

On the significance of equivalent chip thickness

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On the Significance of Equivalent Chip Thickness

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SUMMARY. In this article, the technological importance of the equivalent chip thickness and equivalent chip width is shown. Both quantities are defined with the aid of the total length of engaged cutting edge and the true area of undeformed chip section.

In the Laboratory for Production Engineering at the Eindhoven University of Technology, computer programs have been developed in order to calculate these quantities and their dependence on different geometrical conditions.

A relevant example concerning cutting forces is given.

RESUME. Dans cet article on montre l'importance technologique de l'épaisseur et de la largeur équivalentes du copeau. Les deux grandeurs sont déterminées au moyen de la longueur effective de la lèvre de coupe et la surface réelle de la section du copeau avant sa déformation.

Au laboratoire de Technologie Mécanique à l'Université Technique d'Eindhoven, des programmes sont mis au point pour calculer sur ordinateur les grandeurs susdites en fonction de conditions géométriques différentes. On a ajouté un exemple typique concernant des forces de coupe.

ZUSAMMENFASSUNG. Aus der vorliegenden Arbeit ist die große technologische Bedeutung der Begriffe "Vergleichsspanndicke" und "Vergleichsspanbreite" ersichtlich. Beide Größen werden in Abhängigkeit von der beteiligten Gesamtlänge der Schneidkante und dem unverformten Spanquerschnitt definiert. Zur rechnerischen Ermittlung dieser Größen für unterschiedliche geometrische Verhältnisse sind im Institut für Fertigungstechnik der Technischen Hochschule Eindhoven Computer-Programme entwickelt worden. An Hand der Meißelkraft wird der Rechnungsgang näher erläutert.

IN common practice, both in the workshop and in metal cutting research, the quantities depth of cut and width of cut or even feed are considered to be primary variables independently controlling important technological phenomena like cutting force and life time of tools. From this way of thinking, generalised cutting force relations and life time relations arise of a nature as proposed by Kronenberg[1]. Typically, the process is described by both a specific quantity which is arbitrarily chosen and the exponents of depth of cut and width of cut.

The specific quantity, being specific cutting force or specific cutting speed, accounts for the influence of materials properties. However, the exponents are still affected by the latter. Obviously, in the relations mentioned, the variables chosen are of a geometrical nature rather than being technological. It can be assumed that they do not act separately in the technological process. On the contrary, depth of cut and width of cut are constituents of two basic technological quantities, the total length of engaged cutting edge or equivalent chip width b_e on the one hand and the surface area A of undeformed chip cross-section on the other[2].

From these a third technological quantity is derived, the equivalent chip thickness:

$$h_e = \frac{A}{b_e}$$

or rather

$$h'_e = \frac{A_e}{b_e} \quad (1)$$

where A_e represents the true area of undeformed chip section. Thus accounting for the influence of the nose radius as shown in Fig. 1. Clearly the

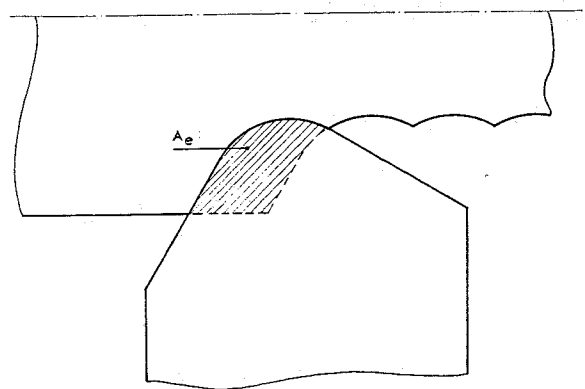


Fig. 1. The true area of undeformed chip section A_e .

introduction of equivalent chip thickness allows for replacing the actual cutting geometry by an equivalent model containing all the parameters of geometry excepting the rake angle. It is noticed that by the very definition of equivalent chip thickness, a variety of different geometries will give the same value of the quantity in question.

Now, a point of major interest appears in that experimental investigation shows that cutting force and tool temperature are merely controlled by equivalent chip thickness irrespective of the separate values of the geometry parameters involved.

This proves that the equivalent model of cutting geometry must not be considered as being a conception of purely academic value. Actually, the model reveals the basic technological quantities governing the metal cutting process.

By this time, restricting ourselves to forces in turning operations, it appears that the reduced cutting force, i.e. the cutting force per unit length of engaged cutting edge, is a strict linear function of the equivalent chip thickness, as shown in Figs. 2(a) and (b). The reduced feed and thrust force are also linear functions of the equivalent chip thickness.

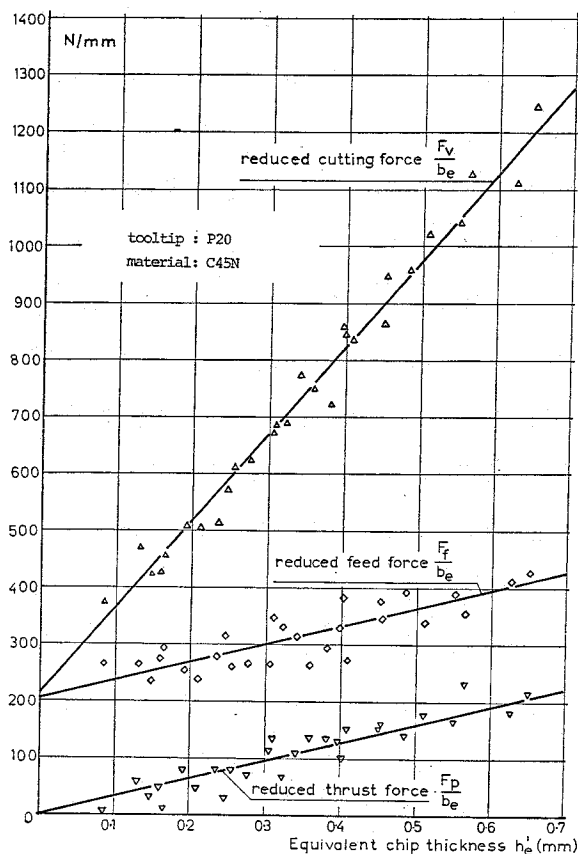


Fig. 2(a). Reduced cutting forces vs. equivalent chip thickness for a cutting speed of $v = 1$ m/sec.

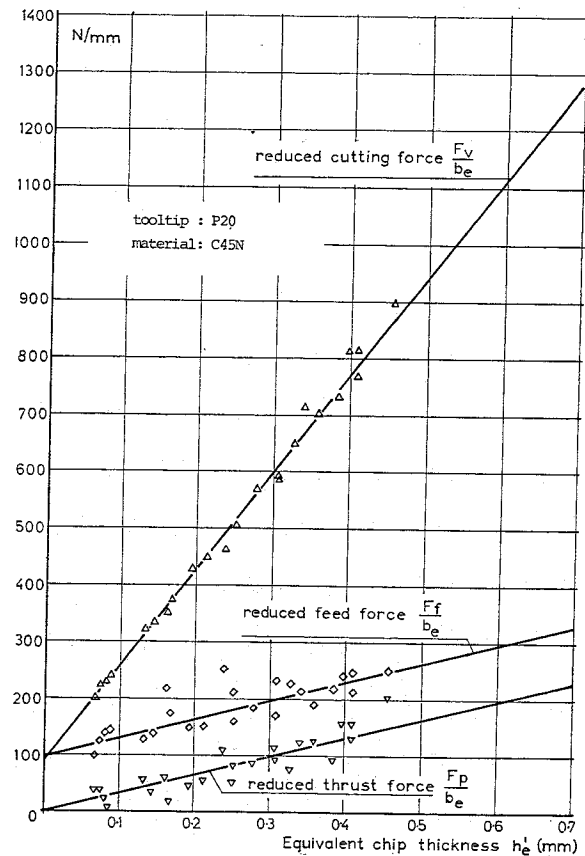


Fig. 2(b). Reduced cutting force vs. equivalent chip thickness for a cutting speed of $v = 3$ m/sec.

Hence, Kronenberg's relations can be replaced by an expression of the type

$$\frac{F_v}{b_e} = \alpha + \beta h'_e \quad (2)$$

From this follows for the specific cutting force or the specific cutting energy

$$k_s = \frac{F_v}{A_e} = \beta + \frac{\alpha}{h'_e} \quad (3)$$

It is concluded that application of the equivalent model reduces the amount of data involved in the transfer of information regarding cutting forces to only two "material's constants" α and β . With an eye to technology transfer, the common geometrical data must be translated in terms of equivalent chip width and equivalent chip thickness. The relevant relation available[3] has only limited value as its application is restricted to the region of feed where the minor cutting edge is not engaged in cutting.

As shown in Fig. 3 a number of different geometrical conditions must be distinguished in order to calculate the equivalent functions. It follows analytically:

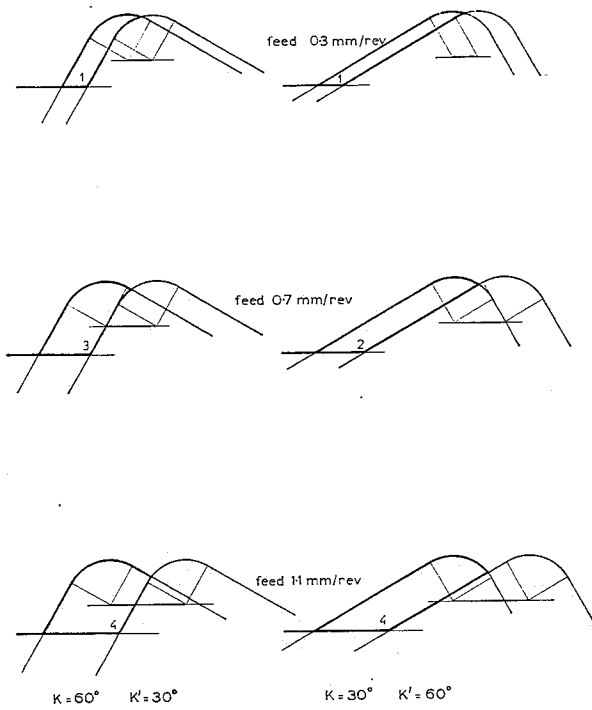


Fig. 3. Different geometrical conditions for a depth of cut of 1 mm and a corner radius of 0.4 mm.

case:

$$(1) (2) b_e = \frac{a - r_e [1 - \cos(\kappa)]}{\sin(\kappa)} + \left[\kappa + \arcsin\left(\frac{s}{2r_e}\right) \right] \frac{r_e}{2}$$

$$(3) b_e = \frac{a - r_e [1 - \cos(\kappa)]}{\sin(\kappa)} + [\kappa + \kappa'] \frac{r_e}{2} + \frac{r_e}{\sin(\kappa')} \left\{ \cos(\kappa') - \sin \left[\kappa' - \arcsin\left(\frac{s \sin(\kappa')}{r_e} - 1\right) \right] \right\}$$

$$(4) b_e = \frac{a - r_e [1 - \cos(\kappa)]}{\sin(\kappa)} + [\kappa + \kappa'] \frac{r_e}{2} + \frac{s \sin(\kappa) - r_e \left[1 - \sin\left(\frac{\pi}{2} - \kappa - \kappa'\right) \right]}{\cos\left(\frac{\pi}{2} - \kappa - \kappa'\right)}$$

$$(1) A_e = s[a - r_e] + r_e^2 \arcsin\left(\frac{s}{2r_e}\right) + \frac{s}{4} \sqrt{(4r_e^2 - s^2)}$$

$$(2) A_e = sa - r_e^2 \left\{ \frac{1}{\sin(\kappa)} - \left[1 - \frac{\left\{ 1 - \sin \left[\kappa - \arcsin\left(\frac{s \sin(\kappa)}{r_e} - 1\right) \right] \right\}^2}{2} \right] \right. \\ \left. * \cot(\kappa) + \cos \left[\kappa - \arcsin\left(\frac{s \sin(\kappa)}{r_e} - 1\right) \right] \right\} \\ * \left\{ 1 - \frac{\sin \left[\kappa - \arcsin\left(\frac{s \sin(\kappa)}{r_e} - 1\right) \right]}{2} \right\} \\ - \frac{\pi}{4} - \frac{\arcsin\left(\frac{s \sin(\kappa)}{r_e} - 1\right)}{2}$$

$$(3) A_e = sa - r_e^2 \left\{ \frac{1}{\sin(\kappa)} - \frac{\cot(\kappa)}{2} + \tan\left(\frac{\kappa'}{2}\right) - \frac{\pi}{4} + \frac{\arcsin\left[1 - \frac{s \sin(\kappa')}{r_e}\right]}{2} \right. \\ \left. + \frac{\sin \left[\pi - \kappa' - \arcsin\left(1 - \frac{s \sin(\kappa')}{r_e}\right) \right]}{2 \sin(\kappa)} \right\} \\ - \frac{\left\{ s - r_e \left[\frac{1}{\sin(\kappa)} - \cot(\kappa) + \tan\left(\frac{\kappa'}{2}\right) \right] \right\}^2}{2[\cot(\kappa') + \cot(\kappa)]}$$

$$(4) A_e = sa - r_e^2 \left\{ \frac{1}{\sin(\kappa)} - \cot(\kappa) + \tan\left(\frac{\kappa'}{2}\right) - \frac{\kappa}{2} - \frac{\kappa'}{2} \right\} \\ - \frac{\left\{ s - r_e \left[\frac{1}{\sin(\kappa)} - \cot(\kappa) + \tan\left(\frac{\kappa'}{2}\right) \right] \right\}^2}{2[\cot(\kappa') + \cot(\kappa)]}$$

In order to make these formulae practically useful, they have been evaluated numerically by means of an ALGOL-60 program. Table 1 shows the typical result referring to Fig. 3. The general program is available on request. To a limited extent, it is also possible to ask for numerical data connected with a particular case of chip geometry.

Table 1. Typical result of the ALGOL-60 program
referring to Fig. 3

Equivalent chip thickness, Progr. A—2403—9		
a	depth of cut	(mm)
A_e	area of the chip section	(mm ²)
b_e	equivalent chip width	(mm)
h_e'	equivalent chip thickness	(mm)
κ	major cutting edge angle	(deg)
κ'	minor cutting edge angle	(deg)
r_e	corner radius	(mm)
s	feed per revolution	(mm/rev)
$a = 1.00$ mm		$a = 1.00$ mm
$\kappa = 60^\circ$		$\kappa = 30^\circ$
$\kappa' = 30^\circ$		$\kappa' = 60^\circ$
$r_e = 0.40$ mm		$r_e = 0.40$ mm

s	b_e	A_e	h_e'	case	b_e	A_e	h_e'	case
0.1	1.3928	0.0999	0.0717	1	2.1524	0.0999	0.0464	1
0.2	1.4437	0.1992	0.1379	1	2.2033	0.1992	0.0904	1
0.3	1.4964	0.2971	0.1986	1	2.2560	0.2971	0.1317	1
0.4	1.5521	0.3931	0.2532	1	2.3117	0.3931	0.1700	1
0.5	1.6143	0.4806	0.2977	3	2.3723	0.4862	0.2049	2
0.6	1.6844	0.5739	0.3407	3	2.4415	0.5760	0.2359	2
0.7	1.7614	0.6617	0.3756	3	2.5284	0.6621	0.2619	2
0.8	1.8449	0.7442	0.4034	3	2.7306	0.7442	0.2726	2
0.9	1.9315	0.8221	0.4256	4	2.5711	0.8221	0.3197	4
1.0	2.0181	0.8956	0.4438	4	2.6211	0.8956	0.3417	4
1.1	2.1047	0.9647	0.4584	4	2.6711	0.9647	0.3612	4
1.2	2.1913	1.0296	0.4699	4	2.7211	1.0296	0.3784	4
1.3	2.2779	1.0901	0.4786	4	2.7711	1.0901	0.3934	4
1.4	2.3645	1.1463	0.4848	4	2.8211	1.1463	0.4063	4
1.5	2.4511	1.1981	0.4888	4	2.8711	1.1981	0.4173	4

REFERENCES

1. KRONENBERG, M., *Machining Science and Application*. Pergamon Press (1966).
2. LEYENSETTER, W., *Wirtschaftlich Zerspanen*. Westermann Verlag (1953).
3. COLDING, B. N., "A wear relationship for turning, milling and grinding. *Machining Economics*. Stockholm (1959).