{1.54} \quad (5)$$

where T is tool life in min.
 V is cutting speed in m/min.
 f is feed in mm/rev.
 w is wear criterion in mm.

This is more or less a Taylor type tool life equation, but in a more general form as it takes into consideration both feed used and flank wear criterion.

B - Cutting force

A linear relationship was found to exist between cutting force (F) in the direction of cut and the amount of flank wear (w), as shown in Figs. 5, 7, and 9. By applying linear regression analysis, the coefficients of correlation of values higher than 0.98 proved the goodness of the linear fit,

$$F = A + m \cdot w \quad (6)$$

where F is cutting force in Newtons
 A is cutting force for sharp tool in Newtons
 m is rate of cutting force increase in N/mm.
 w is flank wear in mm.

The effect of flank wear on cutting force is,



The rate of increase of cutting force (m) was found to increase with both feed and speed, and to decrease with depth of cut, as can be seen in Figs. 6,8, and 10. From Fig.6 for 5 m/min cutting speed and 1.5 mm depth of cut,

$$m = 451 f^{0.68} \quad (8)$$

From fig. 8, for 0.08 mm/rev feed and 1.5 mm depth of cut,

$$m = 50 V^{0.29} \quad (9)$$

From Fig. 10, for 8 m/min cutting speed and 0.12 mm/rev feed,

$$m = 125 d^{-0.37} \quad (10)$$

Hence, a general form for evaluating the effect of flank wear on the cutting force could be constructed as,

$$B = 312 V^{0.29} f^{0.68} d^{-0.37} w \quad (11)$$

C - Cutting power

The increase in power consumption, in Watts, due to the presence of flank wear is the product of cutting speed, in m/s, and the increase in cutting force in N. Thus from equation (11),

$$P = 5.2 V^{1.29} f^{0.68} d^{-0.37} w \quad (12)$$

By applying equation (12), the increase in power consumption (P) could be used to estimate flank wear during machining operation. The power consumption when using a sharp tool should be recorded, and further increase in power will be attributed to the amount of flank wear generated during machining.

CONCLUSION

The results obtained demonstrate the feasibility for constructing a Taylor type tool life equation, and which takes into consideration not only the cutting speed but also the feed and, most important, the wear criterion. Thus, tool life could be evaluated according to a specified practical limit of wear. Tool wear was found to have increasing effect on cutting force and power consumption, and empirical formulae representing that effect were obtained. The formula for the increase in power consumption can be used to estimate the amount of flank wear generated during machining.

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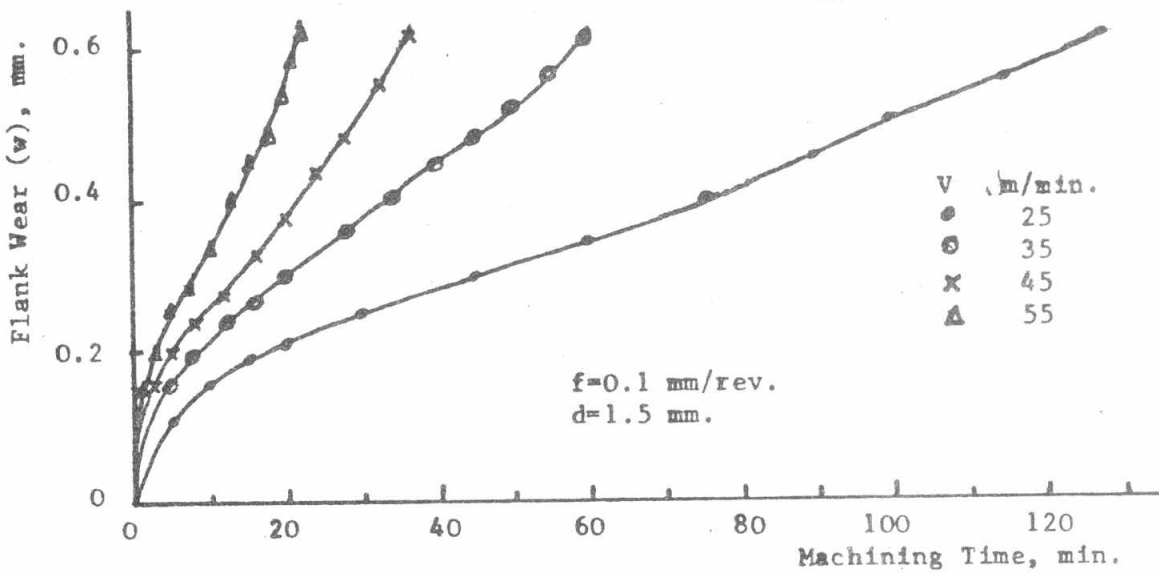


Fig.1 Typical relationship between flank wear and machining time.

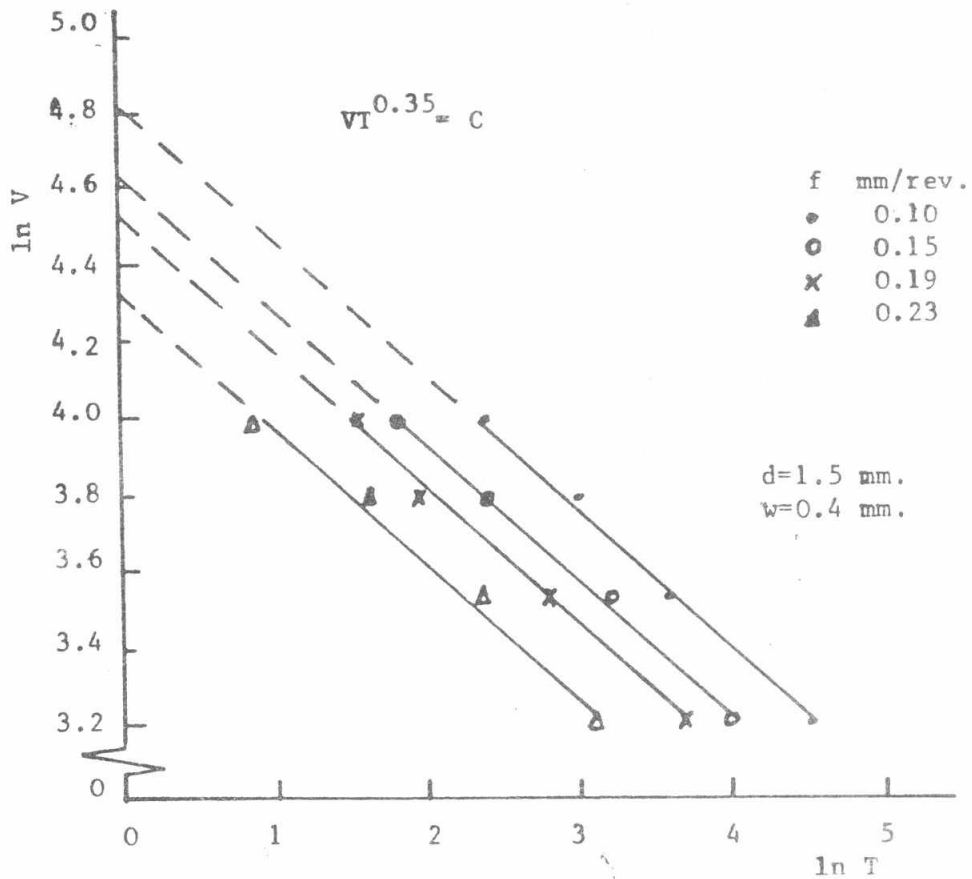


Fig.2 Logarithmic relationship between velocity and tool life.



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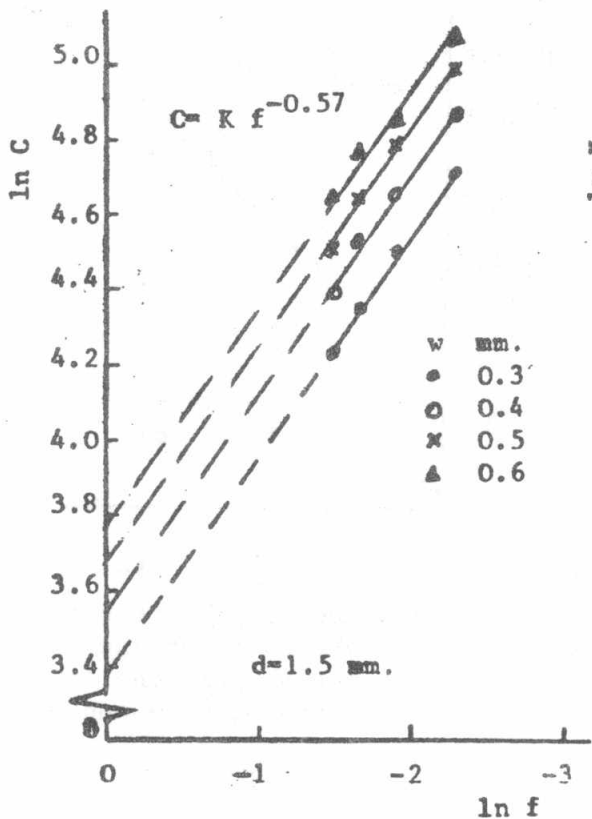


Fig.3 Logarithmic relationship between feed and proportionality constant of V and T relation.

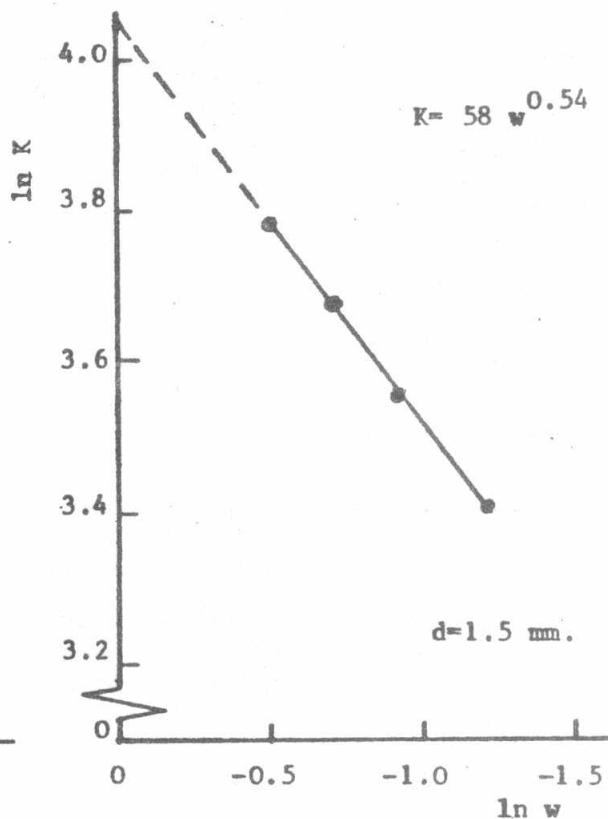


Fig.4 Logarithmic relationship between wear criterion and proportionality constant of f and c.

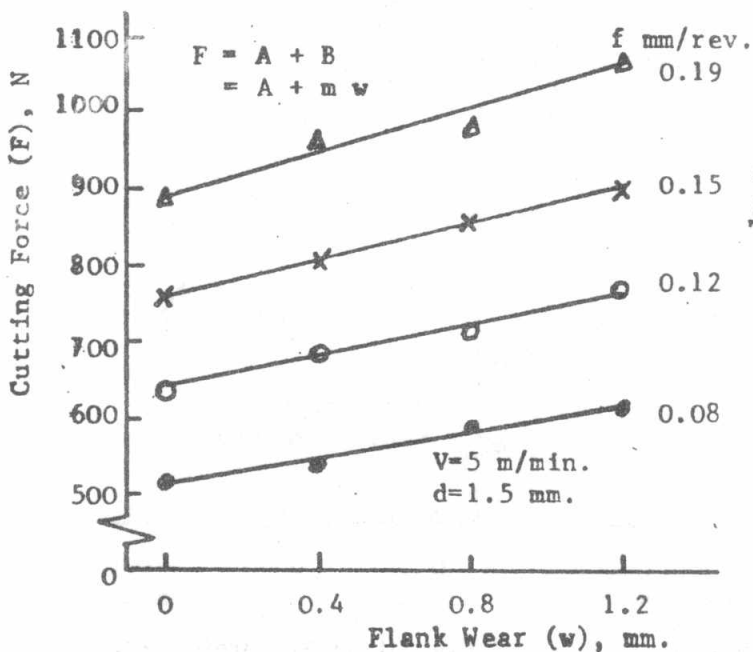


Fig.5 Effect of flank wear on cutting force at constant speed and depth of cut.

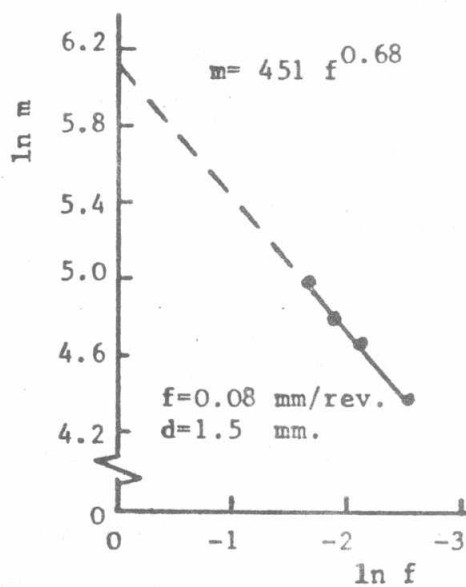


Fig.6 Logarithmic relationship between feed and proportionality constant of F and w.

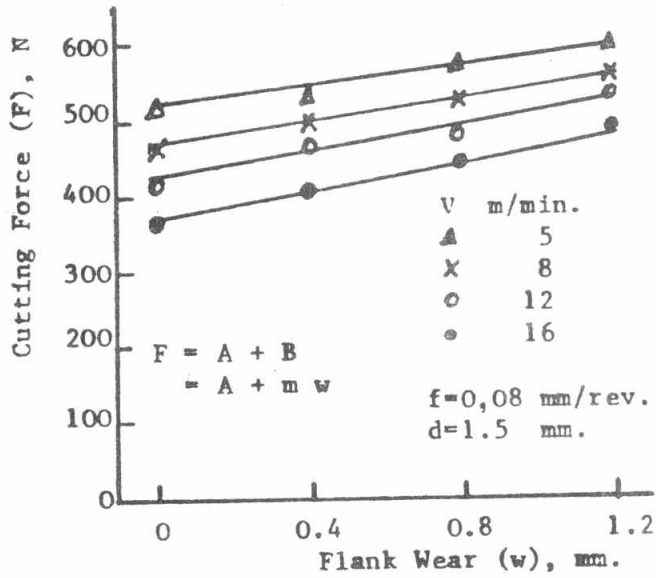


Fig.7 Effect of flank wear on cutting force at constant feed and depth of cut.

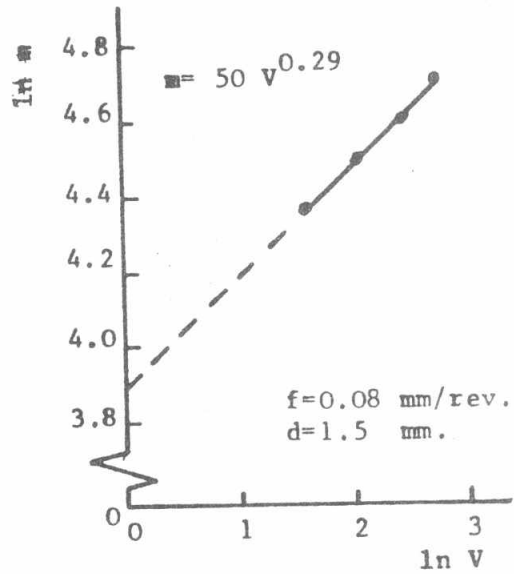


Fig.8 Logarithmic relationship between speed and proportionality constant of B and w.

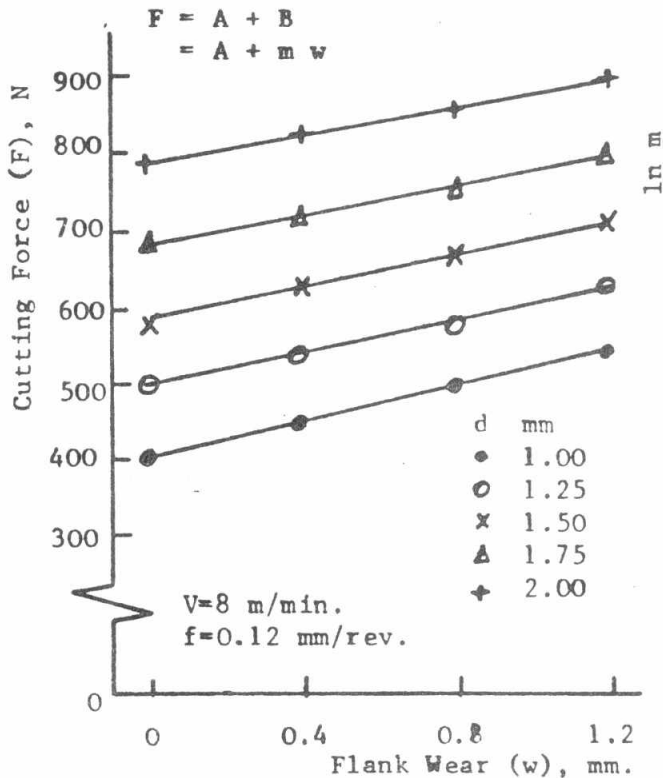


Fig.9 Effect of flank wear on cutting force at constant speed and feed.

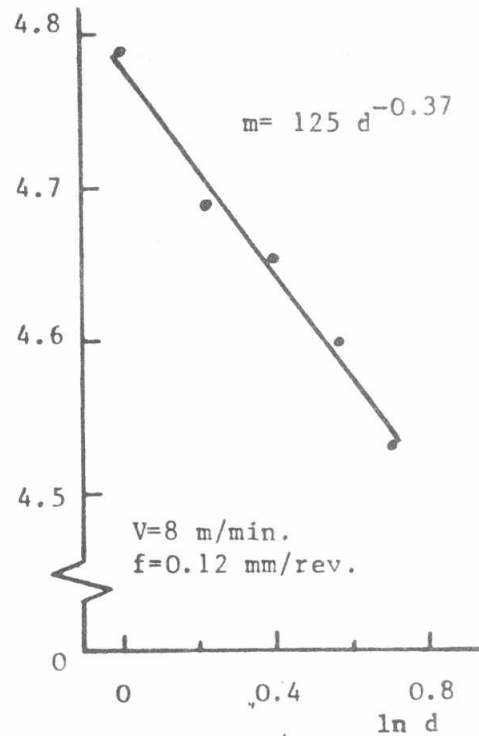


Fig.10 Logarithmic relationship between depth of cut and proportionality constant of B and w.