Introduction

Applying a honed radius to a cutting edge to protect it from chipping is being increasingly employed to enhance tool life. However, it is known that cutting efficiency drops significantly when the uncut chip thickness drops below about two times the edge radius. Inefficient cutting increases mechanical and thermal loads per unit material being removed. Therefore, when the uncut chip thickness is small, such as in hard machining, drilling and finish cuts, edge-chipping protection comes at the cost of increased forces and tool temperature. A better understanding these pros and cons is needed to appropriately size the edge radius to enhance the associated advantages.

For corner-radiused tools used in turning, boring and face milling, the uncut chip thickness reduces along the corner radius and ultimately approaches zero near the tip of the tool. Therefore, if an edge radius is applied to protect the cutting edge from chipping, the associated cutting inefficiency is exacerbated along the corner radius, in particular near the tool tip. An increase in corner radius further increases the region of low uncut chip thickness, making cutting near the tool tip even less efficient, presumably increasing edge temperature and tool wear. On the other hand, it is well known that tools with a near-zero corner radius (sharp-cornered tools) often exhibit an increase in wear that is concentrated near the sharp corner. Therefore, it was hypothesized that some degree of increase in corner radius could serve to spread the overall thermal load across a greater region of the cutting tooth, providing a better heat conduction path to the bulk of the tool, potentially lowering the temperature along the cutting edge and reducing wear.

Approach

Uncoated plain carbide (ISO C3) TPG 43X inserts are used to cut 1035 steel bar-stock with a hardness of 58.5 – 61.3 Rₐ. Three edge-radius levels (up-sharp (~5-10 μm), “small” (25 μm) and “large” (50 μm)) and four corner-radius levels (0.2, 0.8, 1.2 and 1.6 mm) are considered. Tests are conducted at three small feed rates (0.022, 0.037 and 0.083 mm/tooth) representative of those seen in hard machining and finish cuts. For each edge radius, each combination of feed and corner radius is replicated three times using the three edges of the same triangular insert, for a total of 36 wear tests at each edge radius. All tests are performed at 3.05 m/s, or 183 m/min, for a three-minute duration. The depth of cut is chosen to be 2.5 mm, making it at least three times the depth at which the lead edge transitions into the corner radius (per ISO standards), for all corner radii. Flank wear is measured on an optical microscope. Data are recorded as an average of three measurements at the general location on the lead edge beyond the depth of cut notch, and a single measurement at the tool tip. These are referred to as the “lead edge” and “corner-edge” measurements, respectively.

Results

The wear measurements are shown in the figure below. For the up-sharp tools, there is clearly a corner radius that minimizes flank wear. For the small-hone tools (not shown), the results are similar in terms of the trends. In terms of magnitude, wear is higher for the 25-μm edge radius. This is expected since the presence of a sizable edge radius decreases cutting efficiency, which subsequently increases overall tool temperature and wear rate. Both the up-sharp and small-hone tools exhibit slightly lower wear at the tool tip than on the lead edge. These data are consistent with the initial hypothesis that adding a corner radius will improve wear by better distributing the thermal load. The fact that wear eventually begins to increase with further increases in corner radius indicates that the chip thinning (increased thermal load) effect of increased corner radius eventually dominates its beneficial thermal-load distribution effect.

Based on the above, and intuition, one would expect any increase in edge radius to yield a reduced cutting efficiency and subsequent increases in temperature and wear rate. Given that expectation, the large-hone data initially appear inconsistent with wear levels being higher at some corner radii and lower at others. Apparently it is not that simple. Adding trend curves for the large-hone tools, as shown in the figure, highlights a similar trend of decreasing flank wear with an increase in corner radius, most dramatically and quickly for the lowest feed. From this perspective, since the wear cannot continually decrease, it either asymptotically reaches some level as corner radius continues to increase, or there must be a corner radius beyond the range studied that will minimize wear. In either case, these data motivate one to accompany a larger edge radius with a larger corner radius in order to decrease wear. From a physical view, the data demonstrate that the higher thermal loads that come from reduced cutting efficiency at a higher edge radius require a larger corner radius to effectively provide the thermal-load distribution effect seen for the sharper tools.

Benefits

- Flank wear can be minimized by simultaneously and properly selecting corner radius.
- Adding a corner radius to tools that traditionally have a sharp corner, such as end mills and drills, may reduce flank wear.
- When an edge radius is present, the wear-minimizing corner radius is larger, resulting in improved feed-groove finish.