DESIGNING MOLDS AND FIXTURES
for
Reusable Vacuum Bagging Systems
DESIGNING MOLDS AND FIXTURES FOR REUSABLE VACUUM BAGGING SYSTEMS
or EVTs (ELASTOMERIC VACUUM TOOLS)

Torr Technologies manufactures elastomeric vacuum bagging and pressure tools. One of our core products is custom-made reusable vacuum bagging tools made to fit new and existing molds and fixtures. We’ve discovered that vacuum bagging is frequently overlooked in the design phase of a tool, thus making implementation of a vacuum bagging system more difficult and expensive than it otherwise would have been had certain guidelines been followed. This document provides a background on how vacuum bagging systems are made and what should be considered before mold or fixture construction begins. Of course, we realize these are guidelines and they can’t all be followed all of the time. Our intention is to familiarize tool designers and builders with construction practices that result in efficient integration of elastomeric vacuum tools (EVTs).

THE BASICS

1. Provide at least 5” of additional mold width beyond excess layup (not net trim) for vacuum bagging.
2. If the EVT is going to be hinged to the mold, provide an additional 2” along that edge.
3. If gas-springs or other types of mechanisms are used to assist in opening and closing the EVT, provide additional width to accommodate them.
4. Do not extend sharp, defined part contours out into the sealing area of the mold.
5. Transition conic or twisted surfaces into simple, 2D curves in the sealing area.
6. Imagine having to cut, bend, and weld a frame using square tube to fit the tool you’re designing. You’ll find that eliminating twists, spirals, and not changing more than one angle at a time at intersections reduces frame complexity, seal complexity, and cost of construction.

If the mold or fixtures do not meet these requirements, it doesn’t mean it wouldn’t be a candidate for an EVT, though it may end up costing more to construct one. If you can’t provide an additional 5” along an edge for a vacuum bagging system, make sure there is room elsewhere on the mold for vacuum ports and thermocouple ports. The frame and seal occupy anywhere between 1” and 2” of actual mold width, but you also need to consider breather and resin bleed. You don’t want the seal so close to the edge of the layup that it gets contaminated with excess resin, or that the integrity of the seal is compromised by breather getting in the way.

How a mold or fixture has been designed and constructed significantly impacts the cost of an EVT. Molds for parts with simple geometry can have perimeters with complex geometry and very little width. This can compromise what would otherwise be a perfect application for an EVT. An EVT for parts with compound curvatures and complex geometry can be very cost effective when certain design criteria are followed.

The mold on the left, although a relatively easy shape for an EVT, could have been made easier by providing more room on each end for sealing. An extra 2” would also have allowed the use of an unseamed diaphragm, as shown in the mold on the right. The parts being made on these molds only extend ~2” down from the apex. The mold on the left has unnecessary height, adding cost to the mold materials and creating additional stress on the silicone rubber diaphragm. The tapered ends and sides are great, as is the area provided for hinges, vacuum ports, and thermocouple connections. These particular tools were initially designed for a reusable compacting system so it was fairly easy to adapt EVTs for compaction and autoclave curing.
WHY USE A FRAME?

As you read through this document, you'll note that we continually refer to the “frame” of the EVT. Over the many years of manufacturing vacuum bagging systems for existing molds and fixtures, the only ones that survive typical shop use have frames for supporting the diaphragm and seal. What follows is an excerpt from a document provided to our sales representatives on the subject:

“FRAMELESS BAGS: You may be asked about making reusable systems without frames. Torr has made various configurations of frameless bags and other companies continue to sell them, but if you look into their success rate, it’s pretty dismal.

1. Typically, the frameless bag is attached to the mold using conventional tool sealant. It leaves residue on the mold, is laborious to apply and remove, it reacts with the silicone over time and degrades it, and you’re now relying more on the skill of the operator to affect a good seal. For diaphragms attached with an insert, a receiving extrusion needs to be bonded to the mold surface. This extrusion is vulnerable to knives and sharp part edges and will be the major source of leakage on such a tool.

2. The rubber diaphragm usually has integral fittings installed. These can quickly damage the diaphragm when rolled up with the diaphragm, especially when the roll is tossed onto a shelf. If the fittings are removed all the time, you’re adding labor and more chances for leaks to develop.

3. You may have some success with smaller, relatively flat frameless bags. With larger, more complex shapes, the rubber is heavy and awkward to manipulate without disturbing the layup, and sealing to complex mold surfaces can be next to impossible.

A frame gives you a precise, consistent vacuum bagging process every time. The frame provides a high-integrity seal, provides a carrier mechanism for the diaphragm for easy placement, serves as a hard mounting location for vacuum ports, handles, and lifting devices, and helps protect the diaphragm.”

Large, frameless EVT’s are very susceptible to handling damage. Folding or rolling the diaphragm up with quick-disconnects installed, then placing the diaphragm on a shelf or bench are when most damage occurs. Blankets of this size are frequently set on the floor or onto surfaces sometimes cluttered with tools or sharp objects. During installation, the molded pleats are difficult to place over the part since there’s no frame to help suspend them. Fortunately, the customer was aware of the tool’s limitations and only needed it to prove a bonding concept with just one or two parts.

Occasionally, frameless is the only way to go, such as with these molded diaphragms for fitting the inside of a complex duct. We’re still using an elastomeric seal. One end uses an expanding band clamp to apply the required tension, and the other uses conventional snaps to apply seal initiation pressure.
MOLD DESIGN GUIDELINES

Illustrations and photos on designing tooling for economical, efficient implementation of EVTs (Elastomeric Vacuum Tools)

Allowances must be made for breather material, release film, vacuum and thermocouple connections, as well as the vacuum seal. Allow at least 5" beyond the edges of the layup for the sealing area. If the vacuum tool is to be hinged, allow an additional 2" along the hinge edge. In this example, the sealing area of the middle and right molds has been increased. The right mold has gone a step further and eliminated the top horizontal flange.

Eliminate as many curves as possible. If 1 straight section causes the mold to be too large, break up the curve into 2 or 3 straight sections. If curves cannot be avoided, make them along one axis only, i.e. no compound curves. Every curve and angle built into the frame increases costs and limits the option of hinging the vacuum bagging tool to the mold.

This mold has some complex geometry but working with the customer before construction began resulted in a fairly simple EVT. There were a few things that could have been changed, such as a little more elbow room for fittings and hardware, but overall the result was a success.
Eliminate compound curves in the sealing area. Construct the mold so that the sealing area changes direction along 1 axis only, not 2 or 3. Compound curves will increase frame, seal, and diaphragm costs. If you need to follow the part contour more closely, change mold edge direction after or before the curve by at least 3", not in the middle as shown in the left hand mold.

For relatively small molds, or molds used to make channel shapes, truncate ribs or "hat-sections" and provide a flat sealing area whenever possible. The only other option would be to place the entire mold onto a larger baseplate for bagging. In this example, the upstanding portion of the mold has been truncated and tapered down to a flat sealing area. This minor design change will cut the cost of a reusable bagging system by at least 40% and allow the vacuum bagging tool to be hinged to the mold.

On the left is a mold with a typical spar or channel shape. With the channel shape extending to each end of the mold, constructing a frame and seal was more involved than if the channel shape were tapered down to the same plane as the sides per the mold shown at right. The draft or angled sides of the mold on the left helped with adapting a frame and seal to fit.
The mold on the left has a narrow sealing area and the sharp radii of the part extend to the edges of the mold. In the middle, the sealing area has been widened and the radii in the sealing area have been modified. On the right, a flat, planar sealing area has been created. If the part contour allows it, this is the most efficient design.

Do not extend small joggles and curves from the part area into the sealing area. This creates added costs because the frame and seal must be manufactured to extremely close tolerances and be indexed precisely to work correctly. At right, the sealing area margin is wider and lies in the same plane, again significantly reducing the cost and increasing the reliability of a vacuum bagging tool. It also allows hinging of the tool. You could also raise the part area instead of recessing it as shown.

Compound or conic surfaces that intersect the mold perimeter add significant cost to the construction of an EVT, especially if the angular intersections are severe. Transitioning these compound intersections into simpler surfaces along the edge of the mold can make frame and seal construction much simpler.

The mold on the left is the original design. At right is the new design resulting in simpler frame, diaphragm, and seal construction. Designing with a reusable system in mind also reduced the cost of the mold.
Example of a mold where a few design changes would have simplified the EVT, such as providing a few more inches around the perimeter for sealing, and tapering the front of the mold down to the same curved plane as the rest of the tool.

The mold for this C-shaped channel part has a number of good design characteristics, including gentle radii along the bottom, tapered ends, planar sealing area, and plenty of room for hinges and ports.

The narrow flange on each side made it difficult to configure the frame, seal, vacuum ports, and thermocouples. Stress on the diaphragm would be reduced, and frame/seal construction greatly simplified by tapering the ends of the profile down to the same plane as the sides.

A complex part with a straightforward EVT installed. Good tool design was the key to its success.
FURTHER DISCUSSION, REVIEW, MORE EXAMPLES

Try and avoid extending certain part contours into the sealing flange. Extending a step or joggle into the excess area might not be a concern if all you plan on using is conventional bag sealant that adheres aggressively to the mold, but a sharp step for a reusable system means grinding the radii so they’re rounded or adding tooling compound or weld to fill sharp radii. It adds cost and requires a little more precision when locating the EVT.

Here’s a tip we tell every tool designer: Imagine YOU have to build a frame to fit the tool you’re designing using square aluminum tube. Look at each transition, including elevation changes, outside and inside corners, compound joints, curvature, etc. You’ll start to realize how making small minor contour changes will greatly affect the labor involved for making a frame and diaphragm. The seal will be easier to manufacture and align on the tool surface, and replacement diaphragms will be less costly to make and install.

Outline of part (dashed line) is overlayed in this photo. Note how the contour breaks fairly sharply upwards and out to form an elevated flange. This added cost to the mold and dramatically increased the cost of building the frame and seal. Also note how contours are extended to the end of the mold, creating difficult contours for a tube frame and seal to follow.

Here’s an end view of the same mold showing the complex frame construction to accommodate the mold curves. Not only was the mold made unnecessarily complex, but this particular end of the mold was also angled in the curved area, similar to slicing a cylinder at an angle. Imagine having to curve a square tube to fit this contour. The result ends up being a spiral section.

Although this mold has some complex geometry, the actual perimeter was relatively easy to accommodate. We advised the customer on how to design the mold flange and not extend some of the part contours. Inside and outside radii were rounded to at least .5”, and frame construction was straightforward. Note the extended edge to accommodate the hinges. This is a good example of how a fairly complex mold can be designed to keep construction costs of an EVT as low as possible.
SEALING SURFACE

What about the surface of the mold where the seal takes place? There are a number of possible interference problems when certain things aren’t considered.
- Tooling ball holes
- Laser projection system reference points
- Ply orientation rosettes
- Identification engravings or etchings
- Hoist ring locations
- Bushings for locating secondary drilling tools
- A hundred other things

The frame and seal of most systems occupy ~2" of area along the perimeter of the mold or fixture. Within the outer .75" to 1" of this 2" margin you can locate tool stampings, markings, tooling ball holes, or anything that doesn’t protrude more than ~.200". Any higher and you’ll interfere with the frame. Locate them towards the inside of the 2" margin and you’re into the sealing area. You’ll either need to fill the markings and relocate them or the frame and seal will have to be joggled.

Here are two views of a mold that makes a highly contoured part. Note the numerous breaks in the frame to accommodate curves, corners, and TWISTS. Twists, especially a spiraling twist, are difficult to fit a frame to and should be avoided if possible.

Typical section view (full scale) showing the EVT frame, diaphragm, and seal. The strip of Interflow rubber inboard of the seal serves to reduce stress on the diaphragm as it transitions from the frame to the mold surface, and it provides a perimeter breathing channel.
HANDLING AND STORAGE

Hinging is the preferred method for integrating an EVT with a mold or fixture. It eliminates handling damage and aligns the EVT to the mold perfectly everytime. On larger tools, high-temp gas-spring cylinders are commonly used to assist in opening and closing. An added safety device is a gas-spring lock tube that must be disengaged in order to close the tool. Installing a spring-loaded locking pin at the back of the tool along the hinge edge also prevents closure of the tool until the pin is released.

Hinges can be attached directly to the mold surface or on brackets added to the mold structure if there isn’t sufficient area on the mold, or if the mold construction is not robust enough. For hinge types, we have our standard T-7 hinge that is slotted to allow for the seal compression movement, or we can use a fixed-pivot hinge along with swing clamps on the opposite side of the hinge edge. This arrangement compresses the seal when the tool is closed to assure vacuum initiation. The swing clamps are usually required since the fixed pivot hinges tend to keep the seal along the front edge from contacting the mold. Swing clamps are stainless steel L-brackets welded to a stainless steel hinge and attached to the frame. They typically rotate 270° and grip the underside of the mold lip.

Note: For some room-temp production work (example: bonding wood bracing to guitar backs), having fixed-pivot or short-slot hinges and no front clamps is very efficient since the operator simply pushes down lightly on the front of the tool until it initiates, then moves on to the next tool. The clamp is not required and only adds time and complexity to the process.
Frequently, the shape or size of the mold or fixture requires that the EVT be removed from the mold entirely. Handles installed in the frame are one option. Legs or braces on the EVT frame can be attached so the tool is self-supporting when placed on the floor.

Swing clamp with surface-mount keeper, shown in the latched position.

Another method of latching the frame using an over-center clamp.

Handles installed on the ends of the EVT for manual removal and positioning.

Handles installed on a curved mold where hinging is not practical.

Crossbraces can be positioned to serve as handles.

Legs and handles installed so that the tool stands upright and protects the diaphragm and seal when set off to the side.
Additional handling solutions:

Hoist rings are frequently installed in the frame for lifting from an overhead crane.

Hydraulic lifts are used to pick and place this 43’ EVT.

A counterweighted electric lift allows the EVT to be removed from tooling that does not have leg clearance underneath.

This tool was provided to the customer with crossbracing for use with a roll-around hoist that latches on the side, then tilts the frame up to a vertical position for removal.

VACUUM PORTS AND THERMOCOUPLES

Vacuum ports and thermocouple connections may or may not be integrated into the mold. Ports in the diaphragm are typically the most common way of providing vacuum and thermocouple sensors to the part area.

A typical configuration showing a frame-mounted vacuum port with release valve and quick-disconnect, and a type J thermocouple pass-thru in the diaphragm.

Thru-tool thermocouple connection and vacuum port. Note external connections. Inset shows standard thermocouple plug being inserted into surface-mounted female jack.