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- Conference Review: European Thermoforming
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Chairman’s Corner

Looking back on my past two years as SPE Thermoforming Division Chairman, time certainly flew quickly.

Past Chair, Eric Short, passed the gavel to me during the February 2020 board meeting, and I was excited to implement plans that we had prepared as a board. I had a list of goals to accomplish by 2022, and one week after that meeting concluded, it became evident that we were heading into a very serious situation. Within the next few short weeks, the world had shut down along with my intentions and goals I had set for myself as chair.

I am grateful to the board and its helpful guests who are always quick and nimble to react. Zoom and Microsoft Teams challenged people to work regularly and collaboratively in a remote environment. We worked together remotely - and eventually again in person - to accomplish our goals. We planned a fantastic hybrid conference, including workshops and an interactive executive forum. We also launched a series of webinars to provide additional content to our audience. Board members moved into different roles without hesitation to best serve the organization. When COVID-19 returned for a second wave, we contemplated postponing our Grand Rapids conference. After careful consideration, we determined it was best to stay the course.

Conference and technical program planning were underway, and we were faced with yet another challenge. Our devoted division administrator and conference coordinator, Lesley Kyle, advised me that she made the difficult decision to change careers. At that point, much of my focus was devoted to working through this with Lesley and developing a plan while trying to find a replacement(s) to take over the many tasks she handled for us. Out of respect for my dear friend and close advisor, Lesley Kyle, discretion was critical to remaining focused on the conference and other tasks at hand.

Much of my attention turned to succession planning and transition. Lesley stayed on with us the entire way, helped us find the best candidates, and continued as a consultant to educate both board members and her successor on tasks she handled. After many qualified applicants and many interviews, the board selected Shameka Jennings, our new Division Administrator and Conference Coordinator. Shameka recently joined the board in April and met everyone during our spring board meeting in Fort Myers. I wish Shameka great success with our organization.

The Division also on-boarded a public relations firm, Next Step Communications, and we have committed to projects during the next fiscal year to provide content and value to our membership. We introduced a media kit and additional marketing initiatives to create new opportunities for our loyal conference and SPE Thermoforming Quarterly magazine sponsors. In the coming months, we will also expand our social media presence to reach different industries and continue to reach out to synergistic groups on partnership opportunities. We are focused on membership engagement and making it easier for all to get the content necessary to help in their careers. Hybrid conference, committee, and board meeting options will hopefully attract larger audiences who want to learn more about us and get involved. We will not go dark between conference years.

I thank the board for putting its faith in me and supporting everything we proposed. Tireless efforts have gone a long way! I thank the ownership of Formed Plastics, Pat Long and Dave Long, for their encouragement and continued support. I thank my team at Formed Plastics for listening to what I learned from the SPE Thermoforming Division. Your willingness to make changes and your drive toward continuous improvement have provided us with fantastic opportunities. We are better thermoformers because of everyone we have met in this business along the way. That is what the SPE Thermoforming Division does for my company and me. This is why it is so important for all of us to give back when we can. If you are not involved with the board, please consider doing so. I am a strong believer in getting back from what you put in - and pay it forward!

Ed Probst will be the next Chairman. Ed is a heavy gauge thermoforming processor with many years of experience in every angle of the business. A long-time board member, Ed has served as Conference Chair, Communications Chair, and Treasurer. He previously served as chair of SPE's Product Design and Development Division (PD3). Ed brings years of experience and a passion to educate everyone in our industry to his new role.

To new beginnings, new experiences, and new times. I wish all of us continued success in the years ahead. The best is yet to come!

Steve Zamprelli
Formed Plastics, Inc.
Carle Place, New York
I wish we had an ILLIG...

WOW. We’re getting perfect products in 20 minutes. I’ve never seen that on other machines.

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Sinclair & Rush, Inc. Acquires Indepak Corporation - Partnership Expands Capacity and Portfolio of Innovative Packaging Solutions

ST. LOUIS (PRWEB)

JUNE 03, 2022 – Sinclair & Rush, Inc. has successfully completed the acquisition of Indepak Corporation of Portland, Oregon, a thermoform manufacturer specializing in custom trays, blisters and clamshell packaging primarily for medical and food applications. Indepak also supplies world-class manufacturers with highly engineered thermoformed shipping trays used in the aerospace, defense and automotive industries. Sinclair & Rush, a leading manufacturer of clear plastic packaging products, significantly increases their thermoforming capacity and capabilities while also providing a manufacturing footprint on the west coast. Production will continue at the existing Indepak facility along with other Sinclair & Rush manufacturing locations in Arnold and Fenton, MO and Carlstadt, NJ. Sinclair & Rush also offers international manufacturing capabilities in the United Kingdom, China and Australia.

“The acquisition of Indepak Corporation is aligned with our growth strategy for thermoforming and presents us with numerous new business opportunities,” said Brad Philip, President and CEO of Sinclair & Rush, Inc. “This transaction gives us the ability to increase our footprint in the medical and food packaging business and expands our opportunities in industrial markets. Packaging and product design trends change frequently, and by combining our product lines, our services and our years of expertise, our customers gain the unique position of having access to multiple thermoforming and packaging options from one partner. We are pleased to acquire such a forward-thinking company that enjoys solid business relationships with its loyal customers, many of whom are internationally renowned.”

The Sinclair & Rush customer base, particularly those within its VisiPak division, will now enjoy the benefits of having an expanded team of world-class packaging designers, another in-house tooling operation, additional capacity, closer proximity to their operations when located west of the Rockies and a food packaging certified manufacturing option. The Indepak customer base will now have an additional design team and in-house tooling operation, another manufacturing location to consider if their operations are located east of the Rockies and the complete line of Sinclair & Rush packaging and product protection solutions including plastic tube container packaging, clear folding cartons and over 200 variations of in-stock clamshells.

Jeff Barket, Director of Sales and Marketing for Sinclair & Rush, Inc., stated, “The combination of Indepak and Sinclair & Rush brings together two highly innovative organizations that further enhance our place as a North American leader in consumer, industrial, medical and now food packaging. The value of having access to multiple thermoforming and packaging options from one partner is multiplied when projects can begin and end under one roof. The global, regional, and local customers of both companies will gain access to a broader product portfolio, increased product differentiation, redundancy in operations to mitigate supply risks and operating efficiencies that will further enhance their brands and grow their bottom line.”

Connecticut-based Inline Plastics buys Michigan-based Cam Packaging, Opening First Midwest Plant

Sarah Kominek, Plastics News

May 20, 2022 – Shelton, Conn.-based thermoformer Inline Plastics Corp. has opened a new manufacturing plant in Gladwin, Mich., formerly belonging to Cam Packaging LLC, securing its first Midwest production and distribution facility.

Inline needed to expand to meet consumer demand for secure food packaging, such as tamper-evident and tamper-resistant polypropylene containers for hot food, it told Plastics News in an emailed statement.

“Consumers continue to look for convenient packaging that offers … food safety,” the statement said. “This acquisition allowed us to immediately expand our operations and begin producing and supplying our customers from a Midwest location.”

The purchase included Cam Packaging’s thermoforming machines, Inline said. Cam Packaging’s workforce has continued under the new owner, now as Inline employees.
The new facility is up and running, a May 3 news release said.

“[Cam Packaging’s] large-bed thermoforming machines and talented workforce will provide Inline with an instant increase in capacity to fulfill customer and consumer demand for our food packaging that delivers quality, freshness and eye-catching merchandising,” Tom Orkisz, chairman and CEO of Inline Plastics, said in the release.

Inline also has facilities in McDonough, Ga.; Shelton, CT; and Salt Lake City, UT.

Inline is a family-owned business, founded by brothers Rudolph and Gene Orkisz in 1968. The company is No. 33 in Plastics News’ ranking of North American thermoformers, with sales of $86 million.

Joe Oberloier founded Cam Packaging in 2015. He previously owned Packaging Direct and has been in the thermoforming sector for more than 40 years, starting out as a teenager sweeping floors at equipment maker Lyle Industries.

Cam Packaging was tied for No. 163 in the PN ranking, with sales of $3.5 million.

Good Natured Adds Thermoforming Capacity in Texas

Jim Johnson, Plastics News

May 9, 2022 – Thermoforming company FormTex Plastics Corp. is being sold to a Canadian company, Good Natured Products Inc., for $4.8 million.

FormTex, based in Houston, adds $4.9 million in annual sales as well as approximately $600,000 in earnings before interest, taxes, depreciation and amortization for the 2021 calendar year. Revenue for the 12 months ending Feb. 28 was $5.1 million.

Acquiring the company will result in $200,000 to $300,000 in cost savings in the first year after closing, Vancouver-based Good Natured said. The deal is scheduled to close May 31.

FormTex makes packaging for the medical, food, electronic, industrial and retail markets. The company operates seven thermoforming machines in 51,000 square feet of leased space on a 1.9-acre parcel, Good Natured said.

The company currently is only using 40 percent of its manufacturing capacity, so Good Natured sees “significant potential” to increase throughput on current machinery as well as add more thermoforming machines in existing space.

“We believe FormTex represents a very attractive acquisition for Good Natured building on the strong foundation in our packaging business and expanding our geographic reach to highly strategic and synergistic markets,” Good Natured CEO Paul Antoniadis said in a statement.

“We expect to access cost synergies by directing internally produced extruded rollstock sheet for use in FormTex’s operations, expanded capacity to handle the company’s growth trajectory, and through logistic and operational efficiencies,” Antoniadis said.

The combined company plans to supply extruded roll stock sheet from its Ex-Tech facility to FormTex, a move that “is expected to result in material positive financial synergies,” said Good Natured.

Good Natured acquired Ex-Tech, of Richmond, Ill., in May 2021 for $14.1 million. Ex-Tech makes plastic sheet and film products, including extruded rollstock for thermoformed packaging. At the time of that purchase, Good Natured said Ex-Tech operated seven extrusion lines in a 75,000-square-foot facility.

Good Natured will use a term loan of up to $1.8 million as well as $3 million in chase from an $8 million stock offering.

Good Natured also acquired Shepherd Thermoforming and Packaging of Brampton, Ontario, in early 2021. That move added six thermoforming machines in 42,000 square feet of space.

The new owners of FormTex said they “will be able to leverage Houston-based manufacturing, importing, warehousing and logistics to serve the southeastern U.S. market.”

Shepherd Thermoforming and Packaging is No. 141 on the most recent Plastics News list of North American thermoformers with estimated annual sales of $6.5 million. FormTex is tied at No. 144 on the same list.

Solegear Bioplastic Technologies Inc. changed it name to Good Natured in 2017.
East Jordan Plastics Building
$44M Plant in Georgia

Frank Esposito, Plastics News

April 21, 2022 – Horticulture products maker East Jordan Plastics Inc. will spend more than $44 million to build a new facility in Lyons, Ga.

The project is expected to create 80 new jobs. The new plant was announced April 21 in a news release from Georgia Gov. Brian Kemp.

EJP makes thermoformed and injection molded horticultural containers — including pots and trays — for greenhouses, nurseries and garden centers. Most of the firm’s containers are made with a high percentage of recycled plastic and are recyclable. EJP recycles over 20 million pounds of horticultural containers a year.

The new plant will cover 255,000 square feet. In its first year of operation, the site will be used for logistics and distribution, adding recycling and manufacturing operations over the next five years.

“We’ve been laser-focused on producing good jobs in rural Georgia, and East Jordan Plastics will be met with eager, hardworking Georgians … to serve their rapidly growing customer base,” Kemp said in the release.

East Jordan, Mich.-based EJP “is thrilled to be joining the Lyons community, and we look forward to making this project a huge success for all stakeholders,” President Scott Diller added.

“We are grateful to the state of Georgia and Toombs County for their business-friendly and forward-looking leadership providing the opportunity to grow EJP in this strategically significant and beautiful part of the country,” he said.

Family-owned EJP was founded in 1947 and first made wooden greenhouse flats before transitioning to plastic containers. The firm describes itself as one of largest horticultural thermoformers in North America.

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Greiner Packaging Launches New T-IML Cup

Bruce Adams, Plastics Today

February 20, 2022 (edited) – Greiner Packaging has developed a technique for thermoforming cups with in-mold labels (IML) that requires less material, is lighter in weight, and is more recyclable than similar IML cups produced via injection molding.

In addition, the sheet used in the thermoforming process to make the cup can be embedded with barrier properties, which can extend the shelf life of packaged food and help reduce food waste, according to Sebastian Eisenhuber, Global Product Group Manager.

Beyond injection molding–based IML

IML typically is used in combination with injection molding technology. The thermoformed IML cups are more sustainable by several measures, according to Philipp Maurer, Key Account Manager at Greiner Packaging. Less plastic is required to produce thermoformed cups, which saves resources and makes the cups lighter and less costly to transfer. This requires fewer carbon dioxide emissions during transport.

When possible, Greiner Packaging tries to use recycled material, although the use of mechanically recycled material for food applications is limited because of strict approval criteria. Currently, only rPET meets those requirements.

During in-mold labeling, a label is inserted into the thermoforming mold that shapes the product and forms a solid bond with the finished product. Shaping and decoration are performed in a single, efficient process.

Thermoforming achieves 25% weight reduction

After investing in a test mold, Greiner Packaging is able to manufacture 500-milliliter thermoformed IML (T-IML) cups with a diameter of 95 millimeters. By switching from injection molding to thermoforming, the cup’s weight was reduced from 15 to 11.4 grams, a 25% reduction, Eisenhuber said.

T-IML is an especially high-quality form of packaging decoration, the company said. Matte, rough, glossy, or soft-touch decorative effects can be applied, and the printed content is photo quality and “visually outstanding,” Maurer said. “IML packaging solutions are extremely effective at attracting consumers’ attention at the point of sale.

Greiner Packaging employs a workforce of almost 4,900 at more than 30 locations in 19 countries worldwide. In 2020, the company generated annual sales revenue of €692 million ($783 million), including joint ventures, which represents approximately 35% of Greiner’s total sales.
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We invite you to reach out to our skilled technical team anytime for information and advice on the best way to utilize, polish, machine and run with our HYTAC® materials.
Plastics Industry M&A Activity Tracking

APRIL 2022

Editor’s Note: We thank Jon Hart at PMCF for permission to reprint portions of their M&A monthly reports. Visit www.pmcf.com for more information.

Global Plastics M&A slowed in April 2022, recording 26 deals in the month which was down from 36 transactions in March. While April marks the first time since February of 2021 that plastic transaction volumes fell below 30, deal activity remains elevated through the first four months of 2022. This level of deal activity is more in line with transaction volumes witnessed prior to the COVID-19 pandemic. Overall, Global Plastics M&A has exceeded 2021 levels through the first four months of the year and remains robust.

- Public strategic buyers accounted for 39% of the deal volume in April 2022 which was up from 19% in March and 15% in 2021
- Private equity add-on acquisitions remained strong with 9 deals in the month which was only down 1 transaction from March 2022 levels
- Specialty transactions including machinery, distribution, foam, and profile extrusion deals led the way in April with 11 transactions in the month; through the first four months of the year, the Specialty subsector averaged 13 transactions
- The Injection Molding subsector recorded its lowest level of activity since May 2020; Injection Molding M&A activity has slowed in 2022, posting 17 fewer transactions in 2022 compared to 2021 year-to-date
- Consumer and Food & Beverage transactions accounted for 35% of the transactions

### PLASTICS M&A BY SUBSECTOR

<table>
<thead>
<tr>
<th>Subsector</th>
<th>Month-to-Date 2021</th>
<th>Month-to-Date 2022</th>
<th>% Change</th>
<th>Year-to-Date 2021</th>
<th>Year-to-Date 2022</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blow Molding</td>
<td>2</td>
<td>0</td>
<td>-2</td>
<td>8</td>
<td>7</td>
<td>-1</td>
</tr>
<tr>
<td>Injection Molding</td>
<td>12</td>
<td>4</td>
<td>-8</td>
<td>47</td>
<td>30</td>
<td>-17</td>
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<tr>
<td>Film</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>26</td>
<td>27</td>
<td>1</td>
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<tr>
<td>Resin / Color &amp; Compounding</td>
<td>5</td>
<td>3</td>
<td>-2</td>
<td>18</td>
<td>15</td>
<td>-3</td>
</tr>
<tr>
<td>Sheet &amp; Thermoforming</td>
<td>3</td>
<td>2</td>
<td>-1</td>
<td>8</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Specialty</td>
<td>8</td>
<td>11</td>
<td>3</td>
<td>30</td>
<td>50</td>
<td>20</td>
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<tr>
<td>Total Plastics</td>
<td>36</td>
<td>26</td>
<td>-10</td>
<td>137</td>
<td>140</td>
<td>3</td>
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<tr>
<td>Strategic</td>
<td>53%</td>
<td>54%</td>
<td>1%</td>
<td>50%</td>
<td>51%</td>
<td>1%</td>
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<tr>
<td>Financial Buyer - Add-on</td>
<td>31%</td>
<td>35%</td>
<td>4%</td>
<td>28%</td>
<td>33%</td>
<td>5%</td>
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<tr>
<td>Financial Buyer - Platform</td>
<td>17%</td>
<td>11%</td>
<td>-6%</td>
<td>22%</td>
<td>16%</td>
<td>-6%</td>
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</table>

### TOTAL PLASTICS M&A BY END MARKET

<table>
<thead>
<tr>
<th>End Market</th>
<th>Month-to-Date 2021</th>
<th>Month-to-Date 2022</th>
<th>Year-to-Date 2021</th>
<th>Year-to-Date 2022</th>
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<tbody>
<tr>
<td>Food &amp; Beverage</td>
<td>7</td>
<td>4</td>
<td>23</td>
<td>19</td>
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<tr>
<td>Industrial</td>
<td>15</td>
<td>13</td>
<td>50</td>
<td>68</td>
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<td>Consumer</td>
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<td>12</td>
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<td>Automotive / Transportation</td>
<td>10</td>
<td>1</td>
<td>28</td>
<td>12</td>
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<tr>
<td>Total</td>
<td>36</td>
<td>26</td>
<td>137</td>
<td>140</td>
</tr>
</tbody>
</table>

Global Plastics M&A cooled in April 2022 with transaction volumes falling closer to pre-pandemic levels; monthly M&A activity averaged 28 transactions from 2017 - 2019. While it remains to be seen if April is the new normal level of transaction activity, plastics M&A as a whole has remained strong through the first four months of the year. If you are a plastics company considering a merger, acquisition, sale or recapitalization in the short or longer term, please consider leveraging PMCF’s transaction planning and execution expertise to best position your company in a transaction.

Public Entity Performance

Public plastic companies, apart from plastic fabricators, fared better than the market in April. The Plastic Packaging Index only dropped by 2.6% compared to the S&P 500 which fell by 8.8% in the month. Rising interest rates, supply chain disruptions, and inflation have contributed to investor pessimism in the month.
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Our review may consider your operations, products, end markets, financial trends, growth opportunities, and management team.

We are available to brief your management team, ownership, or board with our thoughts on your current value in today’s market.

PMCF can provide a benchmark comparison of your organization’s strengths, weaknesses, and anticipated buyer viewpoints.

### NOTABLE M&A ACTIVITY

<table>
<thead>
<tr>
<th>Date</th>
<th>Acquirer</th>
<th>Target</th>
<th>Category</th>
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</thead>
<tbody>
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<td>04/29/22</td>
<td>Industrial Opportunity Partners, LLC</td>
<td>Raven Engineered Films, Inc.</td>
<td>Film</td>
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<td>04/28/22</td>
<td>Brook &amp; Whittle Limited</td>
<td>Diamond Flexible Packaging Co.</td>
<td>Flexible Packaging</td>
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<td>04/26/22</td>
<td>Trelleborg Sealing Solutions</td>
<td>EirMed, LLC</td>
<td>Injection Molding</td>
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<tr>
<td>04/25/22</td>
<td>Owens Corning (NYSE:OC)</td>
<td>WearDeck</td>
<td>Composites</td>
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<td>04/25/22</td>
<td>Novvia Group</td>
<td>Southern Container, LLC</td>
<td>Distribution</td>
</tr>
<tr>
<td>04/20/22</td>
<td>Avient Corporation (NYSE: AVNT)</td>
<td>DSM Protective Materials Business of Royal DSM</td>
<td>Composites</td>
</tr>
<tr>
<td>04/13/22</td>
<td>Viva Energy Group Limited (ASX:VEA)</td>
<td>LyondellBasell Australia Pty Ltd.</td>
<td>Resin</td>
</tr>
<tr>
<td>04/13/22</td>
<td>Distrupol Limited</td>
<td>Oy Baritec AB</td>
<td>Resin Distribution</td>
</tr>
<tr>
<td>04/11/22</td>
<td>One Rock Capital Partners, LLC</td>
<td>Prefere Resins Holding GmbH</td>
<td>Resin</td>
</tr>
</tbody>
</table>

### Major News

- Inflation Pressures Weigh on Plastics Supply Chain (Plastics Today)
- Interest-Rate Surge Ripples Through Economy, From Homes to Car Loans (Wall Street Journal)
- Blame feedstocks, Supply Chain Issues as Resin Prices Climb (Plastics News)
- U.S. Economy Grows Modestly Amid High Inflation, Ukraine Invasion (Wall Street Journal)
- Shipping Snarls Likely to Last for Some Time (Plastics News)

### Sources

Capital IQ, PitchBook, Thomson Reuters, Company Reports, PMCF

### Use Our Expertise to Maximize Shareholder Value

Since our inception over 25 years ago, PMCF has offered robust transaction planning and preparation services to help business owners achieve the best possible outcome in a transaction whether it be in the short or long term. Our long track record of successful transactions is directly attributable to our focus on preparation and being proactive throughout the transaction process.

### STRATEGIC ASSESSMENT

- PMCF is frequently requested to complete an analysis of a company's strategic positioning within the plastics and packaging marketplace
- Our review may consider your operations, products, end markets, financial trends, growth opportunities, and management team
- We are available to brief your management team, ownership, or board with our thoughts on your current value in today’s market
- PMCF can provide a benchmark comparison of your organization’s strengths, weaknesses, and anticipated buyer viewpoints

### WORKING WITH PMCF

- PMCF is a licensed and FINRA-registered investment banking organization
- Confidentiality is of the highest importance and we welcome the execution of appropriate agreements prior to the exchange of data
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Simulation of Thermoforming Process for Truck Roof Fairing Applications

Amol Avhad¹, Carlos Pereira², Raghavendra Janiwarad¹, Bhaskar Patham¹, SABIC John Perdikouliaς, COMPUPLAST Canada
1. SABIC Technology Center – Bangalore, India; 2. SABIC Technology Center Automotive – USA

Editor’s Note: This paper was originally presented at SPE ANTEC 2021 (virtual).

ABSTRACT

Thermoforming is an efficient, very cost-effective and widely used process for the production of large parts in transportation applications. The long-haul truck roof fairing demonstrates the feasibility of replacing traditional materials with thermoplastics in order to improve aerodynamics and, in turn, cut a truck’s fuel use. Simulation becomes a powerful means for a large part and complex process to arrive at, and optimize process conditions. This, in turn, helps to achieve the desired product quality for a given material.

The present study describes the results from the use of thermoforming simulation as a tool for optimizing sheet thickness, sheet temperature, and processing conditions to achieve a desired thickness distribution and minimal weight of a truck fairing part without sacrificing its structural performance.

The given design of truck roof fairing part is simulated using Accuform’s commercial thermoforming simulation software TSIM® for three different resin materials (acrylonitrile butadiene styrene (ABS), a blend of polycarbonate (PC) and ABS (PC/ABS); and thermoplastic olefin (TPO). These materials are modelled using nonlinear time-dependent viscoelastic K-BKZ model. The model parameters are estimated using stress-strain measurements. The average polymer sheet thickness and sheet temperature of each material varied to study thickness distribution and weight of the part. Finally, simulation results compare the thermoforming performance in terms of thickness distribution and part weight, and recommends optimal processing conditions for each material.

1. Introduction

Thermoforming is widely employed for production of large polymeric parts with medium to low volumes [1]. It is the process of choice where short production runs cannot justify the expense of the more expensive injection tooling, or where short lead times from design to production are critical [2]. The general steps associated with thermoforming of any part geometry are given schematically in Figure 1. The polymer is melted and extruded forming a flat sheet. The sheet is then dried and heated above its softening temperature using heat and pressure in a radiation furnace. The sheet is subsequently stretched to the desired shape and trimmed to form the finished part.

A variety of thermoforming process configurations are employed which may be differentiated by the type of mold (core, cavity, or multi-part), mold material (wood, composite, aluminum etc.), application of force to stretch the sheet (vacuum, air pressure, mechanical aids like plugs, and combinations thereof) or the way of material feeding (roll fed or cut sheet) [3]. In vacuum thermoforming [4], one of the most common thermoforming technologies, vacuum removes air between the sheet and mold, and draws the sheet into the mold cavity to form the final part. In the pressure forming process [5], heated sheet is forced into the die using compressed air. In plug-assist vacuum forming [6-8], a plug forces the sheet into the mold cavity, preforming the sheet, while the vacuum then pulls the sheet into direct contact with the mold, lending the final shape to the part. More complex thermoforming process configurations such as twin-sheet forming may also be employed for production of hollow parts [9,10].

In developing applications and components involving thermoformed parts, several material, design, and processing considerations come into play, and are briefly delineated in the subsequent.
1. **Choice of the type of thermoforming process:** First of all, with so many possible variations available for thermoforming, the selection of an appropriate thermoforming process configuration becomes essential for the success of a given application.

2. **Thickness distribution in the formed part:** A thermoformed part typically will have a distribution of thicknesses depending on the part shape, and local draw ratios [11]. Thickness distribution influences the necessary part weight and affects the mechanical properties like strength and rigidity [12].

3. **Material Selection:** For a given application, the specific performance criteria in terms of mechanical integrity, resistance to chemical and thermal environment, and overall durability need to be established. Again, depending on part size and complexity as well as specific performance criteria, one has to identify a suitable material grade that would have an optimal processability for thermoforming of the part and would be ideal for final performance.

4. **Precursor sheet thickness:** Further, the sheet thickness and temperature may require alteration depending on optimal strains the material experiences during the course of forming.

5. **Forming process parameters:** One would then optimize the forming process conditions (air/vacuum pressure, sheet temperature, sheet thickness, plug design, plug displacement, plug material etc.) to ensure that the sheet establishes complete contact with the mold to attain the shape of the part.

6. **Part Design:** When specific performance requirements do not allow a wide range of material substitution, one may have to redesign the part (and the associated sheet size and thickness) to accommodate the processing performance constraints as governed by the material rheology. Clearly, it is difficult to optimize one parameter completely independent of other considerations listed in the foregoing, and the achievement of a high quality part in thermoforming is an optimization problem with multiple as well as interacting parameters and variables. The optimization of these parameters and variables are widely carried out using experimental trial and error, which can be very expensive, especially for large parts.

With recent advancements in finite element analysis (FEA) and complex computational fluid dynamics (CFD) simulation methodologies, simulations may be effectively used to screen and optimize the complex and interacting set of parameters described above (see e.g., Ref [15-17]). Tulsian et. al. (2004) [18] employed thermoforming simulations to determine coefficient of friction (COF) between polypropylene (PP) sheet and three different syntactic foams used as plug material. Connor et. al. (2008) [19] studied the thermoforming behavior of an industrial thermoforming grade of PP. They used numerical methods to replicate custom-built thermoforming equipment using industry standard FEA software. Kittikanjanaruk and Patcharaphun (2013) [20] studied the effect of sheet and mold temperature on thickness distribution, and found out experimental results in close agreement with numerical simulations. Mohd Ghobadnam et. al. (2014) [21] made polystyrene cups with core and cavity molds using drape and vacuum thermoforming. They further used finite element simulations to study thickness distribution for various parameters in vacuum forming. Marjuki et. al. (2016) [22] used numerical simulations for manufacturing a honeycomb layer using drape and vacuum thermoforming. Thus, simulations can effectively inform, complement, expedite and even substitute experiments in arriving at robust thermoforming conditions chosen applications.

**OBJECTIVE**

The overall objective of this work is to develop a robust, validated and accurate simulation framework for thermoforming process optimization, addressing various aspects listed in the preceding. The specific objective of this study is to explore the capability of simulations in the vacuum thermoforming scenario for an application of long-haul truck roof fairing. This application demonstrates the feasibility of replacing traditional materials with thermoplastics in order to reduce drag and in turn, cut a truck’s fuel use. We have explored Virtual iterations, employing simulations carried out in a TSIM®, a commercially available simulation software, with three different resins and corresponding process-parameter settings. Using these simulations, we arrive at recommendations for settings of sheet thickness, sheet temperature and processing conditions for achieving parts with optimal material utilization.

Section 2 covers the experimental aspects associated with stress-strain measurements of the extruded sheet along with thickness measurement of the thermoformed truck fairing part. Further, the section 3 describes the set-up of sim-
ulations for thermoforming of the part using TSIM®. Section 4 summarizes the results from simulations. Finally, we have presented the conclusions from the study and future work in section 5.

INTRODUCTION TO TSIM®

TSIM® [23] is a processing simulation tool that allows virtual parameter screening and optimization of thermoforming process parameters. TSIM® provides simulation and optimization capability for vacuum, pressure or twin sheet forming. TSIM® employs the Kaye- Bernstein-Kearsley-Zapas (K-BKZ) constitutive equation [24, 25], which offers an accurate and detailed description of the nonlinear rheological behavior of the melt including normal stresses, shear thinning, and extensional strain hardening. Additionally, it offers a few variations of the nonlinear strain dependent damping function to simulate high strain deformation behavior [26, 27]. Temperature dependence is modeled using the Williams-Landel-Ferry (WLF) equation.

2. Experimental

MATERIALS

Thermoforming trials were carried out with three different resins: an ABS, a blend of PC and ABS, and a TPO. Table 1 lists the physical properties of these polymers.

Table 1: Physical properties of materials

<table>
<thead>
<tr>
<th></th>
<th>ABS</th>
<th>PC/ABS</th>
<th>TPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Density (Kg/m³ @ 25 °C)</td>
<td>1060</td>
<td>1130</td>
<td>1166</td>
</tr>
<tr>
<td>Thermal Conductivity (W/(m·°C) @ 190 °C)</td>
<td>0.33</td>
<td>0.33</td>
<td>0.246</td>
</tr>
<tr>
<td>Heat Capacity (J/(kg °C) @ 117 °C)</td>
<td>1234</td>
<td>1234</td>
<td>6156</td>
</tr>
</tbody>
</table>

These materials were characterized under uniaxial compression (using compression molded flat sheet specimens) at three different temperatures, i.e. 180 0C, 190 0C and 200 0C, and at three different strain rates i.e. 0.5 s⁻¹, 5 s⁻¹ and 50 s⁻¹ at each temperature. Figure 2 shows the stress-strain measurement data for the TPO resin. Similar measurements were done for the ABS and PC-ABS sheets.

THERMOFORMING PROCESS

The truck roof fairing geometry employed in this study is shown in Figure 3. Starting with a sheet size of 2692 mm x 2070 mm, vacuum thermoforming was carried out to fabricate the part using a cavity mold. For the forming experiments, three different sheet thicknesses (6.35 mm, 6.98 mm and 7.62 mm) were employed. Different settings of the initial sheet temperature were employed for each material based on their processing range.

Figure 3: The thermoformed air fairing part geometry from one of the experimental trials

THICKNESS MEASUREMENT OF THE PART

The thickness of the thermoformed part was measured using blue light scanning of both outer and inner surfaces, using an ATOS 16M W/850 MV scanner which projects a fringe pattern on the part surface and uses two separate cameras to register the fringe displacement. The estimated accuracy of the thickness measurement based on subtraction of distance is of 0.15 mm.

3. Simulations

Thermoforming simulations were carried out to evaluate virtually the suitable resin and corresponding optimal processing conditions. The objective was to minimize the overall material consumption (mass) of the part, while ensuring that the part thickness at all locations remains above a set threshold (to ensure structural integrity). To validate the simulation methodology, the baseline simulation was set to mimic the processing conditions of the thermoforming of the actual scale part formed using a PC-ABS sheet. In subsequent iterations, while keeping other settings constant the...
resin material (the K-BKZ and WLF parameters), the initial sheet temperature, and the sheet-thickness were systematically varied – to investigate their impact on the objective functions, and to identify the optimal combinations of these variables. This section describes the model development in TSIM® describing part geometry, material data fitting and processing conditions used in the simulations.

SIMULATION GEOMETRY

A uniform initial sheet thickness and sheet temperature was assumed in the simulations (Figure 4a). The sheet geometry was discretized into 398664 triangular elements. The geometry of the cavity mold is shown in Figure 4b.

![Figure 4: (a) Simulation geometry with mesh discretization (b) Thermoforming tool](image)

Material Data and Fitting

The stress-strain data for the materials (cf. e.g., Figure 2) were modelled using nonlinear viscoelastic K-BKZ constitutive model (along with the WLF model to account for non-isothermal effects) to parameterize the material model constants, that are input into T-SIM. The model parameters are available in the form of multi-mode relaxation spectra, listed in Table 2, and the Wagner “irreversible” damping function [26, 27] parameters. The WLF model parameters for the materials were used as provided in TSIM®.

Table 2: Relaxation Spectra of ABS, PC-ABS and TPO

<table>
<thead>
<tr>
<th></th>
<th>ABS</th>
<th>PC-ABS</th>
<th>TPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relaxn Time (s)</td>
<td>Modulus (Pa)</td>
<td>Relaxn Time (s)</td>
<td>Modulus (Pa)</td>
</tr>
<tr>
<td>0.0133</td>
<td>517.8</td>
<td>0.0205</td>
<td>190673.0</td>
</tr>
<tr>
<td>0.0154</td>
<td>10005.4</td>
<td>0.0237</td>
<td>436111.0</td>
</tr>
<tr>
<td>0.0178</td>
<td>156486.0</td>
<td>0.0274</td>
<td>64253.0</td>
</tr>
<tr>
<td>0.0205</td>
<td>142982.0</td>
<td>3.1623</td>
<td>7812.6</td>
</tr>
<tr>
<td>0.0237</td>
<td>364527.0</td>
<td>3.6517</td>
<td>10098.8</td>
</tr>
<tr>
<td>0.0274</td>
<td>149783.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0316</td>
<td>44958.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7783</td>
<td>113945.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THERMOFORMING PROCESS SETTINGS

The settings for vacuum pressure and tool movement used in the simulations are captured in Figure 5. In the first 7.5 seconds, the truck fairing tool was kept at its initial position and a small negative pre-blow of 0.20 kPa was applied. In the next 7.5 seconds, the tool moves by 1778 mm and the negative pressure was removed; it needs to be noted that almost all of this movement is prior to establishing contact with the sheet. After 15 seconds, the tool was kept stationary. At 16.5 seconds, a pre-blow of 82.74 kPa was applied, and subsequently, the blow pressure was ramped to 103.425 kPa in next 0.5 seconds. The pressure was kept constant for the remaining 8 seconds. These settings were applied to closely mimic the actual forming conditions in the baseline experimental thermoforming trial. The simulation ends at 25 seconds, and the subsequent cooling of the thermoformed part was not simulated.

![Figure 5: (a) Model set-up in simulation, showing initial and final position of both the tool and the sheet (b) Process set-up](image)

Heat Transfer and Friction

The settings of the temperatures, heat transfer coefficient (HTC) and friction coefficient are listed in Table 3. The heat transfer coefficient between ambient air and polymeric material referred to be about 5.7 W/m2.K [7]. In addition, the heat transfer coefficient between tool and polymeric material was taken as a typical value for Aluminum as a tool material.
The coefficient of friction (COF) between the tool and the sheet is influenced by the materials of the sheet and tool, the temperature, and the surface roughness [20, 28, 29]. The COF, thus, varies from one process configuration to other. The setting of this parameter in the simulations requires elaborate measurements for various material combinations. In the baseline simulation, the setting of COF was taken as a fitting variable. The COF was varied within realistic bounds to achieve an adequate match between the model predictions with experimental measurement of thickness of the part. Once set in the baseline simulation, the same value of COF was employed for subsequent iterations.

4. Results and Discussion

BASELINE SIMULATION

Baseline simulations were carried out for validating the model predictions. A PC-ABS material was considered with initial polymer sheet thickness of 7.62 mm and temperature of 1930°C. Results of this baseline simulation are shown in Figure 6. The thickness prediction along the half-arc of the cut sections in Y-direction (a-a) and X-direction (b-b) of the thermoformed truck fairing part is compared with the measurement in Figure 6c. The estimates of the variation of thickness along the arc-length match qualitatively well with the measurements, with local maxima and minima occurring at similar locations. The quantitative match is also good especially in the regions that are formed away from the sheet edges. The mismatch between the estimated and measured thicknesses -- especially in areas formed in the vicinity of the sheet edges, where the sheet experiences the highest temperature gradients -- may be arguably ascribed to any inaccuracies in settings of the WLF parameters and the coefficient of friction (COF). The impact of non-isothermal conditions on the COF is expected to be particularly pronounced, and also material dependent. These aspects were not accounted for in detail in the present study. These inaccuracies at the edge notwithstanding, the match between the estimated and measured thicknesses may be considered adequate.

Further, Figures 6a and 6b display the contour plots of the thickness of fully thermoformed part. The part has design complexities like sharp edges, ribs and undercuts. As seen from Figure 6a, the sheet is stretched in the direction of a part and is thinned down more in these regions compared to other regions -- the thickness of the part varies from the initial sheet thickness of 6.98 mm down to 0.95 mm. In order to meet performance requirements, the part thickness at all locations needs to be above a minimum threshold thickness of 1.5 mm. As seen from Figure 6b, there are several regions in the formed part where this minimum threshold is not maintained.

From the foregoing, it is clear that the baseline simulation shows the right qualitative thickness variation, and provides an adequate quantitative estimate of thickness compared to measurements. Also, it is clear that the baseline scenario does not meet the minimum part thickness requirements.
LOW FLEX™ FORMER SERIES
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- Easy maintenance access

LINEAR RAIL TRIM PRESS
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- Numerous quick change features
- Precise tolerances via linear rails

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- Form-Trim Models
- Linear Trim Presses
- Linear Vertical Press
- Heavy Duty Presses
- Tilt Bed (IML)
- Linear Pre-Punch
- Linear Scoring Station
- Rotary Drum Former

PROCESSES
- PP, PET, HIPS, OPS
- PLA, HDPE, PS Foam
- In line/Roll Fed
- Cups, Car Cups, Lids
- Retort Products
- Tamper Evident
- Hinged Trays
- Storage containers
- TML

VALUE
- Energy Efficient
- Production Rates
- Move Times
- Ease of Access
- Reliability

SERVICE
- Training Classes
- Online help
- Process Training
- After hours help
- Included start up service
Figure 6: (a) Thickness contours of a part from different planes (b) Thickness contours of a part below critical thickness (1.5 mm) (c) Comparison of estimated thickness with measurement along two cut sections (cf. Figure 6a)

VIRTUAL DESIGN ITERATIONS

The observations from the baseline simulation in the previous section allow for significant optimization of the thermoformed part. Therefore, simulation-aided virtual iterations were carried out by systematically varying the settings of material, processing temperature, and initial sheet thickness to identify the optimal combinations of these parameters to improve the baseline scenario. The settings of these parameters in the various iterations are listed in Table 4.

Table 4: Comparison of part weight, minimum and maximum thickness for different iterations

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Material</th>
<th>Sheet Temp. (°C)</th>
<th>Sheet Thickness (mm)</th>
<th>Part Weight (Kg)</th>
<th>Min Thickness (mm)</th>
<th>Max Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Base)</td>
<td>PC-ABS</td>
<td>193</td>
<td>7.62</td>
<td>42.46</td>
<td>1.07</td>
<td>7.62</td>
</tr>
<tr>
<td>2</td>
<td>ABS</td>
<td>177</td>
<td>7.62</td>
<td>42.46</td>
<td>0.70</td>
<td>6.98</td>
</tr>
<tr>
<td>3</td>
<td>TPO</td>
<td>180</td>
<td>7.62</td>
<td>42.63</td>
<td>1.79</td>
<td>7.62</td>
</tr>
<tr>
<td>4</td>
<td>TPO</td>
<td>180</td>
<td>6.99</td>
<td>38.91</td>
<td>1.62</td>
<td>6.98</td>
</tr>
<tr>
<td>5</td>
<td>TPO</td>
<td>190</td>
<td>6.99</td>
<td>38.93</td>
<td>1.21</td>
<td>6.98</td>
</tr>
</tbody>
</table>

The resulting estimated thickness distributions in the fully formed part from these design iterations are shown in Figure 7.

Figure 7a displays the part thickness variations along the half-arc cut in the Y-direction, while Figure 6b shows for half-arc cut in X-direction. The part weight, minimum and maximum part thicknesses estimated for these design iterations are also listed in Table 4.

Figure 7: Variation of part thickness of different iterations along the half-arc cut in (a) Y-direction (b) X-direction

It is evident from Figure 7 and Table 4 that the Iter-4 results in the minimum part weight amongst all scenarios. It also meets the desired criterion of exceeding the threshold thickness of 1.5mm at all locations. This case is discussed further in next section.

BEST CASE SCENARIO

The resin material employed in this iteration was TPO. In general, TPOs exhibit high stiffness, impact resistance, and enhanced surface durability comparable to engineering thermoplastics and are preferred for auto exterior applications like roof fairing. The initial sheet temperature imposed for thermoforming was 1800°C, which is appropriate for good processability. The sheet thickness used was 6.98 mm keeping in mind the reduction in weight of the produced part for earlier iterations with same sheet thickness. The process setting, heat transfer and friction coefficient kept same as that of baseline simulation.
Figure 8a shows the thickness contours of formed part from different planes. It is clear that, with TPO resin, the sheet undergoes greater uniaxial stretch during forming (including significant biaxial stretch at the middle), leading to a more uniform thinning of all the regions of the sheet along its length. Further biaxial stretch during blowing thins down the thickest portions of the sheet, resulting in a final formed part meeting a critical thickness magnitude of 1.5 mm in the thinnest regions. This is further seen more correctly in Figure 8b, where uniform color highlights the thickness of the formed part is above the critical thicken of 1.5 mm. The thickness distribution along the half-arc of the part cut in Y and X directions is compared with the baseline simulation in Figure 8c and 8d. It shows an improvement both in terms of achieving the desired critical thickness and thickness distribution.

Figure 8: (a) Thickness contours of a part in different planes (b) Thickness contours of a part in different planes comparing critical thickness. Variation of a part thickness along the half-arc cut in (c) Y-direction (d) X-direction (c)

As it can be noted from the above study that the virtual iterations comprise of trial and error in terms of selecting the appropriate resin material, and imposing the thermal and processing conditions accordingly. It is also much faster and less expensive compared to experiments that involve forming of the physical part from polymer sheets.

CONCLUSIONS

This study evaluated the use of simulations as a means of accelerating the thermoforming process optimization to minimize the overall material consumption (mass) of the part, while ensuring that the part thickness at all locations remains above a set threshold (to ensure structural integrity). Specifically, the TSIM® simulations were carried out for vacuum thermoforming of a large-haul truck roof fairing application. These simulations accounted for nonlinear viscoelastic behavior of the polymer by a constitutive model that accurately captures the large strain deformations associated in thermoforming process. The estimates of the thickness from the simulation showed a good comparison with the thickness measurement of the actual formed part. Further, virtual iterations were conducted by varying initial sheet thickness and initial sheet temperature for three different resin materials. These simulations helped us in arriving at an optimum combination of these variables. The virtual iterations with TSIM® clearly indicated that with TPO as a resin material, and optimum initial sheet thickness and temperature, results in a thermoformed part that meets the desired critical thickness and thickness distribution with minimal part weight.

ACKNOWLEDGMENT

Vijay Kudchadkar is acknowledged for help with TSIM simulation set up, and for coordinating the measurement of stress-strain data.

REFERENCES


Lesley Kyle, CMP
SPE Thermoforming Division Administrator

After 21+ years with the Society of Plastics Engineers, it’s time for me to move on to my next adventure. My SPE career began at SPE Headquarters in March 2001, and I made a soft right turn when I started my consulting business in November 2011. I had forged lasting relationships with many SPE Members, and the Thermoforming Division Board of Directors became one of my first clients.

My role expanded from Conference Coordinator to Division Administrator as I took on additional responsibilities. And while we worked hard, we played hard too! I am very proud of what we accomplished together and the hurdles we overcame as a team: the cancellation of the 2017 conference in Orlando due to Hurricane Irma is an example. Recently we navigated the choppy waters of planning a biennial conference during a pandemic. The 2021 SPE Thermoforming Conference was the most challenging event I planned. Under Steve Zamprelli’s leadership, the Board and I partnered to execute a very successful event during trying and uncertain times.

There are many folks I need to recognize and thank:

- **The SPE Thermoforming Division Board, Past and Present:** Thank you for your never-ending support, the triumphs (large and small), and the laughs we’ve shared.

- **SPE Thermoforming Division Chairs, Mark Strachan, Bret Joslyn, Eric Short, and Steve Zamprelli:** Thank you for giving me a seat at the table and your trust in me.

- **SPE Thermoforming Quarterly and Conference Sponsors and Exhibitors:** Your commitment to the industry and support of the Division’s activities make their good work possible. Thank you for sharing your knowledge with me and making work so much fun!

A new era and adventures await me. Over the years, I’ve seen places I wouldn’t have otherwise seen, created lasting memories, and developed life-long professional relationships and friendships. These past 10+ years have flown by, and I have adored serving in this role.

Congratulations and best wishes to Shameka Jennings, CMP, my successor, as she brings extensive meetings and professional association expertise to support the Board. While a myriad of challenges lay ahead, the SPE Thermoforming Division’s future is bright- and I wish you all continued success! |
Global Dispatches

Conference Review: European Thermoforming
Vienna, Austria

By Conor Carlin, Editor

After twice postponing their flagship event and moving the location from Geneva to Vienna, SPE’s European Thermoforming Division celebrated the return of live programming from March 30 to April 1. With more than 250 delegates attending from 30 countries, it was clear that the thirst for knowledge and networking had not been extinguished over the past two years. While about a dozen U.S. delegates were in attendance, the presence of several multinational companies on the stage suggested that, in theory, information about plastics and packaging can flow across the Atlantic without too much trouble. And though M&A activity might have peaked in the current business cycle, the recent spate of consolidation has created larger companies with assets on both sides of the ocean.

The writer George Bernard Shaw once said that the U.S. and Britain were separated by a common language. This observation could be also applied to the transatlantic world of plastics, especially when it comes to navigating today’s uncertain environment. It’s perhaps an oversimplification, but Europeans are more inclined to regulate while Americans tend to look for market solutions.

Several key trends in Europe were acknowledged during the event that companies in North America most certainly recognize, even if we might “feel” them to varying degrees: the impact of fossil resources on resin prices and transportation; lingering pandemic stresses; global logistics problems; and inflation. And while these elements can and do combine into a perfect storm for manufacturers (as seen in several declared cases of force majeure in the past year), at least a few retailers have decided that switching from paper back to plastics means they can manage weight-based charges more effectively.

Marek Nikiforov of thermoforming equipment manufacturer BMG/GN Europe opened proceedings with a high-level summary of the challenges faced on a shared planet with limited resources. Using data from Project Drawdown, he starkly illustrated the environmental impact of global food production: 25 percent of the world’s freshwater resources are used each year for intensive farming practices. As many of us now know, one-third of all food produced globally is lost or wasted due to spoilage. Enter plastics packaging which increases shelf life dramatically yet poses problems of its own in terms of end-of-life management. Project Drawdown ranks “reduced food waste” as No. 3 on its list of 80 solutions that humanity can take to “draw down” our environmental impact (No. 1 is refrigeration management).

Drivers of Change

Thermoforming conferences tend to be divided into thin-gauge and heavy-gauge processes with some overlap in certain end markets such as medical and automotive. Gérard Liraut from Renault-Nissan-Mitsubishi delivered an insightful talk on the future of mobility. A key premise was a revelation that there is a disconnect between how cars are built and how they are used. For example, he segmented travel distance and use patterns by micro-mobility (0 to 5 miles; scooters), medium mobility (5 to 50 miles; Uber or cab-sharing) and long mobility (over 50 miles; car-sharing). When viewed this way, cars seem to be designed indifferently to how they are actually used, especially in large, urban centers (hence the increased acceptance of congestion charges and rebirth of pedestrian zones).

Renault has a goal of 30 percent reduction in CO2/kg in materials and parts. Today, 20 percent of a car, by weight, is made from polymers, with polypropylene contributing 35 percent of that and elastomers 8 percent. Liraut stressed that polymers will be required in increased volumes as cars become electrified and exploit the benefits of plastics and composites: e.g., in heat management, for batteries and casings, and many surfaces which—highly relevant in pandemic times—will be treated with antimicrobial additives.

While plastics reduce the weight of vehicles by replacing heavier materials, they also serve an important protective role, particularly when it comes to public safety vehicles like police buses for riot squads. Dutch conglomerate VDL Groep, Eindhoven, Netherlands, presented a case study on the chal-
lenges of protecting law enforcement vehicles (and their passengers) in dangerous situations. Specifically, designers, engineers and operators of Mercedes-built police vans in the Netherlands came together to develop polymer-based windows and body panels that could withstand small arms fire and related “melée weapons” such as one might encounter during serious public disturbances. Using 6-mm coextruded polycarbonate (PC) Makrotech from ArlaPlast of Borensberg, Sweden, for body panels and hardcoated, scratch-resistant Saphir Transparent PC for windows, the materials were thermoformed on temperature-controlled block aluminum tools. The components were ultimately assembled on the vehicle exteriors. Teams had to overcome challenges with differences across manufacturing processes which led to poor initial fit and a general learning curve with new material combinations. In the end, however, the project met its stated goals of being UV stable, reparable, on-budget and in-line with relevant EU safety directives.

Innovations in heavy-gauge applications are also found in marine and aviation sectors. Andrew Ferguson of Collins Aerospace, Kilkeel, Northern Ireland, offered data from recent T-SIM thermoforming simulations. (T-SIM software for thermoforming and blow molding simulations is supplied by Accuform of Jetelova, Czech Republic; North American office is in Mississauga, Ontario, Canada.) While Collins only uses T-SIM in 5 to 10 percent of projects, in those where complex geometries make it difficult to predict material behavior and performance, significant efficiencies can be achieved. Working with IKV Stuttgart for material characterization studies using the K-BKZ non-linear, time-dependent method, engineers at Collins reported that 90+ percent of measured thickness locations were within tolerances of +/- 0.005 inch over 17 parts. Process changes reduced variations further leading to time and cost savings.

An international project that included a moldmaker from Italy, a sheet supplier from Austria, an OEM from the U.S., and a processor from Mexico illustrated the benefits of early supplier engagement. Sea-Doo, manufacturer of personal watercraft, uses 19 colors in a gel-coat process for the exteriors of its popular recreational models. The project team was charged with replacing the gel coat due to ongoing problems with aesthetics. The material had to have good chemical resistance as it would be exposed to seawater and fuel spillage. Using a new Closed Mold Technology (CMT), the

| An American Perspective on the European Thermoforming Conference |

For a North American thermoformer who had never attended this conference before, it was very interesting to learn about the differences and similarities across the Atlantic. It was clear from the workshops how important equipment size constraints are for both heavy and thin gauge processors in the EU. Both North American and European processors have similar approaches to finishing parts after forming. Both understand the importance of automation and doing more with fewer employees.

Generally speaking, the European Thermoforming Conference had a strong emphasis on thin gauge processing and recycling. It is very important for a North American processor to be aware of the issues and concerns that EU processors are facing. We will be fighting similar battles at some point.

I saw plenty of networking opportunities in both exhibit table top rooms and in the central hall where many delegates congregated for more intimate discussions. On the second day, I listened to all of the general sessions with mixed topics including an interesting heavy gauge forming case study. On the whole, this was a very well-planned and attended event. I hear it was one of their most successful conferences.

A very impressive awards dinner was held in the atrium of the Museum of Applied Sciences (MAK) where most all delegates were in attendance. It was a very beautiful space and everyone had the ability to tour the museum and network before dinner. Many stayed until the museum closed, enjoying each other’s company late into the evening.

At the end of the conference, ETD Chair, Ken Braney, offered a champagne toast while most attendees stayed for the iPad raffle. People lingered in the hotel lobby after the conference program ended, congregating in groups and talking. It was clear that the organizers are a close bunch who hadn’t seen each other for some time due to strict pandemic lockdowns in most EU countries.

We look forward to a new generation of volunteer friendships with our colleagues in Europe as we share best practices for our shared industry.

— Steve Zamprelli
Waste Not (PET), Want Not (PET)

For those familiar with EU Directives on waste, plastics converters and contract packagers are still working through the realities of the Single Use Packaging Directive originally introduced in 2018 and implemented in 2021. As several presenters pointed out, however, plastics packaging is still forecast to grow at a compound annual growth rate (CAGR) of 4.4 percent from 2021 to 2026. Some of this will be thermoformed containers. According to data presented by Sukano of Schindellegi, Switzerland, approximately 2 million tons of PET was recovered in the EU in 2019, yet overall yields have declined to 70 percent from 81 percent due to contamination.

A PET bottle is often the poster child used for the benefits (or challenges) associated with recycling, but overall rates are below targets on both sides of the ocean. Because recycled PET (rPET) is the de facto standard in rigid food packaging, speaker Thomas Bak Thellesen of Faerch Plast A/S emphasized that other plastics users should not be using PET in non-food applications so that enough is available for hungry food-contact rPET markets. He pointed out that 70 percent recycled content is roughly equivalent to halving the CO2 footprint of a given plastics package.

Thermoform recycling is a very different affair, with tray-to-tray recycling in its infancy. Tray bales from recyclers or reclaimers show lower yields than those for bottles, with contamination (labels, inks, etc.) a major hurdle to sustainable economics. Pots, tubs and trays (PTT) generally have lower IV (intrinsic viscosity) than bottles. Indeed, of 1 million tons of PET sheet consumed, only 15 percent is collected—and this is only clear material. Colored PET, whether green- or blue-tinted bottles or black food trays, is generally discarded, but there does appear to be a novel pathway to upcycle mixed APET colored flakes into heat-stabilized CPET trays.

A team composed of sheet extruder Gneuss, additives manufacturer Sukano and thermoforming OEM Illig delivered details of a project that opens up alternatives to landfilling potentially useful materials. The properties of PET bottle flake are intentionally modified in the extruder by introducing additives. An rPET IV enhancer from Sukano elongates the molecular chain of the polymer and by doing so increases the molecular weight. The additive also improves melt viscosity, which benefits the processing of the plastic at a later stage. As for the sheet extrusion, the additive extends the processing window, increases processing speed and improves the material’s sheet quality. Moreover, the additive ensures a higher impact resistance of the plastic. Due to increased migration at higher microwave and oven temperatures, the sheets used to form rCPET food trays are generally made with a coextruded functional barrier of virgin materials for protection against contaminants in the sheet. Trays were formed under tight processing conditions due to the crystallization requirements to achieve heat-stabilized trays that would pass rigorous oven tests.¹

Again, showing the power of collaboration across multiple companies, another group of European technology providers presented an example of circular economy principles being applied in China. SML (Redlham, Austria), Tomra, (Mülheim-Kärlich, Germany), Erema, (Ansfelden, Austria), Sorema, (Anzano del Parco, Italy), and Kiefel, (Freilassing, Germany), signed a deal at Chinaplas in 2019 to recycle 20,000 tons of PET for food-grade packaging, going from bottle flake to thermoformed trays and cups. A complete recycling plant was developed that featured state-of-the-art sorting and decontamination technology that delivered high-IV rPET for approved food contact. Sheets were coextruded in an A/B/A structure where edge trim was fed back into the recycled B layer.

PP: Challenges and Opportunities

For polypropylene, the forecast is much cloudier due to slower adoption of regulations and standards, especially for food-contact materials. There is significant activity underway, however, as several consortia are working to improve PP recycling, including with Der Grüne Punkt (“The Green Point”) which manages the German dual-system of recycling. According to speaker Thorsten Vebler, Der Grüne Punkt is the single biggest source of post-consumer recyclate in the EU. A highly visible example of Der Grüne Punkt recycled materials is found in the “Poeppelmann blue” line of horticultural plant pots which are made from 100 percent recycled materials and are subsequently recycled in a closed-loop system.

Dr. Martin Bussmann of Neste, Keilaranta, Finland, and Emanuele Burgin of Lyondell Basell in Houston presented results of recent tests showing how a drop-in PP grade de-
rived from waste biobased sources could perform on par with fossil-based virgin equivalents. Lyondell Basell has created a resin grade, Circulen Renew, using Neste’s chemically recycled raw materials. Working with sheet extruder Fernholz of Meinerzhagen, Germany, and Illig, the group compared Lyondell Basell’s Moplen and Circulen Renew PP using identical processing parameters. Running trials on a 30-cavity mold at 29 cpm in the Illig Technology Center, the team reported results within 1 standard deviation for typical thermoformed part parameters: top load strength, shrinkage, material distribution, stack height and haze. The parts made from Circulen, however, recorded over 212 percent CO2-eq savings. The Neste material is certified via mass balance and C14 methodologies.

More Recycling Wanted

The European plastics industry has committed to deliver 10 million tons of recycled content annually between 2025 and 2030. Monitoring Recyclates for Europe (MORE) is a new initiative from the European Plastics Converters Association of Brussels to register all recycled polymers in an effort to reach these targets and report them to the EU. Using a common, voluntary approach, plastics converting companies across the continent report their recyclate figures into a harmonized database that is available in multiple languages.

Proving recycled content is becoming de rigueur in an environment where customers are highly attuned to greenwashing. Despite several large companies using mass balance techniques and gaining ISCC+ certification for products with recycled content, the EU appears to be cool on the methodology due to its complexity, which makes it difficult for consumers to understand or appreciate. This does not mean, however, that traceability is not a critical component of recycling. RecyClass, a Brussels-based organization, describes itself as a “comprehensive cross-industry initiative that advances plastic packaging recyclability and ensures traceability and transparency of recycled plastic content” across Europe. Similar to the Washington, D.C.-based Association of Plastic Recyclers, RecyClass develops testing protocols and recycling guidelines and offers certifications to companies that meet relevant requirements.

The next SPE European Thermoforming Conference will be in 2024 (location to be announced). The U.S. conference will be in Cleveland in September 2023.

PET Thermoform Recycling Study

**Editor’s Note:** RRS is a specialized consulting firm that is undertaking a comprehensive study to improve recycling of PET thermoforms. Our members are encouraged to learn about this project and potentially sponsor Phase 2 and Phase 3 work.

The research project aims to achieve broad access and recycling of PET thermoforms. Only 8% of approximately 1.6 billion pounds of PET thermoforms are recycled in the US and Canada each year (NAPCOR).

**PHASE 1** of the study acknowledged barriers at each point in the recycling supply chain and identified potential pathways to increase recycling of PET thermoforms.

**BARRIERS:** Technical and market constraints at PET reclaimer facilities

**BARRIERS:** Limited MRF sorting capacity for segregated PET thermoform or low value (+ colored bottle) stream

MRFs may not be ready to handle volume increase. Concerns include markets, storage, volumes, price.

**BARRIERS:** Limited end markets; design challenges (e.g., labels, inks, adhesives, colorants, additives)

**BARRIERS:** Inconsistent messages about sortability/desirability of non-bottle PET are a challenge to increasing recycling collection

**BARRIERS:** Low virgin resin price creates competitive challenge

**BARRIERS:** Limited end markets; design challenges (e.g., labels, inks, adhesives, colorants, additives)

**BARRIERS:** Inconsistent education about non-bottle PET is a challenge to increasing recovery volumes

**PHASE 2** will determine interventions to enable greater collection, sorting, processing, and recycling of PET thermoforms. The workplan includes:

Conducting reclaimer trials, MRF audits and end market evaluations

Evaluating costs and technical factors related to potential interventions

Prioritizing opportunities for investments

The most effective and viable interventions will be recommended to the Recycling Partnership’s PET Recycling Coalition as targets for the coalition’s grant making.

GET INVOLVED! Join the current study sponsors in supporting this effort to research, identify, and invest in improving the recycling of PET thermoforms.

CURRENT SPONSORS OF THE STUDY INCLUDE: FPI, NAPCOR, APR, TRP, Sonoco, Mondelez, AMP Robotics, Danone, PFE, DAK Americas, Driscoll’s

NEED MORE INFORMATION? Contact RRS, research lead, at PETthermoform@recycle.com.
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SPE Council Report – Spring 2022

Phillip Karig, SPE Thermoforming Division Councilor

SPE Councilors’ Spring 2022 meeting held virtually on March 30 and reviewed programs and results from the last year.

SPE established first DEI Advisory Board to support STEM education for a broader audience and workforce development for people who may not have considered the plastics industry for a career path.

Last year was most profitable year for SPE National in over 10 years, with currently approximately $1 million in retained earnings. SPE brought Plastics Engineering magazine production back in-house and saved $180,000 by changing bulk mailing rates and using internal staff for artwork. Headquarters staff has been moved to a fully virtual model with expected future savings of six figures by not leasing office space.

Over $200,000 in SPE Foundation Scholarships were awarded, up over 50% from prior year. The reach of PlastiVan was expanded to more middle and high school students. SPE student membership status has been extended to part-time students enrolled in degree granting programs.

ANTEC will be live in Charlotte June 14 – 16. There will be a new “Teach the Geek” Program to help engineers be more comfortable with public speaking and how to make and delivery better presentations.

Councillors’ Round Table was held virtually on May 11 and focused on recruiting, training and retaining Chapter leaders / board members.

The typical board has two types of members: lots of “silent members” and a few “super volunteers” who drive things.

The following observations from experienced individual Councillors were offered:

- There are fewer younger board members than in past as they are focused on their careers and families.
- People are moving from company to company more frequently than in the past.
- General difficulty attracting academics as board members. SPE is no longer the primary source of plastics information that it was 20 or 30 years ago, with various sources of information now widely available online.

The following potential ideas to attract more board members were discussed:

- Identify and approach OEMs / Brand Owners that have large engineering departments and tell them they “should” have people in SPE to benefit from industry knowledge. Referrals through customers, contacts and social media.
- Start with shorter commitments such as one year board terms or have new members fill out the balance of terms from retirees leaving the board.
- Advertise technical committees as sources of plastics knowledge / problem solving for companies. Career fairs and technical conferences.
- Help younger people see that SPE can potentially benefit their careers:
  - Recognition-type awards that members can put on their resumes.
  - Interns partnering with board members to write articles for chapter publications that could allow students to get author credits for their resume.
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