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Photo courtesy of A. Dobringer, DTC
Welcome to the first edition of a new year in thermoforming! Though we don’t have an official State of the Industry to offer, we do have an interesting snapshot of the current rate of growth in thermoforming thanks to our friends at Plastics News. “In fact, the total reported thermoforming sales this year [2021] is nearly triple that of 20 years ago.” This aligns with what our members report: tool shops are very busy; food packaging is on a tear; labor rates are increasing. You can read the complete blog post on p. 11 in our Business of Thermoforming section.

We know that the pandemic has been responsible for significant disruption over the past two years, and it looks like we can attribute some of 2021’s bounce-back growth the after-effects of COVID restrictions. But we don’t have global pandemics very often. What else are processors and converters doing to ensure the viability of their companies and bottom lines? One area where we don’t have universal adoption of change is simulation software. Unlike injection molding or other processes where plastic is in molten state, thermoformers are managing solid state change. Amit Dharia and Jerry Dees, two proponents of modeling, testing, and software discussed this topic on the SPE Communities recently. We have refashioned their point / counterpoint exchange as an article on pp. 14-16.

“What’s old is new again” is a phrase we sometimes hear when ideas or technologies of yesteryear get a fresh coat of paint with a new generation. Dry molded fiber has been around in some form or fashion for 100 years, but the mega-trend of sustainability and the relentless targeting of plastics has led to a renewal of interest in this paper-based process. PulPac, a Swedish IP firm, offers an overview of the technology (pp. 20-24) and presents a perspective that plastics processors might not typically see.

Though our event in Grand Rapids is in the rear-view mirror, our student members are still reliving the glory of their RC Car Race Event. This race continues to gain momentum as a must-see at our conference. The students work as teams and they have the opportunity to design and build their own cars, often with support and help from thermoforming processors. This type of first-hand learning experience is the ideal way to link design and performance. Check out the report on pp. 12-14 from the team at Purdue Polytechnic Institute in Richmond, IN.

This March sees the return of the European Thermoforming Conference, postponed twice but never defeated. Our colleagues will be hosting almost 200 delegates in Vienna, Austria, and the programming is outstanding, with workshops and papers for both thin-gauge and heavy-gauge interest groups. With travel restrictions easing and transatlantic flights filling up again, will this be the year that you join us? If so, be sure to find me so we can raise a glass and toast the health of our industry. Prost!
CUSTOMIZATION CREATED THROUGH INNOVATION

THE JOURNEY BEGINS WITH KYDEX® THERMOPLASTICS

kydex.com
Alpek Buying Octal to Build PET Capabilities

By Karen Laird, Sustainable Plastics

February 2, 2022 - Mexican petrochemical company Alpek SAB de CV is adding downstream operations by buying PET sheet maker and thermoformer Octal Holding for $620 million.

Alpek, based in Monterrey, already produces PET in addition to polyester and industrial and specialty chemicals. Currently, global demand for PET resin is strong, and the company says the acquisition will expand Alpek’s presence in the PET sheet and thermoforming industries, adding more than 1 million metric tons of capacity.

“This transaction is ideal for Alpek. Through a single acquisition we get access to the growing and profitable segment of the PET sheet segment and serve our customers’ increased PET resin demand,” Alpek CEO José de Jesús Valdez said in a Feb. 1 news release.

Octal, based in Muscat, Oman, has a proprietary “direct-to-sheet” technology it calls DPET that allows it to move from raw materials to final packaging faster while also integrating recycled materials quickly. DPET reduces five steps in the recycling process and reduces the carbon footprint of PET packaging from its operations by 25 percent, the company says.

Its Octal Extrusion Corp. facility in West Chester, Ohio, takes recycled PET flake from its thermoforming customers in North America and extrudes the material into new sheet. That site opened in 2015 and expanded in 2019.

It was No. 98 in the most recent Plastics News ranking of North American film and sheet makers with an estimated $50 million in sales. Globally it has an estimated $800 million in annual sales. Octal has thermoforming operations in Saudi Arabia, processing 11,000 tonnes of packaging annually.

“PET sheet represents a highly attractive opportunity for Alpek, serving the growing needs for 100 percent recyclable packaging and providing solid margins in to-go meals, baked goods and produce, just to name a few,” Alpek said in its release. “Growth rates through 2025 are also expected to be strong at 6.4 percent per year.”

The transaction is being structured on a debt-free basis, with financing for the acquisition secured through cash available on Alpek’s balance sheet, funds from its existing businesses and bank loans. No further details were provided.

Alpek has been making other acquisitions recently to build up its catalog and footprint. In 2019 it expanded into Europe with the acquisition of South Korea’s Lotte Chemical Corps United Kingdom subsidiary. In 2020, it purchased Nova Chemicals Corp.’s expandable styrenics business.

In addition to boosting capacity and forward-integrating Alpek into the PET sheet business segment, it ticks other boxes as well.

Octal has operations that span four plants in Saudi Arabia, the U.S. and Oman. Octal boasts the largest integrated PET producing site in the world at any single location in Salalah, Oman. Alpek expects to capture global administrative and operational synergies through the integration of these sites into the existing asset base.

Thermoformer Allied Plastics Picked Up by All-State Industries

The combined business reportedly will be one of the largest providers of nonmetallic components in its markets.

PlasticsToday.com

Jan 12, 2022 - Private equity firm Blue Sage Capital announced that an affiliate of All-State Industries Inc. has acquired Allied Plastics LLC, a Twin Lakes, WI-based thermoformed plastics manufacturer. The acquisition brings additional capabilities and access to new markets to All-State, a supplier of nonmetallic components to OEMs across a range of end markets.
Allied specializes in medium- to heavy-gauge thermoformed plastic components for agriculture and heavy equipment OEMs, consumer products, and packaging/dunnage industries. Under the leadership of founders Tim Neal and Steve Wieder, Allied Plastics has grown to become one of the leading thermoformed plastics manufacturers within its markets due to its best-in-class design resources, vertically integrated extrusion capabilities, and product quality standards, said the news release.

This transaction marks the second sizable acquisition Des Moines, IA–based All-State has completed since partnering with Blue Sage in 2019. The combined business reportedly will be one of the largest providers of nonmetallic components in its markets, with eight total manufacturing facilities in the United States and Mexico.

“We are very proud to welcome Allied into the All-State family, as they have built an exceptional business and are poised for continued growth,” said All-State CEO Scott Pulver. “We are excited about the opportunity this partnership presents as it propels the All-State platform to have unmatched scale and capabilities that allow us to better serve our existing customer base and pursue growth in new, untapped markets. Most importantly, we are adding an Allied organization that has great people and a very similar culture with All-State that will position us for continued success.”

“Our team is eager to partner with Scott and the entire All-State team,” said Tim Neal, President and co-founder of Allied Plastics. “All-State is the ideal partner that we were looking for, and this partnership will provide the resources and scale that will allow both Allied and All-State to continue to deliver the highest level of service and product quality to our customers.”

Neal and Wieder will continue to lead the Allied business under the All-State platform.

Blue Sage partnered with the Pulver family in 2019 to support All-State in solidifying its leadership position within its existing end markets while expanding its capabilities and entering new markets. “This acquisition highlights All-State’s ability to be the acquirer of choice within the fragmented landscape of nonmetallic component providers, and we look forward to further building this platform both organically and through M&A,” said Peter Huff, Managing Member at Blue Sage.

Utah Thermoformer Eyes Growth with New Capital Partners

By Jim Johnson, Plastics News

January 4, 2022 - Salt Lake City-based thermoformer Premier Plastics Inc. is taking on new financial partners with an aim to expand operations.

Banner Ventures, a private equity firm based near Salt Lake City, is the new lead investor in Premier, which was founded by Jim Holbrook in 1989.

Holbrook retains what is described as “a meaningful ownership stake” and will remain CEO of the firm, Banner said.

“What attracted us to Premier was a strong market leadership in the Intermountain West,” said Tanner Ainge, managing partner with Lehi, Utah-based Banner, in a Jan. 3 interview.

For Holbrook, the decision to add partners serves two purposes: helping fuel expansion and ensuring a future for the firm beyond his working years, he said in an interview.

Holbrook made it clear, however, that growth is on the front burner as he’s not looking to exit the company anytime soon.

“I’m 60 years old and there’s going to be another chapter of life in the next three to five years. This sets the company up. We feel this is a very strong position for Premier Plastics growth in the future,” he said.

Joining Banner in the investment are Ron Labrum and Tony Orsini who co-invested through Seventeen Capital LLC.

“We firmly believe in Premier Plastics’ ability to expand and scale to the next level,” Orsini said in a statement.
Orsini and Labrum both previously worked at Flexan LLC, a maker of molded and extruded rubber, silicone and thermoplastic components, sub-assemblies and devices for the medical and specialty markets. Labrum was chairman and Orsini was chief operating officer at the company sold last year to ILC Dover LP.

Premier Products currently has about 65 employees, and the new investors have a goal of doubling operations in the next few years. The company’s “long and steady growth” over the decades attracted the new investors, Ainge said. “With the investment, Premier will be in a position to rapidly expand capacity to meet what we see as an incredible growth plan,” he said.

The company does have some existing capacity to increase business, but not enough to double sales. That’s where the new cash comes in.

While Ainge said he sees a future where sales can double, Holbrook said he sees the potential for even triple the current total.

Premier has relied on organic growth over the years, which was fine. But management decided about 18 months ago that there was an even greater opportunity to expand by starting to consider acquisitions. Bringing on additional investors helps fund those aspirations, Holbrook said.

“For the last 32 years, we have built Premier Plastics into a market leader without any outside capital. We have the team, the capability and the market reputation to double our scale in the near-term — but to do so I needed to bring in capital partners,” Holbrook said in a statement. “After considering all of our options, I felt like Banner was the right partner to continue building on our great legacy and success.

“With this partnership, Premier is not only looking to expand its own footprint to service the existing customer base, but we are developing strategic partnerships with new customers as well as looking for acquisitions in the plastics space,” Ainge said.

Premier will consider “smaller or peer-sized competitors” as acquisition candidates, he said.

Banner was attracted to the investment, its first in plastics, for several reasons. “Really, in this case, it was the chance to invest in a market leader here in our region and the team and the strength of the customer base. Going forward, we think it’s going to be a continually strong segment, particularly within the medical device category,” Ainge said.

Premier was No. 79 in the most-recent listing of thermoformers in North America compiled by Plastics News. The company had 2020 sales of $16.2 million, including 91 percent from packaging and 9 percent from industrial, and seven thermoforming lines, according to the listing.

Holbrook, in the interview, said 2021 sales increased to about $19 million

### Faerch Acquires Leading Dairy Packaging Company PACCOR

**03.01.2022 (Company release)**

Faerch to acquire PACCOR Packaging from private equity firm Lindsay Goldberg. The acquisition is yet another important step in the execution of Faerch’s long-term growth plan and in accelerating the industry’s transition towards circular packaging solutions.

Faerch, a leading European supplier of rigid food packaging and the world’s first integrated recycler of PET food packaging, today announced the acquisition of PACCOR Packaging. The acquisition underlines Faerch’s overall strategy for creating circularity in food packaging and will accelerate the required material conversion towards sustainable packaging solutions in the European dairy sector, the largest segment in rigid food packaging.

Offering a wide range of innovative packaging solutions mainly for the food industry, PACCOR is a European leader in protective packaging for the dairy sector. It has built a long track record of innovation and premium service for the largest and most demanding dairy customers, delivering state-of-the-art solutions mostly in yoghurt, spreads and ice cream packaging.
“With PACCOR’s strong position in the dairy sector, our complementary geographical footprints and our shared ambition to make food packaging circular, PACCOR is the perfect match for Faerch”, Lars Gade Hansen, CEO of Faerch Group, says. “We have always respected PACCOR for their dedication to quality, innovation and customer service, and we are delighted to now join forces with the excellent PACCOR team”, he continues.

“We are very much looking forward to becoming part of the Faerch Group. After years of successful growth, we see in Faerch the perfect partner for us”, Andreas Schütte, CEO of PACCOR adds. “Faerch’s unique integrated recycling capabilities offer fully new opportunities to accelerate the transition towards circular packaging solutions, while combining the two companies’ dedication to innovation and investments in R&D”, he says.

PACCOR was founded in 2011, as a successful merger of several packaging companies. Today the company is present in 18 countries, and PACCOR’s geographical footprint complements Faerch’s pan-European presence. The acquisition comprises 16 production sites in Europe, Asia and the US and more than 3,400 employees. The new company setup marks a strong focus on innovation and when the transaction has been approved, the Faerch Group will comprise of 34 sites and employ almost 6,000 people globally.

“We look forward to welcoming all of our new highly skilled colleagues to the Group. With PACCOR becoming part of Faerch, the industry’s transition towards circularity will gain additional momentum for food packaging being recycled back into new food packaging of the same quality again and again”, Lars Gade Hansen underlines. “With PACCOR’s leading position in the dairy sector, Faerch will be present in all major food packaging segments, allowing the much-needed standardisation away from non-recyclable legacy materials towards truly circular packaging solutions. A comprehensive investment programme for supporting material conversion and scaling our recycling platform will be launched”, he concludes.

The transaction is subject to customary closing conditions and regulatory approval. The PACCOR UK business including their two production sites are not part of the transaction and will remain with Lindsay Goldberg.

Faerch Group was advised by Credit Suisse, Plesner Law Firm, EY, Skadden Law Firm and COWI.

Rohrer Buys Specialty Printing and Thermoforming Firm Jay Packaging

Packaging-Gateway.com

December 20, 2021 - Consumer packaging solutions provider Rohrer has completed the acquisition of specialty printing and thermoforming group, Jay Packaging.

Based in Warwick, Rhode Island, Jay Packaging provides printing, folding cartons, and plastic components across the US northeast region.

The company provides niche packaging for various sectors including beauty, home, and health markets.

Through this integration, both the companies will complement their capabilities in high-end printing and decorating, folded carton packaging carded blister, and thermoformed.

Rohrer Corporation CEO Steve Wirrig said: “Jay Packaging Group is an innovative company with talented employees. It’s exciting to expand our operations to the East Coast and invest in the people, plants, and profitability of both businesses.

“Together, we can provide our customers with best of both worlds – unbeatable packaging solutions through Rohrer’s ezCombo programmes and custom printing and packaging options through Jay Packaging Group.”

The acquisition will strengthen Rohrer’s national manufacturing presence and furthers its eco-friendly packaging target.

In addition, Jay Packaging customers will have access to Rohrer’s inclusive suite of packaging solutions.

Financial terms of the transaction are not disclosed.
Jay Packaging Group CEO and co-owner Richard Kelly said: “I am proud of our team, and the business we have built over the years. I am confident the integration of Jay Packaging Group into Rohrer’s network will make both organisations stronger, and position us for further investment, growth and job creation.”

In October this year, Rohrer acquired Coburn Carton Solutions, a company specialising in printing and converting folding cartons.

Florida-Based MalStra Acquires Italy’s OMV Machinery

By Catherine Kavanaugh, Plastics News

November 30, 2021 - Royal Palm Beach, Fla.-based MalStra LLC has acquired the Verona, Italy-based thermoforming and extrusion machinery company OMV Machinery srl, which was a division of Swiss-based Wifag/Polytype Holding AG.

The new owners — packaging industry veterans Brooke Maltun and Mark Strachan — have renamed the company OMV Technologies LLC and moved its headquarters to Florida while continuing OMV’s manufacturing operations in Italy.

Founded in 1963, OMV builds machinery and offers technology for processors of rigid food packaging from traditional resins, such as polypropylene, polystyrene and PET, but has also been focused on the next generation of sustainable materials. Terms of the deal weren’t disclosed.

All OMV employees will be retained. Strachan will serve as the CEO and Maltun will be president of OMV Technologies.

Strachan has almost 40 years of experience in sheet extrusion, roll fed thermoforming and extrusion inline thermoforming. He is a former two-term chairman of the board of the Society of Plastics Engineers’ thermoforming division.

Maltun is currently the vice president of sales for Los Angeles-based Star Plastic Design Inc.

“Mark and I have spent our careers in plastic packaging, and we share a passion for the business,” Maltun said in a news release. “We look forward to introducing groundbreaking innovations, hands on in-field service, and outstanding customer service to the industry, globally.”

“These are the most efficient and reliable thermoforming machines in the industry,” Strachan said. “OMV is one of the few companies who offer turnkey inline extrusion thermoforming systems with an emphasis on efficiency and closed-loop operation.”

The company also is a world leader in cut-in-place technology and inline rim rolling of round and square containers, which is critical with the drive towards more sustainable materials, Strachan said.

The company will still build machines and tooling in Italy, but the new owners said they will be beefing up operations there and the United States. OMV will open an extrusion thermoforming lab, a product development lab and a training facility in Florida.

Also, all U.S.-based parts and service will be relocated from its current location in New Jersey at Polytype America Corp., which is part of Wifag/Polytype, to Florida.

In addition, Maltun said interviews are underway to add U.S. employees.

“Our headquarters is in Florida, with an office in Los Angeles, and we will be hiring additional sales and service personnel very soon,” she said.
This week’s *Plastics News* has our updated ranking of North American thermoformers for the 2021 fiscal year, and what a year it was, with the average sales for companies soaring.

![Graph showing data]

We were able to gather data for 213 companies with combined related sales of $15.9 billion. We asked our respondents to break out their sales between packaging and industrial thermoforming. Those percentages have varied little over time, with 86 percent and 14 percent, or $2.2 billion and $13.7 billion, respectively.

So then, what has changed? Looking at the largest firms on our list, the top 25, we see a 15 percent jump in fiscal year 2021. That is second only to the 18 percent jump we saw back in 2011. In fact, the total reported thermoforming sales this year is nearly triple that of 20 years ago. Our top 3 breakout firms for packaging: **Pactiv Evergreen Inc.** of Lake Forest, Ill.; **Dart Container Corp.** of Mason, Mich.; and **Sabert Corp.** of Sayreville, N.J.

Our top 3 breakout firms for industrial thermoformers: Kruger **Brown Holdings LLC** of Portage, Wis.; **Sportech Inc.** of Elk River, Minn.; **MacNeil Automotive Products Ltd.** of Bolingbrook, Ill.

After the surveys came in, I took a preliminary look and found an average packaging gain of 21 percent. Food packaging, including cups and lids, was expected to increase due to the pandemic, with more people dining at home, but really this trickled into all end markets — as seen with the average sales per company gaining 15.7 percent to reach $74.4 million.

Resin pricing played an important role in 2021 as well. Most materials saw large increases, with ABS, polystyrene, polyethylene and, most significantly, polypropylene at 110 percent. Only PET prices fell, down 10 percent.

Nearly all — 90 percent — of our ranked firms gave the number of thermoforming employees. Year over year, it showed an increase of 1,227 jobs, bringing this group’s total up to 29,000.

Our biggest gain was **rPlanet Earth LLC** of Vernon, Calif., up 20 percent and moving up 134 spaces to rank at No. 70. The company cited increased demand for cups and deli containers.

**Our biggest movers:**

- **Creative Plastics International Inc.** of Jackson Center, Ohio, moved up 21 spots to rank at No. 124.
- **Universal Plastics Group Inc.** of Holyoke, Mass., is up 19 to rank at No. 3T5.
- **Plastiform Inc.** of Irving, Texas, moved up 18 to reach No. 102.
- **UFP Technologies Inc.** of Newburyport, Mass., moved up 14 spots to rank at No. 96.
- **Plastics Unlimited Inc.** of Preston, Iowa, moved up 12 spots to take No. 70.
- **ShapeMaster Inc.** of Ogden, Ill., moved up 12 to rank at No. 179.
- Mother Lode Plastics Molding Inc. dba **Central Plastics & Manufacturing LLC** of Tracy, Calif., moved up 12 to No. 180.
- **Duo-Form Plastics** of Edwardsburg, Mich., moved up 11 to rank at No. 45.
- **Blisterpak Inc.** of Commerce, Calif., moved up 11 spots to No. 102.
- **Formex Manufacturing Inc.** of Lawrenceville, Ga., moved up 11 to rank at No. 115.
- **Pride Polymers LLC** of Yakima, Wash., moved up 11 to reach No. 143.
- **Wurm’s Woodworking Co.** of New Washington, Ohio, moved up 10 to rank at No. 102.
- **Laird Plastics** of Denver moved up 10 to rank at No. 197.

If you work for a company that is missing from the ranking, we would like to include you next time. Just send a note to Hollee Keller at hkeller@crain.com or mail your information to *Plastics News*, P.O. Box 790, Tallmadge, Ohio 44278.

All of our rankings and lists can be seen online at [www.plasticsnews.com/businessdata](http://www.plasticsnews.com/businessdata). Downloads are available to data subscribers.

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SPE THERMOFORMING DIVISION RC CAR RACE AND DESIGN COMPETITION HELD IN GRAND RAPIDS MICHIGAN

Brayton McKnight, Drake Cunningham, Tyler Dudley, Matthew Johnson
Purdue Polytechnic Institute, Richmond, Indiana

Introduction

Two students embarked on a thermoforming project for their senior capstone. Also, they applied to use their project for the SPE Thermoforming competition. They chose to make their tooling entirely out of wood, milling the sides to get a rough outline, followed by copious amounts of sanding to reach the final product. Unfortunately, those two seniors were unable to attend, so Professor Rex Kanu allowed the authors to take their place to finish the project and attend the conference. Thus, it was time to work with roughly a month before the meeting and little experience with the project. Utilizing approximately six in-class workdays and some late nights spent outside of class, we managed to create a finished product we were proud to present at the conference.

Design

The previous students designed the body shell as a mixture of a Baja racing truck and an antique Cadillac. This design resulted in a low center of gravity body shell that to prevented the model race car from flipping when taking corners at high speeds.

Mold Manufacturing

The mold was made by gluing plywood sheets together and using wood filler to fill the gaps in the mold and smoothing out some of the rougher areas. The mold was essentially finished when we began our work, and we spent time sanding some areas that were causing the thermoformed plastic sheet to stick to the mold, Figures 1a and 1b.

Figure 1a. Initial form after the glue has dried.

Forming

Primex Plastics Corporation, Richmond, Indiana, our industry sponsor, graciously supplied the authors with Polyethylene terephthalate glycol (PETG) plastics sheets. PETG is a lightweight and durable plastic with some crack sensitivity. We started practicing with the mold and the PETG plastics sheets with little time for changes. After much trial and error, we observed that too much heat would cause webbing, and too little would result in a less than adequate seal on the tool. Due to sharp edges on some mold parts, we found higher heat required in those areas. Using our MAAC thermoforming machine, Figure 2, we were able to get the perfect timing to be close to twenty seconds inside the oven.

Figure 1b. Form after sanding and Dremel.

Figure 2. MAAC Single Stage Thermoforming machine used for the project.
thoroughly enjoyed working on the project, and the trip was a very memorable experience. We also want to thank our industry sponsor, Primex Plastics Corporation, for supplying us with material and technical guidance throughout the thermoforming process.

**Special Thanks**

The authors want to sincerely thank SPE for sponsoring and inviting us to this event and allowing us to spend time learning about the plastics thermoforming industry. We thoroughly enjoyed working on the project, and the trip was

**Issues**

The biggest obstacle we encountered was webbing. We understood that the sharp ninety-degree angles on the top and backside of the mold were the culprit. But with limited work time, we were unable to make changes to lessen the amount of material needed to fill these spots. These sharp angles would cause a lot of stress in those areas causing the corners to crack easily, especially when attempting to extract it from the mold. The corners became extremely thin for nearly every mold we made. A small impact would cause cracking and ultimately ruin the product. Hence, we produced so many shells for the conference, accurately displaying our trial-and-error timeline.

**Figure 3.** Our finished car body-shell samples after thermoforming.

**Figure 4.** Finalized race car shell with paint and lights

This timing, paired with correct heating temperatures in different oven zones, resulted in nearly perfect finished products (Figures 3 and 4).

**Special Thanks**

The authors want to sincerely thank SPE for sponsoring and inviting us to this event and allowing us to spend time learning about the plastics thermoforming industry. We thoroughly enjoyed working on the project, and the trip was
SIMULATION SOFTWARE FOR THERMOFORMING: A Solution in Search of a Problem?

Editor’s Note: The following article is adapted from a series of conversations on both SPE Communities and in separate correspondence between Dr. Amit Dharia and Mr. Jerry Dees. With permission from both contributors, the exchanges have been moderated to create a type of “fireside chat” discussion.

Introduction

The quality of thermoforming depends on knowing and controlling several material and process variables, the most important being the quality and uniformity of sheet stock. The extruded sheet can vary in resin microstructure, contamination, amount of regrind, sheet thickness, thermal history, crystallinity, and residual stresses. Effects of such variations manifest during production, resulting in frequent process set-ups, high scrap rate due to non-uniform heating, wall thinning, tearing, haze, pin holes, shape distortion, and difficult demolding. In production, variations mean cost.

In November and December last year, Amit Dharia posted a question to the Thermoforming Division community: given such variations in material, what types of testing are thermoformers doing? While there is no one simple answer (thin-gauge and heavy-gauge processes share some but not all characteristics), it is clear that other plastic processes do a lot more testing than thermoforming. The discussion that follows seeks to understand why this is the case.

Simulating the Thermoforming Process

[Question as posed on original thread: Is your company using computer simulation software for thermoforming? What are the primary benefits and limitations?]

Jerry Dees: I have not seen any responses to your question regarding the use of finite element analysis (FEA) software by thermoforming and blow molding companies. I am guessing, based on my observations, that only a few thermoforming and blow molding companies are using FEA, even though it was introduced to the industry more than 30 years ago (see paper by C.A. Taylor, SPE-ANTEC “Finite Element Simulation of Thermoforming – Experiments and Analysis” 1989).

Simulations can be used to determine the best type of thermoforming or blow molding process for a given product, develop the optimum geometry of a plug assist, and determine the material distribution to be used in a product. I have successfully used FEA for more than 20 years in my consulting business.

Over the years there have been a number of attempts to make the analysis of thermoforming and blow molding into a “black box”, so that the user would not need much of an understanding of FEA to conduct an analysis. For the most part, the “black box” approach does not work very well, especially for complex mold shapes or if a plug assist is used. I have found that the use of more advanced FEA software, such as Abaqus Explicit, is required for complex molds and plug assists because of its ability to handle the contact issues between the material and mold.

Also, the analysis of thermoforming and blow molding has been muddied by the insistence of some that detailed material properties must be determined in each case. However, thermoforming and blow molding are geometry driven processes, and a simple hyper-elastic (rubber type) material model can be developed, as they did in the 1989 ANTEC paper, and I have used successfully for many years.

Dharia: You state that you find that hyper-elastic models (less time dependent vs. viscoelastic model) offer adequate and satisfactory results. Is that for all materials/constructions, or do you only work with a specific type of material (e.g., ABS)?

Dees: A hyper-elastic material model works well for all of the common thermoforming and blow molding materials. I have conducted simulations with a wide range of materials used in thermoforming and blow molding over the last 20 years with very good results. There may be materials where it does not work well, but I have yet to find one. The assumption for FEA simulations is that the materials are heated to their thermoforming temperature window (obviously different for each material) and remain in their thermoforming temperature window until it contacts the mold. Under those conditions, thermoforming materials behave hyper-elastically (retain their initial volume as they are stretched).
Dharia: I agree that TF is shape-dependent (draw ratio is geometry driven). Still, it is susceptible to temperature and temperature distribution (uniform heating). I find it interesting that you do not see properties specific to each material that is not needed. Since only a few companies are using simulation software, it is difficult to find the limitation.

Dees: This is before my time, but I understand that for many years thermoformers used “geometric analysis” to predict thickness distributions in thermoformed and blow molded parts. Mold geometry was broken into simple geometric shapes, from which the material thickness distribution was calculated. Geometric analysis would not have been effective in predicting the thickness distribution if every polymer behaved differently. While it is not incorrect to develop a viscoelastic material model for each polymer at forming temperatures, it is usually not necessary. See the answer to (3) below for the difficulties or limitations due to specific FEA software.

Dharia: In all cases, in available software, you must either assume a temperature profile or consider one temperature (not based on actual heating step). I think this is a limitation.

Dees: Not all FEA solvers are created equal. There are two major types of FEA solvers, standard and explicit. The standard FEA software has been around since the beginning of FEA. Standard FEA involves calculating a stiffness in the x, y and z directions at each node in an FEA mesh. The stiffnesses are assembled into a stiffness matrix (the software does all of this internally). Thermoforming presents a large deflection problem so perhaps a few hundred small iterations are required until the polymer mesh comes in complete contact with the mold mesh. (I am simplifying here, but basically the stiffness matrix is inverted at each iteration during the course of the simulation until it converges on a solution.) This works okay for a simple mold shape, but for more complex molds the standard FEA solver does not handle all of the contact issues between the polymer sheet and the mold very well. It may chatter between two iterations and cannot converge on a solution. The problem can run for hours or days and not solve. I understand that this is the problem with the “black box” software for thermoforming and blow molding, so I am assuming that they use a standard FEA solver.

The explicit FEA solver, originally developed for high-speed impact studies, uses a dynamics approach, basically solving F=ma at each node in the mesh. The explicit solver uses very small iterations, perhaps 500,000 or more small iterations, before converging on an answer. As indicated, this is a dynamic approach so something must be moving during the simulation, in this case the polymer. Explicit FEA handles the contact issues extremely well, and in 20 years of running simulations, I have never had one not converge on a solution. The problem with explicit FEA software is that it is relatively expensive and has a steeper learning curve. I have used Abaqus Explicit software for thermoforming and blow molding. What is the most significant limitation in your view?

Use of FEA in Thermoforming

[Editor’s Note: Dharia responds with 4 specific limitations below. Dees responds to each one. They are present here sequentially.]

Dharia: (1) Too simplistic to use for complex shapes or specific TF processes.

Dees: I have successfully used explicit FEA software for complex shapes and many different thermoforming and blow molding processes. One thing that we need to remember is that FEA is a mathematical approximation and not an exact science. We make a lot of simplifying assumptions with FEA, such as the specific and uniform material properties (but the material properties in reality are probably nonuniform), ideal boundary conditions (but the boundary conditions are likely not ideal), and ideal loading conditions. I have had the opportunity to experimentally “verify” some FEA and the two almost never match exactly, even checking strains and deflections on relatively simple parts. The objective of FEA is to be as close as possible to reality, knowing that there will be some differences.

The role of FEA in most industries is to provide guidance for the design of a product or assembly. I have worked in several different industries and the normal practice is to conduct a series of design/analysis cycles before the first prototype is manufactured. After the first prototype is made, the design/analysis/prototyping may continue for a few more cycles to optimize the design.

The thermoforming industry seems to do the design/analysis process in reverse. They design a product and manufacture an expensive mold, usually without doing any analysis. If there is a problem, they add material to try to get to a
desired minimum thickness. Someone might start filing the plug assist. The last resort might be to do some analysis, and this is when perhaps I get the problem. At this point in the design process there is little chance of optimizing the product design and minimizing the material usage. I have attempted to get thermoformers to follow a standard product development practice, found in nearly every other industry, using FEA during the initial design process, without much success. Thermoforming is ideal for including FEA in the initial design process, things as simple as determining if it is better to have a male or female mold, modifying the product shape for better material distribution, or optimizing a plug assist geometry.

Dharia: (2) Predictions are apparent and not very useful.

Dees: The thickness predictions are very useful and should be conducted as the product is being designed. This is true for all FEA simulations of any kind. Predictions may not be “apparent”, especially when optimizing the plug assist or for a complex mold shape. I have written a white paper on optimizing a plug assist and the material saving that can result (ref. TQ 1, 2009).

Dharia: (3) Expensive to obtain material properties.

Dees: It is expensive to obtain material properties, that is why I use the same hyper-elastic material model for all thermoforming and blow molding simulations. The only drawback is that the amount of vacuum or pressure in the simulation may not reflect reality, but I have yet to have anyone ask what vacuum or pressure is required to form the material.

Dharia: (4) Too complex for an average TF to fully utilize it.

Dees: FEA simulations of thermoforming and blow molding require some expertise in both FEA and thermoforming/blow molding. There is a learning curve for the software and it can be expensive for a small company. However, the material cost is about 70% of the product cost for thermoformed and blow molded products, and significant saving can be realized by using simulations. For high volume products, it would seem that it would be worth the cost and effort to use simulations to optimize a plug assist geometry or compare processes to minimize material costs. For some unknown reason, there has been resistance to using FEA in the industry (perhaps due to the failure of the “black box” approach) and in some cases open hostility toward me when I propose it…perhaps it requires a better salesman than I am. Hopefully, the next generation of engineers will be more open to using FEA and its significant benefits.

Amit Dharia Ph.D. is the owner of Transmit Technology Group LLC and a plastics industry expert with over 35 years’ experience as a research engineer and entrepreneur. He has contributed numerous articles to TQ, is a regular participant in SPE forums, and is also a current member of SPE EPSDIV.

Jerry Dees (now retired) has over 45 years of engineering experience in the areas of structural/mechanical analysis, design, materials research, product development and teaching. Jerry started his company, Engineering Simulations LLC, in 2000, which is primarily focused on non-linear static and dynamic FEA of products and assemblies.

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Film is cycled through the machine. With each cycle, the foil (sheet) is heated by the main heating tunnel with upper and lower heating zones to the desired sheet temperature.

But with each cycle, the heated film stops in front of the cooled tool. The cooled tool has natural radiation and cools down the hot sheet. The slower the machine runs, the more the sheet cools down in front of the tool. This makes it more difficult to form the sheet because it is losing heat. This leads to poor material distribution: eventually you might find holes in the formed cup.

With a higher cycle speed, the cold tool has less influence on the heated foil. This means that with a higher cycle speed, the sheet cools down less: the result is a warmer sheet. This is easier to deform. Better material distribution.

With the foil temperature is 140°C (284°F) in front of the mold, you will form a good cup. If the cycle speed is slow, the sheet temperature must be much higher because the cold tool cools down the sheet. If the cycles speed is low, the foil is partially overheated in order to form the cup. Most cups are brittle when the cycles speed is low because the material has been destroyed.

With a higher cycle speed, the sheet does not have to be heated as much, so there is less stress on the films. And the cups are stable and tough.

With every increase in cycle speed, you will encounter new problems. These are so-called bottlenecks. Bottlenecks have to be solved step by step in order to be able to increase the cycle speed step by step.

<table>
<thead>
<tr>
<th>Cycle Speed</th>
<th>Influence</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 cycles per minute</td>
<td>4 seconds</td>
<td>Influence of the cold tool on the hot sheet</td>
</tr>
<tr>
<td>20 cycles per minute</td>
<td>3 seconds</td>
<td>Influence of the cold tool on the hot sheet</td>
</tr>
<tr>
<td>30 cycles per minute</td>
<td>2 seconds</td>
<td>Influence of the cold tool on the hot sheet</td>
</tr>
<tr>
<td>40 cycles per minute</td>
<td>1.5 seconds</td>
<td>Influence of the cold tool on the hot sheet</td>
</tr>
<tr>
<td>50 cycles per minute</td>
<td>1.2 seconds</td>
<td>Influence of the cold tool on the hot sheet</td>
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Editor’s Note: Our previous issue featured the first “Designer’s Corner” article, a new section of the magazine that takes a look at thermoforming from different viewpoints. This time around, we feature a European perspective of cup forming on thin-gauge machinery.
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How Can Innovation in Fiber Forming Benefit Plastic Converters?

For decades, plastic packaging has been a natural part of everyday life. In many ways it has been the prerequisite for a modern lifestyle and our society would not function without it. Packaging allows us to protect, preserve, store and transport products; it prevents food waste at scale; and it plays a crucial role in sustainability.

Convenience with a flipside

Concerns about plastic pollution began to be heard more and more around the turn of the century. The ‘Great Pacific Garbage Patch’ was discovered and the term ‘microplastics’ was coined. But it all burst into the public consciousness when David Attenborough in the “Blue Planet II” - in the most saddening way - showed us plastic pollution’s effects on ocean life. The emotional message in the documentary made an impact not only in the living room, but also in the board rooms of corporations all over the globe. Things started to stir.

Unlocking the potential of fiber-based packaging

A reasonable substitution for single-use plastics is fiber-based packaging, which is not only among the highest post-consumer collected and recycled waste material, but it is also renewable and biodegradable.

So why haven’t fiber-based materials already replaced more plastics? Since wet molding of cellulosic fibers was invented some 100 years ago, steps towards a cost-competitive, viable, sustainable fiber-based solution have been incremental.

The process of converting cellulose into rigid 3D-shaped packages has disadvantages that have made it difficult to compete with plastic. This was the starting point for the innovation of dry molded fiber, a fiber forming technology that converts cellulose into rigid packaging, that is price competitive enough to replace plastics in many single-use applications.

Opportunity for thought leaders

The packaging industry now must navigate a new landscape. As consumer demands, regulations, laws, directives, bans and bold sustainability commitments from the global FMCG companies multiply, converters need to proactively embrace sustainability issues.

There is no one-size-fits-all solution and various initiatives are needed in the race for sustainable packaging, but the right focus and innovative capabilities can bring new and unexpected growth opportunities for the converters that lead the way.

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as a medium to form and mold the fiber. Dry molded fiber has more similarities with plastics thermoforming, where production processes are fast, than with conventional fiber molding. The dry process enables manufacturing speeds that are up to ten times faster than conventional fiber forming methods. Hence, presenting unit economics competitive to plastic converting. Additional sustainability advantages include reduced valuable water resources, energy compared to wet molding, and lowers CO2 emissions up to 90% compared to plastics.

A patented technology

Dry molded fiber is not a material, a machine, or a product; it’s a technology, a method, just like thermoforming of plastics.

The technology is patented by PulPac and the first patents, were filed in 2016. The IP revolves around a novel production method, dry molded fiber, which is a method of manufacturing three-dimensionally shaped cellulose articles formed from dry fibers with air as a carrying medium and pressed using a heated mold. The company has global IP-coverage and claims ownership of dry molded fiber. The most general patent has been granted for markets in Europe, USA, and Japan. Based on the core IP, PulPac has developed a complete technology platform covering multiple areas of fiber application manufacturing, all driven by the need for disruptive technical solutions to enable a sustainable packaging industry. The portfolio is continuously growing and today there are 22 patent families covering different aspects of the process of dry forming cellulose.

Key aspects of the process

The raw material used is pulp, a commodity item, which has been developed over decades. It is a low-cost material that is globally available. There is no need for new, costly, or specific materials that demand years of R&D followed by scale-up and heavy investment. Chemical pulp is the standard raw material, but the process can handle other types of cellulose-based materials.

The pulp is fed into a mill that breaks it up into separate fibers. Fibers are transported by air to a vacuum belt to create a ductile air-aid material, or a web of loosely tangled fibers. The process enables complete control of fiber distribution and thickness.

The web is coated with barrier additive and laminated with tissue on either side. The barriers or additives are chosen based on the requirements of the product. The tissue adds clean surfaces, process stability, and can be used for coloring or printing the surfaces of the parts.

The parts are molded in a press using pressure and heat. When the part is done, it is form-stable and can be picked and placed. The press includes standard equipment but with uniquely designed tools.

The actual physical molding time of a part is below 0.5 seconds with 3.5 seconds for a full cycle where most of the cycle time is automation.

Up to 99% of trim waste material is recycled back into the process and converted back into air-laid material.


Market-ready applications

The low hanging fruit of the dry molded fiber technology are typically shallow products with simple shapes. These include trays, spoons, lids, and other applications with few compartments that have no or limited food or liquid contact. Those types of products are market-ready, and the first dry molded fiber products will be launched by European converters this spring.

Existing and market-ready barrier additives are already available for dry molded fiber. Within the field of fiber additives there is extensive R&D and future development. Both general and specific developments for dry molded fiber are to be expected.

Sustainable barrier solutions at hand

The dry process opens for new ways of applying barrier additives compared to existing fiber forming methods, especially in in-line production, with spray, laminates, or other application methods. The development of hydro or oleophobic barriers adapted to the dry molded fiber process is an important part of Research & Development around the technology.

Using sustainable, non-toxic barriers is key to making fiber into a viable packaging alternative for the future. It is also necessary to challenge product specifications when shifting from plastics to fiber. The performance of a product should not be over-engineered; it should be designed for its purpose. A coffee lid should be fully functional for a few hours. If it starts to soften after it is used, it is not a drawback - it is a sustainability requirement.

Existing and market-ready barrier additives are already available for dry molded fiber. Within the field of fiber additives there is extensive R&D and future development. Both general and specific developments for dry molded fiber are to be expected.

The products – ultimate proof of the technology

The ultimate proof of any technology is the use of it, i.e., the products that can be manufactured with it.

Going from one material to another requires detailed knowledge of design elements and functionality. It is not a 1-to-1 approach. Material characteristics such as required product strength, design elements including stacking and de-nesting features, and barrier properties are factors that need to be combined to create a functional part.

Looking at the future, the technology sets few limitations on what kind of products it can be used for. It is primarily a matter of research and development. In the lab environment, complex applications, and geometries such as bottles have been made with great success.
Market-ready sustainable fiber barriers holding carbonated drinks with long shelf-life are still lacking. Given that this is somewhat of a Holy Grail for fiber packaging, we should expect to learn more about this in the not-too-distant future. In a similar way, a lot of research is going on around material science, including ways to use different types of agricultural residue.

So, how can plastic converters benefit from Dry Molded Fiber?

PulPac, the inventor and owner of dry molded fiber, is scaling their technology quickly and globally through a licensing model. Their approach on business might breed a different perspective than one normally seen in the packaging industry, but licensing is a proven business model for scale-up of new industrial technologies.

The typical dry molded fiber licensee is as a convertor, often working in close cooperation with a brand owner. Licensees invest in and set up their own production. They co-own the technology and have full access to all present and future IP and know-how within its license, and to non-patentable trade secrets within dry molded fiber technology and processes. Technology as a service - in exchange for royalties.

For plastic converters, this new thermoforming-similar-technology presents an opportunity to get ahead of the curve and explore the future of fiber-based packaging. For technology transfer, support, and supply there is an ecosystem of global dry molded fiber partners, including the company that invented and keeps perfecting the technology.

To date, licensees and partners have invested close to 100 million dollars in dry molded fiber and the company behind the new technology has their aim set on having replaced 1 million tons of plastic by 2025.
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Thermoform Circularity: Unlocking a New Source of PCR Material for Thermoforming

**Editor’s Note:** The following article is adapted from a recent publication by Plastic Ingenuity, a thin-gauge thermoforming company with facilities across N. America. As industry associations and trade groups continue to issue guidance about recyclability, thermoforms are not always considered in the same breath as PET bottles. It is critical that converters pay close attention to design considerations in order to ensure higher levels of recycling for thermoformed parts.

There is no way to achieve true circularity in plastics without including thermoforms.

The demand for Post-Consumer Recycled (PCR) material is steadily increasing due to brand commitments and legislated mandates, but there is not enough material recovered from bottles to satisfy the demand.

The volume of thermoforms in the market presents a tremendous opportunity to build a novel source of PCR material.

Thermoformed packaging made from PET is recyclable when design for recycling guidelines are applied. However, thermoform recovery rates significantly lag beverage containers. 134 million pounds of PET thermoforms were recovered in 2020 according to NAPCOR. This equates to a recovery rate of 7.3%, much lower than the 26.6% recovery for beverage containers. Recovery rates are even lower for non-PET materials like PP. The chart below, data courtesy of NAPCOR, shows the steadily increasing recovery of PET thermoforms.

There simply is not enough PCR from bottles to supply the market.

Although 134 million pounds sounds like a lot of material (and it is!), capturing unrecovered thermoforms has the power to transform the PCR market. Demand for PCR is growing exponentially, driven by brand commitments, and legislated minimum PCR mandates, but supply cannot keep up. The chart below highlights the sizable gaps between brand owner PCR targets and current levels.

Competition for PET PCR from bottles is stiff due to its utility in a variety of end market applications. Although thermoforms are the top consumer in California of bottles recovered in their container redemption system, a significant amount of PCR PET is consumed in fiber and strapping. Carpet, specifically, is a major consumer of PCR PET. The bottom line – PCR PET is in high demand and packaging applications are competing with other industries over the limited supply. When coupled with increasing demand from brand commitments, there simply is not enough PCR from bottles to supply the market.

The following charts using data from NAPCOR shows the recycling rate and investment needed for PCR from bottles to supply all market demand. At PCR content levels of 50%, a bottle recycle rate of 78% and additional investments of $3.1 billion in reclamation capabilities are required. Many legislative mandates and brand owner targets call for this level of PCR by 2030. Thermoforms are a relatively untapped source of PCR that can help bridge this gap.
PET thermoforms are recycled today by inclusion in low percentages with PET bottles collected curbside. MRFs typically cap the level of thermoforms included in bottles bales at 10-20% depending on agreements they have in place with their customers.

Unfortunately, many of these agreements do not allow thermoforms at any level. In an encouraging development, MRFs are starting to sort and market thermoform-only bales on the west coast, as evidenced by the bale pricing chart on the right courtesy of NAPCOR. This signals that a market is emerging for recovered thermoforms.

**Thermoform Circularity Challenges**

When discussing the recyclability of a packaging format, we must consider all four pillars of the practice of recycling: Collection, Sortation, Reprocessing, and End Markets.

**The Case for Optimism**

The exponential growth in demand for PCR materials will accelerate efforts to increase recovery of thermoforms. A very promising sign is the emergence of brand commitments for PCR recovered strictly from thermoforms.

Driscoll’s is an example of a national brand leading the way to thermoform circularity. They have committed to use PCR from thermoforms in their clamshell packaging. The method by which they built a supply chain for this material through collaboration is a best practice from which packaging professionals can learn.

Intelligently crafted policy has the potential to accelerate thermoform circularity. Thermoforms are a major consumer of PCR material but recovery rates need to increase to realize full circularity. Policy that encourages the use of PCR in thermoforms and provides incentives for recovery would be embraced if crafted in collaboration with industry stakeholders. PCR mandates can further bolster demand, but targets must be realistic given PCR supply constraints and competition from other applications.

The rapid evolution of sortation equipment provides another reason for optimism. The rise of artificial intelligence and near infrared (NIR) sortation technology will improve thermoform capture rates and MRF efficiency. This is a must as packaging shapes and structures continue to evolve. These technologies require significant investment, underscoring the need for stable market demand to justify the return on investment. Reprocessing technology is also advancing to keep pace with demand.

Advancements in twin-screw extrusion equipment and IV boosters are promising examples.

Advanced recycling technologies present the industry with a potential long-term solution to the supply gap. These technologies turn the clock back on waste by changing the chemical structure back to its molecular building blocks. Advanced recycling is a potential solution for hard-to-recycle thermoformed structures like multilayer barriers. The technology will require significant time to scale but evidence of sizable investments from capital firms, resin producers, and brand owners is encouraging.

The industry is activated to discover solutions to increase the recovery of thermoforms. This is evident in initiatives like “The Collaborative PET Thermoform Project” led by Resource Recycling Systems (RRS). This initiative is the most significant collaboration of brands, converters, recyclers, trade organizations, and resin suppliers focused on thermoform recovery. These collaborations are essential to achieve circularity.

**The Future of Thermoform Circularity**

The packaging industry must balance the immense benefits of plastic – the fact that it’s lightweight and highly effective at food preservation, while also having a much smaller carbon footprint.
PET thermoform access rates fell below the 60% threshold needed to claim recyclability per a declaration by the Sustainability Packaging Coalition (SPC) in 2020. Simply put, not enough people have access to recycling programs that accept thermoforms. This was primarily due to the market impact on municipal recycling programs of waste import bans. These programs are very costly to operate despite public perception. This lack of recycling access results in a “check locally” designation for thermoformed articles (at best) by SPC’s How2Recycling program.

A strong end market for thermoform PCR creates the necessary incentives for MRFs to sort and recyclers to reprocess recovered thermoforms. The market is in a nascent stage but there is evidence of encouraging market signals, including thermoform-only bales.

If the industry is going to realize the potential of recovered thermoforms, more brands must step up and make the demand commitments to bolster this emerging market.

America’s recycling infrastructure needs modernization. MRF's were originally designed to handle newspapers and glass bottles. The benefit of plastic is that it can be molded into an unlimited number of shapes in sizes. This presents challenges for sortation at large scale. Labels, adhesive, and ink choices can impact the ability to sort and reprocess.

PET thermoforms can be sorted into their own bales, as evidenced by recent market signs. However, to do this efficiently, investments are needed in state-of-the-art sortation technology like robotics, NIR sorters, and artificial intelligence.

Recyclers that process PET thermoforms encounter some unique challenges that must be addressed to fully unlock thermoform recycling potential. Contamination from lookalike packages in the stream such as PLA and PVC, is a prevalent challenge.

PET PCR material for packaging requires additional processing steps to make sure the material can meet the application demands. This may include a step to boost the intrinsic viscosity (IV) to improve physical properties. Thermoforms tend to have a lower IV than bottles collected for recycling due to an additional heat history in the original manufacturing process. Color variation, particularly yellowing, and a higher level of specs and inclusions is a likely outcome.
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- Process: Sheet Extrusion
- Resins: PS, PP, HDPE & PET (...and more!)
- Gauge: 9 – 60 MILS
- Structure: Mono- and/or Co-extrusion
- Winding: 1 & 2 Up
- Rates: 1000+, 2000+, 3000+, & 4000+ pph
- Width: 36 - 68 inch sheet widths

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footprint than alternatives – with the reality that too much plastic goes to waste. Increasing the recovery of thermo-formed packaging is imperative if we are to continue reaping these benefits while ensuring more plastics get recycled.

The good news is viable solutions are available using readily available technology and well-established best practices.

Here are some ideas packaging creators, brands, and other stakeholders can use to maximize their impact:

By working together to improve thermoform recovery, we can lead the shift to a circular economy and ensure a sustainable future for plastic packaging of all formats.

<table>
<thead>
<tr>
<th><strong>PCR Commitment</strong></th>
<th>Pledge to increase the use of PCR in packaging. Specify PCR from thermoform sources to help drive market demand for thermoform recovery.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design for PCR</strong></td>
<td>Engage with internal groups to understand what is truly critical to quality so specifications are suitable for PCR variability.</td>
</tr>
<tr>
<td><strong>Communicate Benefits</strong></td>
<td>Consumers want to purchase products from companies that are sustainable. Communicate sustainability benefits to quench this consumer demand.</td>
</tr>
<tr>
<td><strong>Design for Recovery</strong></td>
<td>Reference the APR design guide for new packaging design. Use features that are preferable to recycling and avoid features detrimental to recycling whenever possible.</td>
</tr>
<tr>
<td><strong>Consumer Education</strong></td>
<td>Use the How2Recycle label for explicit instructions on how to recycle a package.</td>
</tr>
<tr>
<td><strong>Get Involved Locally</strong></td>
<td>Reach out to a local MRF and recycling community. Understand their gaps and bring that info back to internal stakeholders for consideration.</td>
</tr>
<tr>
<td><strong>Collaborate</strong></td>
<td>Consider joining groups focused on improving recycling such as APR, SPC, TRP, NAPCOR, HPRC, and FPI. Reach out to suppliers at all levels of the packaging supply chain. Understand their challenges and areas where help is needed. <strong>Challenge them!</strong></td>
</tr>
</tbody>
</table>

By working together to improve thermoform recovery, we can lead the shift to a circular economy and ensure a sustainable future for plastic packaging of all formats.
Thermoforming & Sustainability

Exploring the Sustainability of Bioplastics
By Jimmy Shah, Sr. R&D Engineer, Impact Group, Hamlet, NC

Sustainability is a broad concept prone to varying definitions depending on the market, situation, or application. Generally speaking, there are three main pillars to consider for plastics or another industry segment when evaluating sustainability:

1. Environmental impact (CO₂ emission, waste management, etc.)
2. Economical impact (governance, risk management, etc.)
3. Social impact (end to end stakeholders including community)

These are sometimes represented as Environmental, Social, Governance (ESG). As a core definition, being sustainable or achieving sustainability means meeting the needs of the current generation without compromising the ability of future generations to meet theirs. Sustainability presumes that resources are finite, and should be used conservatively and wisely with a view to long-term priorities and consequences. Sustainability can very well be compared to traditional cultures where you are always taught to save - save for the future, for retirement, for children and grandchildren.

Why is this so important now?
So why is the topic of sustainability in packaging materials, particularly plastics, so commonplace now when plastics have been around since the 1900s, with relative production rate change over 75% from 2000 to 2015 to a booming 380 million tons annually. Consumers and industry professionals have come to the realization that infrastructure is lacking to properly handle the amount of plastic production in a manner that reduces waste and promotes circular economy practices while still enjoying all the benefits that plastics offers in our modern society. Various data sources indicated that the latest worldwide plastics production count is over 380 metric million tons and the US recycling rate is under 10%. Since 1990, the plastics recycling rate increased on average by about 0.7% per year and with more and more recycling infrastructure (recyclers, both mechanical and chemical) coming on board globally, it is expected that by 2050 the recycling rate could quadruple to almost 44% than where it stands today based on extrapolated historical trends. In 2015, an estimated 55 percent of global plastic waste was discarded, 25 percent was incinerated, and 20 percent recycled.

Exploring the sustainability of bioplastics
Sustainable packaging materials are those that promote or increase the 3 Rs - reduce, reuse, and recycle. Each “R” achieved would ultimately contribute to the three pillars of sustainability goals. The concept of bioplastics, including biodegradable and compostable plastics, have taken center stage in recent years as converters and brand owners attempt to develop viable solutions that both fulfill the requirements of the packaging and address societal concerns regarding waste.

These three terms - bioplastics, biodegradable plastics and compostable plastics - are often used interchangeably, but they are not synonymous and they are not the same when it comes to end use performance. The key is to understand the material’s source and its ultimate destination at the end of its useful life.

- **Bioplastics** refer to a large family of plastics which are sourced from renewable biomass sources such as corn starch, cellulose, vegetable fats and oils, sugars, and acids, etc. which are metabolized into organic biomass at the end of their life (biodegradable), or both. Not all bioplastics are biodegradable, nor do certain of them biodegrade more readily than fossil fuel-derived plastics.

- **Biodegradable** plastics are those that can be decomposed into water, carbon dioxide, and biomass over time with the help of micro-organisms. The biodegradability of a plastic material lies in the chemical properties of the polymer. Thus, biodegradable plastics can be made with petrochemicals, microorganisms, renewable raw materials, or a combination of all three. Biodegradable product disposal type (physical properties, shape, thickness, surface area) and environmental conditions (temperature, photodegradation, hydrolysis, presence of microorganisms) vary dramatically from one place to another, thus biodegradation is never linear or uniform. Biodegradation of polymers can be tailored specifically for controlled degradation under inherent environmental stresses in biological systems either alone or by enzyme-assisted mechanisms. Depending on the chemical backbone of the polymer, we can classify degradability.
For example, there are several hydrocarbon compounds such as n-alkanes that have the least resistance to biodegradation compared to branched alkanes, low molecular weight aromatic cyclic alkanes, and high molecular weight aromatics or polar polymers that have the highest resistance to biodegradation. Biodegradable material can be designed to break down in soil, fresh water, or salt water.

- **Compostable** plastics are part of the biodegradable plastic family and refer to materials that, when put in industrial or home composting conditions, will degrade within a certain timeframe. All compostable plastics are biodegradable, but not all biodegradable plastics can be considered compostable. There are two primary categories of compostable plastics differentiated by the environment in which the composting process happens:
  - **Industrial Compostable:** Bacteria will break down plastics into organic waste under rigorous favored temperature and conditions designed and available at industrial scale facilities only. Almost 99% of the material designated for composting refers to industrial composting systems and is not suitable or would not decompose if attempted in home composting.
  - **Home compostable:** Bacteria will break down plastics into organic waste in a home environment including backyard/garden compost bins over time under normal temperature and humidity conditions. Currently, there are no international standards that define home compostable plastics, but there are several national standards that specify the properties, conditions, and test methods that a material must meet in order to be in compliance to be certified as home compostable.

**Processing techniques for bioplastic materials**

Just like traditional plastics and polymers, biodegradable, compostable, and compostable additives can be processed using traditional techniques including injection molding, extrusion-blown film, and rigid sheet thermoforming. There are a few polymers that need extra attention and care due to their inherent hygroscopic and corrosive nature where standard carbon/iron-based materials can be compromised.

**Standards and tests to measure biodegradability of plastics**

Today, most of the biodegradable or compostable materials, polymers, and additives commercially available are certified and comply with either ASTM or European standards. There are several test methods under both sets of standards for each environmental requirement, e.g., aerobic (presence of free oxygen) and anaerobic (absence of oxygen but presence of other chemical elements) composting conditions. ASTM D6400 (“Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities for Aerobic Conditions”) and EN13432 (“Packaging Requirements for Packaging Recoverable Through Composting and Biodegradation for Anaerobic Conditions”) are the most popular test standards. Current international standards for biodegradation propose that a material is considered biodegradable in water if it shows complete degradation in 56 days, and in soil if it biodegrades in 2 years. Certification and compliance to these standards ensures that the packaging material can be industrially composted.

**If traditional plastics are industrially or home composted, will they degrade and create microplastics?**

Due to a lack of knowledge and understanding, and sometimes deliberate greenwashing, there are several marketing claims where “oxo plastics” are promoted as biodegradable. Oxo plastics refer to polymers with the addition of bio-additives and metal oxide additives that cause the plastic part to fragment into smaller and smaller pieces, but not to the point where the material reverts to its molecular or polymer level and can be considered biodegradable. Depending on the chemical composition of the polymer and or additive used in the product, an oxo-degradable plastic could degrade into microplastics which are particularly detrimental to the environment, especially for ocean and marine life. So, just like any other plastics in landfill or ocean, microplastics created from oxo-degradable plastics will be left in the environment indefinitely with little to no chance of recycling. There are several countries where use of oxo-additives and/or oxo-plastics is banned.

**Advantages and disadvantages of biodegradable/compostable materials**

There are several advantages and disadvantages to consider when evaluating the use of bioplastics, though it should be acknowledged that there are divergent opinions across regions of the world:
Advantages:
• Made from renewable plant based raw materials
• Low carbon footprint and energy demand compared to some traditional polymers
• Potential to breakdown with no residuals or pollutants
• Compostable and biodegradable in relatively short duration
• Cleaner environment

Disadvantages:
• Limited material properties and material functionality
• High cost and limited capacity
• Requires specialty metallurgy and or coated tooling configuration to process
• Could contaminate standard recycling streams with high maintenance and repairs cost
• Mislabeling could create more landfill problems
• May not degrade or compost in marine life and thus not an answer to marine litter
• Could lead to high litter rate in developing countries if mislabeled as easy to compost or home compostable

The end or the beginning?
I am strongly inspired by, and believe in, Mahatma Gandhi’s quote: “Be the change you wish to see in the world.” As individuals and businesses, I believe this should be the mindset and goal when it comes to sustainability. Sustainability starts from within and everything we pursue affects the world in a positive or negative way. Plastic is such a great invention and resource, but we expect plastics to disappear, yet there is a different perspective on glass or metals which are also found in landfill and marine environments. We blame plastics for all the land and marine world pollution, but it is in fact humans who are the principal agents, who do not care enough about plastics and recycling, and now we are looking for a quick fix. As consumers our goal should be to reduce single use plastics, reuse and recycle what we can, segregate the plastics waste for recycling, and be proactive by educating ourselves on plastics and recycling. As designers, processors, converters, we should always put sustainable design and material solutions as the primary goals for all the end market segments, we serve, whether food, medical, automotive, or other custom product and packaging applications. Bioplastics, biodegradable plastics and compostable plastics have potential and while they are not perfect, they are important in today’s world as we strive to reduce our environmental footprint. With continued research and breakthrough, hopefully someday there will be solutions that can meet the characteristics and performance of a traditional plastics while also meeting the three pillars of sustainability.

Jimmy is a Sr. R&D Engineer at Impact Group and is based in North Carolina. Jimmy’s expertise lies in sheet extrusion, material formulation, and cost estimation for rigid multi-layer high barrier and non-barrier food and medical packaging applications using sustainable material resources. Jimmy works very closely with suppliers and customers for new product and process development from the concept phase to the commercialization for new product development to support commercial team. Jimmy is an active member for Society of Plastics Engineering (SPE) and serves as a Chair for Young Professionals Committee (YPC) by SPE that helps connect young professionals to industry veterans.

Impact Plastics currently offers biobased PET rollstock and is actively working with suppliers and customers to evaluate biodegradable additives well as cellulose-based sustainable material solutions that are home compostable for various food and medical packaging applications. Reach out to us to learn more about our sustainable material solutions for your next thermoforming project.

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