Method of Independent Determination of Cutting Forces on the Rake and Clearance Faces of a Lathe Cutting Tool.

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ABSTRACT

The exact nature of cutting forces acting on cutting tools are vital in the study of machining processes of metal cutting. In this study, it was found that in order to accurately determine the cutting forces, the thickness of cut is usually extrapolated to zero. This is very difficult to attain as in the process the cutting conditions may greatly be altered, thereby making the obtained results doubtful. This study proposes a method of extrapolation of the wear plane on the cutting tool to zero as against extrapolation of the thickness of cut to zero. In this study, stainless steel of different compositions, ferrite-pearlitic and austenitic, severed as work-piece materials while cemented carbide tools: straight carbides (WC), tungsten-titanium carbides (WC-TiC), and tungsten-titanium-tantalum carbides (WC-TiC-TaC) were used as cutting tool materials.

(Keywords: cutting force, extrapolation, thickness of cut, wear plane, ferrite-pearlitic, austeniti, straight carbides, tungsten-titanium carbides, tungsten-titanium-tantalum carbides)

INTRODUCTION

Measurement of cutting forces during modern processing techniques are carried out from different points of view and hence different techniques are used (Venkateshi, 1987). In the study of the processes of metal cutting, it is sometimes important to separately or independently determine the cutting forces acting on the rake face, as well as the clearance face of the cutting tool. In the theory of metal cutting, the method of determining the cutting forces on the clearance face of the cutting tool, by extrapolation of the thickness of cut to zero, is very common (Talantov, 1992). The shortcomings of this method are clear: while reducing the thickness of cut is achieved mainly by reducing feed, there is a reduction in cutting temperatures, in most cases leading to a considerable change in the type of contact at the tool-chip interface. That is, turning with a small feed, even at high speeds, may result in the cutting force acting not on the wear plane of the clearance face of the cutting tool, but on the "clearance face" of the built-up edge. A modification of this method, when cutting temperature and chip shrinkage are kept constant, is linked with increase in cutting speeds as the feed decreases, resulting in changes in temperature regimes and cutting forces in the actual wear plane (Talantov, 1992).

It is important, at this point, to point out that the understanding of cutting with absolutely sharp cutting tool is nothing but an assumption. This is because, at the very first moments or microseconds of cutting, there is a radius, ρ, formed on the cutting edge of the cutting tool. At the same time, one of the main advantages of this suggested method is actually in the extrapolation of the assumed sharp cutting tool with the assumption that $\rho = 0$: the rounded part of the cutting edge of the tool is substituted for by corresponding parts on both the rake face and the wear plane. With this method, all the accumulated error is far smaller than the actual resultant cutting force at the cutting edge radius. Since the value of the cutting edge radius is so small compared to the width of the wear plane, the error also tends to be negligible. In nearly all cutting cases, the natural cutting edge radius, formed on the cutting tools is not more than 0.01 mm. This fact makes it possible for this suggested method to use flank wear, h_z, ≥ 0.05 mm.

In this case, cutting is carried out with cutting tools having different values of wear plane and the resultant cutting force is obtained experimentally. A graph of resultant cutting force, R, against the values of wear plane on the flank face, h_z, is plotted and by means of extrapolation of these variables to zero wear plane, the cutting forces acting on the rake face of the cutting tool is obtained. The resultant cutting force, acting on the clearance edge at a specific value of the wear plane is obtained by subtracting the resultant cutting force, acting on the rake face, from the total resultant cutting force.

In this study, a new method, extrapolation of the wear plane to zero as against extrapolation of the thickness of cut to zero, is being suggested.

METHODOLOGY

The experiment is carried out to measure the flank wear (hz), by straight turning two steel work pieces of different composition, the ferrite-pearlitic (fp) and austenitic steel (as). Three different types of cemented carbide tools, straight carbides (WC), tungsten-titanium (WC-TiC), tungsten-titanium-tantalum, and (WC-TiC-TaC) were used.

Table 1: Flank Wear Plane, hz, mm.

	Straight Carbides, WC	Tungsten-Titanium, WC-TiC	Tungsten-Titanium-Tantalum, WC-TiC-TaC
Ferrite-pearlitic (fp)	0.55	0.65	0.6
Austenitic steel (as)	0.6	0.75	0.7

(cutting speed, V, = 60 m/min, cutting feed, s, =0.3 mm/rev, cutting depth, t, =1.5 mm)

In order that the results of this work may compare favorably with the generality of other woks in this area of interest, the most commonly used rake angle in practice, $\gamma = 0^o$, (Dallas, 1976, Kosilova, 1987, Oberg and Jones, 1957) was adopted.

Other geometrical parameters, $\alpha = \alpha_1 = 10^o$, $\varphi = 45^o$, $\varphi_1 = 25^o$, $\lambda = 0^o$, of the cutting tool are chosen in the range of the ones most commonly recommended for use in practice. In order to reduce experimental time, an artificial wear plane of width 0.1 – 0.4mm was made on the cutting edge of the cutting tool. It was experimentally established that the natural wear plane formed on the cutting tools as a result of the cutting operations, are not parallel to the vector of the cutting speed. For this reason, while making the artificial wear plane, a special template, inclined at -1.5^o to -2^o, to the vertical plane passing through the cutting edge was prepared.

Cutting was carried out using the most commonly recommended cutting conditions for manufacturing works, being – cutting feed, s = 0.3 $mmrev^{-1}$ and cutting dept, t =1.5 mm (Dallas, 1976, Kosilova, 1987, Oberg and Jones, 1957).

The cutting speed (v) varies within the limits of 30 $mmin^{-1}$ and 120 $mmin^{-1}$. At any rate, it must be mentioned and understood, that the major criteria for determining the particular cutting speed to be used at any particular time depends on the material of the work-piece and the type of cutting tool. The cutting speed must be chosen to be higher than the cutting speed for the development of the built-up edge phenomenon for the pair of work-piece material – type of cutting tool, and at the same time, lower than that lower-limit for the beginning of the formation of crater wear on the rake face of the cutting tool.

The component cutting forces P_z, P_x, and P_y were measured using a cutting force dynamometer connected to a four-channel signal amplifier. The component cutting forces P_y and P_x were transferred to a single horizontal component force:

$$R_{xy} = \sqrt{P_x^{\,2} + P_y^{\,2}} \qquad \textbf{(1)}$$

The quick stop mechanism was used to obtain the specimen, “chip root”, for the analysis and study of the chip-tool interface and interaction. The contact part of the chip and tool on the rake face of the cutting tool, an important part of the study, was measured with the aid of an instrumental microscope, having a magnification of about x 50.

RESULTS AND DISCUSSION

The method of determination of the cutting force acting on the rake face of the cutting tool, P_{zo}, and R_{xyo}, by extrapolation of function $P_z(h_z)$ and $R_0(h_z)$ to a zero wear plane is shown in Figure 1. The graph also shows the total force P_z and R_{xy} acting on the cutting tool at h_z = 0.2mm with this, force acting on the wear plane is determined as the difference between the total force and the force acting on the rake face of the cutting tool:

$$P_{zh} = P_z - P_{zo} \qquad \textbf{(2)}$$

$$R_{xyh} = R_{xy} - R_{xyo} \qquad \textbf{(3)}$$

It must be mentioned here, that the experimental data collected and collated on the functions of component forces P_z, R_{xy}, and the wear plane h_z in a wide range of the cutting conditions were practically linear (see Figure 1). This helps to reduce the number of experiments to be conducted as results of two experiments will be enough to plot the linear graph. Apart from that, this method could even be used in the conditions of intensive crater formation on the rake face of the cutting tool; it is possible, for example, to measure component cutting forces using a dull cutting tool and later, regrind only the clearance face and re-measure, during usage, the component cutting forces and later compare.

CONCLUSIONS

In conclusion, it was established that the length of contact portions of the chip and the tool on the rake face, height of the contact plastic deformation zone as well as the chip shrinkage have very little influence on the value of the wear plane, h_z. in this wise, width of the wear plane, h_z, does not have any clear influence on the temperature regime existing on the rake face of the cutting tool.

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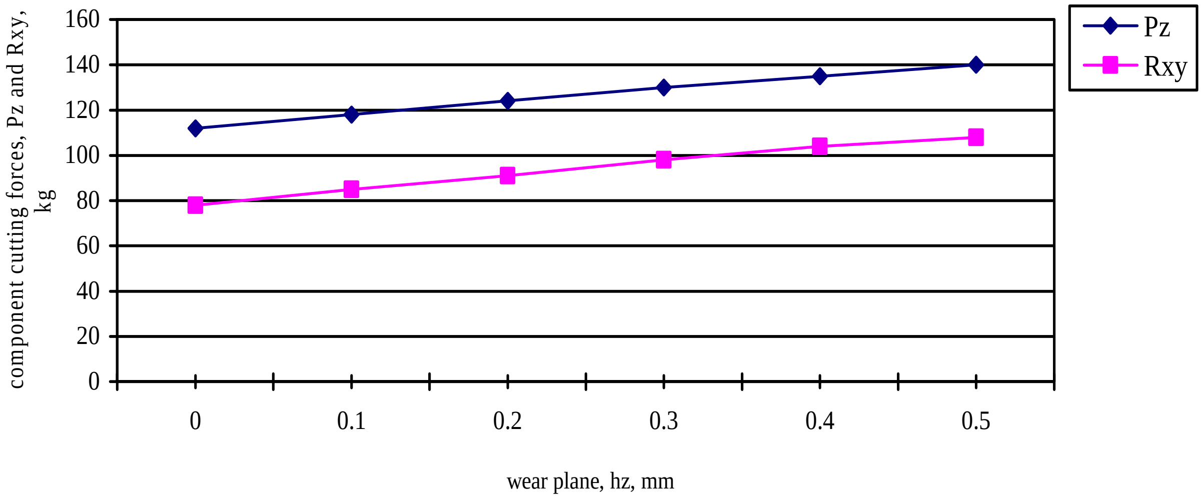

Figure 1: Determination of Cutting Force on Rake Face by Extrapolation.

APPENDIX - NOMENCLATURE

Symbols	Definitions
R	Resultant cutting force
h_z	Flank wear plane
ρ	Cutting tool nose radius
γ	Rake angle
α	Clearance angle
α_1	Auxiliary clearance angle
φ	Angle in plan
φ_1	Auxiliary angle in plan
v	Cutting speed
s	Cutting feed
t	Cutting depth
P_x	Axial component cutting force
P_y	Radial component cutting force
P_z	Tangential component cutting force
WC	Straight carbide tools
WC-TiC	Tungsten-titanium carbide tools
WC-TiC-TaC	Tungsten-titanium-tantalum carbide tools

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