

# Introduction

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Thermoforming was one of the earliest methods for fabricating thermoplastic materials. This involves shaping thermoplastic sheets into distinct parts. The United States has contributed to plastic processing methods. However, most of these techniques originated in Europe. It was not until the mid-twentieth century that a comprehensive understanding of its true nature was achieved [1].

Thermoforming has undergone significant growth and development with the introduction of cellulosic sheet materials, followed by acrylic and vinyl. In the 1890s, baby rattles and teething rings were thermoformed, but growth was slow until the 1930s, when roll-fed machines were developed in Europe. This process made significant progress in the 1950s using high-impact polystyrene for manufacturing containers and lids in the dairy industry. In addition, it has been used in the production of signage, exhibits, toys, and packaging materials. Initially, the thermoforming industry was limited by the lack of suitable sheet materials and forming equipment. However, in recent years, the process has rapidly advanced due to its advantages such as low machine and mold costs, low temperature and pressure requirements, ease of forming large parts, and fast mold cycles [2].

The emergence of plastics, synthetic materials that showcase human creativity and ingenuity, coincided with this understanding. Among the various methods utilized for processing plastics, thermoforming is a widely used technique for shaping extruded sheets into desired forms. This process is commonly used to produce large parts with low production volumes. It is a more cost-effective alternative to injection molding, which incurs higher expenses due to substantial fixed costs.

Thermoforming is a straightforward processing technology [2]. This involves modifying polymeric materials or systems to enhance their usefulness. Thermoforming is a cost-effective alternative to other plastic molding and forming methods. The process discussed here is often associated with the production of packaging materials such as blister packs and disposable

## 2 THERMOFORMING

coffee cup lids. However, it is important to note that the cost and time benefits of this process can be extended to a wide range of products in various industries.

Thermoplastics dominate the global polymer market and account for 85% of all polymers [3]. Most thermoplastic production focuses on large-volume, low-cost commodity resins, such as polyethylene, polypropylene, polystyrene, and polyvinyl chloride. Engineering plastics, such as acrylics, acrylonitrile-butadiene-styrene (ABS), and high-impact polystyrene (HIPS), are chosen for their performance and cost-effectiveness. However, there is an increasing demand for high-performance materials, which has led to the utilization of engineering plastics such as polyacetal (POM), polyamides (PAs), and polycarbonate (PC), and polyesters such as polyethylene terephthalate (PET), polybutylene terephthalate (PBT), and polypropylene oxide, as well as their blends. Polymers such as liquid crystalline polymers, polyetheretherketone (PEEK), and fluoropolymers are commonly used in high-temperature applications [4].

Thermoforming presents numerous advantages over alternative thermoplastic fabrication techniques. These advantages encompass several aspects, such as the ability to fabricate components with a large surface area, reduced expenses for molds and equipment due to its low-pressure requirement, the capability to produce extremely thin-walled parts, increased production rates for high-volume thin-walled products, and the ability to manufacture low-volume heavy-gauge products at lower tooling costs [5].

This realization coincided with the advancement of plastics, which are synthetic materials that showcase human ingenuity and resourcefulness. The process involves shaping the thermoplastic sheets into precise components. Thermoforming has gained considerable importance as a method for processing plastic sheets, particularly for producing larger components [6].

Thermoplastics, which have gained significant popularity in the global polymer market, are exceptionally suitable for thermoforming processes because of their ability to be produced in high volumes at lower costs. This versatile procedure can be used for any thermoplastic sheet material, which demonstrates the necessary dimensional stability and impact resistance. Thermoforming presents numerous advantages over alternative thermoplastic fabrication techniques.

The market for thermoforming is experiencing growth due to its increasing use in the production of complex shapes and a wider range of materials. Thermoforming is widely regarded as a viable and economically advantageous alternative to various plastic molding and forming methods.

The development of applications has largely been brought about by the introduction of new manufacturing methods. New methods have encouraged the development of new forming machines and techniques. This has brought the thermoforming industry to a new level in terms of processing technology.

