

The Design of Plastic Cutting Tools

Routing and trimming has become one of the most common operations performed during the manufacture of plastic components and finished goods during the last ten years. CNC routing has taken those operations to the next level and allowed plastic fabricators to put a finished edge on products that previously may have needed further finishing operations. Interestingly, this ability was not an original intent of the routing industry; conversely routing was historically a means of quickly shaping and cutting wood and aluminum with occasional forays into the plastic and plastic composites market. With the explosive growth of market demand for thermoformed plastic components, POP displays, and thermoset plastic goods, one router tooling manufacturer began to develop tooling that was dedicated solely to the machining of plastics.

As stated before, router tooling was originally segmented into two market areas - wood and aluminum. Wood tooling is generally a carbide tipped or solid carbide tool with cutting geometry that allows the fibrous material being cut to be sheared off cleanly, leaving no chips or grain fuzzing. The designs were further refined as applications began calling for faster material removal rates, better finishes, or as new wood composites began to enter the market place. Even with the dozens of specialized tooling lines that service the wood industry and the hundreds of refinements in cutter body material and shape, the basic underlying cutting geometry remained the same. A few specific combinations of rake angle and clearance angle (**see Fig. 1 for definitions**) in conjunction with the helix angle of the cutter (0° for straight tooling and up to 35° for spirals), combine to yield the results that the wood fabrication industry desires.

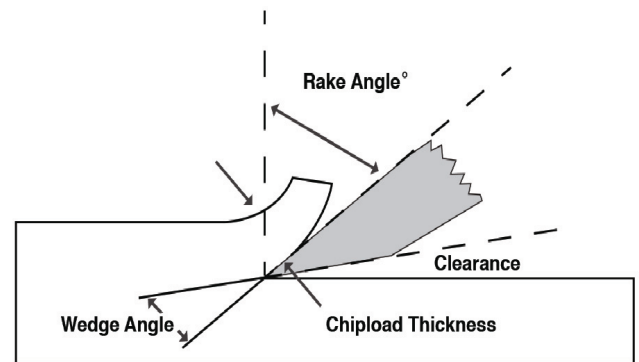


Figure 1

Similar results are true for the machining of aluminum. Whereas the wood industry sees only material variations such as density and moisture content, aluminum machinists typically need only to worry about the hardness and temper of the part being cut. Using high speed steel or solid carbide spirals, a few specific cutter geometries machined almost all of the product being produced.

Plastics machining, on the other hand, has completely changed the router industry outlook on cutter design. Each plastic manufactured can exhibit different cutting characteristics and may respond differently to different cutting geometries. This has led to an explosion in the number of cutter styles offered to cut plastics as well as the development of new technologies used in the manufacture and development of the router bits. Because of the immense number of variables associated with routing plastic (composition, thickness, temperature) and the continuing importance placed on the ability to produce a finished edge without secondary operations, it has become necessary to design tools that are extremely specific in their application.

A general discussion on plastic cutting tool geometry can be started by dividing plastic into three general categories: hard, soft, and reinforced. The cutters geometries designed for plastic vary widely, much more so than their counterparts in wood and aluminum. For this reason, it is much easier for the sake of discussion to break the plastics up into categories that reflect how they actually respond to machining.

Soft Plastic

Soft plastics are routed by removing long, curly chips from the face of the material being machined. (See Fig. 2) Normally the release of these chips is quite easy and there is little or no instance of burring or fuzzing at the edge as seen in the comparable release of similar chips from wood or aluminum. The nature of wood and aluminum necessitates that the wedge angle (see Fig. 1) of the router bit cutting edge be large. This translates to a lower rake angle and a lower clearance angle. If the wedge angle is reduced, premature wear of the cutting edge occurs due to the abrasiveness and/or hardness of the material being cut. With soft plastics, however, the abrasive and impact wear is greatly reduced and the rake angle can be increased significantly, resulting in a much easier release of the chip from the material. This allows faster feed rates and less movement of the part due to cutting pressure.



Figure 2

The tradeoff of high rake angle in a cutting tool is that it becomes very aggressive. If anyone has ever used dedicated CNC plastic tooling in hand routers, they can attest to the fact that it wants to "run" and can sometimes rip the router from your grasp. The solution for this aggressiveness has been to change both the angle and type of clearance put on soft plastic tooling. By using a low angle radial (or eccentric)

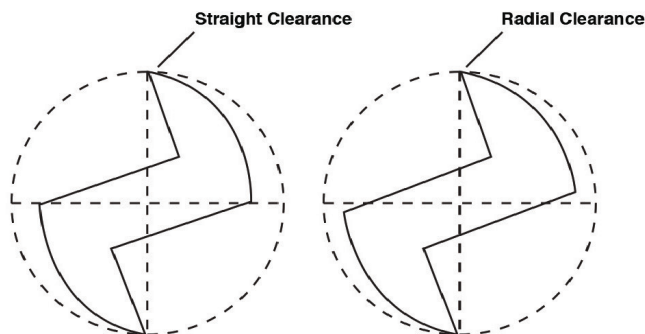


Figure 3

relief grind on the clearance angle (see Fig. 3), it is possible to "calm" the tool down and allow the high rake angle to cut freely while still maintaining control of the cutting tool. This radial clearance is designed to rub ever so slightly along the cut surface and provide some stability to the cutting tool. One or two degrees of too much relief, and the cutting tool will begin to chatter. The resultant knife marks along the cutting edge produce a subsequent poor finish. One or two degrees of too little relief and the router bit will rub too much, producing heat and melting the material.

Hard Plastic

Hard plastics machine much differently from their soft plastic counterparts. The largest difference is in their production of chips. Those machining wood, aluminum, or soft plastic are used to the sight of large chips ejecting from the router bit path and having enough weight to actually carry for some distance before landing on the router table. Hard plastic chips appear very different and are normally very small shards that resemble crystalline fragments or dust. Unlike soft plastic chips, hard plastic waste is

formed by frequently breaking small, individual chunks of material from the base material. (See **Fig. 4**) This necessitates different cutter geometries from that seen in any other application.



Figure 4

Like soft plastics, hard plastic tooling benefits from an increased rake angle that allows the material to be broken away much easier than if you were using a lower rake wood or aluminum tool. Unlike soft plastic tooling, however, the need for a dramatically increased rake angle is not present. Because of the willingness of most hard plastics to release their bonds in response

to a sharp cutting edge, a moderate increase in rake angle will usually produce the best results. Commensurately, the clearance angle does not need to be lowered as much to control the tool and frequently a straight relief angle is all that is required to control the tool and prevent chatter.

Hard plastic suffers from the same chatter and melt problems as soft plastic and it must be controlled through the same tight tolerances for rake and clearance angles held by soft plastic cutting tools. Hard plastics also exhibit a cutting effect that is rarely seen in softer materials which is "cratering". Because of the manner in which hard plastic is machined, if the rake angle becomes too high, the tendency for the material to break and release its bonds is greatly exaggerated and the chips will actually pull additional material from within the cut edge leaving a "cratered" or dimpled surface along the finished edge. By tightly controlling the designed wedge angle of the cutting tool, this can normally be prevented for a reasonable range of cutting speeds.

Whereas soft plastics respond best to "O" flutes, hard plastics generally rout best with modified "O" flute or straight rake face geometry. This combined with the smaller chips produced, allow multi-fluted spirals to effectively cut the material with a superior finish and good chip extraction.

Reinforced Plastic

Reinforced plastics are frequently a polyester, epoxy, or phenolic base with either a fibrous or glass material woven or otherwise embedded to add rigidity to the composite. While this can add significant strength to the material itself, it causes it to be extremely difficult to machine.

There are two different methods for attacking the tooling design problem associated with machining abrasive plastics. The first involves using a high rake angle and high clearance angle to allow the bit to cut freely and aggressively and reduce the amount of heat built up during the cutting operation (this heat is a major factor of accelerated tool wear in these operations). The adverse side to this is that the resultant wedge angle is very small and a weak cutting edge is continually presented to the reinforced plastic which can lead to chipping of the tool and a general break-down of the cutting edge.

The other method employed in the design of these special cutting tools is to present a very strong cutting edge to the material by greatly lowering the rake angle and slightly decreasing the clearance angle. This method reduces the chipping of the cutting edge but can lead to tremendous heat buildup. The best application of these tools requires decreased spindle speeds to reduce the material heating but this can lead to increased cutting forces and cause part movement.

Machining of reinforced plastics requires that great care be made when choosing one of these two tool-

ing types and that the spindle RPMs and feed rates are matched to the cutting tool selected, as each requires different cutting properties and heat characteristics to function best. Cutting tools typically consist of spirals and straight rake face tools with either radial clearance (for low RPMs, strong cutting edges) and straight clearance (for high RPMs, free cutting action).

Tool Selection

The general groups listed before are just the beginning of the categories that plastic cutting tools are designed for. There are many sub-groups that require modification of the basic cutting geometry formula to take into account thickness, temperature, fixturing concerns, as well as the combination of multiple materials such as acrylic/ABS (a hard plastic and a soft plastic used in the many bathtubs and liners), laminated phenolics (desktops and lab table tops), and co-extruded PVC/ABS (fence posts).

CNC and non-CNC router tooling for plastics has increased in both breadth and depth in the market place. Router bit manufacturers must attempt to stay ahead of both the burgeoning plastic development industry and the focused attention that CNC router manufacturers have given the plastic fabricators. This trend will continue and the number of application specific tooling will increase correspondingly along with the growth of the demanding market. Continue to look for new innovations from the leader in the router tooling market as both the quality and the speed of the cut is increased in the next few years.

Van Niser

For more information
about the company's
cutting tools,
call (800) 234-1560 or
visit www.onsrud.com