Standard Thermoforming Equipment Overview

There are three standard configurations for thermoforming equipment:

1. Heat and Cut-in-Place Forming
2. In-Line Forming with Steel Rule or Forged Steel Trim wand Air Pressure and/or Plug Assist
3. Two Station Forming with Air Pressure and/or Plug Assist and Secondary Matched Metal or Forged Steel Trim

In this section, each of these types will be considered from the perspective of thermoforming polyester rollstock. An overview of the technology will be offered, followed by a quick look at the advantages and disadvantages of that equipment for processing PET.

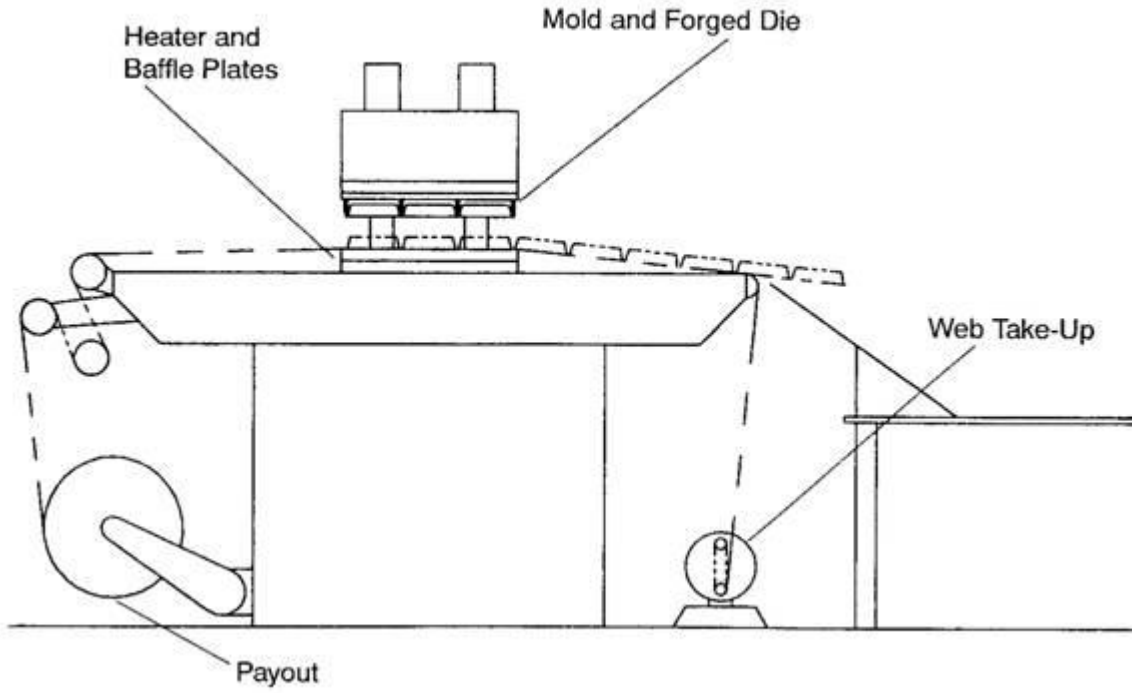
1) Cut-in Place Thermoforming Process

With this technology, the forming and cutting are accomplished in a single station, and the desired geometry is accomplished without the benefit of a mechanical plug assist. This can be accomplished because the mold is mounted to an upper platen, inside of the perimeter of the forged steel die, directly above the lower heated platen. The process begins by first holding the sheet against the heated platen by means of air pressure introduced through the mold, or vacuum introduced through the heated platen, after the leading edge of the forged steel cutting die engages the surface of the plastic. This contact provides the seal needed for the next step in the forming process. Now air pressure, usually introduced through the heated platen, pushes the heated plastic into the mold geometry mounted inside the perimeter of the forged steel die. After cooling, the forged steel die is pushed the rest of the way through the plastic, into contact with the platen, and the part is cut. The part is ejected from the mold by means of air pressure, spring assisted ejection rings, or both. It is then conveyed to the next station inside the web. This is facilitated by tiny precise notches in the cutting edge of the die. These notches hold the plastic in the web while being conveyed, but are kept small enough so the parts can be easily separated from the web for packing or filling. A simplified cut-in-place process description would look like this:

1. The plastic is pulled from the roll by index arm bars at the front of the machine, just above the roll stand and indexed into the heat/form/cut station.
2. The bottom platen strokes up as the top platen strokes down
3. The leading edge of the forged steel cutting die engages the surface of the sheet and penetrates far enough to create a perimeter seal.
4. Air pressure is introduced through the mold, or in some cases vacuum introduced through the lower platen, holds the plastic against the heated lower platen.
5. The heated plastic is pushed off the lower platen upward into the mold on the platen above.
6. Once cool enough to maintain the desired geometry, the part is cut as forged steel die is brought into contact with the lower platen.
7. Both platens retract and the part is ejected from the mold with air or mechanical assistance or both.

8. The machine indexes and conveys the formed parts to the packing station.
9. Parts are removed from the web manually or mechanically.
10. The web is conveyed to a coreless winder that rolls the web into bales for recycling.

Simplified Drawing of a Cut-in-Place Thermoformer



Advantages

The cut-in-place technology available today has several advantages. This type of equipment generally produces the least amount of trim waste. This is primarily because the cutting die not only cuts the part perimeter, but is also used to form the airtight perimeter seal needed to form the plastic. Another advantage is that the plastic is generally warm when it is trimmed. This is highly desirable when cutting PET because warm plastic requires dramatically less pressure to trim. These lower pressures usually extend the usefulness of the cutting edge of the die significantly. An additional advantage is in accuracy of trimming the part geometry. Today's modern contact heat formers are achieving trim accuracy that approaches the precision found in match metal trim stations, at a significant cost savings. Finally, some plastics allow for extremely fast cycle times in parts of all geometries in shallow draft , shallow draw applications.

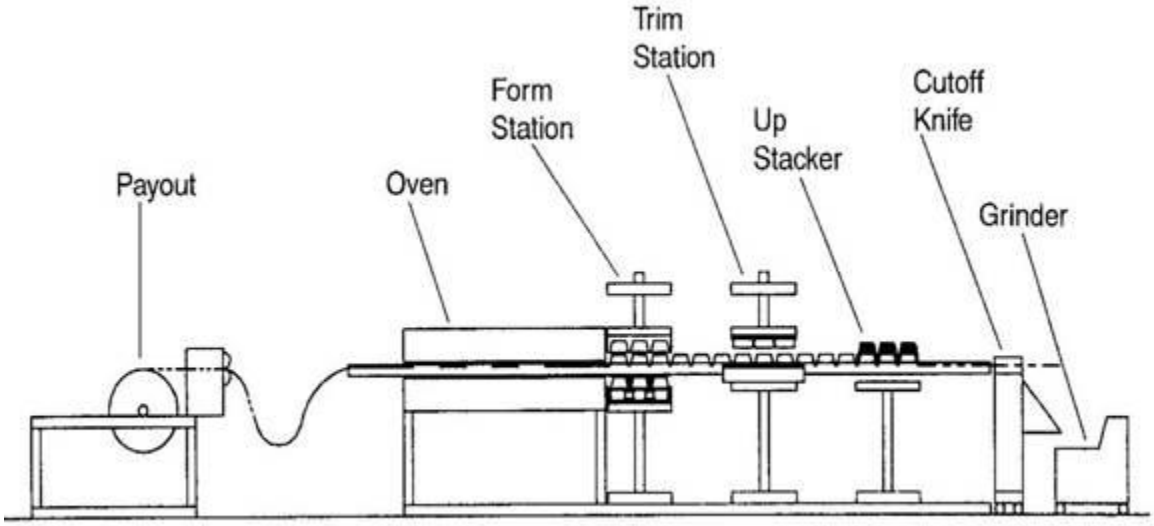
Disadvantages

The Cut-in Place thermoforming machine is not optimal if the end use of the PET parts made

with this process requires cold temperature resistance to fracture failure. Parts produced using this technology tends to exhibit higher percentages of residual stress when examined using polarized light. Birefringence reveals this stress in clear PET parts and is observed as prismatic rainbows of color. These rainbows reveal where the stress is in the clear PET part. The likelihood of fracture failure is much greater in the highly stressed areas of these parts. Birefringence is caused when the light passing through the plastic splits, bends, or changes direction. When not all the stress can be eliminated, the process should then be adjusted to balance the observable stress. Parts that have unbalanced stress can also experience a significantly higher incidence of fracture failure than parts that exhibit low or balanced stress, at any temperature. The incidence of residual stress in contact heat thermoforming are usually attributable to the inability to heat both sides of the sheet equally, or to a limited number of temperature zones in the heated lower platen.

2) In-Line Thermoforming with Steel Rule or Forged Steel Trim with Vacuum, Air Pressure and Plug Assist

This is a simplified drawing of an in-line thermoforming machine:



In-Line Process Overview

With this type of machinery, the forming and cutting are accomplished in a two separate dual platen stations. Achieving the desired geometry can be enhanced with the assistance of a mechanical plug assist. In the first station, if the mold is female in geometry, the mold is usually mounted to the upper platen and the mechanical plug assist is mounted to the lower platen. If the mold geometry is male, the mold is usually mounted to the lower platen and a grid assist is mounted to the upper platen. If steel rule or forged steel dies are used, the cutting die is usually mounted to the upper platen of the second station and the cutting plate is mounted to the lower platen. The process begins by indexing the sheet off the roll by means of pin chains mounted on rails that capture the sheet along its edges. The pin chain carries the captured sheet into the radiant heat tunnel oven. The surface of the plastic is heated, preferably from both sides, by various types of electric resistance radiant heat sources. CalRod, quartz panel, quartz tube, and

other similar electric heaters are generally set up in zones to provide an adjustable heat profile to maximize caloric output and help manage energy costs. These radiant heaters should be adjusted so the wavelength of the heater output is in one of the infrared zone. This will maximize heat penetration of the sheet and provide for the shortest possible cycle time. Once the sheet is up to temperature, the machine indexes again and the sheet, held along its edges by the pin chains, is conveyed into the forming station. Some thermoforming machines are equipped with pin chain rails that are adjustable throughout the length of the section that transports the sheet into the forming station. The adjustable rails can be configured to accomplish a graduated stretch of heated plastic in the transverse direction as the machine indexes. This stretching is called camber, and it takes most if not all of the sag out of the heated sheet. There are several advantages to using camber including improved residual wall distribution, reduced edge trim scrap, and faster cycle times. The cycle time is reduced because of the reduced distance the forming platens must travel. Once the heated plastic is to station, the upper and lower platens close, and the part is formed by the combined effects of mold and plug assist, and cooled by contact with the mold. The heat transfer from the part to the mold is enhanced by air pressure introduced through the pressure box that surrounds the mold or the plug assist. The machine indexes, bringing a new length or "shot" of heated sheet into the forming station. Simultaneously, the shot containing the formed parts is indexed into the cutting station. In the cutting station, the parts are cut from the web using steel rule or forged steel dies. When the process indexes the formed parts out of the cutting station, the parts are held in the web and transported to the next station by means of small conveyance notches. These tiny notches are filed or punched into the cutting edge of the die. The parts break free from the web when they are manually or mechanically stripped from the web and stacked for packing. The waste web is then conveyed to a coreless winder that rolls the web into bales, or it is fed directly into a grinder that converts it into flakes. In either case, this final station provides the pulling action needed to keep tension on the web, once the web has left the pin chains. If the scrap is ground, the resulting flake is usually blown or otherwise conveyed into a poly-bag lined corrugated gaylord container for recycling.

A simplified in-line process description would look like this:

1. Plastic is pulled off the roll by a roll feed fixture at the front of the machine, just after the roll stand, and is fed into the pin chain rails where it is held by its edges, and indexed into the oven
2. In the oven the sheet is heated, preferably from both sides, until it reaches the desired temperature for thermoforming
3. The machine indexes and the heated plastic, still held by its edges on the pin chain, is carried into the forming station, and a new length of plastic is moved into the oven
4. Once the plastic is at station, the upper and lower platens move together. The heated plastic is formed by a combination of the mold and the plug assist, and the effect of vacuum and air pressure. Once the formed plastic is cool enough, the upper and lower platens open
5. The machine indexes and the formed parts, or "shot", is conveyed into the cutting station
6. Cutting is accomplished by the combined action of the upper and lower platens. Usually, the lower platen moves first, coming to within 95% to 98% of station. Then the upper platen with the die moves to 100% station. Once the upper platen is at station, lower platen is then "bumped to 100% station by air or hydraulic cylinders, and the cut is accomplished
7. The machine indexes and the cut parts, still held in the web by the conveyance notches, leaves the pin chains and moves to the manual and/or mechanical stripping and stacking station

8. The parts are stripped from the web, and then stacked and packed in containers for shipping
9. The machine indexes and the waste web is either wound into a coreless bale, or pulled into a grinder for recycling

Advantages

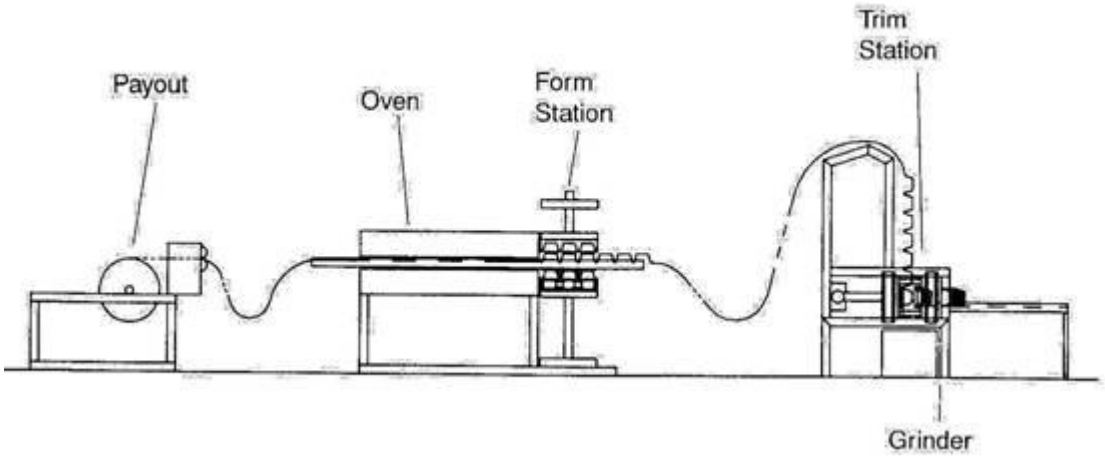
The in-line thermoforming process is used to form almost every type of plastic used in the packaging industry. It is extremely versatile and may be modified and configured in many ways and is the ideal general-purpose thermoforming machine. New projects can be prototyped quickly and inexpensively. In addition, more than one type of part geometry can be formed and trimmed in each shot. This combination of geometries is referred to as a combo-run or combo-shot. The net effect is that it is possible to form the separate components needed for a complete assembly every time the machine cycles. Finally, the cost of this type of thermoforming machine, while generally more than contact heat machines, is usually significantly less than two-station, matched metal technology.

Disadvantages

The principal disadvantage is because the forming and cutting processes are inseparable and are slaved to the same tangent of motion. While this simplifies the operation of the machine, it limits the finishing options available to the part designer. There are also limitations in the ability to control the distance of platen travel, and this extra motion adds waste to the cycle. The slaved design of the forming and trim stations can also limit the amount of force available for trimming the part. While steel rule and forged steel dies are excellent ways to trim plastic parts, the closest tolerance trimming is accomplished utilizing a punch and die assembly often referred to as matched metal trimming. The clearance and range of motion needed by the matched metal tool virtually eliminates it a trimming option available on an in-line machine.

Modular Two-Station Forming With Matched Metal Trim

This is a simplified drawing of a modular two-station thermoforming process featuring matched metal trimming.



Two-station thermoforming has the most flexibility and can be used to produce parts from general purpose thermoforming grades like PET to engineering grades of plastic and other difficult to form plastics like CPET.

The two-station process is similar to in-line equipment except that it features a separate trim station. This type of process almost exclusively utilizes matched metal trim dies, but forged steel or steel rule can also be used if desired. Because the trim station is autonomous, and not slaved to the same stroke as the forming station, a six-cavity mold can be trimmed by a two cavity matched metal die by running a faster cutting stroke.

The two-station process looks like this:

Station one

1. Plastic is pulled off the roll by a roll feed fixture at the front of the machine, just after the roll stand, and is fed into the pin chain rails where it is held by its edges, and indexed into the oven
2. In the oven the sheet is heated, preferably from both sides, until it reaches the desired temperature for thermoforming
3. The machine indexes and the heated plastic, still held by its edges on the pin chain, is carried into the forming station, and a new length of plastic is moved into the oven
4. Once the plastic is at station, the upper and lower platens move together. The heated plastic is formed by a combination of the mold and the plug assist, and the effect of vacuum and air pressure. Once the formed plastic is cool enough, the upper and lower platens open.
5. The machine indexes and the formed parts exit the pin chain and are transported to the independent trim station. The plastic is conveyed to the trim press on an arched shaped guide.

Station two

1. Plastic is pulled into the cutting station by indexing arms that push on an indexing lug formed into the plastic.
2. Cutting is accomplished by the combined action of upper and lower platens. Usually, there is a close tolerance matched metal punch and die assembly doing the cutting. The platen speed and cycle time are independent from the cycle time of the forming station.
3. The parts are then stacked and packed in containers for shipping

4. The waste web is either wound into a coreless bale, or pulled into a grinder for recycling.

Advantages

The matched metal thermoforming process is used to form almost every type of plastic used in the packaging industry. It is extremely versatile and may be modified and configured in many ways and is the ideal machine for long running items. The cutting die has a longer life expectancy than steel rule and forged steel dies, and once adjusted and broken in, will cut parts with great consistency for the life of the die. This type of equipment can run as much as 35% faster than in-line equipment running similar parts.

Disadvantages

The main disadvantages of this process are up-front cost, new part development cost, change over cost, and set up cost.