(JZS)Journal of Zankoy Sulaimani,September 2006, 9 (1) Part A{43-50}
گۆڤاری زانكۆی سلێمانی ئەیلول ٢٠٠٦ بەرگ ٩(١) ژمارە (١) بەشی A لاپەرە {٤٣-٥٠}

Effect of The Contact Angle between the Cutting Edge and Surface of Cut on the Flank Wear Width in Turning Operations

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Abstract

In metal cutting studies, the flank wear width (VB) is commonly used as a criterion or as a limit measure for the cutting tool life. From the point view of this work, there is a critique concerning the traditional limit measure (VB). The researchers in this domain do not take the diameter of the work-piece into consideration. In this situation, the contact angle, between the tool and the work-piece, should be determined from the limit measure of flank wear width. This work deals with the effect of the work-piece diameter on the limit measures and proposes a related limit measure for each diameter. For the experimental approach, certain confirmation tests were achieved. It seems that the work-piece diameter could modify the limit measure and it could be increased for large diameters, or decreased for small ones.

Keywords:-Flank wear, Flank wear land, surface roughness, contact angle.

Introduction

During turning operations, the desired geometry of the cutting edge of the tool is abraded down with two modes of wear, the flank wear on the clearance face and the crater wear on the rake face of the tool. The tool wear is strongly influenced by cutting parameters, particularly cutting speed, which generates a local high temperature, due to the relative sliding of the cut work-piece and the chip on faces of the cutting edge. For machined parts, the surface quality is one of the most specified customer requirements where major indication of surface quality on machined parts is surface roughness [1]. In fact, there are still several gray areas in understanding of function-finish relationship [2]. On the other hand, the crater wear, does not generally lead to a catastrophic failure of the tool and does not influence surface roughness and dimension accuracy [3, 4]. In analysis of the tool wear it is recognized that the flank wear is of prime concern [5]. In metal cutting studies, the width of the flank wear land (VB) is measured directly on the worn tool as a straight line and used as an indicator for the tool life [6- 11]. Certain values of the flank wear width (VB) are used as a criterion for acceptable values of surface quality and dimension accuracy. There is some diversity for choice of the limit values of the flank wear width (VB). Some references [8, 11] use a limit value of (VB= 1.58mm) for high speed steel tools and (0.76mm) for carbide tools. While, others [6] use a limit value of (VB= 0.4mm), for tool life, for coated carbides. In other references [10], the value of (VB= 0.3mm) is considered as limit for polycrystalline cubic boron nitride tools (PCBN tools). For the standard tool life criterion, S. Kalpakjian and S. Schmid [12] in their book (Manufacturing engineering and technology, 2002) presented a table for allowable average wear land (VB), for cutting tools in various operations. They

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indicated a maximum allowable flank wear land of (1.5mm) for high speed steel tools and (0.4mm) for carbide tools. In these limit values, the diversity is due to the tool material; it belongs to non-studied factors, as the work-piece diameter. The effect of this factor would appear more effectively, for the round nose tools, which established their potential in surface quality [8,13]. For such tool the limit value of the flank wear width is decreased, so the effect of the non-studied factors, i.e. the work piece diameter and contact angle between the work and the tool clearance face, should be more deepened.

The importance of the flank wear width (VB) is to control the wear damage on the flank face of the cutting edge, which acts directly on the tool life with the surface finish and dimension accuracy of the machined products. For controlling these problems, some researchers [14] assumed artificial wear lands, for saving the work-piece material and enabling to get wear lands characterized by desired width or area. In reality, the control of the wear damage leads to a decrease in the non-productive time and the material lost in recharpening operations.

From the point view of this work, all of these studies use the flank wear width and neglect the effect of the work-piece diameter. For example, the same limit value is applied to the small and large diameters. Further more, reference [15] has presented a table for a considerable number of studies (1970-1983) and investigated the general effects of the cutting speed, feed, depth of cut, nose radius and others on the surface roughness. In this summary, also, the work-piece diameter or the angle of contact is not taken into consideration.

In this work, an attempt has been made to contribute in this domain, by relating the flank wear width (VB) with the work-piece diameter. So, a diameter related width (VB′) is proposed and a contact angle, between the flank face of the tool and the surface of cut, is determined.

Experimental Approach

For confirming the theoretical approach of this work, a high-speed steel tool with a normal clearance angle of (8°) and a normal rake angle of (20°), is used in turning of a stepped brass shaft, figure (1). Three diameters (16.3mm, 26mm, and 42.5mm) are taken in finish turning. These diameters are chosen for the speeds (780, 490 and 300 r.p.m.) respectively, to obtain the same cutting speed of (40m/min.) for all experiments. The depth of cut are fixed as (0.04mm) and five feed rates (0.50, 0.056, 0.063, 0.069 and 0.075mm/rev.) are investigated. The distance of cut (π D n) is taken as 100m for each experiment and the surface roughness average Ra is measured with a Taly-Surf 10 roughness-testing machine. The average of three readings was taken for each experiment.

Theoretical Analysis

(i) – The contact angle (θ):

In the turning operation, once the progressive wear is initiated, the flank wear width (VB) is created on the flank face of cutting edge.

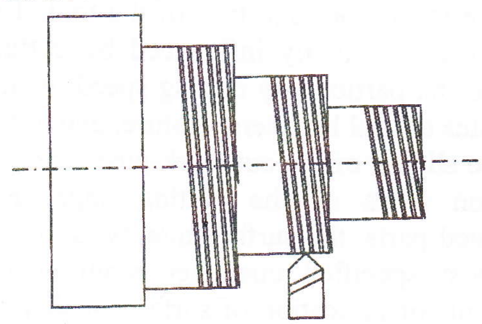


Figure (1): Test specimen and cutting conditions.

Diameter (mm)	Spindle Speed (rpm)	Cutting Speed (m/min)	Depth of cut (mm)
16.3	780	40	0.04
26	490	40	0.04
42.5	300	40	0.04

This width is commonly used as a diameter-free limit measure for the tool life and, for the aim of this work, it could be translated to a contact angle between the clearance face of the tool and the surface of cut. The complexity of this problem can be explained in the following points and as illustrated in fig. (2)

- In the beginning of cutting operation, when the cutting edge is sharp, the first contact is initiated in a single point, seen in the cross section of the cutting edge, as in fig (2.a). In such a case, the flank wear width and the contact angle will be zero for all diameters.
- As the cutting operation is continued, the flank wear land (VB) will be initiated and the contact area will be increased as a curved line according to the diameter of the work-piece, fig. (2.b). In this situation the flank wear width (VB) does not equal to zero.
- In metal cutting studies, the length between the two ends of the curved line of contact is measured and used as the flank wear width (VB), fig. (2.c).
- The curved shape of the worn area corresponds to a portion from the circumference of the work-piece and generates an angle of contact (θ) at the center of the work-piece, fig. (2.d).
- The angle of contact (θ) can be determined from the following relations, fig. (2.e):

In triangle OCD

$OC = OD = R$

$CE = CD/2$

Angle COE= θ/2So,

$\sin(\theta/2) = CE/OC$ Or,

$$\sin(\theta/2) = VB/2R \;\ldots\ldots\ldots(1)$$

When,

$$\sin^2\theta = (1-\cos 2\theta)/2$$

$\sin^2\theta/2 = (1-\cos\theta)/2$ Or,

$2\sin^2\theta = (1-\cos\theta/2)$ So,

$$\cos\theta = 1-2\sin^2\theta/2$$

When the equation (1) is considered,

$$\cos\theta = 1-1/2\,(VB/R)^2 \;\ldots\ldots\ldots(2)$$

(ii)- Diameter related flank wear width (VB′).

From the relation (2), explained above, it is seen that the angle of contact could be changed according to the work-piece diameter. Also, the limit measure of the flank wear land (VB) could be modified, in relation with the work-piece diameter. For example, when the limit measure of VB is of (1.58mm) for high speed steels, as in references [8,11], and 3 diameters of (20mm, 30mm and 40mm) are taken arbitrarily into consideration, three values of the contact angle is obtained for each case, as illustrated in table (1). Now, if the limit measure of (1.58mm), which generates a contact angle of (6.038°), is assumed to be acceptable for 30mm diameter works, the limit measure could be changed for the other diameters, as in table (1).

From equation (1):

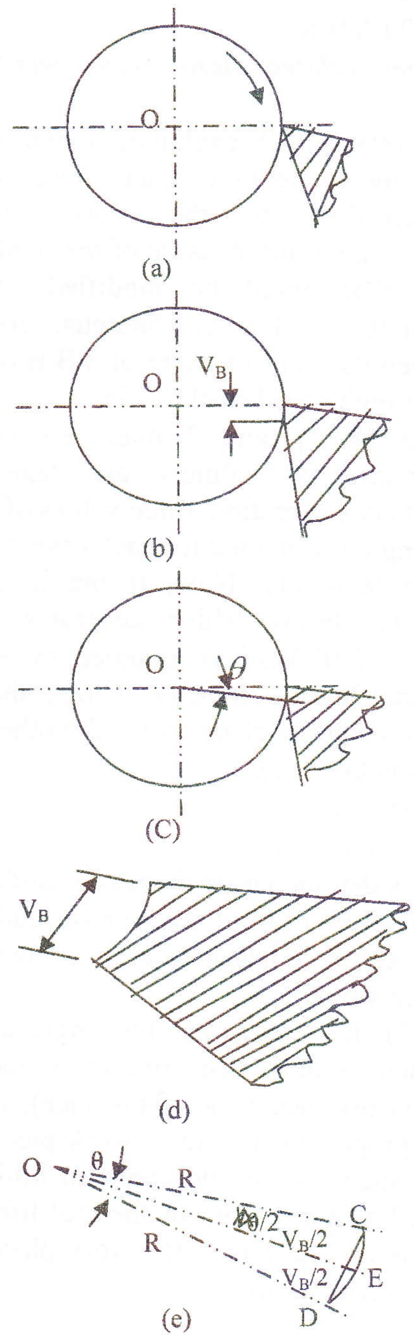
$$VB' = 2R.\ \sin(3.019^\circ)$$

This means that the larger diameters could accept larger values of limit measure of flank wear land because it has a smaller contact angle and vice-versa.

In table (1), it is seen that the angle of contact, which controls the friction in the interface of (work-piece: tool flank face), is inversely proportional to work-piece diameter. In such a case, the common limit measure, used as a criterion for the tool life, could be revised, with taking the work-piece diameter into consideration.

Table (1):

Diameter (mm)	Contact angle (θ°)	VB′ (mm)
20	9.062°	1.053
30	6.038°	1.580
40	4.527°	2.102



Fig(2): The angle of contact between the work-piece and the tool flank face:
(a)Sharp cutting edge (VB=0).
(b)Initiation of the flank wear land (VB).
©The width of flank wear land (VB).

Confirmation Test

For confirming the theoretical results obtained for the effect of the work-piece diameter, some experiments were performed in cutting a distance of 100m on each diameter. It is seen that the surface roughness decreases when the diameter of the work-piece increases. In figure (3), the average roughness of the five feed rates is compared together, for illustrating the effect of the work-piece diameter. Here also, the increase in diameter, as it decreases the angle of contact, acts positively on the surface finish of the shaft diameters used in this work. This phenomenon is due to the frictional area between the flank wear land (VB) and surface of cut, which is decreased when the shaft diameter is increased. For example, if the limit measure of the flank wear land is (1.58mm), as mentioned by references [8,11]; three contact angles are obtained from equation. (2), and as in the following:

(i): when D= 16.3mm

$\theta = 11.125^\circ$

(ii): when D= 26mm

$\theta = 6.968^\circ$

(iii): when D= 42.5mm

$\theta = 4.261^\circ$

From these values, it is seen that larger diameters give smaller contact angles and vice versa. Or, when the measure limit of the flank wear width remains constant for all diameters, the contact angle will be inversely to the diameter of the work-piece. For this reason, it is seen that the small diameter (16.3mm), which has a great contact angle ($\theta = 11.125^\circ$), is more rough than the large diameter (42.5mm), which has a smaller contact angle ($\theta = 4.261^\circ$).

On the other hand, it is possible to analyze the ratio of the contact land for each revolution of the work-piece (VB/π D), as in the following:

(i): when D= 16.3mm, VB= 1.58mm

$VB/\pi D = 1.58/\pi . 16.3$

= 3.08/100 (ii): when D= 26mm, VB= 1.58mm

$VB/\pi D = 1.58/\pi.26 = 1.9/100$

(iii): when D= 42.5mm, VB= 1.58mm

$VB/\pi D = 1.58/\pi. 42.5 = 1.18/100$

From these results, it is seen that the contact ratio is decreased when the work-piece diameter is increased. Or, the relative frictional area decreases for the large shafts and as consequence, the surface roughness will be decreased. Now, when the limit measures of flank wear width (VB) is treated in relation with work-piece dimension, relative limit measures are obtained for each diameter. Or, if the limit measure (1.580mm) is acceptable for the diameter of (26mm), it can be modified the other diameters (16.3mm & 42.5 mm):

(i): when D= 26 mm, $\theta = 6.968^\circ$

$VB' = 2R. \sin \theta/2$

$= 1.580$ mm

(ii): when D= 16.3mm, $\theta = 6.968^\circ$

$VB' = 2R. \sin \theta/2$

$= 0.990$ mm

(iii): when D= 42.5mm, $\theta = 6.968^\circ$

$VB' = 2R. \sin \theta/2 = 2.582$mm

In table (2), all of these informations are compared. It is clear that the larger diameters generate smaller contact angle and contact area and larger flank wear land limit. So, better surface finish could be obtained.

- The results of the confirmation test coincide with the theoretical analysis. For the same distance of cut, cutting speed, and depth of cut, the surface roughness decreases when the shafts diameter increases and vice-versa.

Table (2)

D Mm	Contact angle θ°	VB/π D 1/100	VB' Mm	Ra.Av µm
16.3	6.968°	3.08	0.990	0.942
26.0	6.968°	1.9	1.580	0.904
42.5	6.968°	1.18	2.582	0.876

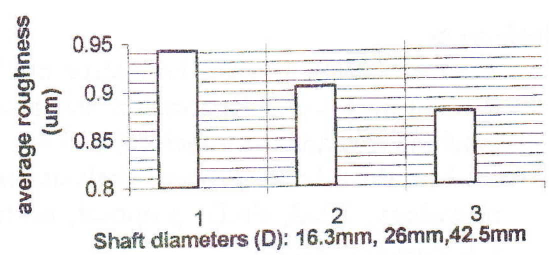


Fig (3): The average routhness.

Conclusions

- When the width of the flank wear land (VB) is taken as the same and free from the piece diameter, as used in cutting studies, the contact angle and the ratio (VB/π D) will be decreased with the increase in the diameter. For this reason, the limit measures of (VB), could not be valid for all diameters.
- The width of the flank wear land (VB), measured as a straight length, can be converted to a contact angle between the surface of cut and the clearance face of the cutting edge. In this work a simple relation, equation ($\sin \theta = VB/R$), is proposed for determining the angle of contact from the width of the flank wear land (VB) and the diameter of the work-piece.
- When the work-piece diameter and the contact angle are considered, the width of the flank wear land (VB) should be related to the work-piece diameter. In such a case, the relative flank wear width (VB') could be determined as a diameter-related limit measure for each dimension. It could be increased with the increase in the shaft diameter.

Finally, when the limit measure of (VB) gives promising results for certain diameters, it could be too sever for smaller diameters and too lean for larger ones, since the contact angle is inversely proportional with work-piece diameter.

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کاردانەوەی گۆشەی لێکەوتن لە نێوان دەمی بڕین و رووە بڕاوەکە، لە سەر پانی داخورانی رووی پێشەوەی قەڵەمەکە لە کاری تۆرنەسازیدا

شیرکو عبدالکریم توفیق بابان   سفین یاسین عزالدین قه ساب
کولیجی ئه ندازیاری / به شی ئه ندازیاری میکانیك / زانکوی سەلاحەدین /هەولیر/ هەرێمی کوردستان-عێراق

پوختە

لە ئەو توێژنەوانەدا کە لەسەرکانزا بڕیندا ئەنجام دەدرێن، پانی داخورانی رووی پێشەوەی قەڵەمەکە بەکار دەهێنرێت وەك ئەندازەیەك بۆ دیاری کردنی تەمەنی دەمی بڕین. لە ئەم باسەدا رەخنەیەك هەیە لە بەرانبەر ئەو ئەندازەیە، ئەویش ئەوەیە کە توێژەرانی ئەو بوارە بایەخ نادەن بە تیرەی پارچەکە. لە بارێکی ئاوهادا، دەبێت ئەو ئەندازەیە بە رادەی گۆشەی لێکەوتن لە نێوان دەمی بڕین و رووە بڕاوەکە بدۆزرێتەوە. ئەم نیشە دەکۆڵێتەوە لە تەشەنەی تیرەی پارچە بڕاوەکە لە سەر نرخی پانی ئەندازەیی داخورانی رووی پێشەوەی قەڵەمەکە. لە رووی کردەنیەوەو ریزێك پراوە ئەنجام دراوە ئەو پراوانە دەری دەخەن تیرەی پارچە بڕاوەکە بۆی هەیە کە پانی ئەندازەیی داخورانی رووی پێشەوەی هەموار بکات. واتە دەشێت زیاد بکرێت بۆ تیرە گەورەکان، یان کەم بکرێت بۆ تیرە بچووکەکان.

تاثير زاوية التلامس بين الحد القاطع والسطح المقطوع على عرض منطقة البلى لسطح الخلوص في عمليات الخراطة

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الخلاصة

في الدراسات المتعلقة بقطع المعادن، يتم قياس عرض بلى سطح الخلوص وذلك لاستعماله كمعيار لتحديد عمر الحد القطع للقلم بغية الحصول على نعومة سطحية مقبولة. ومن وجهة نظر هذا البحث، هنالك انتقاد للمعيار المستعمل و هو أن الباحثون في هذا المجال لا ياخذون قطر الشغلة في الاعتبار. وفي حالة كهذه يجب أيجاد المعيار المحدد لعمر القلم بدلالة زاوية التماس بين وجه القلم والسطح المقطوع. يتناول هذا البحث تاثير قطر الشغل على عرض المعياري لبلى سطح الخلوص. ومن الناحية العملية، تم إجراء مجموعة تجارب والتي تظهر بان لقطر الشعلة تاثير ملحوظ على تعديل العرض المعياري لمنطقة التآكل سطح الخلوص، حيث يمكن زيادته للأقطار الكبيرة وتقليله للأقطار الصغيرة.

Received on 7/12/2004 Accepted 3/12/2005

وەرگرتن لە ٢٠٠٤/١٢/٧ دا پەسەند لە ٢٠٠٥/١٢/٣.