5.5 TOOL WEAR AND TOOL LIFE

Introduction

The life of a cutting tool can be terminated by a number of means, although they fall broadly into two main categories:

❶ gradual wearing of certain regions of the face and flank of the cutting tool, and
❷ abrupt tool failure.

Considering the more desirable case ❶ the life of a cutting tool is therefore determined by the amount of wear that has occurred on the tool profile and which reduces the efficiency of cutting to an unacceptable level, or eventually causes tool failure (case ❷).

When the tool wear reaches an initially accepted amount, there are two options,

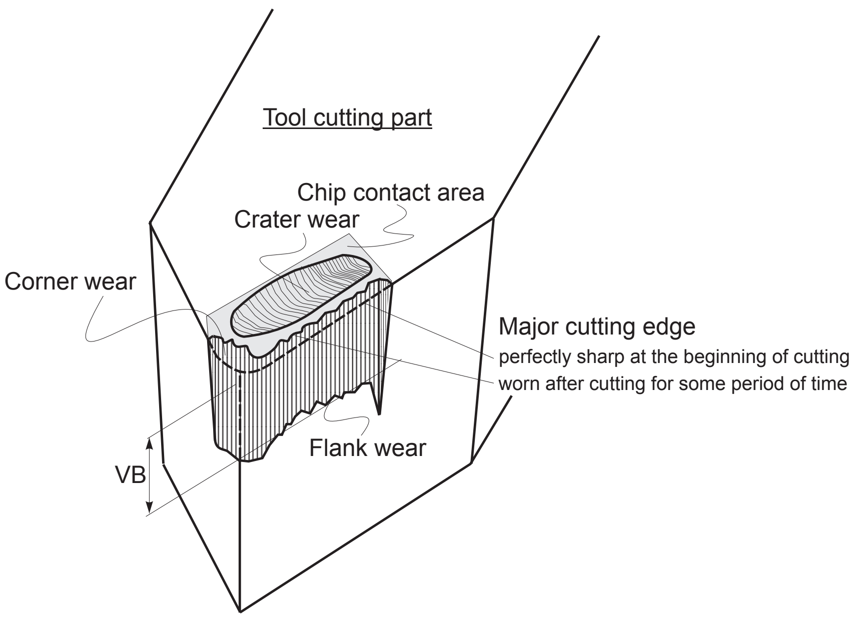
❶ to *resharpen* the tool on a tool grinder, or
❷ to *replace* the tool with a new one. This second possibility applies in two cases, (i) when the resource for tool resharpening is exhausted. or (ii) the tool does not allow for resharpening, e.g. in case of the indexable carbide inserts discussed in *Section 5.8*.

Wear zones

Gradual wear occurs at three principal location on a cutting tool. Accordingly, three main types of tool wear can be distinguished,

❶ crater wear
❷ flank wear
❸ corner wear

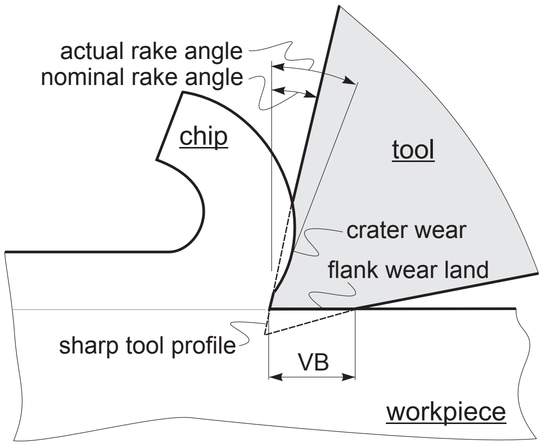
These three wear types are illustrated in the figure:



Types of wear observed in cutting tools

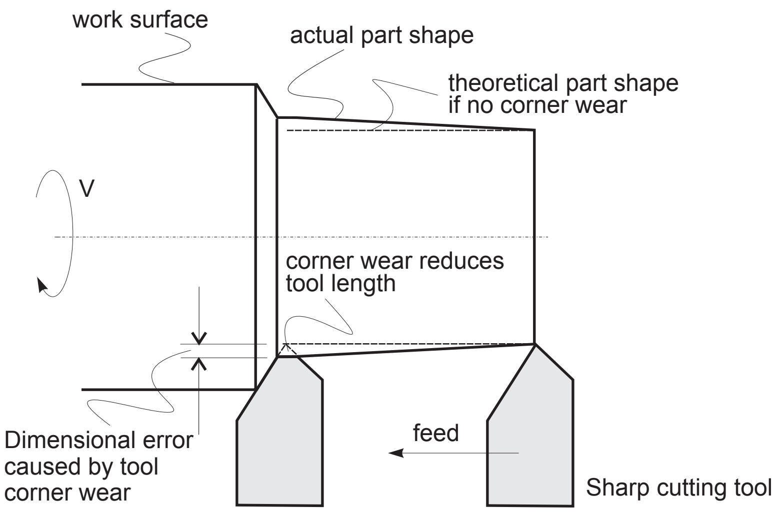
❖ *Crater wear*: consists of a concave section on the tool face formed by the action of the chip sliding on the surface. Crater wear affects the mechanics of the process increasing the actual rake angle of the cutting tool and consequently, making cutting easier. At the same time, the crater wear weakens the tool wedge and increases the possibility for tool breakage. In general, crater wear is of a relatively small concern.

❖ *Flank wear*: occurs on the tool flank as a result of friction between the machined surface of the workpiece and the tool flank. Flank wear appears in the form of so-called *wear land* and is measured by the width of this wear land, VB, Flank wear affects to the great extend the mechanics of cutting. Cutting forces increase significantly with flank wear. If the amount of flank wear exceeds some critical value (VB > 0.5~0.6 mm), the excessive cutting force may cause tool failure.



Cross-section perpendicular to the major cutting edge of a worn cutting tool showing the effect of crater wear on the tool rake angle and the flank wear land

❖ *Corner wear*: occurs on the tool corner. Can be considered as a part of the wear land and respectively flank wear since there is no distinguished boundary between the corner wear and flank wear land. We consider corner wear as a separate wear type because of its importance for the precision of machining. Corner wear actually shortens the cutting tool thus increasing gradually the dimension of machined surface and introduc ing a significant dimensional error in machining, which can reach values of about 0.03~0.05 mm.

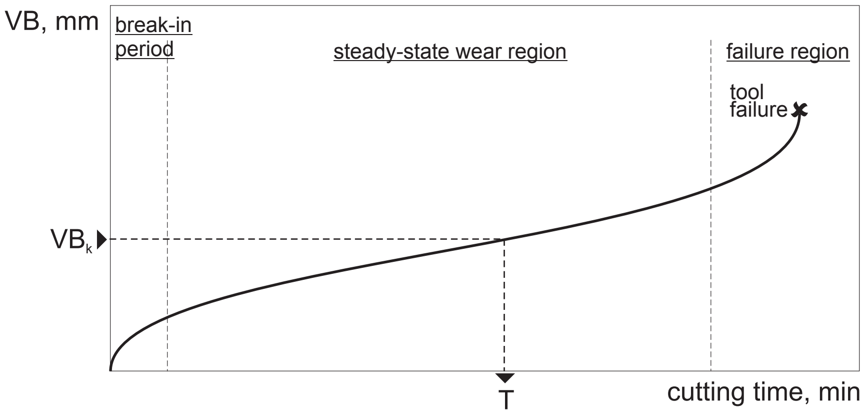


Top view showing the effect of tool corner wear on the dimensional precision in turning

Tool life

Tool wear is a time dependent process. As cutting proceeds, the amount of tool wear increases gradually. But tool wear must not be allowed to go beyond a certain limit in order to avoid tool failure. The most important wear type from the process point of view is the flank wear, therefore the parameter which has to be controlled is the width of flank wear land, VB. This parameter must not exceed an initially set safe limit, which is about 0.4 mm for carbide cutting tools. The safe limit is referred to as *allowable wear land (wear criterion)*, VB_k. The cutting time required for the cutting tool to develop a flank wear land of width VB_k is called *tool life*, T, a fundamental parameter in machining.

The general relationship of VB versus cutting time is shown in the figure (so-called *wear curve*). Although the wear curve shown is for flank wear, a similar relationship occur for other wear types. The figure shows also how to define the tool life T for a given wear criterion VB_k.



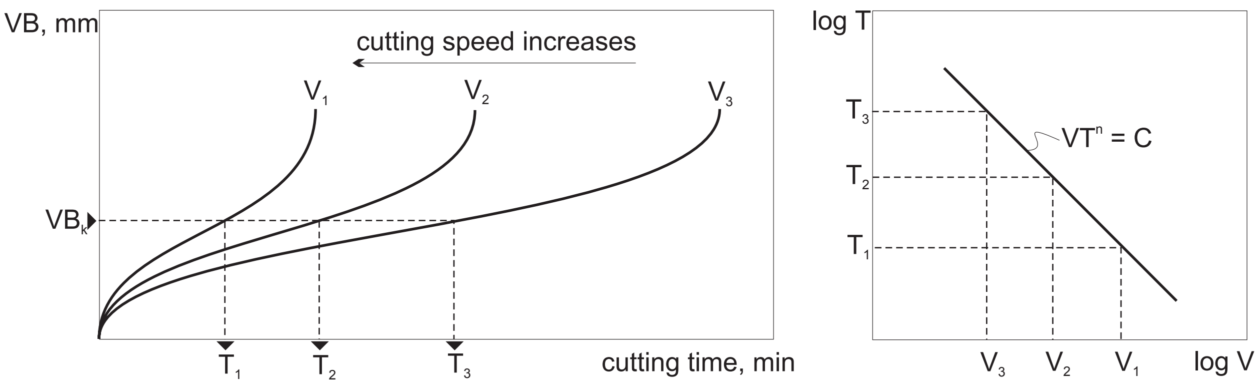
Flank wear as a function of cutting time. Tool life T is defined as the cutting time required for flank wear to reach the value of VB_k

The slope of the wear curve (that is the *intensity* of tool wear) depends on the same parameters, which affect the cutting temperature as the wear of cutting tool materials is a process extremely temperature dependent.

Parameters, which affect the rate of tool wear are

- *cutting conditions* (cutting speed V, feed f, depth of cut d)
- *cutting tool geometry* (tool orthogonal rake angle)
- *properties of work material*

From these parameters, cutting speed is the most important one. As cutting speed is increased, wear rate increases, so the same wear criterion is reached in less time, i.e., tool life decreases with cutting speed:



(*Left*) Effect of cutting speed on wear land width and tool life for three cutting speeds. (*Right*) Natural log-log plot of cutting speed versus tool life.

If the tool life values for the three wear curves are plotted on a natural log-log graph of cutting speed versus tool life as shown in the right figure, the resulting relationship is a straight line expressed in equation form called the Taylor tool life equation:

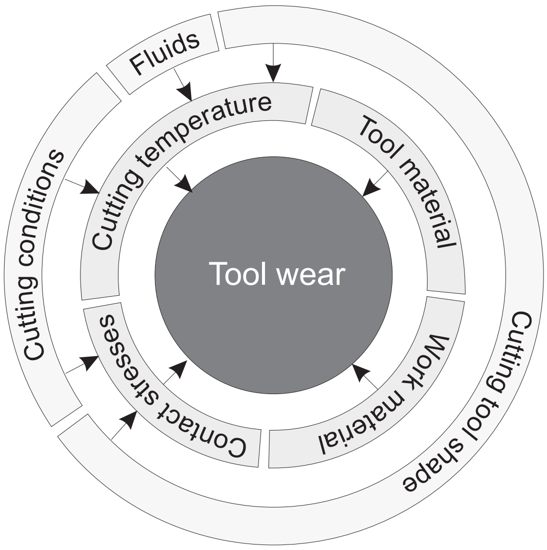
$$VT^n = C$$

where n and C are constants, whose values depend on cutting conditions, work and tool material properties, and tool geometry. These constants are well tabulated and easily available.

An expanded version of Taylor equation can be formulated to include the effect of feed, depth of cut and even work material properties.

Wear control

As it was discussed earlier, the rate of tool wear strongly depends on the cutting temperature, therefore, any measures which could be applied to reduce the cutting temperature would reduce the tool wear as well. The figure shows the process parameters that influence the rate of tool wear:



Cutting tool wear as a function of basic process parameters

Additional measures to reduce the tool wear include the application of advanced cutting tool materials, such as *coated carbides*, *ceramics*, etc., problem which is discussed in *Section 5.8*.