

Reading Zorev's book "Metal Cutting Mechanics"
Pergamon Press: Oxford, 1966
Translated by H.S.H. Massey
Edited by Milton C. Shaw

**Translation from English into English or "Hay Mr.
Editor"**

Personal view of Viktor P. Astakhov

There are not many books published on metal cutting. Among them, the book by Zorev "Metal Cutting Mechanics" is still a landmark although it was published long time ago. Unfortunately, this fact was never recognized and thus occasional references to this book in metal cutting literature are of mostly polite nature. The question is "Why?", i.e. why the book which should be considered as *the Bible of Metal Cutting* did not grab attention of researchers in the field.

It must be recognized that this work is the most extensive experimental work in the field of metal cutting ever. No other study known to the author offers the results of so many well-conducted experiments performed using a number of different work materials, tools, and cutting conditions. It is understood that it is next to impossible to accomplish all these by a single researcher. In reality, the book summarizes the results of the many years of experimental studies performed at the leading in the former Soviet Union research institute, which coordinated manufacturing activities in the USSR industry. Professor Zorev was the director of the institute and the chairman of its scientific committee where the main results presented in the book have been discussed in details. As a result, the book should be considered as a scholarly treatment of the Mechanics of Metal Cutting and thus should represent a valuable source for researchers. In my opinion, the book deserves to be considered as the Bible of Metal Cutting. Unfortunately, that is not the case even though each serious study in the field cited it as a reference.

The reason for this is an extremely poor translation and editing of Zorev's book that make it very difficult to follow, particular for a North-American reader who should spend a great deal of time to understand the terms used in the book. For example, the term 'plane chip formation' used instead of the plane strain state; 'tangential stress' instead of the shear stress; 'acute-angle cutting' and 'free cutting at the right angle' instead of orthogonal cutting; 'shear lines' instead of slip lines; 'flexible recoil of the machined material' instead of spring back of the machined material; 'cutting ratio' instead of chip compression ratio which is reciprocal to the chip ratio; 'true angle of cut' and 'true cutting angle' instead of the deviation of the chip sliding velocity from the normal to the cutting edge; 'chip speed vector' instead of chip velocity vector (speed is a scalar); 'relative deformation' instead of strain; relative shear strain' instead of true strain; page 33, first paragraph reads "The force acting on the rake surface produces chip formation process so the work of this force can be called the chip formation force"; on

page 55 (conclusion 21) a statement “The resistance of the machined material to deformation in the plastic zone depends on the creep stress (Oh, my Goodness!) of the machined material...” rises reasonable doubts, etc. Moreover, the designations of Russian work and tool materials are used throughout the book without pointing out that practically all these materials have *AISI* analogs with which a North American reader is much more comfortable.

Therefore, to understand the value of this book, someone should translate it from English to English changing the terms used in the book, which are mostly exact replica of the Russian terms, into the corresponding appropriate terms accepted today. Realizing significance of this book, I will do such a translation. So far, I have completed only Part 5 (upon a request of my PhD student) and you can enjoy the results in the table below. I hope it will be interesting for metal cutting professionals to read the left column, take a guess on what it really means and then to read the right column to see how good was the guess.

Chapter 5 Some Peculiarities of the Process of Non-Free Cutting
(Should be “Kinematic Relationships for Non-Free Cutting”)

Page	Written	Should read
348,p2	Another peculiarity of non-free cutting is that the direction of shear in the chip formation zone and the direction of departure of the chip depend on the working length of the cutting edge and its relative arrangement.	Another feature of non-free cutting is that the shear angle and the chip flow angle are functions of the cutting edges active length and their relative location with respect to the tool coordinate system.
349,p5	The subsidiary cutting edge	The minor cutting edge
349,p.5	...the main and subsidiary angles in plan.	...the cutting edge angles of the major and minor cutting edges in the reference plane.
350,p2	The planes NN and N_1N_1 , which are at right angles to the main and subsidiary cutting edges respectively, are not planes of symmetry for the profile of the working sections of the cutting edges	The planes NN and N_1N_1 passed through the point of the intersection of the major and minor cutting edges are normal planes for the major and minor cutting edges.
350,p.2	The direction of departure of the chip...	The chip flow direction...
350,p.3	... the main angle of deflection of the chip...the subsidiary angle of deflection of the chip	...the chip flow angle with respect to the x-axis....the chip flow angle with respect to the y-axis.
350,p.5	In this case, as is well known, the chip leaves at right angles to the cutting edge OA and the angle of deflection of the chip becomes equal to zero.	As such, the chip flow direction is perpendicular to the cutting edge OA and thus angle η becomes equal to zero
351,p.4	... the shear rate vector..	The shear velocity vector...
351,p.5	When the length of the subsidiary cutting edge is a long way from zero the chip speed vector v_1 deviates from the main cutting plane by the angle η .	When the length of the minor cutting edge becomes significant compare to that of the major cutting edge, the direction of chip flow (considered in the reference plane) deviates from the normal plane of the major cutting edge by angle η .

Page	Written	Should read
351,p.5 p.6	By adding the rates of shear v_{EXZ} and v_{EY} the resultant shear rate v_{E} is formed which no longer lies in the main cutting plane. By similar arguments, it can be shown that due to the action of the main cutting edge...	The resultant shear velocity v_{E} is the sum of the shear velocities on the major, v_{EXZ} and the minor, v_{EYZ} shear planes and its direction if not normal to the major cutting edge.
351,p.7	From the condition for the formation of a common chip departing at a speed (v_{T}) it therefore follows that when the two cutting edges work together the shear rates on the main and subsidiary shear planes must be equal to (v_{E}), i.e. they must coincide in value and direction.	Because a single continuous chip is produced, the shear velocities on the major and minor cutting edges should be the same and equal to v_{E} .
352,p.1	Any other idea leads either to the conclusion that the continuity of the chip is broken or to the conclusion that the existence of the shear mechanism of the chip formation is impossible, which is contradicted by experimental data.	Any other assumption either violates the continuity conditions or questions shearing as prime mechanism of chip formation and thus in obvious contradictions with practical observations.
352,p.2	The rate of normal shear in the main shear plane is...	The shear velocity on the shear plane in the normal cutting edge of the major cutting edge is..
352,p.3	The rate of lateral shear in the main shear plane is...	The shear velocity on the shear plane in the direction perpendicular to the normal cutting edge of the major cutting edge is..
352,p.4	The rate of normal shear in the subsidiary shear plane is...	The shear velocity on the shear plane in the normal cutting edge of the minor cutting edge is..
352,p.5	The rate of lateral shear in the subsidiary shear plane is...	The shear velocity on the shear plane in the direction perpendicular to the normal cutting edge of the minor cutting edge is..
352,p.8	...is the longitudinal cutting ratio , then $\xi = \cot \beta_0$...is the longitudinal chip compression ratio, then... $\xi = \cot \beta_0 \quad (131)$
354,p.2	... differentially thin element of the layer being removed...	Small element of the layer to be removed.

Page	Written	Should read
354,p.3	Naturally the chip is really formed not as a result of periodic shear of elements, but as a result of the continuous shear flow of material inside the zone...	Nonsense.
354,p.3	Naturally the chip is really formed not as a result of periodic shear of elements, but as a result of the continuous shear flow of material inside the zone...	Nonsense.
355,p.1	The boundary between the chip and the unreformed material is characterized by the shape of the cutting edge of the tool.	Nonsense.
356,p.2	Let us examine the question of the shape of the cross-section of the chip.	Considering the profile of the chip cross-section....
356,p.3	Plane XOY is taken as the front surface of the cutting element.	In Fig. 278, the rake face of the cutting element is considered as located in the XOY plane.
357,p.1	...so the main angle in plan is $\varphi=90^\circ$, and the subsidiary angle in plan is $\varphi_1 = 0^\circ$. Under these conditions the cross-section of the cut HODB is rectangular in shape with dimensions a and b .	So the cutting edge angle of the main cutting edge $\kappa = 90^\circ$, and that of the minor cutting edge is $\kappa_1 = 0^\circ$. As such, the uncut chip cross-section has parallelogram profile having the length of its sides a and b respectively.
357,p..2	, b_1' being able to be determined from the geometrical rations of figures AHODK,...	, b_1' is determined from the analysis of geometry of AHODK...
357,p.7	Since $a/b=1$ and $\eta = 45^\circ$ with an equal-sided cut (k_b) becomes equal to infinity, i.e. the cross-section of the chip acquires the shape of a triangle.	If follows from the above considerations that when $a/b=1$, e.i when the uncut chip profile has a diamond shape, coefficient $k_b \rightarrow \infty$. As a result, the cross section of the chip becomes triangular.

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359,p.4	<p>...the thickness cutting ratio (ξ_a) is</p> $\xi_a = \frac{\cot \beta_0}{\cos \eta}$ <p>Therefore, during non-free cutting one cannot precisely determine the resultant shear angle (β_0) from the cutting ratio (ξ_a) if the angle of deflection of the chip is unknown.</p>	<p>...the transverse chip compression ratio ξ_a is</p> $\xi_a = \frac{a_1}{a} = \frac{\cot \beta_0}{\cos \eta}$ <p>As follows from this equation, in non-free cutting the resultant shear angle β_0 no more can be determined accurately using only the values of the transverse chip compression ratio ξ_a determined experimentally. The chip flow angle is also needed for such calculations.</p>
359,p.7	<p>This formula is true for a cutting angle of zero. If the cutting angle deviates appreciably from zero the more general relationship must be used....where (γ_0) is the cutting angle in the plane of departure of chip.</p>	<p>Equation (131) is valid only when the rake angle is equal zero. When this is not the case, i.e. when the actual rake angle is more than $\pm 5^\circ$, the following more general equation should be used to calculate the longitudinal chip compression ratio...where γ_0 is the rake angle in the plane which is perpendicular to the reference plane and contains the vector of the chip flow direction. Hereafter this plane is referred as the chip flow plane.</p>
360,p.1	<p>There is therefore interest in establishing the relationships which determine the size of the angle of deflection. These relationships may be obtained from the following arguments.</p>	<p>Therefore it is important to know the chip flow direction. The following should be considered to calculate this angle.</p>
360,p.2	<p>As has been shown previously, if each of the edges of a non-free cutting element is made to work separately without the aid of other edge, the chip which forms will leave in a plane at right angles to the working edge.</p>	<p>As shown above, if each edge of a non-free cutting element is considered independently, i.e. without the influence of the other cutting edge then the chip formed by this edge flows in the direction perpendicular to this edge.</p>

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360,p.3	Since the shear strain vectors on the main and subsidiary shear planes are parallel to each other and lie in the plane of departure of the chip, the tangential forces on the shear planes cannot influence the direction of departure of the chip.	Because it was assumed in Fig. 272 that the shear forces on the major and minor shear planes have the same direction and lie in the chip flow plane, the share forces on these shear planes cannot affect the chip flow direction.
361,p.1	From relationship (139) it also follows that the chip leaves in the plane of action of the resultant of the normal forces (N) and (N ₁).	It follows from (139) that the chip flow direction is determined by and thus coincides with that of the resultant of the normal forces N and N ₁ .
362,p.2	The relationship shows that the angle of deflection of the chip rises as the length of the subsidiary cutting edge decreases and drops as the length of the main cutting edge increases.	This equation shows that the chip flow angle increases when the length of the minor cutting edge increases and decreases when the length of the major cutting edge increases.
362,p1	Therefore, the chip is deflected the same amount from the main and subsidiary normal planes.	Therefore, the chip is deflected at the same angles from the normal planes of the major and minor cutting edges.
362,p.5	For “reverse” chips ($l < l_1$) $\sin 2(\varphi - \eta) \frac{l_1}{l} \sin \varphi \quad (143)$	For “reverse” chips ($l < l_1$) $\sin 2(\varphi - \eta) = \frac{l_1}{l} \sin \varphi \quad (143)$
363,p.2	In other words, with an “equal-sided” cut the cheap leaves in the direction of the bisector of the angle at the apex of the cutting element	In other words, when the width of cut is equal to the uncut chip thickness, the chip flows in the direction of the bisector of the tool nose angle (the angle between the major and minor cutting edges).
363,p.4	...as the main plan angle increases.	As the cutting age angle of the major cutting edge increases.

Page	Written	Should read
364,p.1	<p>For the influence of the rake inclination angle to be taken into consideration equation (145) must be used to calculate the angle of inclination of the front surface in the plane at right angles to the direction of departure of the chip (η_λ)</p> $\tan \eta_\lambda = \tan \lambda \cos \eta + \tan \gamma \sin \eta$ <p>(145) where η is the angle of deflection of the chip from the main normal plane; λ is the angle of inclination of the main cutting edge; γ is the rake angle in the main normal plane.</p>	<p>In the previous considerations the rake angle, γ and the cutting tool inclination angle, λ_s are assumed to be zero. When the geometry of a cutting tool includes two cutting edges, rake angle γ and inclination angle λ_s, non-free, non-orthogonal cutting is the case. As such, the direction of chip flow further deviates from the direction of chip flow calculated above by angle η_λ.</p> $\tan \eta_\lambda = \tan \lambda \cos \eta + \tan \gamma \sin \eta \quad (145)$
364,p.3	<p>The meaning of relationship (146) can easily be shown to apply to the extreme case when the length of the main cutting edge is larger by comparison with the length of the subsidiary cutting edge.</p>	<p>To understand the meaning of Eq. (146), consider the extreme case when the length of the major cutting edge is much greater than that of the minor cutting edge.</p>
364,p.3	<p>This is in accordance with the results of experiments on free cutting at acute angles⁽⁴⁷⁾, when there is no subsidiary cutting edge.</p>	<p>This result is in agreements with the known experimental results obtained in free oblique cutting (for example, [47]).</p>
364, p.6	<p>In these cases, apart from the main and subsidiary shear plane, there is a transition shear plane on which the normal force acts, which in turn has an additional influence on the direction of the departure of the chip. Therefore when there is a transition cutting edge the angle of deflection of the chip will differ from that which would be the case under the given conditions if there were no transition cutting edge.</p>	<p>When this is the case, the normal force on the shear plane due to the transition cutting edge also affects the direction of chip flow so that this direction changes compare to that without the transition cutting edge.</p>

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365,p.2	Considerably simpler formulae ...	Considerably simpler equations...
366,p.2	Figure 282 shows a rectilinear transition cutting edge with an angle in plan of ϕ_n ...	Figure 282 shows a straight transition cutting edge having the tool cutting edge angle ϕ_n ...
366,p.2	The force acting on the chip in plan plane XOY from the side of the transition shear plane is designated P_n .	The projection of the additional force acting on the chip due to the transition cutting edge into the XOY plane is designated as P_n in Fig. 282.
366,p.5	$l_e = l_n \frac{\sin \phi_n}{\sin \phi}$ (147)	$l_e = l_n \frac{\sin \phi_n}{\sin \phi}$ (147)
367,p.1	When there is a transition cutting edge and at $\phi_1 = 0$ the lengths of the main and subsidiary cutting edges are connected with the depth of cut and the feed by the relationships	When a tool design includes a transition cutting edge and the minor cutting edge having a zero tool cutting edge angle (i.e., $\phi_1 = 0$), the lengths of the major and minor cutting edges are directly correlated with the depth of cut and the feed per revolution as
368,p.4	During non-free cutting the ratio of the projections of the cutting forces P_z, P_y and P_x depend on the feed and the depth of cut. Thi can be explained by the fact that the feed and the cutting depth influence the direction of departure of the chip and thus also the direction of the force of friction between the chip and the front surface. In order to see how the direction of departure of the chip influences the relationship of the projections of the cutting forces let us turn to Fig. 283 where the diagram is shown of the forces acting on the front surface of the tool at an inclination angle of the main cutting edge of zero ($\lambda = 0^\circ$).	During non-free cutting the proportion of the orthogonal components of the cutting force, $P_z : P_y : P_x$ depends on a particular combination of the feed and the depth of cut because the latter affects the direction of chip flow and thus that of the friction force on the tool rake face. In order to illustrate how the direction of chip flow affects the discussed proportion, Fig. 283 shows the force diagram for a cutting insert with zero cutting edge inclination angle.
369,p.2	The subsidiary rectangular system of coordinates lmn is so orientated that the n axis at right angles to the front face, and the l axis coincides with the cutting edge which forms a main plan angle of ϕ with X axis.	Additionally to the tool coordinate system xyz , an auxiliary coordinate system lmn is set at the same origin as follows: the l axis coincides with the cutting edge and thus forms angle ϕ with the X-axis; the n axis is perpendicular to the tool rake face as shown in Fig. 283.

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370,p.3	...and bearing in mind the intensity of cutting conditions, a value of μ must be selected. One can be guided by the following approximate rule when selecting the values: for working with a hard-alloy cutting tool $\mu = 0.6$, for working with a high-speed steel tool $\mu = 0.8$.	To calculate the ratios (159)-(161), a particular value of the average friction coefficient on the tool rake face μ should be known. Although this value depends on many cutting parameters, the following values can be used to the first approximation: $\mu = 0.6$ when using carbide cutting tools and $\mu = 0.8$ when using high speed steel tools.
370,p.4	From equations (156)-(158) relationships (162) follows, which can be used to determine the angle of deflection of the chip of the projections of the cutting forces are measured:	It follows from equations (156)-(158) and (162) that the chip flow angle can be calculated using the experimentally obtained projections of the cutting force as:
372,p.1	<p>At $v = 0$ equation (163) changes into equation (164) since</p> $P_y \cos \varphi + P_x \sin \varphi = P_{xy} \text{ and}$ $P_y \sin \varphi + P_x \cos \varphi = 0$ $\mu = \frac{P_z \sin \gamma + P_{xy} \cos \gamma}{P_z \cos \gamma - P_{xy} \sin \gamma};$ <p>it is clear that equation (164), which is usually used for determining the mean coefficient of friction during non-free cutting, is, generally speaking, not suitable for this since it is true only for the case of $v = 0$. Equation (163) should therefore be used for calculating (μ) during non-free cutting, and not (164). It is understood that the equations (156)-(163) are true only for cutting at right angle with comparatively small forces on the rear surface.</p>	<p>If $v = 0$ is assumed in Eq. (162) then</p> $P_y \sin \varphi + P_x \cos \varphi = 0 \quad (A)$ <p>it follows from Fig. 283 than</p> $P_y \cos \varphi + P_x \sin \varphi = P_{xy} \quad (B)$ <p>where P_{xy} is the resultant force in the xy-plane.</p> <p>By substituting equations (A) and (B) into Eq. (163) the following equation is obtained</p> $\mu = \frac{P_z \sin \gamma + P_{xy} \cos \gamma}{P_z \cos \gamma - P_{xy} \sin \gamma} \quad (164)$ <p>Equation (164) is the well-know equation [from Merchant to today – any book on metal cutting], which widely used to determine the mean friction coefficient using the measured force components is not correct. To illustrate the significance of the discrepancy between the derived equations (163) and the widely-used (164) consider a practical example.</p>

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		<p>It follows from Fig. 284 that in machining of a medium carbide steel (0.4%C, 1%Cr, 1%Ni, 1%Mo) using the following cutting regime: cutting speed – 70 m/min; depth of cut – 2 mm; feed – 0.805 with a carbide tool having the following geometry: the tool cutting edge angles are $\phi = 60^\circ$ and $\phi = 1^\circ$ for the major and minor cutting edges, respectively; normal rake angle $\gamma = 0^\circ$; nose radius $r = 0.1\text{mm}$, the orthogonal components of the cutting force are: $P_z = 300\text{kg}$, $P_y = 65\text{ kg}$, $P_x = 58\text{ kg}$. Substitution of these data into Eq. (163) yields $\mu = 0.335$ while into Eq. (165) yields $\mu = 0.275$.</p> <p>We may conclude, therefore, that Eq. (163) should be used when one tries to evaluate the friction coefficient using the experimentally obtained projections of the cutting forces if the latter were obtained from the convention turning test.</p> <p>It should not be forgotten that equations (156) – (163) are valid only when the cutting edge inclination angle is zero and the flank forces are small compare to those on the rake face, i.e. when the tool is sharp.</p>
372,p.4	The data of Fig. 284(a)-(c) were used together with equation (162) to find the values of the angle of deflection of the chip (ν), shown in Fig. 285.	Figure 285 shows the values of the chip flow angle, ν calculated using Eq. (162) and the experimental data presented in Fig. 284(a)-(c)
373,p.1	According to Fig. 285 the cutting speed does not influence the angle of deflection of the chip, although the cutting ratio changes at the same time over a fairly wide range (Fig. 286).	As seen from Fig. 286, the cutting speed has no effect on the chip flow angle although the chip thickness (characterized by the chip compression ratio, ζ) changes significantly with the cutting speed as seen from Fig. 286.

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375,p.3	It should be pointed out that the experimental values of (ν) differ considerably more from the calculated for medium- and low-hardness steels as large plane angles (φ) .	It was found the discrepancy between the calculated and the experimentally obtained chip flow angles increases when machining steels of low hardness with a tool having a large tool cutting edge angle, φ .
pp.376-377	<p style="text-align: center;">Conclusions</p> <ol style="list-style-type: none"> 1. During non-free cutting each edge of the cutting element produces a corresponding family of shear surfaces in the chip formation zone. If these edges are straight it may be approximately considered that each of these families may be replaced by one conventional shear plane passing through the given cutting edge. During non-free cutting, there are so many specific shear planes as there are cutting edge participating. 2. The mutual arrangement of the shear planes is determined by mutual arrangement of the cutting edges, the chip flow direction and the condition of parallelism of the shear direction on all shear planes. 	<p style="text-align: center;">Conclusions</p> <ol style="list-style-type: none"> 1. During non-free cutting, two or more cutting edges take place in cutting. Although the deformation process in the machining zone of each participating cutting edge is a complex issue, it can be thought of, at least to the first approximation, as taking place along a single shear plane if the considered cutting edge is straight. Therefore, during non-free cutting, the deformation zone is represented as consisted of a number of single shear planes passing though corresponding cutting edges. 2. In free cutting the orientation and location of each shear plane is uniquely determined by the location and orientation of the corresponding cutting edge, its rake angle and by the cutting regime. In non-free cutting, the orientation and location of each shear plane is mainly determined by the chip flow direction and by the location and orientation of the corresponding cutting edge with respect to other cutting edges involved in cutting. As such, to assure continuity of deformation, the directions of shear deformation must be parallel on all the discussed shear planes to form one chip by all the cutting edges.

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	<p>3. The condition of parallelism of the shear direction on all shear planes is fulfilled until one solid chip is formed on the non-free cutting element, and a crack occurs in the chip deformation zone. If for some reason or other the directions of shear on the various shear planes ceases to be parallel, the two or more separate chips are formed or the solidity of the chip formation zone is disturbed along one of the shear planes (a local crack forms).</p> <p>4. In the general case of non-free cutting the direction of chip flow is not at right angles to any of the edges of the cutting element. It is convenient to use as the characteristic of the direction of chip flow the values of the angle of deflection of the chip (ν) which is determined by the chip speed vector and the plane at right angles to the main cutting edge.</p> <p>5. The direction of chip flow is determined by the conditions of equilibrium of the forces on the tool face.</p>	<p>3. If the coherency of the deformation on a certain cutting edge is violated, i.e. the direction of shear deformation on the corresponding shear plane is not parallel to that on the other shear planes because the latter is not admissible for the considered shear plane, a crack forms at the interference of the chip flows due to the difference in their velocities. As such, two or more separate chips are formed instead of a single solid chip.</p> <p>4. In the most general case of non-free cutting, i.e. when several cutting edges participate in cutting and $\gamma \neq 0$, $\lambda \neq 0$, the chip flow direction is not perpendicular to any of these cutting edges. As such, this direction can be characterized by the chip flow angle ν between the vector of chip sliding velocity and a normal to the major cutting edge and measured in the plane coincident with the rake face.</p> <p>5. The direction of chip flow is determined by equilibrium of the forces on the tool rake face.</p>

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	<p>6. If the tool face is at right angles to a plane drawn through the cutting speed and chip speed vectors the chip deflection is determined by the condition of equality of the projection onto the tool face of the normal forces acting on the shear surfaces. In this case the chip direction coincides with the direction of the resultant of the aforementioned projections of forces. From this it is possible to calculate the angle of deflection of the chip by means of simple formulae which take into account the ratio of the areas and the mutual orientation of the shear planes.</p> <p>If the tool face is not perpendicular to the plane drawn through the cutting speed and the chip speed vectors the angle of deflection of the chip can be calculated approximately from the equation with a correction introduces for the angle of deflection of the normal to the tool face from the said plane.</p>	<p>6. When the cutting edge inclination angle is zero, i.e. when orthogonal non-free cutting is the case, the chip flow direction is in the direction the resultant of projections of the normal forces on the shear planes of the participating cutting edges into the tool rake face.</p> <p>When the cutting edge inclination angle is not zero, i.e. when oblique non-free cutting is the case, the experimentally obtained correction to the chip flow direction determined in the direction of the force resultant can be used.</p>

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	<p>7. The greatest influence on the angle of chip deflection is had by the ratio of the feed to the depth of cut, the ratio of the length of the transition cutting edge to the depth of cut, the inclination of the front surface in the plane at right angles to the chip speed vector, and the main and transition plan angles. The cutting speed, the inclination angle, the subsidiary plan angle, the properties of the machined material and the coefficient of friction have little influence (or no influence at all) on the angle of chip flow.</p> <p>8. The angle of the chip deflection rises as the ratio of the feed to the depth of cut, the ratio of the length of the transition cutting edge, to the main plan angle increase. The angle of chip deflection decreases as the transition plan angle, the rake angle and the angle of inclination of the main cutting edge increase.</p>	<p>7. Among process parameters, the greatest influence on the chip flow direction have the following rations: the feed/the depth of cut, the length of the transition cutting edge/the depth of cut, and the following parameters of the tool geometry: the rake angle and the tool cutting edge angles of the major and transition cutting edges. The cutting speed, the cutting edge inclination angle, the tool cutting edge angle of the minor cutting edge, the properties of the work material and the coefficient of friction on the rake face have little influence or no influence at all on the chip flow direction.</p> <p>8. The chip flow angle increases as the ratio of the feed to the depth of cut, the ratio of the length of the transition cutting edge to the tool cutting edge angle of the major cutting edge increase. The chip flow angle as the tool cutting edge angle of the transition cutting edge, the rake angle and the inclination angle of the major cutting edge increase.</p>

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	<p>9. For a given cutting element the ratios of the cutting force projections P_x, P_y, and P_z depend considerably on the angle of chip deflection. By virtue of the existence of this relationship the angle of chip deflection can be calculated from the results of measuring the cutting force projections. In turn, the ratios of cutting force projections can be calculated if one knows the angle of chip deflection and the mean coefficient of tool face friction.</p> <p>12. The angle of the chip deflection influences the shape of its cross-section. When the cut is rectangular in cross-section the shape of the cross-section of the chip deviates more and more from the rectangle, taking first the shape of a trapezium and then a triangle, as the angle of chip deflection increases. If the angle of chip deflection is not zero the width of the corresponding surface of the chip is always greater than the width of the cut.</p>	<p>9. For a given cutting geometry, the orthogonal components of the cutting force depend considerably on the chip flow angle. This angle can be calculated using the derived relationship and experimentally determined cutting force components. In turn, the ratios of the orthogonal components of the cutting force can be calculated if one knows the chip flow angle and mean friction coefficient on the rake face for a given cutting conditions.</p> <p>12. The chip flow angle defines the chip cross-section profile under a given uncut chip profile. When the latter has a common parallelogram shape, the chip cross-section profile first take shape of a trapezium and then a triangle, as the chip flow angle increases. In any case, when the chip flow angle is greater than zero, the maximum chip width is greater than that of the uncut chip width. (note that a simple equation can be used to calculate the maximum chip width, b_{max} $b_{max} = \sqrt{t^2 + (t \cot \varphi + s)^2}$ where keeping Zore'v notations t is the depth of cut; s is the feed, mm/rev; φ is the tool cutting edge angle of the major cutting edge, auth.)</p>