Technical Datasheet #0051

Extrusion cutter blade design

Eight pointers to a better cut finish

Blade shape & position, thickness, width, length, and bevelling & sharpening - here's a look at the critical aspects of an area too often overlooked or else taken for granted.

Because this area is still more of an art than engineering science & because the wide range of extrusions that our Servo-Torq® rotary cutter can cut, we've put together the following general suggestions.

1. Blade shape & position: The angle of attack:

The angle of attack (see Fig 1) in a rotary cutter is that angle formed between the cutting edge of the blade at the moment of impact & a line that runs between centres of the extrusion to be cut and the blade support.

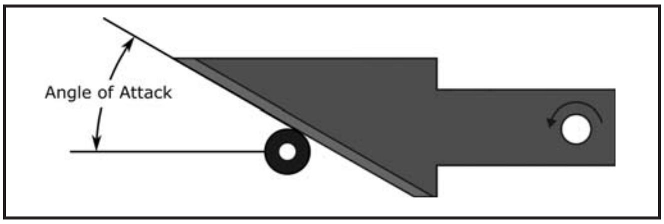

Fig. 1 - The angle of attack.

Ideally, the size of the angle of attack is related to, and limited by, the amount of "slice" required to produce a clean cut, and the amount of force needed to cut through the material.

"Slice" is a component of motion along the edge of a blade. It is the lateral motion imparted to a blade in its cutting stroke; a slicing motion. The angle of attack of the cutter blade can relate a sliding motion between the knife & the extrusion. This relative motion of blade against material is shown in Fig 2 below.

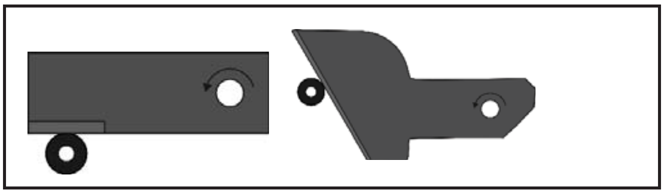

Fig. 2 - A rotating knife with no angle of attack (left) and high angle of attack (right).

The length over which a knife's edge traverses – relative to the material being cut – will not change if the angle of attack is zero (see Fig 2). But as the angle of attack increases, so does the sliding length.

It is also important to understand the principles of curved blades. With curved edges, the angle of attack continuously varies (see Fig 3).

The value of the curved blade is that: 1) it facilitates a pronounced slice to produce clean cuts, and; 2) it permits a varying force to be applied to the material.

The curve can be directed hyperbolically (inwardly) or parabolically (outwardly). Some compound blades have several curves in them.

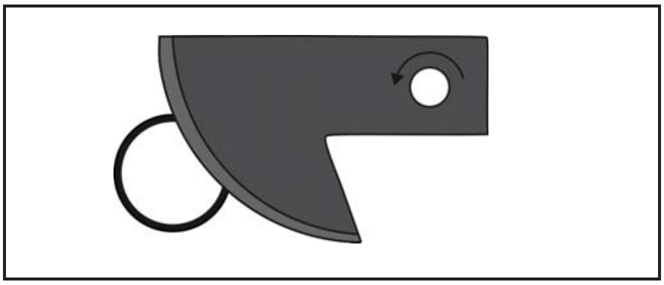

Fig. 3 - Here's an example of a knife of varying radius to cut thin-walled tubing.

Slicing gives a smooth, clean finish to a cut.

This quality results from redirecting part of the cutting force to the lateral motion which relieves compression of material ahead of the blade. Without this relief, ragged or wavy cuts result.

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1. Blade shape & position: The angle of attack (continued):

Compression causes random deflection of the material during cutting. This compression results from a low-stress condition, which causes the material to move along ahead of the cutting edge instead of being cut.

To increase the stress at the point of cut, a slicing motion is introduced. Often, a simple straight-edged blade with a high angle of attack is sufficient to impart this slicing motion.

On the other hand, there are materials that require compound blades which have several different angles, each of which increases the stress at specific points. In determining the use of simple vs. compound shapes, it is best to begin with the simple and work up toward the more complex.

For example, a flexible thin-walled piece of plastic tubing of large diameter would require a blade that has a very high angle of attack at the time of impact & penetration in order to prevent collapse. In transit, a low angle of attack would be needed to allow for faster cutting in order to prevent buckling. A blade of varying ratios (see Fig 3 above) could be used.

Curved blades also are used to cut very thin material and profiles that have a tendency to continue moving in a forward direction while being cut.

If the angle of attack is too high so that the blade speed is not fast enough, or in-transit time is too great, the cut edge of the material will be angled upstream.

The angle of attack also affects the cutting force necessary to cut through a particular material.

Essentially, the higher the angle, the less the force required. As the angle of attack decreases (low angle), more and more of the cutting force is redirected back into the blade support. This is not critical in the design of a knife for a cutter with sufficient power to drive the blade through large diameter product.

Large diameter tube or pipe will limit the height of the angle of attack and therefore require more force for cutting.

2. Cutting & impact forces determine blade thickness:

Two factors are important in determining blade thickness; cutting force and impact force.

The forces directed back to the blade are directly related to the density and hardness of the material to be cut. Blade shape, angle of attack and knife support must also be given consideration, but the general criterion is to keep the blade as thin as possible – without breakage.

The principles of inclined planes (i.e. wedges) also applies to the "wedging" effect of a blade. In general, the greater the blade thickness, the greater the force required (see Fig 4 below).

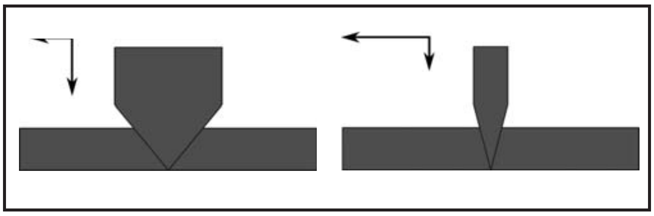

Fig. 4 - These illustrations show the wedging action of thick and thin blades.

Cutting and impact forces are also both related to another force: the cutting torque.

Since thin blades represent smaller wedges than thick blades, they require less power to penetrate and cut. Thus, there is an optimum area within which the knife is thick enough to withstand the force of cutting and thin enough not to generate additional load.

There are other important limitations to thinness resulting from the dynamics of cutting. Among these are blade flex, fatigue and vibration.

With a given metal, the thinner it becomes, the less it can withstand the cutting load; at some point it will break. Even if the blade can withstand the load, it may be thin enough to flex with a resultant wavy or un-square cut.

Unfortunately, blade flex cannot be predicted, but is detected by looking for wavy or non-square cuts during trial & error tests.

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2. Cutting and impact forces determine blade thickness: (continued):

Blade flexing occurs most often on rigid materials. Low compressibility of the rigid plastics results in the build-up of high lateral forces while the knife is in transit.

These forces can cause the knife to deflect from its path with a resultant un-square cut; eventually this leads to metal fatigue and breakage.

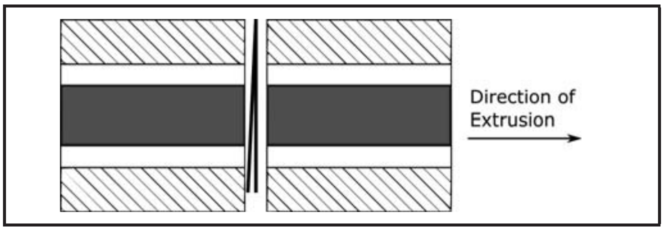

Fig. 5 - Lateral stress leading to knife flex.

Vibration can lead to premature failure by fatigue, or by being directed away from the cutting path. Vibration occurs when thin blades are out of alignment and are driven at high rotational speeds.

The slightest misalignment will cause rotating knives to oscillate – the thinner the blade, the greater the change of oscillation. If the amplitude of the oscillations becomes great enough, the blade will hit one of the cutter bushes.

This danger can sometimes be overcome in thin blades by thinning only that portion of the blade that passes between the bushes, leaving the remainder of the blade thick.

3. The extrusion size sets the blade length:

Knife length is much more simply determined than either blade thickness or the angle of attack.

The most important determinant is the dimensions of the extrusion to be cut. The length of the blade should extend slightly beyond the cross-sectional area of the material to be cut for guiding purposes.

While the cross-sectional dimensions of the material to be cut are of prime importance, other factors – such as blade thickness, cutting torque, and hold-up time – must also be considered.

3. The extrusion size sets the blade length: (continued):

As the distance from the centre of rotation to the tip of the blade increases, blade speed also increases. Therefore, the in-transit factor is reduced continually along the length of the blade – from its point of attachment to its tip.

Unfortunately, at the same time, the blade's load-bearing capacity is also reduced along the axis of its length.

The reduction of load capacity along the length of a blade can result in excessive flexing and breakage. Also, the load reflected back into the cutting machinery increases with length.

The extremely high impact loads that can be generated are reflected back into the cutter drive train, causing stress and wear that can shorten a machine's life.

4. Blade width: keep it small, but have a knife with 'substance':

Blade width is the dimension from the cutting edge to the trailing edge of the knife.

The key guideline on knife blade is to have it as small as possible to minimize the in-transit period, but there still must be enough substance in the blade to maintain its rigidity so that it does not break during cutting.

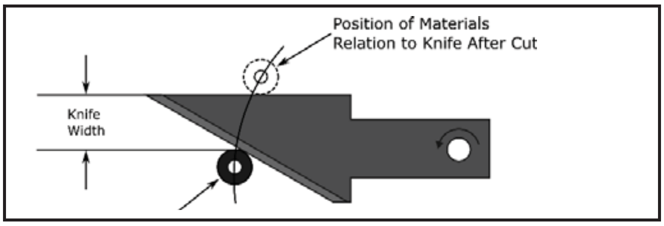

Fig. 6 - Knife width.

The width, therefore, is dictated by other design factors and the characteristics of the blade's metal.

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5. Blade material: hard & flexible; not brittle:

A wide selection of cutting metals are available on the market – from spring steel to tool steel. Each has a unique set of quantities in hardness, brittleness, tensile strength etc.

Generally speaking, a blade material should be selected that allows the width of the knife to be small enough to meet cutting design requirements without a loss of rigidity.

For the vast majority of applications we recommend spring steel (either stainless or standard), razor blade stainless steel or high-speed tool steel.

Very hard grades of steel, as well as ceramics, should be avoided, as they tend to crack or shatter on impact.

6. Bevelling: some pointers:

The bevel along the cutting edge of a blade is dictated by its intended use.

The optimum angle is a compromise between a high angle for easier penetration and cutting & a low angle that deters dulling & deformation caused by the impact force.

Generally, the harder the material to be cut, the lower the optimum angle.

No list of optimum angles has been compiled, nor are there ideal cutting angles.

For this reason,experience & empirical experimentation are the only guidelines available to find the optimum compromise that leads to long blade life and clean cuts.

7. Sharpening: some tips:

There are two sharpening tips that are both time-saving and helpful in producing cleaner cuts:

- **Streamlining:** This technique helps prevent the occurrence of dust and slivers; in other words, it helps provide a cleaner cut.

  Streamlining over the point where bevels meet the sides of the blade is a small, sometimes tedious job, but it does pay off.

- **Changing the bevel:** Another worthwhile practice is to change the bevel along the blade's edge through changes in the angle of attack.

  Where there is a high angle of attack for slow penetration, the blade can be bevelled at a sharp angle.

  As the angle of attack decreases, the bevel angle can be made broader to withstand the high cutting force.

Re-sharpening the blade is a simple and straight-forward operation:

The following is one method. Special tools or fixtures are not necessary.

1. Scribe a line at a fixed dimension back from the cutting edge that follows the shape of the blade edge.
2. Using a belt sander or file, form a new bevel on each side of the blade using the scribe line as a guide. Carefully maintain symmetry and the desired bevel angle.
3. Hone on a coarse stone, but make sure you maintain the proper bevel angle (or angles), and follow with finer stones until the desired sharpness is reached.
4. To prevent the blade's edge from buckling under initial impact, dull the knife slightly by lightly running a fine stone along its cutting edge.

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8. Material collapse: how to overcome it:

A commonly occurring problem in extrusion cutting is the problem of material "collapse". It is most common with large-diameter, thin-walled plastic tubing and very flexible rubbers.

Collapse occurs when the material cannot support itself against the motion of the oncoming blade. The impact force is distributed over a line of conduct. There is no penetration; the material is pushed ahead of the blade.

Eventually the collapse reaches appoint at which the material can support itself against the blade: penetration and cutting then occur. However, compressive forces have already distorted the material so that the cut has a ragged or wavy edge.

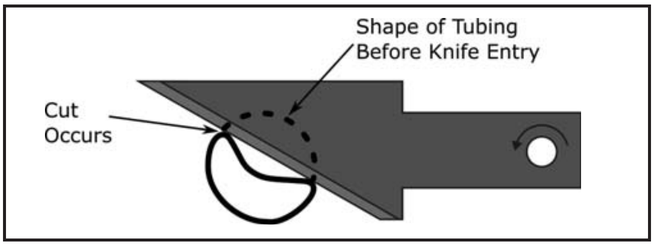

Fig. 7 - Collapse occurs when material can't support itself against the motion of the oncoming knife. This shows sequence of collapse of thin-walled tubing to the point of penetration.

One method of solving this problem utilizes a blade with an initial high degree of slice to transfer most of the cutting load to a small point on the circumference – which eases penetration.

Once penetration is effected, the angle of attack is suddenly decreased to reduce in-transit time. Since a high hold-up time are inherent in this technique, a high blade speed is recommended.

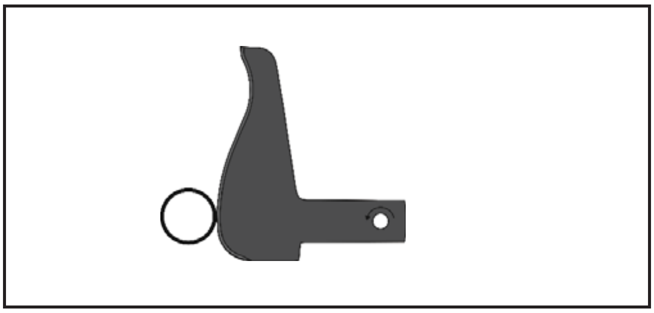

Fig. 8- High-low angle of attack to penetrate and cut thin-walled tubing.

Employment of the thinnest blade possible – and a good blade support – is also recommended.

Of equal importance is to fit the inner diameter of the cutter bush very closely to the outer diameter of the extrusion.

A close fit of these dimensions will reduce the tendency to collapse by helping to maintain the tube's round configuration.

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