AdeptGroup

Thermoforming for Packaging

PACKAGE ENGINEERING TECHNICAL KNOWLEDGE TRANSFER

The purpose of these Package Engineering Technical Knowledge Transfers (PETS) are to provide specialized information to Package Engineers regarding aspects of packaging. They contain details necessary to duplicate most aspects of a package or process. These don't replace detailed specification, drawings or individual expertise but are intended to provide details using generally accepted industry standard terminology.

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White Paper Overview

What is Thermoforming?

Thermoforming is a method of processing a sheet material into finished parts.

A sheet of material is heated to a specific temperature and shaped to a desired configuration. The sheet becoming more pliable after heating enables it to be formed in detail with a minimum amount of force. Pressure is maintained until the part has cooled and the part is then trimmed out of the sheet used to hold it during the processing.

Definition of Trade Terms Used in Packaging*

Thermoform: A process of forming sheet material, which involves heating the sheet and forcing it through a mold via vacuum, mechanical or air pressure. Used to produce blisters, skin packs and thin-wall cups, trays, platforms, clamshells and other sheet formed containers or components. The term Thermoforming is an overall designation for vacuum forming, pressure forming and combinations of these.

Vacuum form: A sheet forming process which employs atmospheric pressure sometimes in combination with mechanical, pneumatic or hydraulic force.

Pressure form: A process for making hollow plastic articles by forcing heat-softened sheet into a mold cavity by mechanical or hydraulic pressure. Generally used to make thin-wall, single use containers such as cups. High precision is possible through control of process conditions.

Source: Glossary of Packaging Terms fifth edition

WHITEPAPER INCLUSIONS

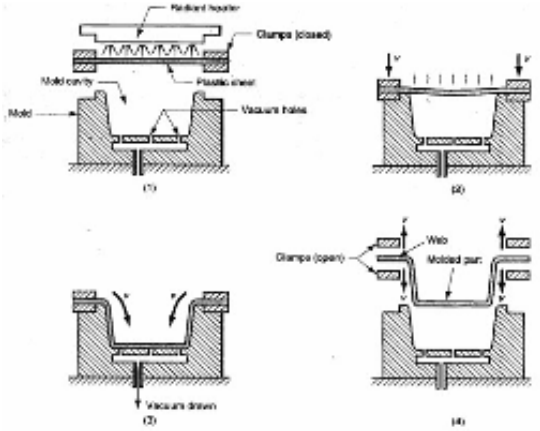
The Seven Basic Fundamentals

1. **Resin:** Plastic type needs to be determined based on the needs of the part to hold a product.
2. **Sheet Material:** Consistency is required both in thickness as well as uniform homogeneous mix to ensure hassle-free forming.
3. **Heating the Sheet:** The core of the sheet must be heated uniformly to its specific processing temperature.
4. **Vacuum & Compressed Air:** The most pressure that can be obtained from vacuum at sea level is about 14.7 psi. All vacuum systems should have a rated pressure of at least 29 inches of mercury. The typical thermoforming steps addition of 50 psi of compressed air pressure greatly helps the rate of thermoforming and improves the properties, cycle time and details of the finished part. The use of compressed air with vacuum is called pressure forming.
5. **Mold Temperature:** To achieve a quality part at economical cost. temperature-controlled molds must be used. Proper mold temperature should be determined and maintained.
6. **Cooling the Part:** Ideally you should remove heat from both sides of the part at the same rate and the same way.
7. **Trimming:** When using a sheet to produce multiple parts, it's necessary to trim the excess material from the part.

SPECIAL POINTS OF INTEREST

- Romans used tortoise shell (Keratin) and heated oil to shape food utensils.
- During WWII aircraft canopies were vacuum thermoformed.
- Industrial thermoforming is used to make large parts for Planes, Trains, Automobile & Boats.

Typical Thermoforming Steps



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Mold Types

Positive vs. Negative (Male vs. Female)

There are two basic types of thermoforming tools: Positive (Male) and Negative (Female).

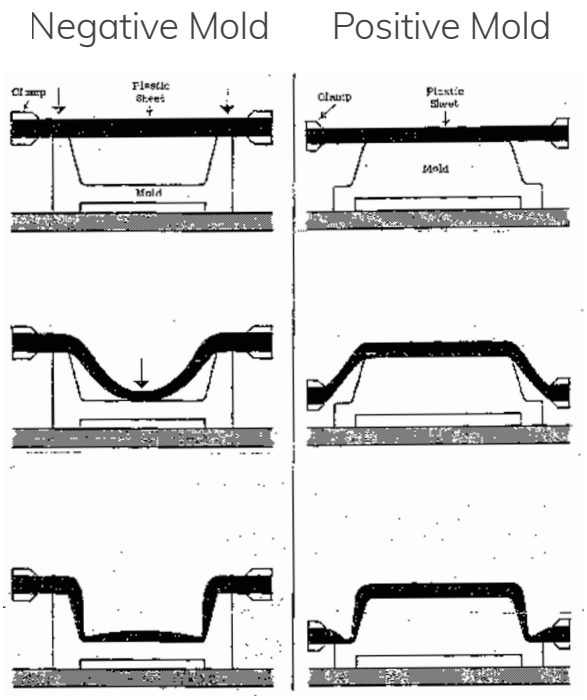
In a Positive tool the hot sheet of material is draped over the shaped mold. Male molds have a tendency to have stronger bottoms and thinner flanges. A general rule of thumb is that Positive tooling layout require a one to one ratio. This means that if the tool is one inch deep then the cavities need to be one inch apart from each other.

Positive tooling is used for parts that are not deep draw or that have little detail. Detail will be on the inside of the part. Positive molds are typically less expensive than Negative tools. Positive tools are approximately one third the price of Negative tools.

In a Negative tool, the hot sheet of material is forced into the cavity mold. Negative tools have thicker flanges and thinner cavity bottoms. The thicker flanges can assist in certain types of surface seals such as Radio Frequency.

Negative tooling has a one to one-half ratio. If the tool is one inch deep, then each cavity can be one half inch apart. Thus, the Negative tool can have a higher density of cavities in the same sized sheet.

Negative tooling is used on parts that have a deeper draw or will require more detail. Detail will be on the outside of a female part. Closer tolerances can be held on Positive tools. As the part cools it has a tendency to shrink away from the mold.



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Draft Angle

Why Have Draft?

Draft is the degree of taper of a vertical sidewall to facilitate the removal of a part from a mold. Molders will insist on some draft as opposed to not having draft.

REASONS TO HAVE A DRAFT

- Allows easier removal of the part from the mold.
- Will usually give you more even distribution of sheet material.
- More detail can be molded into side wall.
- Chill marks can be minimized.

DESIGN GUIDELINES

- Never less than 1 degree draft.
- When possible, draft should be 5 degrees or more.
- Draft is more important on corners than sidewall on Positive tools.
- Draft is less important in Negative cavities than sidewalls of a Positive tool.

Example:
Tangent of 1 degree = 0.017
With 6° draft and a 1” draw the part will need to be 0.105” bigger per side.

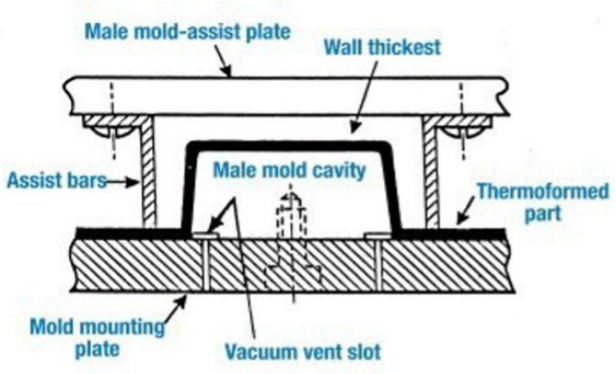
How to Avoid Webs with Assist Plates

Positive tools have a tendency to web at the corners and between parts. To avoid webs, an assist plate is used to push the webs down around the tooling.

The assist plate fits inside the pressure box above the tooling. As the forming station closes, the pressure box touches the material first, then the tool comes up and pushes the material through the assist plate. Assist plates are normally made from aluminum.

Negative tools have a problem with thinning out the bottom of each cavity. Plug assist stops this problem. A plug assist pushes the material down to the bottom of the cavity. This action prevents the hot material from contacting the relatively cold mold as the sheet is stretched into the cavity. The plug stops about 10% from the bottom of the mold and should be about 85% the size of the part. Plug assist are made from aluminum, wood or syntactic foam.

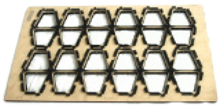
Sources: Thermo Forming -1987 James L Throne, SPE
Industrial Thermoforming Symposium Workshop 1999—Bill K. McConnell, SPE
Thermoforming Handbook 1996 —Robert Peter- son, Klockner Pentaplast



Assist Plate

Plug Assist

The Many Die Options Available for Trimming in Thermoforming



Steel Rule

Consist of a pre-sharpened, pre-hardened steel rule blade inserted into a plywood or aluminum base.

- Suitable for trimming moderate volumes of thin gauge parts
- Lowest cost, faster fabrication
- Edge hardness, joint spreading, extensive make-ready and blade instability are common problems

Forged

Also known as High Dies, this die consists of strip steel which is cut to height, forged, heat treated and finished to specific job requirements.

- Suitable for trimming high volumes of thin gauge parts
- Heavy steel construction, 1/4 to 1/2” thick
- Used for cut-in-place, inline, contoured and multi-level applications

Matched Metal

Also known as Shear or Positive/Negative tooling, matched metal die consist of a male punch and a female die, both machined from solid tool steel.

- Industry standard for high volume trimming
- Advantages include accuracy, repeatability, ease of tool set-up, and minimal maintenance
- Disadvantages include high initial tool cost, high repair cost, fix trim position therefore no adjustment for change of material or shrinkage

Contour

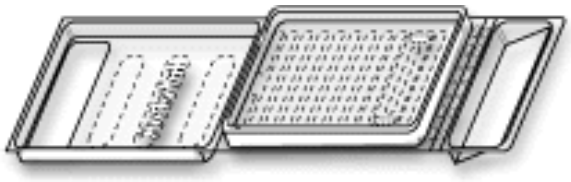
Consists of a forged or machined trim die that is contoured to suit a part which cannot be trimmed on a flat surface.

Hinged Design Practices to Follow

Thermoformed parts are formed initially on a single plane. Most are surface sealed to another material or set into another tray/box after trimming. However, with the use of hinges the thermoformed part can be formed in such a way as to allow the part to fold over upon itself.

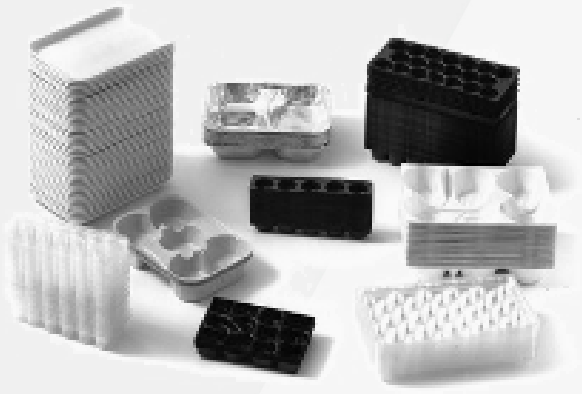
The mold design can add hinge features to be formed into the part. Good design practices would be to balance the depth of both sides of a hinged part to prevent the part from warping.

A self-standing setup part can be designed with the use of double hinges. The part is folded together and locks into place with indented designs. The part can then stand upright using one of the sides as a bottom platform. In this way the product inside can be displayed and positioned for optimal viewing.



Double-Hinged Part Laying Flat

De-Nesting or Stacking Feature: Why thermoformed parts are designed to be stacked one upon the other



Stacked Thermoformed Parts

Many thermoformed parts are designed to be stacked one upon the other. Parts are stacked right after the trim station then packed out. The stack of parts will then be de-nested and transferred one at a time onto the production line.

In order to reduce the cube necessary to transport the parts, it is desirable to pack/stack as many parts as practical together. The balancing required that need to be made is to optimize the distance between nested parts while still allowing the parts to be separated.

Design features are added to the part to allow one part to slide over another part without crushing or sticking. Normally four or more features are added to allow the part to float level.

Good design practices would be to blend the stacking feature into the existing part features as much as possible making them almost invisible. Features include steps, bumps and draft angle changes

Thermoforming Machine Categories

Thermoforming machines fall into several categories such as narrow web and wide web roll feed; cut sheet feed and pellet-to-product extrusion feed.

Roll Feed & Sheet Feed Machines

Narrow Web Roll Feed

These machines are usually high speed with webs of 12" or less. They are typically form fill seal machines intended to integrate package directly with product. Various blister package machines fall into this category as well as food or commodity packages. These machines normally have the following stations: web feed; heat; form; product load; seal a lid stock (which could be printed in-line); trim and exit or feed other equipment such as carton, etc. Machines could be intermittent or continuous.

Wide Web Roll Feed

These types of machines have web widths of 24"–48". These machines process plastic from a roll to form plastic cups and lids, bowls, surgical packages, blister packs, horticulture packages, deli containers, meat trays and other various plastic products. The wide web allows for a large number of cavities up per machine stroke. These machines typically have the following stations: web feed; heat; form; trim & stack off. Trim presses can be in-line steel rule or a separate forged or match metal machine running several times faster than the former.

Cut Sheet Feed

These machines are typically large format. Cut sheet thermoforming machines use pre-cut sheets of thermoplastics to produce products for a variety of industries such as automotive, appliance, recreational products, construction, dunnage, and horticulture. Cut sheet thermoforming machine configurations include both single station and rotary machines in vacuum, pressure, and twin sheet models from small to very large, to cover virtually all cut sheet applications.

Pellet to Product

This class of machine takes raw resin pellets and extrudes them into thin webs and feeds them directly in the th thermoformer. These thermoforming systems are designed to run 24/7 at high speeds, and are capable of producing hundreds of thousands of parters, per hour, while saving energy and operating costs.

Trim Presses

Can be added to thermoformer lines and offer precise match metal product trimming from the formed web. Trim presses are capable of a variety of tasks from straight perimeter trimming, progressive trim applications for pre-punching and perimeter trim, counting and stacking. Trimming is completed in single or multiple rows and available in both horizontal and vertical configurations.

Source: Brown-Machine.com