Description

Image



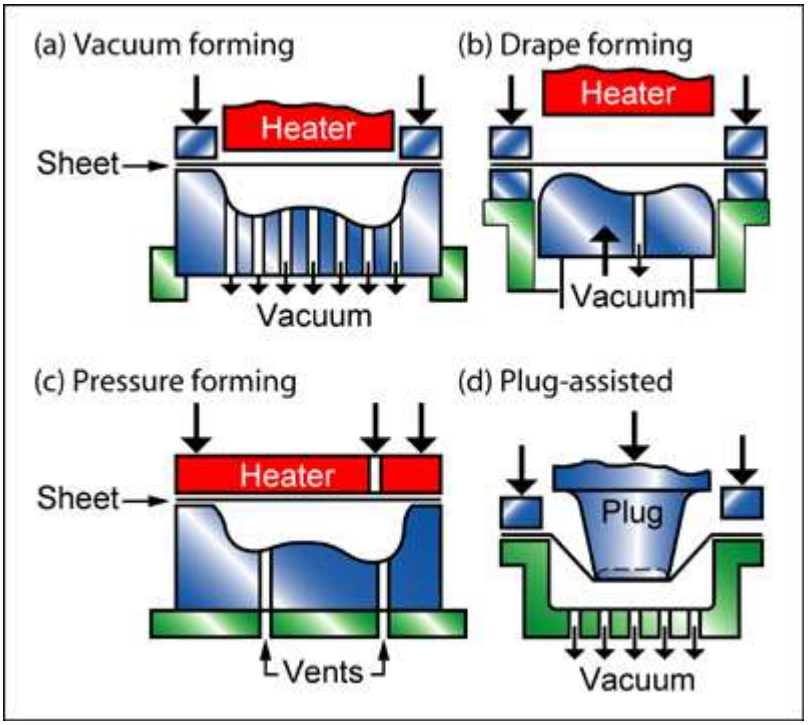
Image caption

(1) Ceramic Thermoforming Tool © Ncastelucci at Wikimedia Commons (CC BY 3.0) (2) A vacuum-formed plastic dome © Jordanhill School D&T Dept at flickr (CC BY 2.0) (3) Blister with pills © Alex Khimich at Wikimedia Commons [Public domain]

The process

Large thermoplastic sheet moldings are economically made by THERMOFORMING. In vacuum thermoforming a thermoplastic sheet, heated to its softening point, is sucked against the contours of a mold, taking up its profile; it is then cooled, solidifying against the mold. Drape thermoforming relies partly on vacuum and partly on the natural sag of the hot polymer to form the shape. Plug-assisted thermoforming augments the vacuum with a compression plug. Pressure thermoforming uses a pressure of several atmospheres to force the hot polymer sheet onto the mold. Male or female molds are possible and - for vacuum thermoforming - can be machined from wood, polymer foam, or from aluminum (for larger batch sizes).

Process schematic



Material compatibility

Foams	✓
Polymers - thermoplastics	✓

Shape

Dished sheet	✓

Economic compatibility

Relative tooling cost		low		
Relative equipment cost		low		
Labor intensity		high		
Economic batch size (units)		10	- 1e3	

Physical and quality attributes

Mass range	*	0.0661	- 22	lb
Range of section thickness		9.84	- 236	mil
Tolerance		19.7	- 39.4	mil
Roughness	*	0.0118	- 0.063	mil
Surface roughness (A=v. smooth)		A		

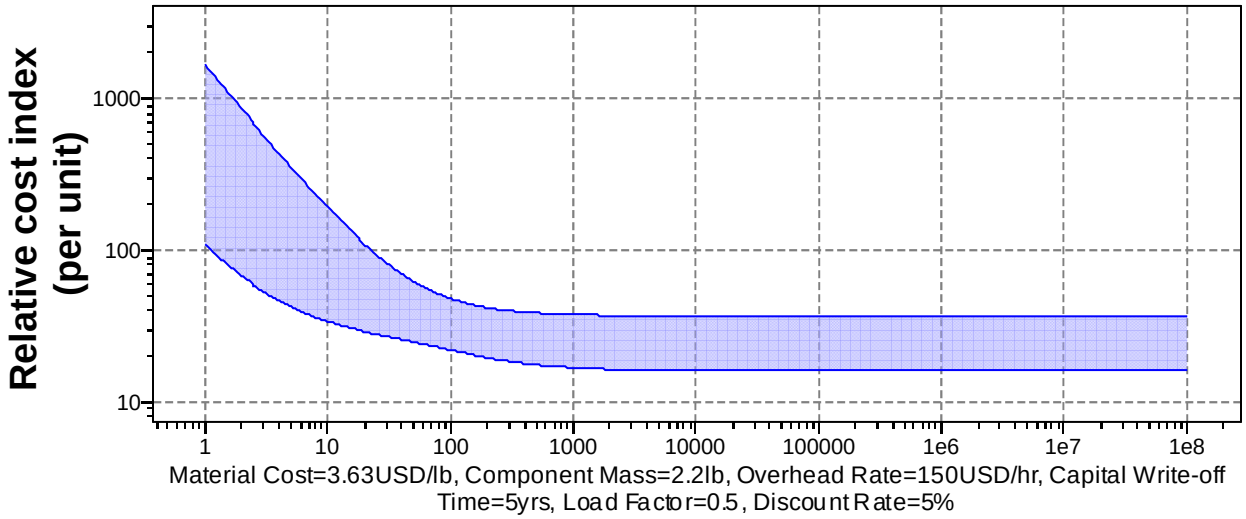
Process characteristics

Primary shaping processes	✓
Discrete	✓

Cost model and defaults

Relative cost index (per unit)	* 16.8	-	37.7	

Parameters: Material Cost = 3.63USD/lb, Component Mass = 2.2lb, Batch Size = 1e3, Overhead Rate = 150USD/hr, Discount Rate = 5%, Capital Write-off Time = 5yrs, Load Factor = 0.5



Capital cost	* 8.2e3	-	8.2e4	USD
Material utilization fraction	* 0.6	-	0.9	
Production rate (units)	* 6	-	30	/hr
Tooling cost	* 82	-	1.64e3	USD
Tool life (units)	* 1e4	-	1e6	

Supporting information

Design guidelines

The low pressure in vacuum forming gives poor reproduction of fine details; pressure forming, using higher pressures, gives sharper features but is more expensive because wooden molds cannot be used. The surface of the sheet in contact with the mold tends to mark, so the tool is usually designed with the finished side away from the mold. Colored, textured or pre-decorated sheet can be molded, reducing finishing costs.

Technical notes

Thermoforming is used to shape thermoplastic sheet, particularly ABS, PA, PC, PS, PP, PVC, Polysulfones, PBT, PET, foams, and short-fiber-reinforced thermoplastics. The maximum depth-to-width ratio of the molding is in the range 0.5 to 2. Inserts can be molded in. The process is able to cope with a very large range of sizes from products as small as disposable drink cups to those as large as boat hulls; and it is economic for both small and large batch sizes. It gives products with excellent physical properties but the starting material is more expensive (sheet rather than pellet). The product has to be trimmed after forming, and sheet scrap cannot be directly recycled.

Typical uses

Appliances, refrigerated liners, bath tubs, shower stalls, aircraft interior panels, trays, signs, boat building, hulls, drink cups.

The economics

The tooling required is cheap; stiff (metal or epoxy) or flexible (elastomer) molds are both possible. For small tooling the price is under $100, for large tooling it is a few thousand dollars.

The environment

No environmental problems

Links

MaterialUniverse

Reference