Urethane forming

The use of urethane tooling at the press brake is relatively new. It is a technology that many press brake operators and companies do not understand or perhaps even know about.

These pads are often used for Profound Radius Bending applications or in cases where die marking and smoothness of outside surface of the bend are important factors. Urethane tooling can offer some advantages under the appropriate conditions and can outperform standard tooling in some cases.

Urethane can also be found as a variation of traditional press brake steel dies, exactly the same except these dies are made of a urethane elastomer, figure 1. An elastomer can be described as a material with high elasticity, the ability to stretch to a great extent under load and then recover when the load is released. A quick point of note, Urethane and Polyurethane are interchangeable terms.

One of the first aspects of using urethane we will look at is the hardness of the urethane, its Durometer.

Durometer

Urethanes are rated over four different scales: Shore 00, Shore A, Shore D and the Rockwell-R scale. Urethane Press Brake tooling is normally in the Shore-A and Shore-D ranges, beginning with 20A, which soft is as chewing gum, up to 75D which is as hard as a bowling ball.

Urethane tooling can be divided into two sub-groups: deflecting and non-deflecting. All urethanes will have varying amounts of deflection depending on the durometer.

- (0) – soft, 35% deflection, 80A durometer.
- (1) – medium, 25% deflection, 90A durometer.
- (2) – hard, 15% deflection, 95A durometer.
- (3) – very hard, 5% deflection, 75D durometer.

In figure 2, you see the comparisons between Urethanes, Rubbers, Teflons and Plastics along with the various scales they are rated by.

Functionally, urethane or polyurethane is often referred to as a “solid hydraulic”. When pressure is applied to urethane, that pressure is dissipated uniformly in all directions, without any change in the volume in the urethane. Higher durometer urethanes allow for forming too, within two to three material thicknesses of the part edge.

Each grade of urethane is color coded for quick and easy identification. However, there is no industry standard for this coding. So one manufacture’s Black is another’s Lime Green; refer to the documentation that comes with the pad or tool for the details.
Hysteresis

The most common reason for the failure of a urethane pad is hysteresis, the build-up of internal heat within the pad. This in part is why the correct selection of pad size, grade and deflection characteristics is necessary for the life of the pad and the quality of the product.

When stress is applied to a urethane there is a small, but positive time lag before it takes up the corresponding strain.

This results in the stress / strain curve not following the same path as when the stress was applied and released. That causes a loss of energy called “hysteresis” which is the conversion of energy into heat. This loss of energy can then be measured in terms of resilience and its ability to return to its original shape.

It is possible to destroy urethane by having a pad size that is too small for the application which causes hysteresis or trying to bend a flange that is too short.

A short flange in a low durometer pad will dig into the pad rather than bend. All of these will manifest as the pad disintegrating into small pieces.

Pad Size

At a minimum, the urethane pad thickness must be three times the penetrating volume of the punch and material combined, figure 3; and the pad volume must be at least ten times the volume of the penetrating punch and material.

\[
\text{Pad width (Pw)} = \text{Punch penetration (Pp)} \times 2
\]

\[
\text{Pad thickness (Pt)} = \text{Punch penetration (Pp)} \times 3
\]

\[
\text{Pad volume (Vp)} = \text{length} \times \text{width} \times \text{height}
\]
Punch volume (Pv) = p * (Mt + Rp) \(^2\) * length

Working pad volume (Wv) = \(Pv \times 10\)

Next is tonnage. As compared to a standard steel tool die set (air forming) the urethane tonnage starts at three to five times that of the tonnage for air forming. This tonnage will increase in direct proportion to an increase in the punch radius, material volume and the durometer of the urethane.

To decrease the required tonnages, specialized pad shapes were developed for some specific styles of bend. Look at how a "U" bend was formed using a custom shaped pad with relief hole through the center, figure 4.

Because of the many variables, a true predictable tonnage is difficult. To get close to the required tonnage the following formula will work if a multiplier is used.

\[
\text{Tonnage per-inch} = \frac{(575 \times \text{Mt}^2)}{\text{die width}} / 12
\]

True, this is the same formula as the standard V-die. The width would be selected as the “optimum die width” for the radius and material described.

Urethane tonnage per inch = multiply by 3 to 5 times for a mid-range durometer. That would be a high-Shore A to Low-Shore D)

Working tonnage = Urethane tonnage * the workpiece length.

Retainer Box

To control the great pressures that develop inside the pad and retainer box, an air channel is provided below the pad.

The air channel allows the pad to “flow” into the channel. It also allows greater penetration of the punch and material into the pad, minimizing the compressive strain while lowering the required tonnage.

There may also be an air channel(s) through the center of the pad for the same reasons.

This channel is sometimes created with machined deflection bars. Many smaller retainer boxes may not have a machined air channel. If this is the case, one should be created if possible by the placement of round-stock deflection bars adjacent to the long sides of the retainer box.

The diameter of these bars may be varied as necessary to achieve the desired results, including using multiple bars in decreasing diameters. The bars can be graduated in size to control the deflection characteristics of the urethane pad.

There is another form of deflection compensation: rods or tubes can be placed in the through holes of the pad to vary forming pressures as needed, a concept that is shown in the following video, courtesy of Polyurethane Products Corp.

smartpad

Urethane Press Brake Dies
Courtesy of Polyurethane Products Corp.
V-pads

Urethane also comes in pre-formed “V” shapes, designed to be placed into a standard V-die, allowing the V to become the retainer box, figure 6.

Die opening is based on the necessity of pad volume. The pad must be at least ten times the volume of the penetrating punch and die. Pads larger than ten times are fine. Review the three photographs, figures 7, 8 and 9; this is a piece of 16ga mild cold rolled steel being formed.

Notice the lack of die marks on the finished piece.

Die protection

Another style of urethane is sheet urethane, sometimes referred to as “die protect”. The sheets average .030-inch to .060-inches in thickness and come in a variety of widths to accommodate every die opening.

Placed over a steel die, the sheet places a protective layer between the workpiece and the die radii, figure 10.

Hard Urethane Dies

Most standard “off the shelf” press brake die shapes and sizes are available in high durometer urethane Shore 75DD, including American planed or European precision ground styles.

These, too are for mar-free forming, but will not be able to withstand the same tonnages as steel dies. These die are relatively inexpensive, and if used continuously, will wear or become impregnated with any residue from the material being formed.

Once impregnated with residue, the dies will begin to scratch the workpiece, indicating the need to replace the die with a new piece, figure 11.

Punches are also available for large radius forming.

The tool shown there is made up from a series of concentric rings (tubes) that build the radius .06-inches at a time. It is made from Shore 75D Urethane with little or no deflection, figure 12. Figure 13 is the color-to-diameter chart from the face of the tool.

Urethane Forming and Profound Radius Bending

Urethane dies offer some definite advantages over the standard steel V-die in forming profound radius bends.

The biggest advantage is the entire elimination of the multi-breakage phenomenon, leaving an almost perfect bend radius every time. The difference between the finished workpiece radius and the measured punch radius in rarely more than 1% of the punch radius, figure 14.