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Thermoplastic Fabrication Processes

PERP 08/09S4

Report Abstract
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INTRODUCTION

The thermoplastics fabrication industry has witnessed amazing growth over the past 80 or so years. Advancing essentially in lock step with the technology to commercially produce thermoplastics resins, plastics fabrication processes continue to be impacted by an astounding range of creativity and engineering talent, which further pushes the envelope of plastics fabrication capability in terms of throughput, cost, and efficacy. From the first commercial injection molding machine produced in 1926 by Eckert and Ziegler (German Patent 495362) and the first screw extruder specifically for thermoplastic processing built in 1931 by Heidrich (Germany), the thermoplastics processing industry has exhibited amazing vibrancy, creativity, and engineering prowess in advancing the frontiers of thermoplastics processing.

This report seeks to profile the leading thermoplastic resin processing technologies, by providing information on the processes themselves and technology trends currently underway. Representative thermoplastic resins have been selected which are widely used in that particular fabrication process, and market overview information on the end-uses of such fabricated products provided. This market information has been provided for North America only (United States and Canada), as the desire is only to be indicative of the size, scope and usefulness of the various processes. Snapshot views of the economics of the different processes are also provided.

The thermoplastic fabrication techniques profiled in this report include the processes used to produce over 90 percent of the fabricated thermoplastic products currently consumed globally today. These processes and the representative materials include:

Process	**Material**
Compounding	Polypropylene
Blown Film	LLDPE/LDPE
Thermoforming	PS, PP, ABS
Bi-Axially Oriented Film	Polypropylene
Injection Molding	PS, Filled PP
Blow Molding	
• Extrusion Blow Molding	HDPE
• Injection/Extrusion Blow Molding	HDPE
• Stretch Blow Molding	PET
Profile Extrusion	PVC
Woven Bags	Polypropylene

OVERVIEW OF PLASTICS EXTRUSION

In its simplest form, a plastics extrusion involves feeding a plastic material (typically in pellet form, though other forms are employed), from a hopper into the throat of an extruder barrel. Additives may be incorporated (often by means of an additive concentrate encased in plastic also called a masterbatch) just prior to entry into the extruder. The extruder barrel is heated or cooled to provide or remove heat if necessary.

COMPOUNDING

For the purposes of this report, a compound is defined as a mixture of a thermoplastic resin and ingredient(s) in specific proportions to give a defined result or product, which is then utilized in a subsequent and separate fabrication step. The production of a blend of materials (e.g., increasing polymer toughness by incorporating small amounts of some type of rubber) is considered to be compounding. In addition, the "in-line" production of polymer materials containing high levels of additives, most notably fillers, is also considered compounding in this report. However, the incorporation of small amounts of additives during polymer manufacturing is generally not considered to be compounding. Similarly, products made by incorporating and mixing ingredients into a thermoplastic as part of the fabrication process is also not considered compounding.

- This report highlights the compounding of polypropylene – a commodity thermoplastic resin that is frequently compounded. In practice, essentially all thermoplastic resins are or could be compounded, depending on the need to better tailor the thermoplastic resin to meet the requirements of the end-use product.

- Various compound types that are in common usage with polypropylene, i.e., mineral filled, glass fiber, thermoplastic olefinics (TPO), thermoplastic vulcanizates (TPV), and additive masterbatches, are discussed in the report. The primary changes in compounding equipment over the past 20 years are also briefly reviewed.

- A cost of production estimate was developed for a single 92 millimeter high torque compounding line producing a 35 percent talc filled polypropylene compound. (USGC basis)

- End-use markets for polypropylene compounds such as mineral filled, TPOs, TPVs, glass reinforced are discussed in the report.

- Charts illustrating polypropylene sales, polypropylene compounds by type and polypropylene compounds by end-use market for North America are given.

BLOW FILM EXTRUSION

Blown film extrusion (film blowing) is a relatively simple process used to produce the vast majority of plastic films. In terms of absolute finished product volume, polyethylene is the dominant polymer converted into film by the process.

Blown film extrusion has been used for many years as a method to produce the majority of packaging films. Typical applications include industrial films and packaging, grocery and merchandise bags, trash bags, and food packaging. Over the years, developments are constantly being made with respect to process and equipment design in order to improve efficiency of the process.

- The report gives an overview of the process technology.

Cost estimates have been developed for three cases considered for the production of blown film, all assume the addition of a single blown film line to an existing facility and it is assumed that the final product is rollstock (film in a tube sold on rolls) for Form, Fill and Seal (FFS) applications:

- The first case assumes a low-cost line made in China.
- The second case is for a computer-controlled line with three layer capabilities from a leading United States or European equipment manufacturer.
- The third case is for a computer-controlled line from a leading United States or European equipment manufacturer producing a seven-layer oxygen barrier film.

End-use markets are briefly outlined and demand chart for North American blow film extrusion is given.

THERMOFORMING

Thermoforming offers a vast potential for high volume thermoplastic package or parts fabrication. There are many thermoforming variations, but by definition, thermoforming is a two-step process of elevating the temperature of a thermoplastic sheet material to a workable level and forming the material into the desired shape through any one of several techniques (which are described later in the report). The material is then held and cooled sufficiently for shape retention, and removed from the mold. Thermoforming implies only those processes applicable to thermoplastic resins.

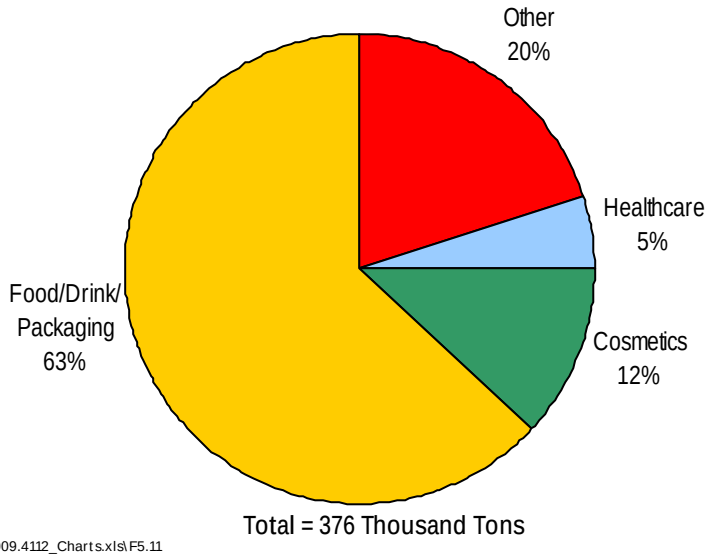
- An overview of the process technology and brief review of recent trends are given in the report.

Costs of production estimates for the following are given in the report:

- Refrigerator liners and doors (three layers – two outer layers (7.5 percent of total thickness each) of 100 percent HIPS, one inner layer (85 percent of total thickness) of ABS plus regrind. (USGC basis)
- Polystyrene (PS) yogurt containers (via extrusion and thermoforming - low-cost equipment). (China basis)
- Polypropylene (PP) yogurt containers (extrusion and thermoforming - high throughput equipment). (China basis)

The report briefly outlines end-use markets for North America, summarised illustratively in the figure below.

North American Thermoformed Container/Part Demand by End-Use Market, 2009



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BI-AXIALLY ORIENTED POLYPROPYLENE FILM

Bi-axially oriented polypropylene (BOPP) film exhibits outstanding clarity, reasonably good stiffness, good resistance to UV light, excellent chemical and abrasion resistance, and a smooth surface; the film can also be prepared with a matte surface. The clear material has a reasonable scuff resistance and great acid resistance. The film's combination of stiffness, clarity and smooth surface (offering "sparkle" plus a nice smooth surface to print on), makes it a material of choice for the quality packaging of high-end products.

The two main ways of manufacturing BOPP are by the Cast Stenter process or the Tubular Bubble Process.

- An overview of production technology (Tenter and Tubular Bubble processes) as well as a brief review of technology trends are given in the report

A cost of production estimate for:

- BOPP film on a single tenter line is given. (USGC basis)

End-use markets for North America are briefly outlined.

INJECTION MOLDING

The injection molding process was initially introduced in as a way of producing celluloid products such as buttons and combs. Use of this process increased dramatically with the introduction and commercialization of large-volume thermoplastic resins in the late 1940s and 1950s. Advantages of the process include high production rates, high repeatable tolerances, low labor costs, minimal scrap losses, and limited need to finish resulting parts. Disadvantages of the injection molding process include somewhat expensive molds and equipment; also, due to

different shrinkage characteristics of different plastics, the molds frequently are not interchangeable among different plastics.

The injection molding process can manufacture parts from both thermoplastic and thermoset plastic materials (though only thermoplastic materials are considered further in this report). Common thermoplastic materials that are used in injection molding include polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), acrylonitrile butadiene styrene (ABS), polystyrene (PS), and the engineering thermoplastics, which include polyamide (PA), polycarbonate (PC), polyesters, polyacetal and modified polyphenylene oxide (MPPO).

- Process description and brief review of technology trends are given.

Costs of production estimates for the following are given:

- Injection molded polypropylene door panels (front and back panels – four panels per car) for a four door car. (USGC basis))
- PS utensils (from GPPS feedstock). (China basis)

North American end-use markets are briefly outlined.

BLOW MOLDING

Blow molding is the production of a hollow container or part by forming or blowing the container or part in a mold. The idea of blow molding thermoplastic resins is conceptually similar to glass blowing in molds – a practice that is thousands of years old. Blow molding of synthetic resins was first developed to produce baby rattles in the late 1800s. The process was substantially perfected and automated in the late 1940s and early 1950s upon the development and introduction of large scale plastic resin production.

While perhaps initially intended for the production of containers, present blow molding technology can produce a wide range of other products from the blow molding process. Complex parts and irregular shapes can be produced, including drums, toys, auto seat backs, surfboards, tool cases, cabinet parts, gasoline tanks, garbage cans, and appliance parts.

- An overview of production technology (extrusion-, stretch- and injection-blow molding, container finishing) and brief review of technology trends are given.

Cost of production estimates for the following are included:

- HDPE bottles (dual sided blow molding machine, extrusion blow molding). (USGC basis)
- HDPE bottles (injection blow molding). (China basis)
- PET bottles (stretch blow molding, high volume). (USGC basis)

North America polyolefin end-use markets are briefly outlined.

PROFILE EXTRUSION

Extrusion is a process in which molten plastic is forced through a small opening or die having the shape of the finished product. Extrusion is the method employed to form thermoplastic materials into continuous sheeting, film, tubes, rods, profile shapes, and filaments, and to coat the outside layer onto wire, cable, and cord. Common extrusion methods include film and sheet extrusion, pipe and tube extrusion, wire coating, and profile extrusion.

Major end-use of polymer profile extruded products are mainly found in automotive, windows, window sealants, medical tubing, building siding, hose, and strapping applications.

While the most utilized material in extrusion profile processes is PVC other thermoplastics such as polyethylene, polypropylene, styrenics, and elastomers may also be used.

- Process technology and technology trends brief reviewed.

Cost of production estimate for the following is included:

- PVC pipe utilizing a profile extrusion process (USGC basis)

North American end-use markets are briefly outlined.

WOVEN BAGS

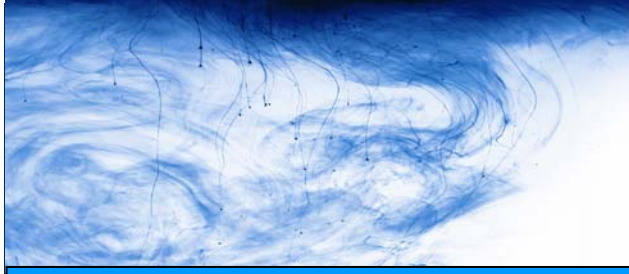
Woven sacks are a sub-market of the fibrillized film (raffia) polypropylene fibers end-market. This is a segment in which polypropylene has been very successful replacing traditional materials such as burlap (jute), textiles, and paper.

- An overview of the process technology and brief review of recent trends are given in the report.

Cost of production estimate for the following is included:

- Polypropylene woven bags. (China basis)

North American end-use markets are briefly outlined.



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