DEFORM™ Application #352

Tool Wear During Machining

Background:

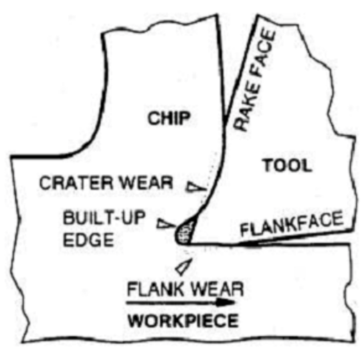
In machining processes, tool failure due to wear and breakage is often the main factor that limits the process efficiency in terms of material removal rate. In a typical machining environment, edge wear at the cutting tip often precedes tool breakage and hence dictates tool life. To design the correct range of cutting conditions for a given machining process, it is important to understand the tool wear behavior and process parameters that effect the tool wear. Tool wear tests on the shop floor are useful, but very time consuming. The simulation tools available today can give the designer the critical process information without exhaustive shop floor trials.

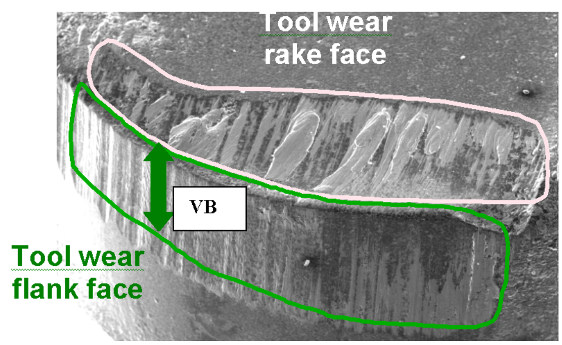
Tool Wear:

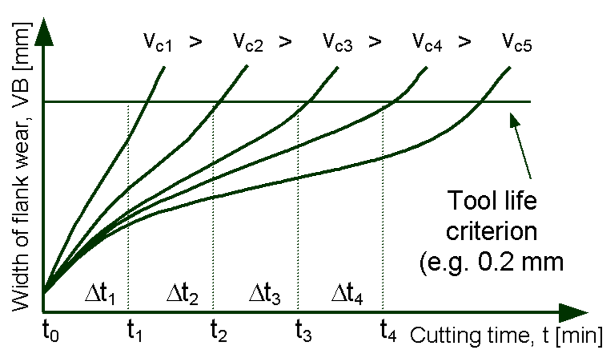
Since tool wear is an unavoidable effect of the machining process, it is usual practice to adopt a set of cutting conditions that lead to predictable wear rates and tool life. There are different types of wear mechanisms that contribute to tool failure. Of these, testing standards are available only for flank wear (ISO 3865).

From the process mechanics and experimental data, historically it has been identified that the basic variables that directly influence wear are temperature, sliding velocities and the stresses at the interface. Variations in workpiece and tool materials and geometry will influence the wear rates on both the flank and rake faces of the tool.

It has been experimentally observed that flank wear takes place in three distinct stages, i.e. initial wear, steady state wear and tertiary wear (accelerated wear). The portion of these stages in a given tool wear curve are dictated by the cutting velocity. For example, at low cutting velocity the steady state wear dominates the other two stages. While at higher cutting velocities very little distinction can be made between these stages. Therefore modeling the steady state behavior of machining process can provide critical information about tool wear.







The image on the upper-left summarizes terms used for tool wear. The upper-right is an image with actual wear labeled. The lower model demonstrates the three phases of tool wear.

DEFORM™
Design Environment for FORMing

Simulation:

DEFORM™-2D has been used by researchers to implement wear models that relate tool wear to temperature, stresses and the sliding velocities that occur at the tool/chip and tool/workpiece interfaces. Based on the experimental wear data and the prediction of process variables by DEFORM™-2D, successful prediction of tool wear and tool life has been reported from Ohio State University. In this work, a combination of measured and simulated values were used to predict the constants of a Usui's (Usui, 1978) wear equation. The wear rate equation used in this study is given as follows.

$$dW/dt = A \cdot \sigma_t V_s \exp(-B/T)$$

In the above equation, normal stress (σ_t) , relative velocity (V_S) and absolute temperature (T) on the flank sideare obtained from DEFORM™ simulations, and the constants A and B are evaluated by experimental measurements on flank wear and curve fitting techniques. After obtaining these constants, which are valid for a given range of cutting conditions and materials, the above equation was used in DEFORM™-2D to predict the flank wear. Tool wear and tool life predictions of this model were subsequently compared to those measured experiments for a different set of cutting conditions and are found to be in good agreement.

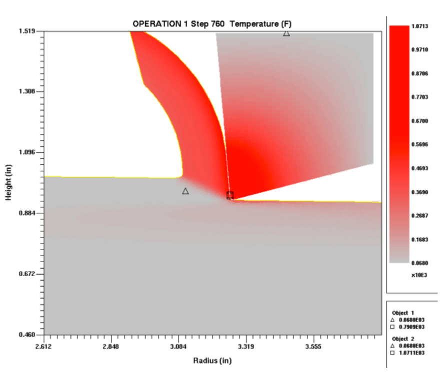
Conclusion:

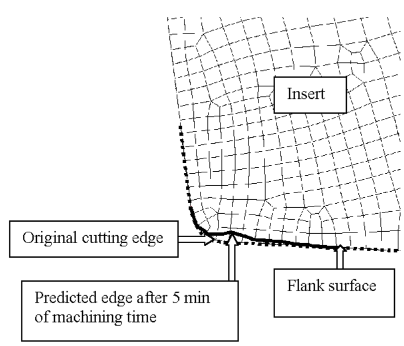
Modeling and prediction of wear behavior and tool life helps to achieve optimum machining processes. Accuracy is dependent on the ability to capture the complex process conditions involving contact, friction, thermal boundary conditions and special techniques to handle steady state conditions. DEFORM™ is a tool that can fulfill these requirements.

Recent Developments:

Some of the recent developments in DEFORM™ include the ability to model steady state processes such as machining. For example, the steady state temperature distribution in both the workpiece and the tool, steady state chip curvature and deformation can give important input to the tool wear models.

This capability allows the wear calculations to be carried out in real time scale and eventually leading to a tool wear curve, and predicting tool life. In one of the recent efforts at the Ohio State University, the worn out edge profile of the cutting edge has been successfully predicted.





The image on the left shows the temperature distribution in a 2D steady-state simulation. The image on the right summarizes the prediction of the wear model.

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