Thermoforming Quarterly®

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Waste Not, Want Not

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SPE Thermoforming Quarterly®

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A JOURNAL PUBLISHED EACH CALENDAR QUARTER BY THE THERMOFORMING DIVISION OF THE SOCIETY OF PLASTICS ENGINEERS

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Innovation Is In Our DNA

Bret Joslyn

As we approach the end of 2016, it's worth taking a quick look back at the year that was before we gear up for the holidays. This year marked a very special anniversary for our annual conference – 25 years strong. As you will see in the photos and in the review of the Parts Competition (pp. 38-43), it was a tremendous year for innovation. With over 200 ballots cast for the People's Choice award, the judges had to deal with a new level of enthusiasm from attendees. Next year will be a new chapter for the Thermoforming Division as the conference heads south to Orlando for the first time.

Speaking of innovation, we feature two articles in this issue that can certainly claim to represent the bleeding edge of thermoforming technology. Real-time data acquisition and visualization for process control offers operators the ability to measure and manage what they're doing (see article on p. 14). We often speak about art vs. science in our industry, but these graphs and charts that help to optimize the forming cycle should be considered the best of both. Looking at global megatrends, 3D printing (more accurately known as additive manufacturing) continues to make inroads into thermoforming, though perhaps not to the extent seen in other industries. Our friends at Stratasys (see article on p. 18) share some findings and data from FDM-built tools that might give thermoformers some additional reasons to consider how and where additive manufacturing can speed time to market, especially in the prototype stage.

Our editor offers an upbeat global perspective with a report (see p. 32) from the largest plastics show on earth, the K Fair. With over 230,000 attendees visiting Dusseldorf, Germany, K2016 was the biggest show yet. By all accounts, including many international trade press outlets as well as the official channels, the plastics industry is red-hot with growth forecast in all areas of the world. In our next issue, we'll have a report on thin-wall packaging trends in Southeast Asia, one of the most dynamic global regions.

Another megatrend that affects our industry is sustainability, and more specifically, plastics recycling. The good folks at NAPCOR continue their important work to ensure that PET thermoforms are making it into the recycling stream (see article on p. 44). Despite swings in commodity prices that have made some recycling operations uneconomical, consumers and brand owners still demand recycled content in their packaging. Converters, both extruders and thermoformers, cannot ignore the impact of non-virgin materials on their process and final products.

Finally, I encourage everyone to read the current issue (Nov/Dec) of *Plastics Engineering* which contains several articles on thermoforming, including a commentary on the secrets of our division's success over the past 30 years. Spoiler alert: it's all about the volunteers.

So, what are you waiting for? Join us! Get involved! Write an article, mentor a student, endow a scholarship! Let's work together and create the next 25 years of innovation.

Have an idea for an article?

Submission Guidelines

- We are a technical journal. We strive for objective, technical articles that help advance our readers' understanding of thermoforming (process, tooling, machinery, ancillary services); in other words, no commercials.
- Article length:1,000 - 2,000 words. Look to past articles for guidance.
- Format: .doc or .docx Artwork: hi-res images are encouraged (300 dpi) with appropriate credits.

Send all submissions to Conor Carlin, Editor, at cpcarlin@gmail.com

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Thermoforming an Updated Charity Bin for the 21st Century

by Roger Renstrom, *Plastics News*

SEPTEMBER 9, 2016 – Goodwill Industries and thermoformer Ray Products Co. Inc. are taking charity donations into the 21st century.

The goBin indoor collection container is designed to go inside apartment building lobbies and office complexes where people already are, rather than forcing them to make an extra trip to donate household items.

Some of the goBins are also "smart" boxes, with a QR code on the side of the boxes that donors can scan to get an emailed receipt, and a sensor inside that alerts charities when the bins are full.

The Goodwill program also is targeted at clothing items such as shirts, pants, dresses and even shoes, which are far more likely to end up in the dump than being recycled.

"As we approach our 100th year serving the San Francisco community, we are innovating on our processes and services as we develop our strategies" for the next century, William Rogers, interim president and CEO of Goodwill San Francisco, said in a telephone interview. Goodwill SF developed the goBin with design group frog design Inc. and Ray Products of Ontario, Calif.

Goodwill SF has goBins for use in its own market and has also sold them other community operations: In Indianapolis for central Indiana; Albuquerque for New Mexico; Goodwill Keystone for portions of Pennsylvania; Fort Worth, Texas; Cincinnati for the Ohio Valley; San Jose, Calif., for Silicon Valley; and Goodwill Ontario Great Lakes in London, Ontario
.
GoBin locations include multi-unit apartment and condominium buildings, office structures, urban commercial centers and hotels.

"So far, it is working," Rogers said of the program. "People are giving a lot of donations through goBins, and sensors are providing alerts on the need for pickups."

Frog design worked on a pro bono basis with Goodwill and the first prototype — molded with wooden tools — was installed at the San Francisco commercial building of Kilroy Realty Corp. in July 2015.

A textile focus

A "smart" version of the goBin, illustrated here, includes a QR scanner on the side to email receipts to donors and a WiFi-enabled sensors to let Goodwill know when the bin is full and ready for collection.

From the start, Goodwill San Francisco wanted to focus on clothing donations. On average, each American sends 70 pounds of textiles to the dump every year, rather than donating them.

For San Francisco, that translates to 4,500 pounds of textiles entering landfills every hour, making up 5 percent of the total volume of waste. Increasing donations of soft goods to Goodwill not only helps the charity, it helps the city toward its goals of reducing waste, Goodwill officials noted.

But because San Francisco residents tend to drive less, getting bags of donations to collection centers can be complicated. Putting bins into prime locations — and making them look good — became a driver behind the goBin.

"Convenience is the most important factor for people deciding what to do with the items they no longer need," said SFGoodwill Director of Donations Leslie Bilbro in a news release. "Paradoxically this is why many textiles end up in landfill. Historically it's just been easier to throw them away.

"Responding to today's urban lifestyle, our goBin will help people to do the right thing for the environment and for their fellow residents who need a second chance in life." Discussions between Goodwill San Francisco and Ray Products began in August 2015.

"Our purchase order to begin production came in January 2016, and we shipped out the first units in early March" to Goodwill of Greater Washington D.C., said Jason Middleton, vice president of sales and development for Ray Products.

Goodwill DC began its goBin involvement with support from the Bozzuto Group real estate firm of Greenbelt, Md. Ray Products uses standard ABS sheet in forming the goBin components with starting thicknesses of 0.25 inch for the sides and 0.125 inch for the lid.

"The original design was created with a three-part assembly for the sides of the bin to accommodate a thermoformer with a smaller capacity than ours," said

Middleton. "Because our equipment can thermoform up to a full 10-by-18 feet with up to 40 inches of depth, we were able to consolidate those three parts into just two. This helped to lower the per-unit costs, increase the rigidity of the final product and make on-site assembly quicker and easier."

Ray Products uses cast-aluminum temperature-controlled tooling and vacuum forms the components on a large-format 10-by-18-foot rotary thermoformer from Modern Machinery of Beaverton Inc. For finishing the parts, Ray uses a fully-automated six-axis trimming station from Fanuc Corp.

Goodwill directly distributes an optional electronic module to the end users. Donors can scan a QR barcode to receive a tax receipt via email, and an internal sensor automatically alerts the local Goodwill that a bin is full and in need of emptying.

Locations or regions not opting for the electronic component empty goBins the traditional way, when the bins' monitor or building manager notifies Goodwill about the need for a pickup.

Typically, Ray Products ships each bin to its final location in ready-to-assemble form.

"We handle everything from thermoforming to applying graphics and packaging each unit with assembly instructions and hardware," Middleton said. "When Goodwill is ready to deploy more units, they just let us know, and we ship them out to their final destinations."

Rockville, Md.-based non-profit Goodwill Industries International Inc. provides job training, employment placement services and other community-based programs for people with disabilities through 164 semi-autonomous organizations in 17 countries.

The Goodwill San Francisco organization, for example, has 19 retail stores, 33 donation sites and an expanding e-commerce segment. Goodwill San Francisco provides opportunities to nearly 7,000 persons annually.

Goodwill San Francisco received a $50,000 grant from the San Francisco Department of the Environment for partially funding the goBin initiative as part of a zero textile waste awareness campaign.

"Environmental sustainability is a big part of what we do," Rogers said.

Family owned and operated Ray Products employs 50, occupies 48,000 square feet and operates five pressure-vacuum forming machines and five Fanuc six-axis trim centers in an ISO 9001:2008-certified environment.

Ray Products had estimated sales of $8.5 million ranking 109th in Plastics News most recent listing of North American thermoformers. The firm's top end markets are medical, electronics, telecommunications and recreational vehicles.

Huhtamaki Investing $100 Million in Arizona Production

by Jim Johnson, *Plastics News*

SEPTEMBER 19, 2016 – A new $100 million project in Arizona will include production of thermoformed plastic cups and lids as well as a variety of paper products.

Huhtamaki North America unveiled plans Sept. 19 for the new manufacturing and distribution location for foodservice packaging and retail tableware in Goodyear, near Phoenix, to serve the Southwest and West Coast.

The subsidiary of Huhtamaki Oyj of Espoo, Finland, a global packaging company that also has a big presence in flexible packaging, said the new location will create about 300 jobs.

"The new facility will expand our footprint and will build off the success of our earlier expansions. The facility will not only grow our capacity, but improve our distribution capacity in the region," said Clay Dunn, executive vice president of Huhtamaki North America, in a statement.

The 750,000-square-foot project, using an existing structure, will begin distribution early next year. Infrastructure work is slated to begin during the second quarter, and commercial production is expected for late next year, the company said.

"This facility gives us the ability to continue on our path of building 21st century work environments that are good for our customers, employees and communities," said Fred Betzen, vice president of operations for Huhtamaki North America, in a statement.

Along with making plastic cups and lids in Arizona, Huhtamaki said the site also will manufacture paper drink cups, insulated hot cups, food containers and pressed paperboard plates.

Huhtamaki owns the well-known Chinet product line, maybe best known for its paper products, but which also includes a wide variety of plastic goods. The company, additionally, offers its own StrongHolder brand line of plastic cups, plates and bowls as well as private label plastic cups, cutlery, plates and bowls.

Thermoforming Systems Investing in $1.5 Million Expansion

by Bill Bregar, *Plastics News*

OCTOBER 27, Dusseldorf, German – Thermoforming Systems LLC is building a $1.5 million expansion onto its thermoforming equipment factory in Union Gap, Wash., and plans to install a thermoforming machine at Michigan mold maker Future Mold Corp.

TSL broke ground in mid-October for a 20,000-square-foot addition, said Roger Moore, vice president of sales. He is the project manager for the expansion. TSL currently has 55,000 square feet of space in the headquarters factory.

"So basically in 10 years, now we have the need for expansion that will give us the ability to increase our production by about 50 percent," Moore said.

Right now, Thermoforming Solutions has four manufacturing bays, so it can build four machines in various stages of production at any given time.

"We're adding the equivalent of three bays," he said. Moore said the expansion will give TSL the capacity to ship about 36 thermoforming machines a year.

The thermoforming lines, to make cups, food service items and other packaging, can run 100 feet long, including the trim press, Moore said. TSL builds the production lines, runs each one off with tooling, then takes it all apart for shipment. That takes a lot of space.

TSL employs 95 people and plans to add more for the expansion.

"It gives us more base for production and gives us efficiencies," Moore said.

At the same time, TSL is teaming up with Future Mold to place a Low Flex 3.0 thermoformer at the thermoforming mold maker's factory in Farwell — near the thermoforming capital of Beaverton, Mich. TSL is building the machine now and plans to ship it at the end of the second quarter of 2017, Moore said.

Future Mold is building a 7,000-square-foot addition in Farwell, with higher ceilings than its main 36,000-square-foot factory to house a showroom for the new machine, according to Mike Otto, Future Mold's vice president. The mold maker hired Jim Martin, who has 30 years of thermoforming experience, to be responsible for the Low Flex 3.0.

The thermoformer is a prototyping machine for running trials, but it has the same design as a full-production machine, Moore said.

"When you look at the pounds consumed by thermoformers in North America, the majority of it is consumed in-process by formers producing disposable food packaging," Moore said. "When you look at the products, there's not really a prototype machine out there that completely replicates all of the product that's being produced out there."

The Low Flex 3.0 is big enough, with enough depth of draw to make large cups, and it has independent servo-driven plugs. "Our focus is to make a prototype machine that has all the identical features of these big machines that were used in production," TSL's Moore said.

Both companies gain from the partnership. For the Washington-based Thermoforming Solutions, having a machine showroom in Michigan makes it easier for customers to see the technology closer to the action in the heart of thermoforming expertise.

Future Mold has not had its own mold-trial machine in-house before. Otto said the company takes molds out to local thermoformers for trials and mini production runs.

Having the Low Flex 3.0 also will allow for customers to work with Future Mold on prototypes and more easily discuss molds for specific packaging designs. Otto said material manufacturers also can try out new formulations on the line.

The showroom will include the TSL thermoforming machine, Tria granulating equipment for recovering in-line scrap and a DJS automation system. Future Mold also will install two of its lip rollers.

"We're calling it a lab line or show line," Otto said. "It's a development line for us, and it's a showpiece for them to bring people in. It will be used for us to support our customers."

Thermoformer Ameriform Plans Second Expansion in Two Years

by Michael Lauzon, *Plastics News*

OCTOBER 13, 2016 – Ameriform Inc. is expanding thermoforming capacity and warehouse and assembly space in Muskegon and Norton Shores, Mich.

The company qualifies for a 12-year tax abatement on the $1.4 million project, said Norton Shores City Administrator Mark Meyers.

"This is a significant operation," Meyers said in a phone interview. The expansion is one of four underway in the area's industrial base. About 150 new jobs are slated for the area, of which 60 jobs would be accounted for by Ameriform.

Meyers said Ameriform is the biggest plastics business in the region. Furniture manufacturing and GE Aviation's jet engine components operations are other major employers.

Ameriform produces Sun Dolphin kayaks and other watercraft and sporting goods. Warehousing space will be relocated into the new building, freeing up room for thermoforming machinery in an existing facility in Muskegon. The new building in Norton Shores should be ready for occupancy in early 2017.

The expansion is the second for Ameriform in less than two years. In 2015 it added two thermoforming lines in Muskegon as part of a $7.5-million expansion of its thermoforming, rotational molding and extrusion operations.

Thermoformer Direct Pack Adding NC Location

by Jim Johnson, *Plastics News*

AUGUST 12, 2016 – More than 90 new plastic packaging jobs are coming to North Carolina over the next five years as thermoformer Direct Pack Inc. will open a new manufacturing facility.

The new location, in Rockingham, will employ 94 and cost $12.7 million to construct, according to the Economic Development Partnership of North Carolina.

"We feel Rockingham is ideally situated to service both our existing East Coast customer partners and our plans for future domestic expansion," Direct Pack Inc. President Craig Snedden said in a statement.

Direct Pack, a division of PMC Global Inc., is receiving a performance-based grant of $300,000 from the One North Carolina Fund, which provides financial assistance through local governments to create jobs.

Annual payroll at the new site is expected "to add more than $2.3 million to the local economy each year," according to the EDPNC, a public-private non-profit partnership.

Direct Pack is based Azusa, Calif., and operates locations in Sun Valley, Salinas and Ontario, Calif., as well as Bloomfield, N.J., the state said.

PMC Global, of Sun Valley, previously known as Plastics Management Corp., invests in what it calls a wide range of industries, including plastics and packaging.

Direct Pack makes thermoformed products from a variety of materials, including PET, polylactic acid, polypropylene, PVC and polystyrene.

"We specialize in custom designed packaging for sales to supermarket chains, QSR and food processors for bakery, fresh cut produce, deli and confectionery," according to the company.

REDUCE! REUSE! RECYCLE!

Visipak Buys Clamshell Packaging Maker National Plastics

by Jim Johnson, *Plastics News*

OCTOBER 13, 2016 – VisiPak did not look far for the company's latest acquisition.The unit of Sinclair & Rush Inc. acquired National Plastics Inc. of St. Louis in a move that expands its thermoforming production to include additional shapes and sizes. National Plastics makes clamshell packaging.

VisiPak has a manufacturing site in Fenton, Mo., and administrative offices in Arnold, Mo., both outside of St. Louis.

"The acquisition correlates directly with our long-term strategies regarding increased product offerings and market reach," said Brad Philip, chief operating officer of Sinclair & Rush, in a statement.

VisiPak extends its clamshell packaging portfolio with the addition of more than 140 sizes and styles through the transaction. The company now has more than 170 offerings.

National Plastics customers gain access to VisiPak's line of plastic tubes, clear folding cartons, flexible vinyl caps and plastic plugs.

Sinclair & Rush will continue manufacturing at each location.

"Through this acquisition, we expect to accelerate our growth efforts and expand our presence as one of the largest plastic packaging manufacturers in North America," said Jeff Barket, sales and marketing director for Sinclair & Rush, in a statement.

Along with St. Louis area manufacturing sites, the company has operations in Carlstadt, N.J., the United Kingdom, China and Australia.

VisiPak, last year, acquired Tulox Plastics Corp., a maker of custom packaging tubes. Other Sinclair & Rush companies include StockCap, GripWorks, VynaFlex, Castle Bay and Software.

Need help with your technical school or college expenses?

If you or someone you know is working towards a career in the plastic industry, let the SPE Thermoforming Division help support those education goals.

Here is a partial list of schools and colleges whose students have benefited from the Thermoforming Division Scholarship Program:

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Thermoforming Technical Problems I Wish I Could Solve

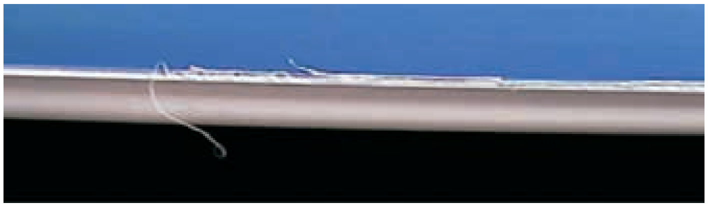
In thin-gauge thermoforming, is the sheet compression-cut or flex-fractured?

By Jim Throne, Dunedin, FL

Prologue

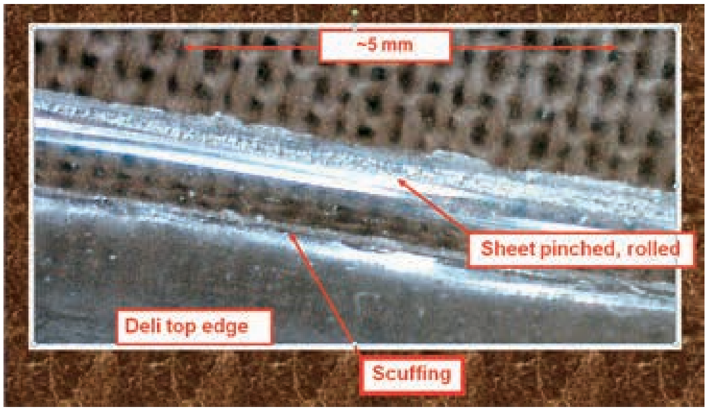
At thermoforming conferences some time back, I gave mini-lectures on trimming. I always prefaced my remarks with the axiom, "The act of trimming is the breaking of one piece of plastic to two or more pieces of plastic." Rich Freeman called me down on this, contending - in a friendly way (I think) - that thermoformers trim, not break, plastic. So I've stopped calling trimming "breaking." As a matter of fact, I've even stopped lecturing on trimming, in general.

I've always been told that in a traditional punch-and-die operation, the sheet is pinched between the edge of the die and the incoming punch. If the trim press is set so that there is a slight interference fit between the punch and the die, the mechanism of failure is one of flexural fracture, meaning that the sheet is increasingly bent over a sharp edge until it fractures. I thought that made sense because if there is a gap between the punch and the die, certain fiber-forming plastics (PP, PE, PET) could be split into more than two pieces. The plastic caught in the gap is often a microfiber, as shown here:

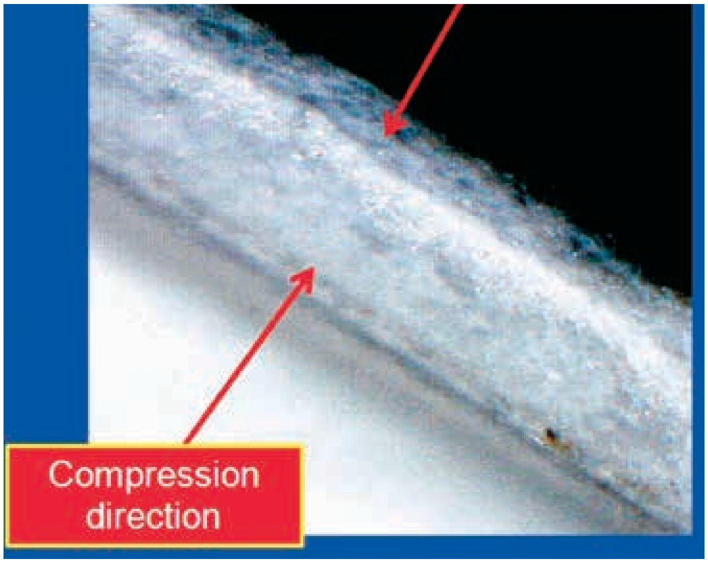


So why are we reconsidering this topic?

Let's take a look at some cut edges. I first examined the cut edge of an ordinary unfoamed PET tray and saw this:

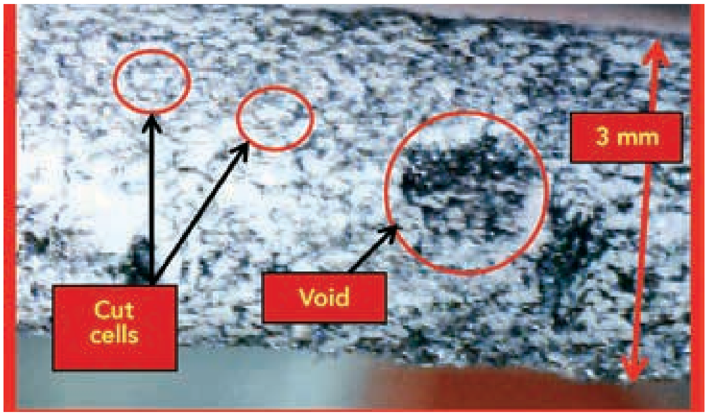


I then examined the cut edge of an ordinary low-density polystyrene foam egg carton under a microscope and saw this:

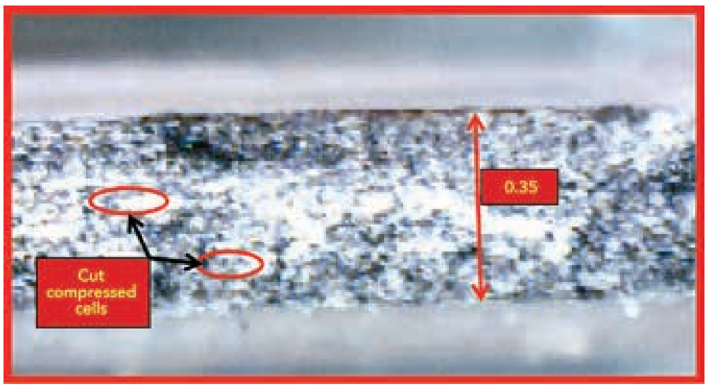


It is my understanding that both of these products were trimmed on conventional punch-and-die presses. Yet it seems to me that there is substantial difference in the trim mechanism. As we would expect, the surface of the unfoamed part exhibits a nearly-clean cut surface, albeit with some microfibers. We might classify a cut of this nature as a near-brittle fracture.

But look again at the cut edge of the foam. Polystyrene is a brittle plastic, with room-temperature elongation-to-break in the single digits. If we simply take a piece of this foam and bend it, it will fracture, exposing broken cells across the broken surface. Here's what the foam cut surface should look like:



But wait. From examining the white line at the edge of the foam in the earlier photo, it appears that the foam has been highly compressed prior to separating. See any exposed broken cells? Neither do I. In fact, the surface appears nearly smooth. We know plastics can be welded in various ways, including localized compression. It appeared (to me, at least), that the localized interference compression in the punch-and-die, melted and welded foam. But, as seen below (albeit a little pixellated), simply compressing the foam from 3 mm to 0.35 mm elongates the cells but does not fuse them.



So what is the dilemma here?

What is the mechanism by which foam (and by inference, other softer materials) is cut? Is heat and pressure required to weld the foam edges? If so, how do we know when we are sealing off the cut edges and when we are not? And, I guess, the bigger question is: is this really an issue?

From my early experiments I'm really not sure. Certainly generation of microfibers or "fuzz" is an issue. Suppose that these fibers are melt-formed during the shearing action in the gap between the punch and die. Keep in mind that the shearing action is intense and short, the cutting surfaces may be quite hot from friction (and/or supplemental heat) and the thermally insulating plastic might be quite warm.

Is this the same mechanism that occurs when pinch-cutting foams? Again, I'm not really sure. So how can we approach this problem? Is it possible to deliberately create microfibers using just impact/compression or must we have shear present as well? As a first step, I would contemplate creating a set of parametric experiments to determine if compression is important. Typical parameters would be the impact energy and the compression residence time. Ultimately, I would hope we could make a valiant attempt to model the compression/flexural action of the punch-and-die. And once we gain an understanding of this issue, we can segue over to the steel rule/forged die arena to examine compression and shear there.

So whether we call this trimming or solid mechanical fracture, we need to get our arms around what is really happening when we squeeze and shear our plastic between two high-speed, juxtaposed solid surfaces. |

Optimizing Cycle Time by Analyzing Mold Behavior

By Jose Noriega, Director of Engineering, ToolVu, LLC

Introduction

Graphical visualization is an essential component to understand and manage tool behavior during forming time. ToolVu is an in-mold process monitoring system designed specifically for thermoforming and addresses the needs of today's data-driven manufacturing environment. It enables real time graphical visualization, cycle by cycle, of the forming process variables inside the mold.

This article will explain how cycle time can be improved with ToolVu by analyzing the timing of a forming process 'shot' (or cycle) using samples of actual recordings.

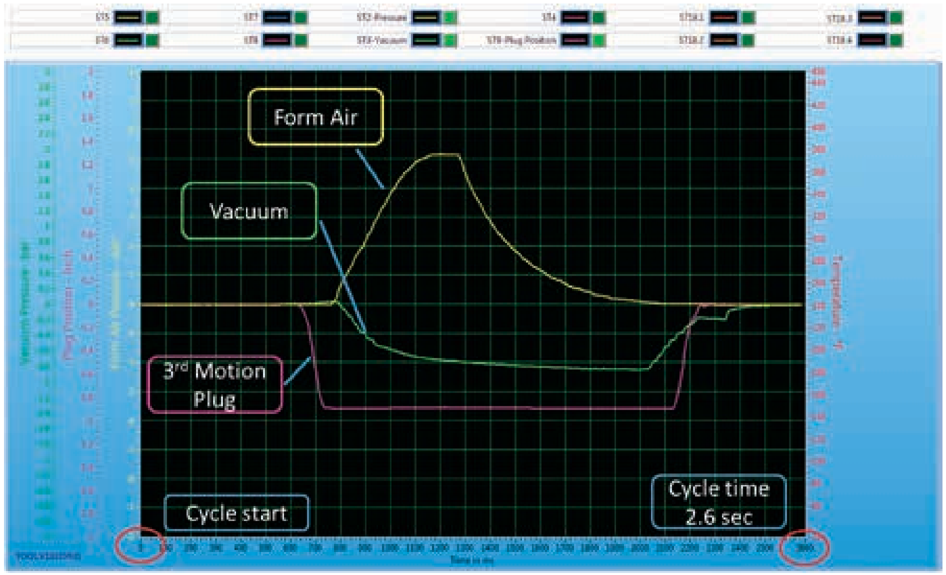


Figure 1

Establish process baseline:

Refer to the graph in Figure 1. This simplified graph illustrates the primary actions when forming. We can see the timing and magnitude of three process variables: form air, vacuum, and 3rd motion plug position. On the bottom of the graph, or X-axis, we can see that this cycle, or shot, currently takes 2.6 seconds to complete.

We can identify that at about 650ms after sheet index, the plug has begun to move in to the mold (note: platen position graphs omitted for clarity). Once the plug reaches full extension we can see that the Form Air and Vacuum are later activated. As time continues, we then see that the form air and the vacuum are purged followed by the retraction of the plug assist. This completes one forming cycle and we can expect the same profile for each following cycle.

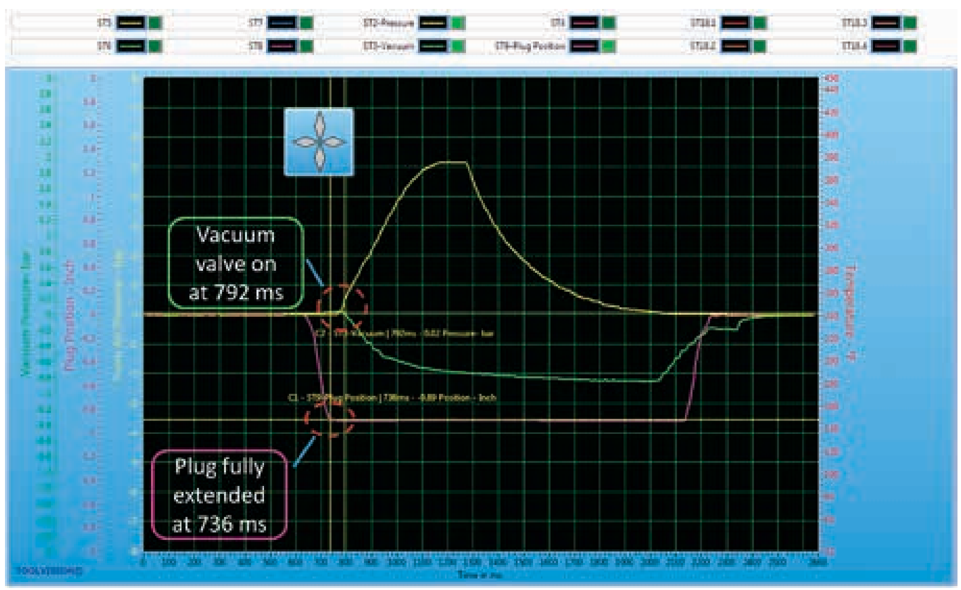


Figure 2

Analyze cycle-time contributors:

Refer to the graph in Figure 2. Utilizing ToolVu's analysis features we can identify that the plug is fully extended at the 736ms mark. The vacuum starts inside the mold cavity at the792ms mark. This is a delay of 56ms per cycle. Typically, the vacuum should begin right at full plug insertion but as we noted earlier it is lagging.

This may be caused by several factors including valve aging or wear, propagation delays through plumbing, or simply an improper timing sequence. Now that you can see and quantify the unwanted delay you can make vacuum timing adjustments and validate them in real-time as they are made. By turning the vacuum on sooner, you can complete the vacuum cycle faster without compromising the part's cooling time while in the mold.

In this case, you have the opportunity to reduce cycle-time by 2.10% while improving machine through-put and equipment utilization time.

Other cycle-time analysis:
Refer to the graph in Figure 3. In this case, we examine a different mold or product. Here we have included the upper and lower platen position graphs (note: the female cavity of the mold is attached to the upper platen). Now referencing the graph in Figure 4, we have again used ToolVu's analysis tools to evaluate the timing between the upper platen opening and the vacuum bleed-off at the end of the forming cycle.

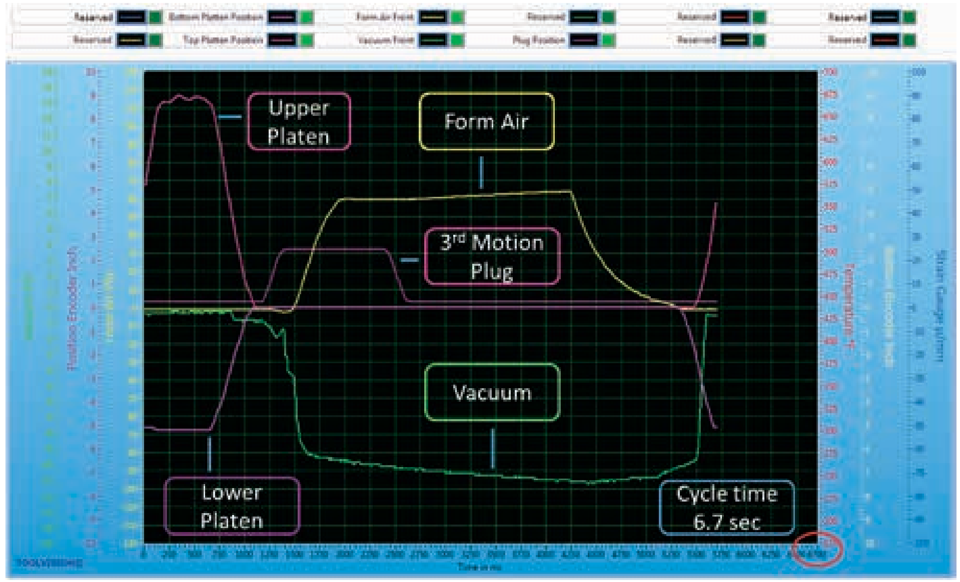


Figure 3

At the 5120ms mark we can see that the vacuum has begun to bleed-off as the cavity pressure rises in a sloping fashion. Then at the 5504ms mark, we see the vacuum very abruptly release as indicated by the nearly vertical response. Notice at the same 5504ms mark we see the upper platen beginning to retract. This is an indication that the platen has opened too soon and a rapid re-pressurization of the mold has occurred. This can often create additional stresses on mold gaskets and other seals.

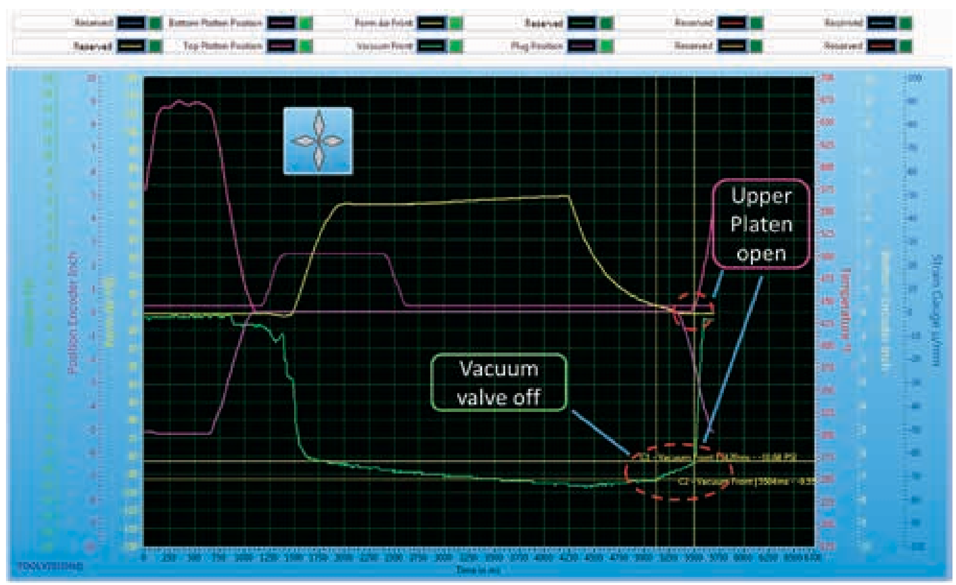


Figure 4

If this sudden equalization of pressure were to occur in the form air chamber it would be recognized as a loud 'pop' with each forming cycle. ToolVu allows you to see this sudden pressure equalization even in the absence of sound allowing for corrections to be made which will prevent seal damage.

Conclusion

In this brief report, we focused on just two aspects of the forming cycle and demonstrated how ToolVu allowed visualization of the process and helped to optimize it. This technique can be applied to other aspects of the forming cycle to achieve further cycle-time reductions and process optimizations.

Additive Manufacturing for Thermoforming Molds

By Patrick Price, Additive Manufacturing Research Engineer, Stratasys

Traditionally, thermoforming tooling has been made from wood, RenShape board or machined metals. Although these legacy techniques are still relevant today, quality and cost concerns associated with these methods are driving thermoform part manufacturers to look for new tooling solutions for low- to moderate-quantity production runs. The market need for a solution led the engineers at Stratasys® to investigate the feasibility of additively manufacturing thermoform tooling using FDM® (fused deposition modeling) to reduce tooling cost, material waste and lead time. Figure 1 shows a part being formed over an FDM tool.

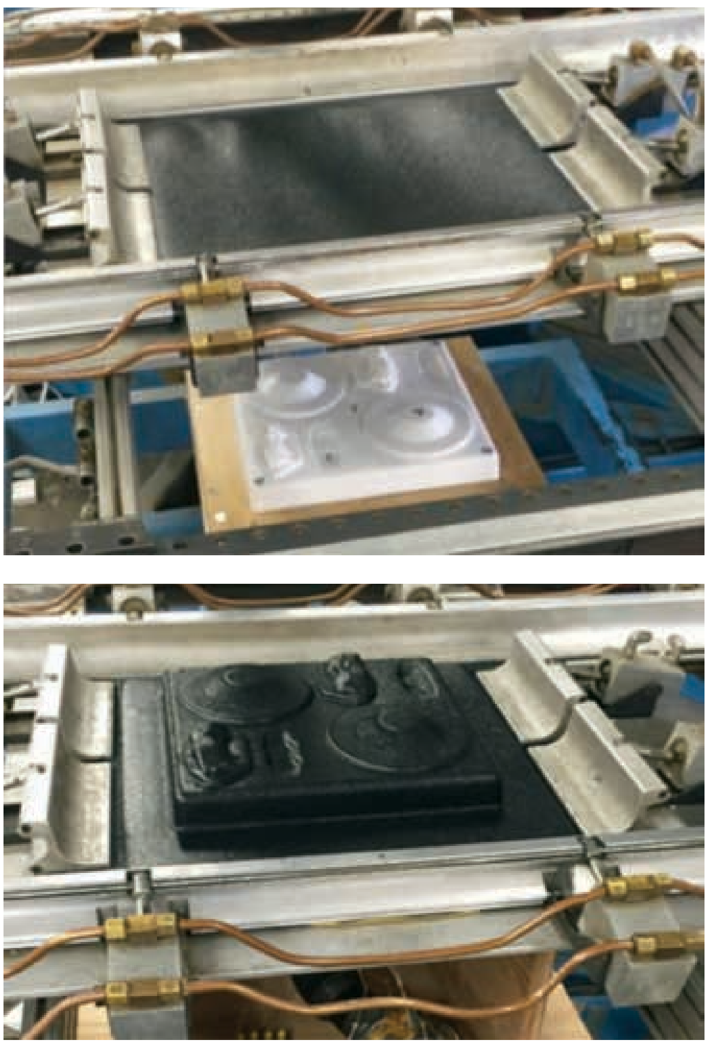


Figure 1: An FDM tool being raised into the heated ABS sheet (top) and forming the ABS part over the FDM tool (bottom).

Lifecycle testing was performed using ABS and Kydex thermoforming materials formed over additively manufactured tools. Pairing these thermoforming materials with additive manufacturing materials such as Polycarbonate (PC) and ULTEM™ 9085 resin (a Polyeitherimide [PEI] blend) led to an understanding of the design criteria and best practices needed to meet requirements within various industries including automotive and aerospace. Criteria included draw ratios, heat transfer during the forming process and tool heat dissipation rates that affect tool wear and tolerances over time due to thermoplastic warp and thermal shock.

Compared to machining, additive technologies begin with an empty build tray and place material only where needed. FDM technology reduces material waste by extruding filament out of a tip instead of filling the entire build chamber with raw material such as a powder or liquid like other additive systems. FDM allows for lights-out manufacturing, reducing production labor. The part can simply be started on the machine (such as a Fortus 450mc™ or Fortus 900mc™ Production System) and does not require human intervention until completion. FDM uses engineering-grade thermoplastics that are naturally lighter than some traditional tooling such as machined aluminum. FDM thermoform tools are also built using an internal lattice structure, which reduces build time, material usage and weight. This weight reduction allows an individual to lift and move a large tool that normally would require a crane or forklift. FDM tools are naturally porous due to the nature of the manufacturing process that is further enhanced by the reduced-density internal lattice structure, eliminating the need to drill vacuum channels.

FDM thermoforming tool design is similar to how tools are designed in conventional manufacturing methods for most features including draft angles, corner radii and draw ratios. The coefficient of thermal expansion (CTE), thermal conductivity and inherent porosity of the FDM tool must be considered during the design process as they differ from traditional materials and tooling methodology. The CTE of FDM materials is typically much higher than traditional tooling materials such as aluminum. This CTE value must be taken into account when designing the tool so that the expansion of the mold meets the desired part tolerance when the tool reaches an elevated, steady-

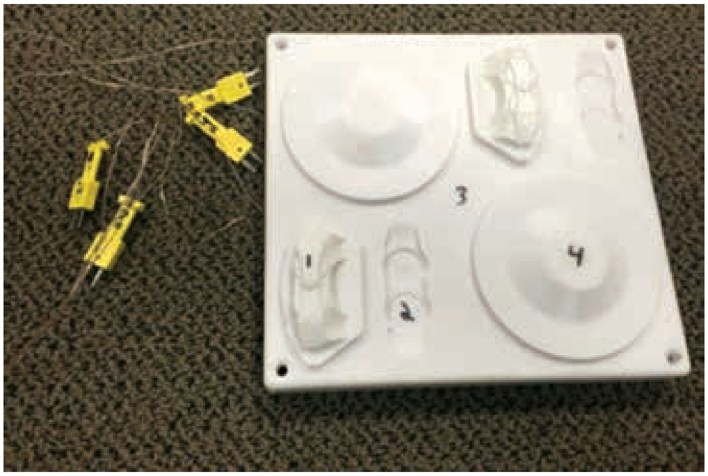


Figure 2: A tool that had many different features was used for cycle testing. The tool contained four thermocouples at the marked locations to measure tool temperature during forming.

state temperature during the forming process. Thermal conductivity is reduced compared to that of aluminum and will also need to be considered. Longer cycle times or additional cooling fans may be required to ensure the mold does not overheat. The inherent porosity of FDM tooling is typically an advantage but for some geometries, sidewalls or elevated flat surfaces may need to be sealed with a high-temperature epoxy to prevent vacuum from being drawn through these regions to promote sheet flow.

Cycle testing was performed on a PC tool paired with ABS forming sheets and an ULTEM 9085 resin tool paired with Kydex forming sheets. The tools were approximately 12" x 12" x 2.5" with embedded thermocouples to profile tool temperature during forming (Figure 2). The tools were also scanned with a metrology-grade laser scanner after they had been produced to acquire a profile baseline. Parts were formed on the tools and the baseline scan was then compared to other scans generated at various intervals to measure any tool degradation.

A tolerance of 0.010" was targeted for the cycle testing. The PC tool was able to form 223 ABS parts that were 0.118" thick at 360 °F with a 2 minute, 30 second cycle time before it drifted out of tolerance. Higher temperature materials (such as Kydex) were also formed over a separate PC tool but did not produce favorable results as the tool surface began to melt. PC tools are recommended for materials formed at or below 360 °F and have a 2.5 minute or longer cycle time. Figure 3 shows the temperature profile during the forming process with ABS. The temperature of the tool increased dramatically at the beginning of each cycle when the hot sheet initially made contact with the tool (each spike on the graph represents the beginning of a new cycle). The tool then cooled for the remainder of the cycle as the part was cooling and being released from the tool. The tool continually increased in maximum temperature during each cycle until a steady state was reached after roughly 5 cycles. The steady-state temperature of the tool remained below 220 °F, 60 °F

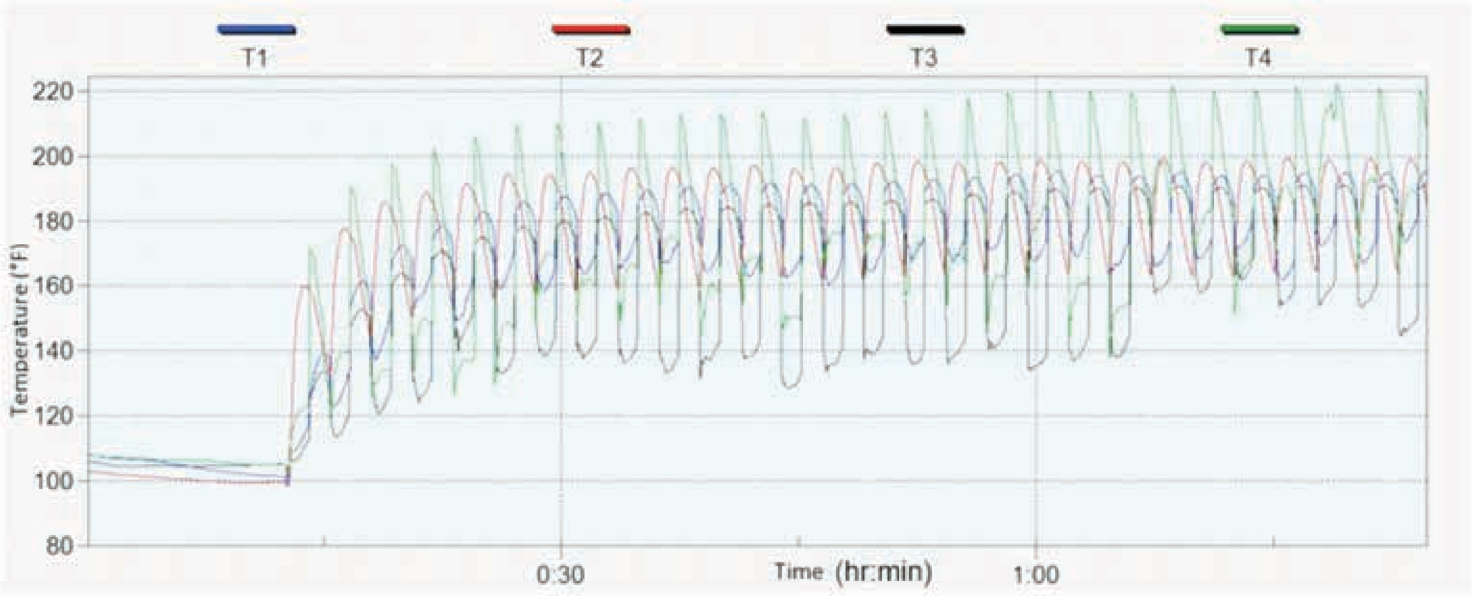


Figure 3: Thermocouples embedded in the PC tool while forming ABS allowed observation of the temperature profiles in various regions of the tool.

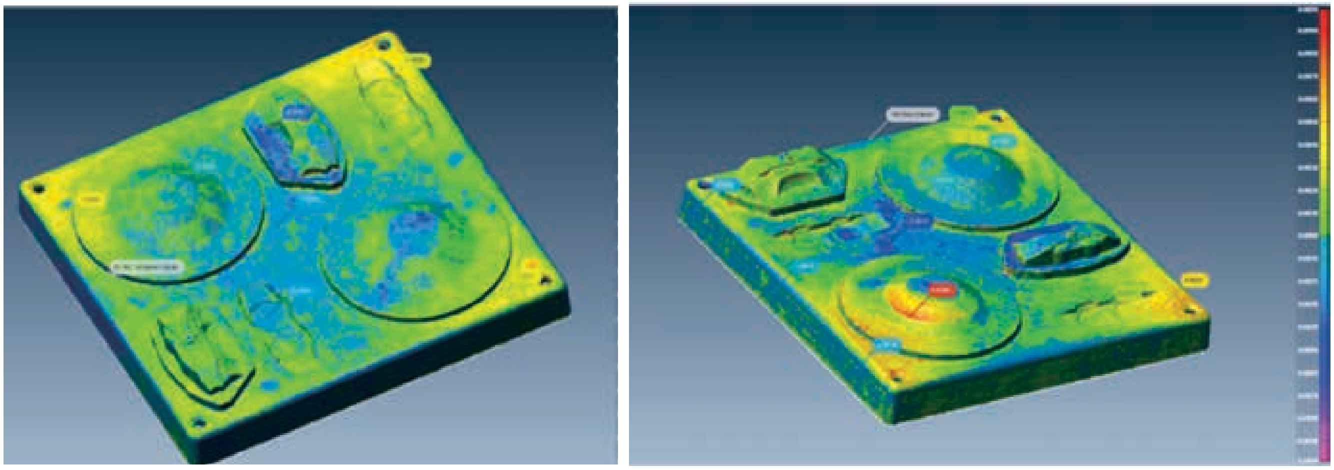


Figure 4: Comparison scan of the tool after 123 cycles (left) and 223 cycles (right) to the base scan with a scale of 0.010"

below the heat deflection temperature of PC at 66 psi, ensuring that the tool did not soften during the forming process.

Figure 4 shows a comparison of the PC tool after 123 and 223 parts had been formed. The tool remained in good condition for the first 123 cycles but then started to degrade toward the end of the 223-cycle run. The tool was on the edge of being in tolerance after 223 cycles except for one of the cones, which began to lift slightly from the rest of the tool. It was determined that 223 cycles was the maximum number for this tool and forming material.

Similar testing was performed using the ULTEM 9085 resin tool paired with Kydex. The geometry remained the same and Kydex was chosen to validate a higher temperature material on an FDM tool. The Kydex sheets were 0.19" thick and formed at 400 °F with a 3 minute, 20 second cycle time. 23 parts were formed over the tool to ensure it did not melt when reaching a steady-state temperature. Figure 5 details the temperature profile throughout the forming process. The tool reached a steady state temperature of 260 °F during the forming process.

Figure 6 shows the scan data after the 23 cycles. The tool did not melt, remained in tolerance and showed similar deviations to the PC tool for the same number of cycles. Further cycle testing of the ULTEM tool was not performed

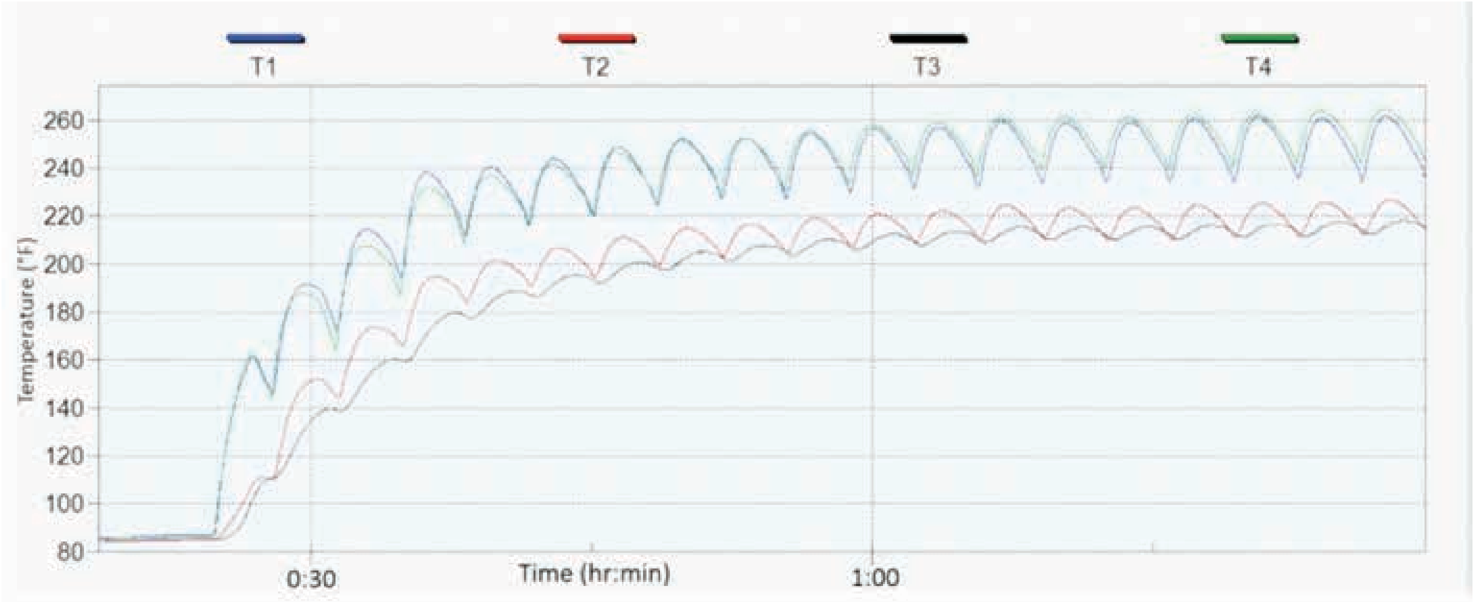


Figure 5: The observed temperature profile of the ULTEM 9085 resin tool while forming the Kydex material.

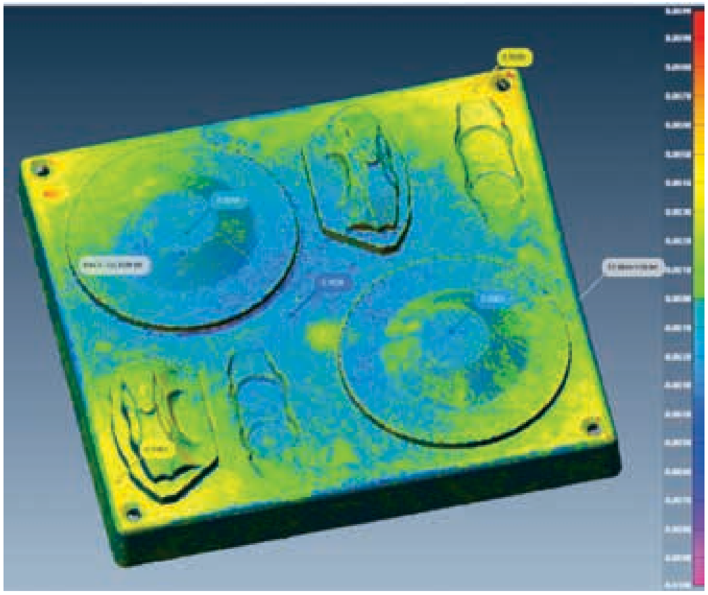


Figure 6: Comparison scan of the ULTEM tool after 23 cycles to the base scan with a scale of 0.010"

as the purpose of this experiment was to validate higher temperature materials.

"At RP+M, we've been utilizing Stratasys FDM technology to investigate thermoformed tooling for plumbing and automotive applications. In this case, thermoforming tools manufactured by FDM offer a low cost, reduced lead time alternative to a traditionally machined aluminum tool. In addition, taking advantage of additive design, we can reduce material consumption though use of a honeycomb or lattice interior. The result is a tool system that performs well, but satisfies the need for a quick turn solution to a simple manufacturing problem." — Dr. Tracy Albers, Rapid Prototyping and Manufacturing CTO

FDM thermoform tooling is a cost-effective alternative for producing low-volume thermoformed parts. Although legacy tool production methods including wood, RenShape board and machined metals still have particular applications within the thermoform tooling industry, FDM thermoform tooling solves many problems seen within the industry including high tooling cost, long lead times and complex geometries.

For more information or documentation on this application, contact Alissa Wild at Alissa.Wild@Stratasys.com. |

Editor's Note: Last year, the Thermoforming Division underwrote an effort to build an archive for all articles and magazines produced since the inception of our division.. The result was a catalog of more than 575 articles over 35 volumes going back to 1975. Though some individual issues have been lost in the mists of time, we now maintain a digital record of contributions to our society. To celebrate our past achievements, we will occasionally republish elements from the archives.

Volume 7, No.1 Spring, 1987

NEWSLETTER

SPE THERMOFORMING DIVISION

Man of the Year Award

On Monday November 10, 1986, Herman R. (Dick) Osmers was presented with the 1987 Thermoforming Division Man of the Year Award at the monthly meeting of the Rochester Section.

From left to right: Bill McConnell, John Grundy, Dick Osmers, Jim Throne, John Kelly.

The award was presented by the first recipient of the award, Mr. Bill McConnell. In addition to the members of the Rochester Section, (and there were many), John Grundy, Jim Throne, and John Kelly were there to represent the Thermoforming Division.

Dick Osmers single handedly put our Division back together in 1980 when he and three others showed up for the annual Division meeting, only to find that there was no organized meeting, and no Division officers present! Dick and three or four others put together a steering committee that reorganized the Board, elected officers, and charted our present course.

Involvement in Division activities is a voluntary effort, and involves a fair amount of dedication from the individual in order to be worthwhile and productive. Dick was one of the most effective and productive members of the Board, in addition to being one of the finest human beings that ever walked the earth. It is through the efforts of individuals like Dick that the SPE is successful today.

First Ever National Thermoforming Exposition

In Conjunction with SPI/SPE "Plastics West" Oct. 20 - 22, 1987 Las Vegas, Nevada

A special pavilion containing thermoforming exhibits by machinery manufacturers, mold makers, material suppliers, auxillary equipment and custom thermoformers will be set aside by the Plastics West management.

Special round table thermoforming seminars and a social get together will be part of the program.

This show will be international in scope and its advertising and publicity will be directed to all U.S.A. and worldwide visitors and exhibitors.

I urge all thermoforming industry segments to attend and exhibit at this show.

For booth applications and visitor information contact,
Mr. Stan Rosen
SPE Thermoforming Div. Exposition Committee
c/o Hydro-Trim Corp.
167 Western Highway, W. Nyack, N.Y. 10994
(914) 353-1382

Support the Thermoforming Industry by attending and exhibiting in Fun City, Las Vegas, Nevada.

Parts Competition

The Thermoforming Division is sponsoring a parts competition. All thermoformers are invited to submit their entries which will be judged at the Las Vegas Thermoforming Exposition October 20 - 22. 1987. Sample parts should be labeled as such and sent to:
Ray Products
11565 Federal Dr.
El Monte, CA 91734-1087

Further information will be included in the next newsletter of call Dick Fassett, (517) 424-3877 (at Brown Machinery in Michigan.)

Jade Photech and LINDAR Develop New Lenticular Film

Jade Photech and LINDAR recently announced a joint venture with a new, specifically designed extrusion line for lenticular material. Operating under the brand name Optica, the joint venture produces micro-optical material in a new and novel way. The process sets a new standard to which all other lenticular material will be compared.

Optica combines the resources and expertise of Jade Photech's 3D technology using its new, proprietary micro-optical material solutions in tandem with LINDAR's advanced plastics manufacturing knowledge in the industries of paint products, food packaging, and OEM parts. The result is consistent micro-optical material and the most sustainable lenticular material produced.

"Our team has taken on the process of developing this new material," said Tom Haglin, LINDAR president. "We are very excited to add lenticular extrusion to our manufacturing processes and to redefine the lenticular marketplace. Our partnership with Jade Photech has pushed our manufacturing goals."

The design and build of the multi-million-dollar machine was completed through a collaboration of Jade Photech and SML, a builder of precision manufacturing equipment located in Lenzing, Austria. The machine is located at LINDAR's Baxter facility and is ready for production. It delivers recycled plastic to comply with eco-friendly initiatives for a variety of 3D applications allowing multiple messages or motion on one single label or panel. Applications include packaging, point-of-purchase displays, 3D labels, counterfeit-proof ID cards for events, concert admissions, government use, and more.

"The consistency of our Optica material makes flexographic printing for 3D motion graphics available," said Dan Fosse, LINDAR director of sales. "This provides very high-resolution print quality and guaranteed consistency across the entire width of the plastic sheet—from 8 to 33 gauge. This is a game changer in the motion graphic market."

Once the lenses have been extruded, either into roll stock or sheets that are cut to size, the images are printed directly onto the Optica material. This causes the image to pop with 3D graphics, morphing graphics, flip graphics, and up to 24 frames of motion graphics being viewed through the lenticules.

"Jade Photech has taken a systems approach to producing more cost-effective and attractive 3D images," said Dr. Bill Karszes, Jade Photech CEO and the machine's lead designer. "We have designed and built a process to produce the most uniformly consistent micro optical material available in the market. Now our partnership with LINDAR has furthered our goals by utilizing their

Figure 1: View of new lenticular extrusion line at Lindar Corp. (photo courtesy of Lindar Corp.)

manufacturing expertise and experience. The material has been successfully printed and has proven to be cost-effective."

"Often in production, volume impacts quality, and vice versa," said Bruce Hinkel, Jade Photech president. "But we can consistently deliver both for a variety of different industries using our breakthrough 3D technology with the new machine. We believe the joint venture with LINDAR is a good starting point."

The new 3D images are a result of Jade Photech's arrangement with its affiliated company Photon3D Ltd. of Hong Kong, using its 3D operating system and platform for both 3D digital and print applications.

"Our new technology allows us to deliver superior 3D images that match the human visual system without the need for 3D glasses," said Dr. Jerry Nims, Photon3D chairman.

The joint venture provides a complete package of lenticular printing services, which allows LINDAR and Jade Photech to complete the entire process in making a product that has been created with lenticular extrusion, including support for 3D graphics interlacing, prepress, and printing.

For more information on Optica material, visit www.optica3d.com.

The Production of Drinking Cups, Part 1

Written in cooperation with Paul de Mink, Borealis AG, Austria, and Norbert Hufnagl, Kiefel GmbH, Germany

[Editor's note: the following article is adapted from Advanced Thermoforming by Sven Engelmann Dipl. –Ing., Director of Packaging Technology at Illig in Heilbronn, Germany. Mr. Engelmann has a distinguished career in polymer science and thermoforming technology. Prior to his return to Illig, Mr. Engelmann was a Director of R&D at EBB Microparts and the Director of Polymer Technology at Gerhard Schubert GmbH, a leading designer and manufacturer of innovative form/fill/seal technologies. In addition to his work in the private sector, he is a lecturer at the University of Stuttgart and the Aalen University of Applied Sciences where he teaches "Basics of Thermoforming." He is the author of numerous articles published in both the US and Europe on thermoforming, polymer processing and injection molding. His recent book, published by Wiley, can be purchased on Amazon. He can be contacted at sven.engelmann@illig.de. This particular chapter was written in conjunction with Mr. Paul de Mink who recently passed away. Mr. Engelmann would like to acknowledge Paul's contributions and recognize his friendship over many years.]

Drinking cups made from plastic are being used all over the world (Figure 36.1). The reasons for their use are quite different. Organizers of big events appreciate the safety aspect of plastic cups compared to glass containers to avoid the possibility of breakage. Plastic cups thus prevent accidents. Their one-time usage also eliminates cleaning of cups. Some regions of the world do not have decent working water pipelines. This makes the supply of water a hygienic problem. The solution could be water in thermoformed and sealed containers. These containers could be packaged in transport trays and delivered rightaway to the consumer.

Plastic containers are being used for millions of items. The item discribed in here is the drinking cup made of polypropylene.

There has been a great innovation upswing for polypropylene in the recent years.[1] Because of the recycling tend promoted by an environmentally conscious public, and also economic factors, the use of PP has greatly increased. In particular, extruded PP applications—mostly in the packaging industry—are the motivation for continual development of an entire group of this material. The enormous research that is being done has brought much variability to the characteristics and properties of PP (better catalytic converters, better polymerization technology, compounding, etc.). It is now possible to expand into areas of applications where before the standard PP could not be used.

Thanks to the willingness of the engineering industry (extrusion, thermoforming, etc.) to innovate and develop polypropylene, PP is in the position to take a big share in the packaging industry.

Figure 36.1: Drinking cup (Courtesy of Kiefel GmbH)

In this chapter the example of the drinking cup is used to show the basics of PP, PP modifications and developments. Additionally the discussion will extend to all major influences on PP film's characteristics and the ability to thermoform as are due to the different processing conditions (in the production of PP film).

Worldwide demand for PP is more than 30 millions tons, with average growth of 6-7% per year. Western Europe, North America, and Asia handle 70% of this demand. The major areas of applications are found in the food industry, consumer items, and the automotive industry. The most important customers in western Europe are Germany, Italy, the United Kingdom, and France.

The factors for the relatively high growth rate of polypropylene are, next to its broad variety of use, its economic and environmental advantages. These attractive characteristics of polypropylene are quite numerous:

- Economical material (monomer costs)
- Low density (0.9 g/cm3)
- High durability temperature
- Good chemical resistance
- Good processing and recycling performance
- Modifiable in wide range
- Ecological benefits

36.1 From Monomer to Polymer

The first time polypropylene was polymerized and used in a technical way was at Montecatini, Italy, in the 1950s. With a speedy development of catalysts it was possible to increase the PP turnover enormously per catalyst unit. Polyolefins such as polypropylene and polyethylene are produced through polymerization (Figure 36.2).

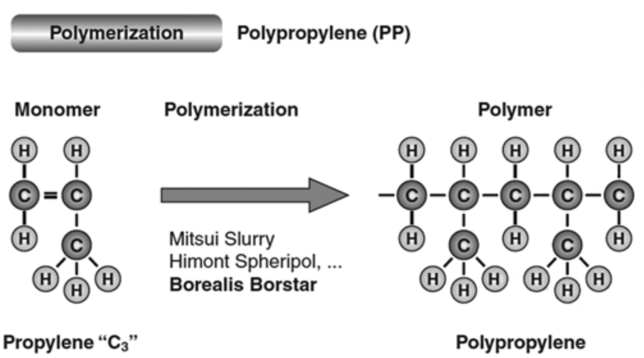


Figure 36.2: Polymerization (Courtesy of Borealis AG)

Polymerization is the connection between a single molecule (monomer) to a bigger molecule (macromolecule) with the employment of the correspondent catalyst ystem. The size of the macromolecule is determined and stated by its molecular weight or the degree of polymerization.

The degree of polymerization is the number of smaller molecules (monomeren) combined to form one macromolecule. The weight of the molecules is defined by the combined weight of atoms that are contained in one molecule. The weight of the macromolecules is calculated by mulitiplication of molecular weight of the monomers with the degree of polymerization. The CH3–groups can be placed in different orders in space. This has an influence on crystallinity. There are isotactic, syntactic, and atactic orders.

36.2 Mechanical and Thermal Behavior of PP

Areas of processing and application (temperatures of usage) of PP are mainly determined by the thermal mobility of the macromolecules. The characteristical conditions and transitional areas are simplified in Figure 36.3.

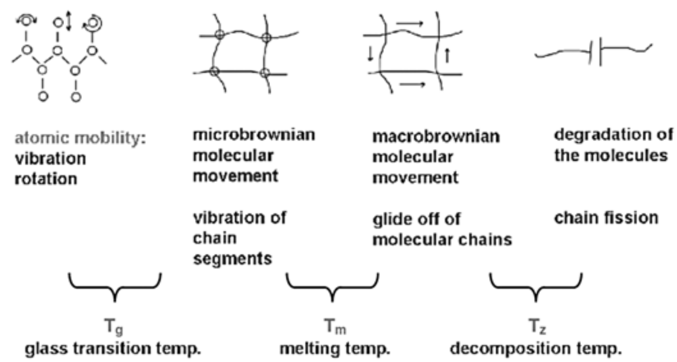


Figure 36.3: Thermal mobility of macromolecules (Courtesy of Borealis AG)

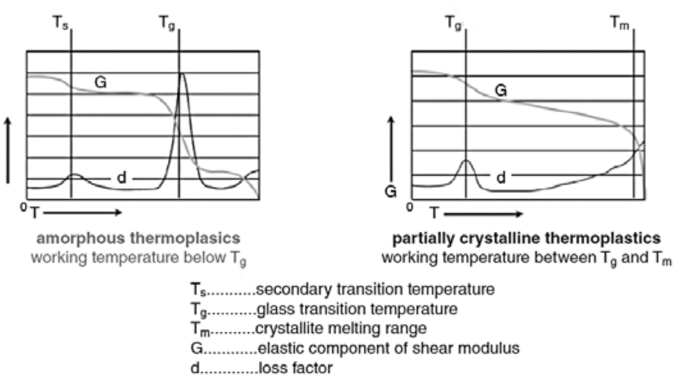


Figure 36.4: States and working ranges (Courtesy of B orealis AG)

The glass condition of thermoplastics is based on a strong cohesive strength due to the low temperatures. Because of the high minor valence forces between the macromolecules, only mobility between the hydrogen atoms is possible (vibration, oscillation, and rotation).

With a corresponding raising of the temperature, the glass transitional temperature (ceding to a brittle-glassy thermoelastical condition) reached. This is the point where minor valences, which lie in disarray between the chains of molecules, are overcome and become movable against each other. There will be oscillations of chain segments (micro-Brownian molecule movements). In practice, it is at this point that the polypropylene has reached the usage temperature. At the usage temperature, all "adhesive points" between the macromulecules dissolve, and slip-off occurs in the molecular chains (melting range). This is the area where the micro-Brownian molecular movement transitions to the macro-Brownian molecular movement (melting condition). As in succession the temperature decline is reached, there comes a decline of molecules due to the high thermal strain. This transitional behavior is described by the torsion pendulum test. The successive curves of the mechanical-thermal behavior of amorphous, semicrystalline thermoplastic are shown in Figure 36.4 and illustrate the fact that PP (partially crystalline) thermoforming is, in comparision to, for example, polystrol (which is amorphous), a little more critical structured.

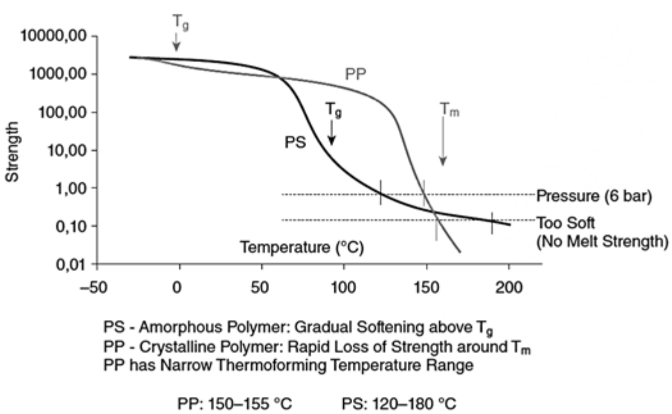


Figure 36.5: Strength/temperature (Courtesy of Borealis AG)

The ideal state during thermoforming of thermoplastics is when the substance is in the transitional stage between thermoelastic and thermoplastic. The glass transitional temperature of amorphous thermoplastics is higher than the usage temperature. The mechanical ease factor d (damping) reaches its maximum in this stage. There will be then a relatively broad thermoforming range due to a gradual softening. Unlike the semicrystalline thermoplastics that have their glass-transitional point below the usage temperature the maximum of mechanical alleviatin—factor (maximum mobility of the molecular chain) is reached short off the crystalline melting point.

A more or less abrupt changeover from thermoelastic to thermoplastic condition occurs in the tide processing window when working with the thermoforming of polypropylene. The diagram in Figure 36.5 shows that fact very clearly.[2] While with raising temperature the PS curve shows great length in the working range (pressure

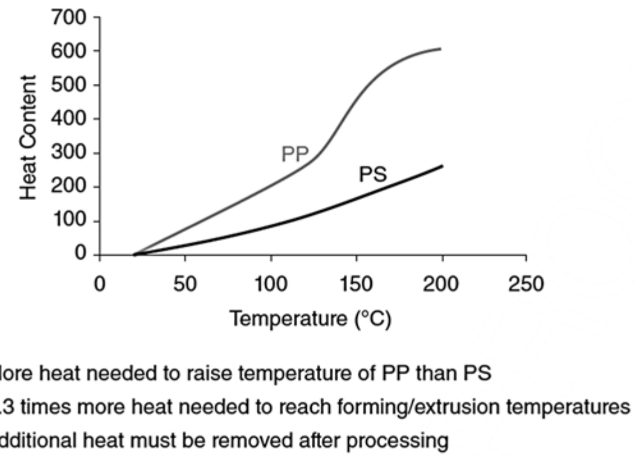


Figure 36.6: States of heating/cooling (Courtesy of Borealis AG)

6 bar and too soft, no melt strength), drops the curve of PP nearly through this area. For PP processing more temperature control is necessary the thermoform machine. To keep the film from sagging, the machine needs to supply longer heating length of the heating system, which will be described next.

The relative heat absorbtion, respectively the specific heat conductivity, of polypropylene differs greatly compared to amorphous thermoplastics. That is why more energy is needed to heat up or cool down PP compared to PS (Figure 36.6).

The torsion pendulum test can be used to describe the mechanical-thermal behavior of thermoforming films. Besides the material-specific characteristics, this shows the influence of the film's "production history" (influence of PP film production on crystallinity and morphology) based on

Material	Shrinkage [%]
ABS	0.3–0.8
SAN	0.5–0.6
MIPS	0.5–0.6
PS	0.3–0.5
LDPE	1.6–3.0
HDPE	3.0–3.5
PP	1.5–2.2
RPVC	0.4–0.5
FPVC	0.8–2.5
PC	0.6–0.8
PMMA	0.3–0.8

Figure 36.7: Shrinkage data (Courtesy of Borealis AG)

corresponding differences in the curve's progression. From the shape of the curve conclusions can be drawn about the thermoforming behavior of the PP film.

One more considerable difference between amorphous and semicrystalline materials during processing (extrusion and thermoforming) is the shrinkage of these materials. Allowance must be made in the mold design to compensate for shrinkage. Shrinkage guideline values for different thermoplastics as used to calculate thermoforming molds and tools are combined in Figure 36.7.

36.3 Difference Between Mold Shrinkage and Free Shrinkage

Is is important for the processor of synthetics and consequently for the thermoformer to have knowledge about the difference between the mold shrinkage and the free shrinkage.

36.3.1 Mold Shrinkage

Thermoplastics are subject to a volume contraction during freezing in a cavity. This causes the dimensions of the formed parts to be smaller than the respective tool dimensions by a certain shrinkage value.

36.3.2 Free Shrinkage

If thermoplastics are heated beyond the glass-transition temperature, there is shrinkage due to an orientation relaxation of the molecules. The extent of shrinkage depends on the degree of orientation forced on the thermoplastic during processing. A number of factors can contribute to shrinkage:

- Shape of formed part
- Evenness of wall thickness of formed part
- Tool temperature
- Deep drawing ratio
- Forming temperature
- Filling material in plastic material

The total shrinkage follows from the processing shrinkage and the post-shrinkage.

The most shrinkage happens shortly after processing. So, to measure the total shrinkage, it is necessary to take the post-shrinkage into consideration. This is why the measuring of a particular part for shrinkage should take place after 24 hours.

36.4 Polypropylene Modifications

Basically there are three types of PP modifications (Figure 36.8)[3].

Homopolymer. Polymerization from pure propylene.

Random copolymer. Polymerization from propylene with ethylene as comonomer, which is statistically distributed in the chain.

Block copolymer. Heterophasic system, with one homopolymer as a continuous phase in which the EPR as a second component is polymerized.

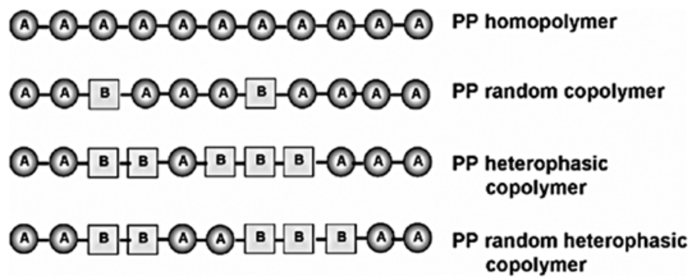


Figure 36.8: Basic polymer knowledge (Courtesy of Borealis AG)

The choice of PP modifications appropriate for a certain application is always based on the requirement profile of the finished part. Figure 36.9 compares the different PP modifcations and shows the mechanical and optical attributes of the thermoforming films. The greatest stiffness with relatively low toughness is reached with the PP homopolymers.

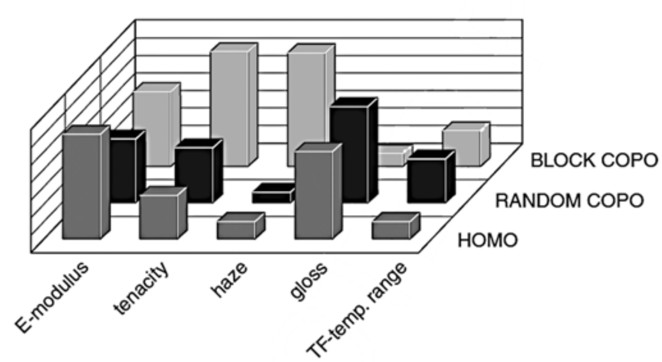


Figure 36.9: Mechanical and optical properties (Courtesy of Borealis AG)

PP block copolymers are used when toughness is needed (even at low temperatures). Block copolymers are, based on their rather poor optical attributes, not adequate for transparent applications. Random copolymers display good optical attributes. Random copos are rarely used for thermoforming because of their insufficient stiffness, and therefore weak thermal resistance. Random copos are used for certain applications when a gloss-and-sealable coating is needed, or they are used for a blending component to enhance its optic, toughness, and process ability by transparent applications. In regard to thermal moldability, copolymers as compared to PP-homo are characterized by a broader temperature-remoldability range.

Another important criterion when choosing a corresponding PP material is the application temperature range of the finished part (Figure 36.10). Based on the predetermined glass- transitional temperature range of the single PP modification, use of the PP-homo polymer is possible only above 0°C. The thermoformed packaging of, for example, yogurt, which is stored without a mechanical enchroachment on cooled shelves at +7°C, is a standard application for PP-homo.

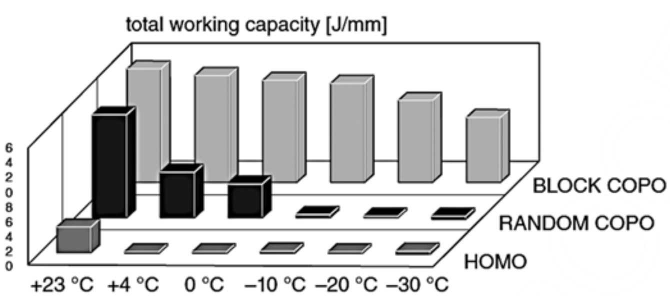


Figure 36.10: Toughness on TF-films (Courtesy of Borealis AG)

PP random copolymers show, depending on their C2 concentration, greater toughness at lower temperatures. However, the temperature-durability upward, is reduced. The PP modification with the most diverse temperature-application range is the PP block copolymer. Because of their excellent toughness in the lower temperature ranges, combined with the corresponding temperature durability upward (similar to PP-homopolymer), PP block copolymers are suitable for frozen food packaging applications (e.g., convenience food). These can be microwaved as needed.

The market demands even more property improvements.[4] And the end of property improvements has not yet been reached. Research aiming to create a material with the following properties is continuing at companies like Borealis AG:

- Stiffness like PP-homo
- Toughness like PP-heco (even at low temperatures)
- Transparency like PP-random
- Processability like PS

While it still is not possible to quite meet all these properties in a single PP type, the profile of the present heterophasial PP type has been enlarged to include stiffness like PP-homo, toughness like the standard PP-heco, and transparency like the PP-homo.

36.5 Thermoforming Conditions and Finished Part Attributes[5]

Figure 36.11 shows the basic visual differences achieved with PP modification. In addition there is, with rising thermoforming temperature, the issue of greater haze. As is implied, PP-random copolymer types have the widest and homopolymers the narrowest remolding temperature ranges.

The dependencies of mechanical characteristics are shown in Figure 36.12. With diminishing thermoforming temperatures, a definite increase in E-modulus evident based on the accordant higher degree of streching

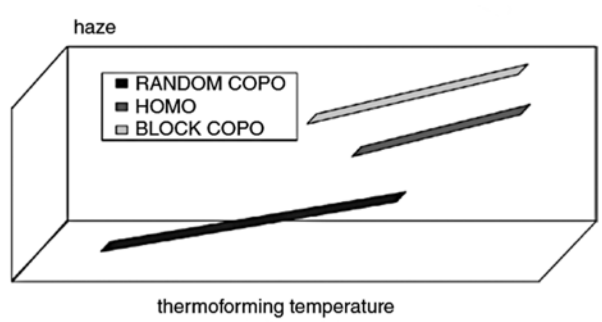


Figure 36.11: Transparency versus TF-temperature (Courtesy of Borealis AG)

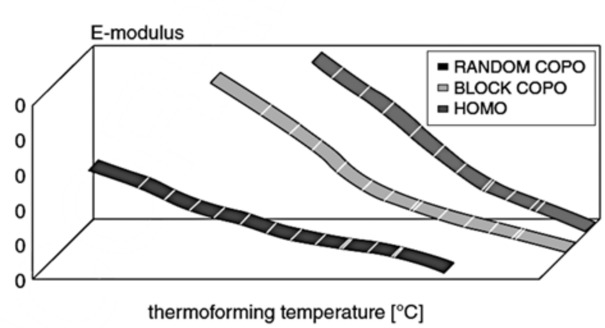
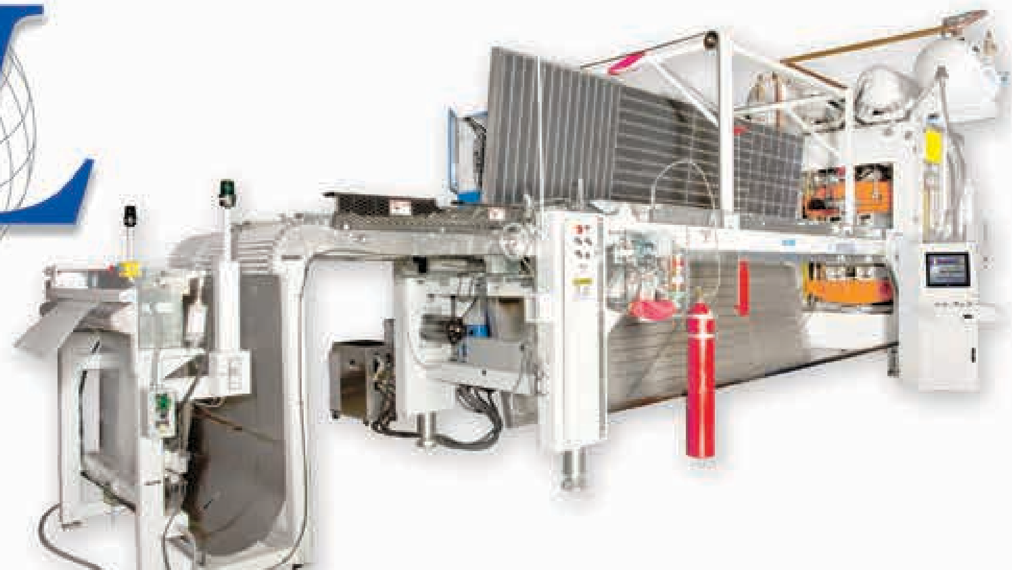
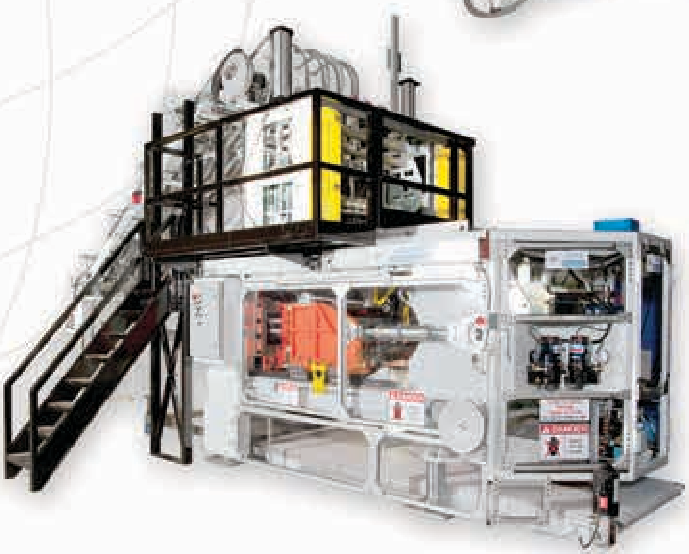


Figure 36.12: E-modulus versus TF-temperature (Courtesy of Borealis AG)





(orientation). Not shown, however, and worth mentioning, is that with declining forming temperature, shrinkage will also rise.

36.6 Distribution of Molecular Weight

Besides the basic (general) differences in characteristics of different PP modifications, the mechanics, optics, and the thermoforming behavior will be influenced through the distribution of molecular weight of the particular polypropylene.[6] Basically a distinction is drawn, between the standard PP (broad molecular weight distribution) and CR-PP (controlled rheology PP with narrow molecular weight distribution); see Figure 36.13.

In simple terms, the molecular weight distribution is the

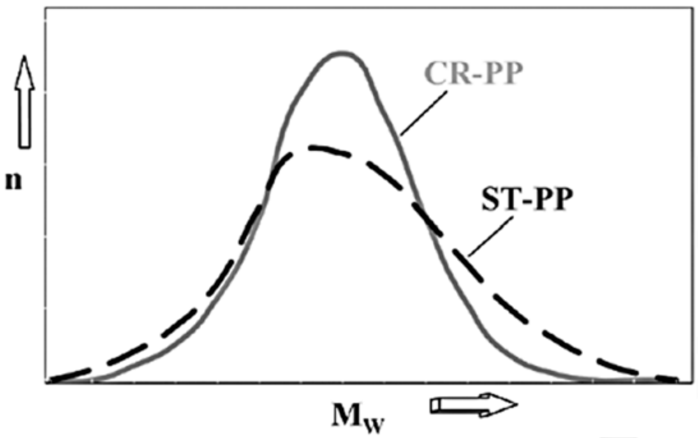


Figure 36.13: Molecular weight distribution (Courtesy of Borealis AG)

ratio of the medium molecular mass (depending on the length of macromolecules) to the number of molecule chains. In the production of CR-PP standardization of the existing macromolecular chain length is reached will through chemical degradation with peroxide. This modification causes a change in the flow characteristics (viscosity) and morphology, on the one hand, and in the mechanics and optics of the thermoforming film, on the other. Also the forming temperature range will be influenced (Figure 36.14). The biggest advantage of CR-PP while thermoforming is the relatively low mold shrinkage. This is associated with a narrower forming temperature range.

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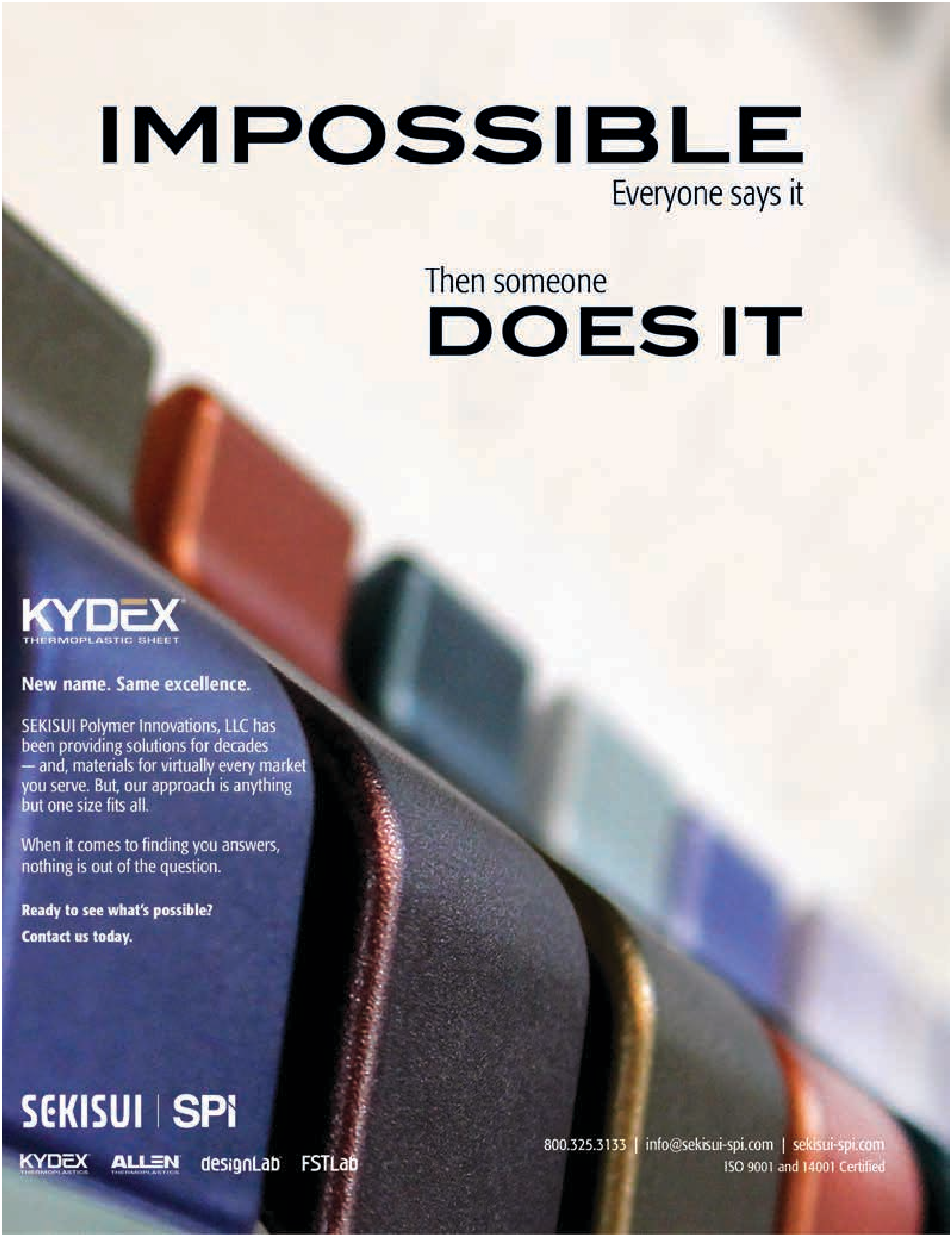

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Global Dispatches: K2016, Düsseldorf, Germany

By Conor Carlin, Editor

Note: This review includes contributions from the official media partner of K, Messe Dusseldorf, as well as abbreviated versions of corporate press releases issued to the media before and during the event.

K2016 broke all the records: attendees, exhibitors, deal volume and possibly altbier and schweinhaxen consumption. To quote Ulrich Reifenhäuser, Chairman of the K 2016 Advisory Board, "I have never seen such a vast number of decisive customers willing to buy at a trade fair before! The number and magnitude of deals, some of which were concluded here spontaneously, as well as the many concrete enquiries about new projects by far exceeded our expectations. It was clear from day one that customers wanted to not only find out about new technologies but also purchase them. There is strong investment in all our customer industries and in all regions of the world."

230,000 visitors from 160 countries participated in this year's event, marking a high point for the world's largest plastics exhibition. With just 6% of all foreign visitors, the proportion of visitors from the US and Canada remained stable. The US was fairly well-represented on the sell-side with 119 exhibitors showing their products and services. In addition to individual exhibitors, there were two US Pavilions which were organized by Messe Düsseldorf North America and co-sponsored by The Society of the Plastics Industry (SPI), the plastics industry trade association.

The Big Picture

At the outset of the exhibition, members of the press were invited to a conference hosted by EUROMAP, the umbrella organization of the European plastics and rubber machinery industry which accounts for some 40% of worldwide production and 50% export volumes. EUROMAP represents around 1,000 companies manufacturing

Serious business: K attracted 77,000 people in the first two days. Photo courtesy of Messe Dusseldorf/C. Tillmann equipment for the plastics and rubber industry in the field of core machinery (pre-processing, converting, post-processing). EUROMAP is forecasting 1.8% sales growth for machinery sales through 2018 though total global industry growth is projected to be 3.4%. The difference is due almost entirely to China: over the past decade, China has been supplying its own market with equipment. In fact, when one compares data from 2005 to 2015, you see a significant increase in China's share of the machinery market, to the detriment of both EU and North American suppliers. Over that same decade, the total production growth of machinery was an astounding 83%.

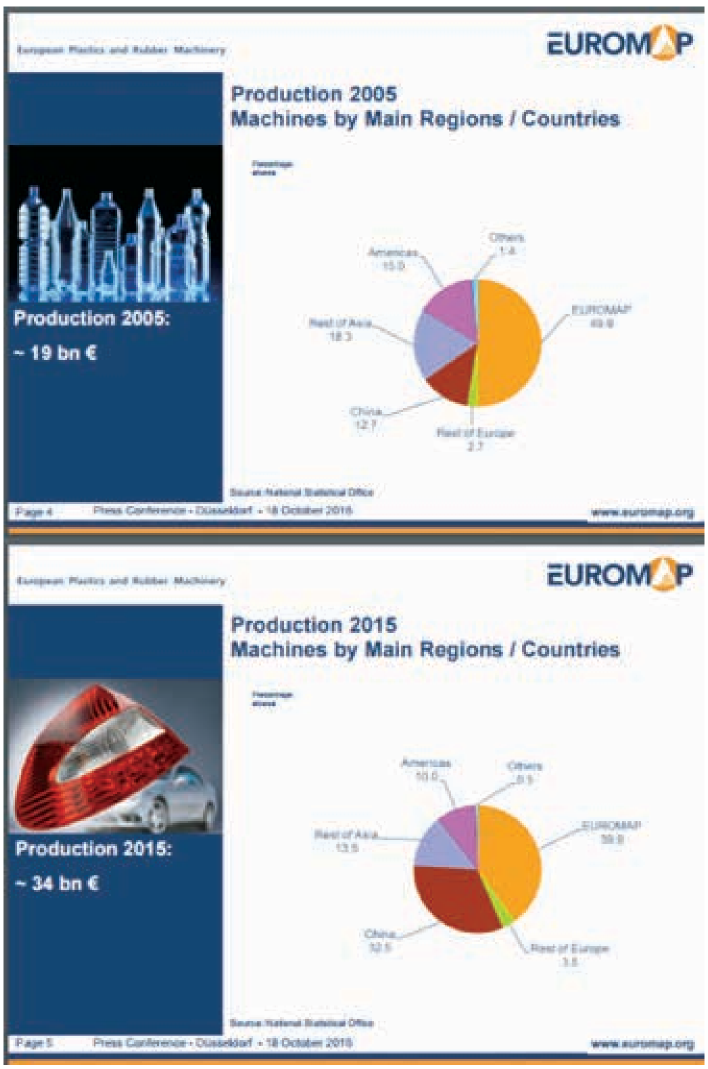


Figure 1: Comparative data showing growth of plastics / rubber machinery worldwide. (Source: EUROMAP)

Luciano Anceschi, President of EUROMAP, shared specific insights into country-based statistics, including Poland, India, Mexico and the US. Mexico, for example, imports more machinery than India, a country with 10 times the population. This can be explained in part by the growth of the automotive sector in NAFTA with many large US auto suppliers increasing production levels in Mexico. 44% of all machinery imported to the US comes from EUROMAP member countries, with Germany, France and Italy providing the lion's share. From a trough in 2009 at the end of the recession, the value of imported machinery has more than doubled. The US market continues to demand and absorb increased levels of foreign-produced equipment.

Thermoforming Review

There were at least 30 companies dedicated to thermoforming that exhibited this year, the clear majority of which were found in Hall 3. For those who have been to the Messe multiple times, it was reassuring to find many of the key players in the same locations as in previous shows. Machinery companies including Gabler, Illig, Kiefel, GN, OMV and WM cycled machines every hour, staggering their schedules to allow for multiple viewings. Many booths advertised Milliken's Millad NX8000 clarifier technology for polypropylene, illustrating the continued demand for transparent parts.

Increased speeds and integrated automation were the primary themes shared across OEMs in Hall 3. Servo-driven tilt-mold technology continues to be the platform of choice for high-speed production with Gabler and WM introducing new models. In this respect, the US diverges from the rest of the world: 50"x 50" tools and in-line extrusion are commonplace for massive production runs that reach over 7000lbs per hour. That said, European OEMs have found success in North American markets for products that are more effectively made on high-precision cut-in-place machines. In the steel rule die segment, output speeds are increasing while platforms are becoming more flexible to allow for different tools that can be adapted from other machines. Automation, whether in T-IML or as modular end-of-line systems including pick-and-place and automated sleeving/bagging/packing, was more prevalent than in 2013. Illig continues to champion the T-IML method for decoration, though other technologies such as offset printing continue to provide high-quality graphics for cylindrical products.

The following is a summary of the machines/systems displayed:

• Several people referred to **OMV**'s new RM77 as "best in show" in terms of thermoforming innovation. OMV, part of

Swiss industrial group Wifag-Polytype Holdings Ltd, named the equipment "Revolver" because of its revolving mold. The formed part remains in the cavity for an additional cycle, which improves part quality, while having two cavity sets allows for an increase in production speed. The system is fully automatic, with in-mold trimming, mainly for making cups. (For more complete details, see "Innovation Briefs" in TQ vol. 35, no. 2.)

• **Gabler** introduced the M100, the newest and largest model in their successful M series (tilt mold machines). The M100 offers an output increase of 40% over previous models. Marbach provided the 84-cavity tool with HYTAC XTL plug assists from **CMT Materials**.

• **Illig** displayed their IC-RDM 70K roll-fed machine with a forming area of 680 × 300 mm (~27" × 12"). The former was coupled with a RDML 70b IML unit to decorate PP cups in different geometries. The 18-cavity mold produced approximately 17,280 rectangular PP cups/hr that were simultaneously decorated on all four sides and the bottom. Tooling was provided by Illig. The company also displayed their RDK 54 thermoformer equipped with a 12-cavity cup mold with a shallow forming segment base, forming APET film with an anti-blocking additive.

• **Kiefel**, part of the Brueckner Group, displayed multiple machines in several booths thanks to the acquisition of toolmakers **Bosch Sprang** and **Mould & Matic** earlier this year. Kiefel showed their newest "Speedformer", the KMD 78 Power. The pressure-forming machine was producing high-quality, click-on domed lids that were made with a precisely positioned hole for a straw thanks to a new design. The tooling was developed by Bosch Sprang and featured a combined positive/negative forming procedure with HYTAC FLX plug assists from CMT Materials. Kiefel also displayed their KTR-6 tilt-mold machine.

• Italian OEM **Amut Comi** exhibited the ACF 820 series, a high-speed form/trim/stack machine for packaging that combines the features of the firm's V and F series. The ACF machines can be integrated with a T-IML system using a side-entry robot to load labels inside the forming mold to decorate the articles.

Canadian OEM GN was one of the major players in Hall 3 where thermoforming is concentrated. Photo courtesy of Messe Dusseldorf/C. Tillmann

• **OMG**, also from Italy, produced polypropylene meat trays on its Elektra PVE thermoforming machine. The Elektra featured integrated process control technology from **ToolVu** (see pp. 14-15 for details on the ToolVu system).

• **WM Thermoforming Machines** of Switzerland debuted the "Twist 700", a tilt-mold machine with a new drive system and integrated automation. Tooling was provided by Kiefer Mold of Germany.

• **GN**, in partnership with **Agripak s.r.l.** in Italy, exhibited their new form/trim/stack machine, the GN800. The GN800 has a forming area of 800 × 570 mm (31.5" × 22.4") and can form 150 mm above and below the sheet line. The cutting force of the forming/cutting stations is 75 tons. The GN800 has additional space between the forming and cutting stations, providing extra cooling time when running heavier-gauge materials or PP.

• **TSL**, **Irwin** and **Brown Machine** all displayed their respective trim press technologies.

• **Guven Teknik** and **Inpak Makina** from Turkey displayed tilt-mold and steel-rule die machinery, respectively. As in 2013, the Turkish Plastics Federation had a very public profile as the country continues to increase its output in the plastics sector.

Düsseldorf: The Place for Plastics Business

As reported by the show organizers, the percentage of executives among the trade visitors from all countries was extremely high. Some two thirds were from the top or middle management and almost 60% had final decision-making authority or are decisively involved in their companies' investment decisions. The K show is a major hub for the plastics industry when it comes to investment decisions: almost half the visitors stated that they waited for the trade fair before deciding on any purchasing projects.

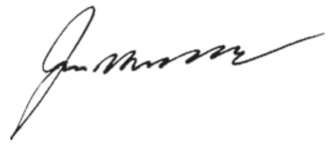
Visitors were reported to be "delighted with the wealth of new technical developments presented by raw materials producers, machinery manufacturers and producers of semi-finished and technical parts." Over 70% of visitors stated that they received information on news and trends, 60% of industry decision-makers visited the trade fair with concrete intentions to invest and 58% found new suppliers.

There is no question that K remains the premier event for plastics processing, including thermoforming. While Chinaplas continues to grow in size, it cannot yet compete with the Messe on the Rhine in terms of influence.

1 *If you haven't been to Dusseldorf, altbier is the local, dark brew. Schweinhaxen is a regional dish of pork knuckle that is not for the faint of heart.*

The next K will take place from October 16 – 23, 2019. Photo courtesy of Messe Dusseldorf/C. Tillmann

SPE Council Report



Greetings!
There has not been another Council Meeting since Quebec this past August. We will be having a telephonic conference on December 7, 2016. The agenda is on the Leadership Chain for your review.

As I reported previously, SPE and the Councilors are working actively to improve divisions. Sounds simple, right? Well, it's not as easy as it sounds because we have never gone in-depth to look at how we define success. The net results are that we have some great divisions, Thermoforming being one of the leaders, and some not-so-great divisions.

The new Divisions Committee of SPE has been formed to look at this issue. We have a Vice President, Divisions, under the new governance structure of SPE. The following is what this committee is about:

Mission Statement
The Divisions Committee will strive to develop and sustain satisfaction of our SPE volunteer board members.

This committee shall accomplish its mission by:
1) Improving communication between the Executive Board and the Councilors to enable each Division to be proactive in the establishment and execution of Work Plans & Goals.
2) Increasing the efficiency of Divisions through the implementation of a common organization chart that includes roles & responsibilities.
3) Enabling Divisions to be more effective in transferring technology to membership by aligning resources with other Divisions and Sections as well as with Headquarters.
4) Driving improvement of the services offered to Divisions by SPE Headquarters.

The intent of this questionnaire is to learn how your division achieves members' needs.

What does a successful division look like for you and your members?
o Create organizational chart with roles and responsibilities with active executive officers.
o Membership number goal?
o Seminar (TOPCON, Conference, etc.) goals?
o ANTEC involvement goal?
o Other goals?

Does your group have an operating plan?
o If so, how many years' outlook do you have?

What are the biggest issues affecting your division?
What are the biggest issues affecting SPE as a whole?

What other divisions do you communicate with?
o How often? o What method? o How successful?

Are there other divisions you would like to communicate with?

How often does your division meet?
o In person? o Do non-board members attend?

How effective is the communication from SPE Headquarters to your division?
How involved is the Division with other Sections?
What is your Division's biggest need?

Discuss SPE Headquarters' Services:
o Are you aware of the new membership tool (feedback)?
o Discuss other services
o Do these services meet the Divisions' needs?

The Divisions committee will be reaching to all the Divisions in SPE with these questions. This is one portion of the new SPE. In addition to Divisions Committee, there are:

- VP Business and Finance (serves as Treasurer)
- VP Marketing & Communications
- VP Events
- VP Sections
- VP Technology and Education
- VP Young Professionals

Your new Executive Committee consists of the VPs, President, Immediate Past President and President-elect. Each one of the VPs has a committee. Membership in the committees are not limited to Councilors, so don't be shy about getting involved! More to follow on the new structure as it develops.

Another important review is the revamp of the Pinnacle Awards. We are now looking at 5 Pinnacle Awards. Many people reported that the Pinnacles had just become a paper exercise. The program is now being revamped and hopefully the new awards and metrics will be rolled out at ANTEC 2017. I am working on the Education Pinnacle award committee and it is a very interesting process.

Your Division is also evaluating a new membership dashboard that will allow us to see a better picture of our members and demographics. It will also allow us to compare ourselves against other divisions. It's currently in beta-testing, so time will tell.

2016 Thermoforming Parts Competition

By Bill Bregar, *Plastics News*

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Schaumburg, Ill. — For thermoformers, the annual parts competition at the Society of Plastics Engineers' Thermoforming Conference is a big deal. And one company that always seems to take home hardware picked up three awards this year.

Profile Plastics Inc. won the gold award in two categories: a cover set for surgical waste management system won the award for heavy-gauge pressure forming, as well as the People's Choice Award. The Lake Bluff, Ill., company also won for two twin-sheet body protection plates.

Matt O'Hagan said more than 200 ballots were cast for the People's Choice by conference attendees, which is a record.

"It was a great turnout this year. Another great set of parts," he said before announcing the winners at a dinner Sept. 27.

"Getting into the heavy-gauge, things got really, really difficult for the judges, especially on the twin-sheet side, because there were a lot of parts," said O'Hagan, who is sales manager for non-automotive and distribution for LyondellBassel's Equistar business. He is based in Lansing, Mich.

The student award winner was Sara Allgeier for her pizza box made of twin sheet thermoformed polypropylene sheet — eliminating the soggy cardboard pizza box. Allgeier is enrolled at Penn State Erie.

The Thermoforming Conference was held Sept. 26-28 in Schaumburg. Below is a recap of the parts competition winners.

Roll-fed consumer, gold

Jamestown Plastics Inc. of Brocton, N.Y., won the gold for its Click-it Clam, a clamshell package with a patented locking feature so it can be opened and closed with one hand. The user simply pushes on the power part of the flange under the pin, which forces the wall to deflect, releasing the pin and letting the lid pop open. Snapping it closed again makes an audible "click." Jamestown officials said Click-it Clam is safe to use — no more cutting and tearing to pry open a clamshell — as well as beneficial for arthritic, visually impaired and elderly customers. And it's a reusable storage container.

Click-it Clam, Jamestown Plastics Inc.

Roll-fed consumer, silver

Transparent Container Inc. of Addison, Ill., won silver for a package holding 30 Sharpie markers for a special limited edition collection for Wal-Mart's Black Friday sale. The challenge in 2015 was to fit 30 markers in a package that had held 28 before, but without making the package any larger.

The final package has two large front panels that open like doors to reveal the markers. They have a four-color printed graphic of a lion's head, and a clear PET window.

The Sharpie tray is formed from PVC sheet.

Sharpie Tray, Transparent Container Inc.

Medical orthopedic implant, Placon Corp.

Surgical knife sterilizer, OMG

"Frozen" clamshell, Innovative Plastech Inc.

Roll-fed, gold

The Barger division of Madison, Wis.-based Placon Corp. picked up the gold for a package for medical orthopedic implants. Thin-gauge, vacuum formed thermoplastic polyurethane offers protection for the implants, and adds impact resistance to the glycol-modified PET sterile blister packaging.

The package protects round, femoral heads, one of several components that complete an assembly for a medical hip implant.

Thermoformed TPUs are highly abrasion-resistant, important because, according to Barger, many orthopedic implants have very coarse, textured surfaces that allow for bone growth into the implant. Traditional packaging for orthopedic implants, such as closed-cell foam and vinyl, cannot stand up to those rough surfaces and can abrade, the company said.

Barger listed some challenges with thermoforming TPU, including difficulty to demold the parts, which tend to turn inside out for complex-geometry shapes. The company used a proprietary method to cleanly eject the part. Also, the material can shrink so Barger resulted that issue with process controls.

Roll-fed, silver

OMG srl of Givoletto, Italy, gained silver for designing, building and testing a thermoforming machine to produce a container for sterilizing surgical knives. The machine can feed polystyrene rolls or sheets, at the choice of the operator.

The system is OMG model RV 81 PN-M-LB.
OMG's display at the conference included the containers, plus a complete documentation of the production process.

Roll-fed recycled, gold

Innovative Plastech Inc. of Batavia, Ill., scored for its clamshell to hold a book and recorder musical instrument for the movie "Frozen."

Retailers can display the eye-catching clamshell package, which is formed from recycled PVC.

For securing the package while hanging, the clamshell is designed with six button snaps around the perimeter.

The platform snap can lose effectiveness for such a long package, to the button snaps give a consistent and sure closure — and the consumer can open and close it, to the clamshell acts as a protective case for the instrument and book.

The production tool is a two-cavity aluminum mold, attached to a water-cooled block.

Heavy-gauge vacuum forming, gold
Associated Thermoforming Inc. of Berthoud, Colo., earned the gold for a touch tower soft drink dispensing system, employing LED touch technology for the dispensing choices.

The colorful, curvy structure is made by assembling to the skins vacuum formed ribs. The tooling was temperature controlled billet and cast aluminum.

Heavy-gauge vacuum formed, silver
Electro-General Plastics Corp. of Grove City, Ohio, won for a bright red koala display, with an attractive structure and embedded, eye-catching graphics.

Each part was formed with ABS WeatherPro T-30 using red metallic color, for weather resistance and impact strength.

To the construct the assembly the company uses a structural adhesive metal to bond the metal to the ABS sheet. Electro-General uses aluminum, water-cooled tooling on a four-frame rotary thermoforming machine. Three tools are used to form the parts. All parts get CNC trimmed to machine a close tolerance.

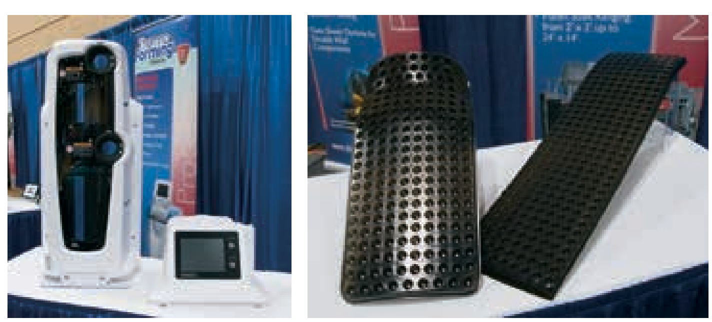
Heavy-gauge pressure formed, gold and Heavy-gauge innovation, gold
Profile Plastics won gold for its surgical system cover set and two twin-sheet body protection plates.

Heavy-gauge pressure formed, silver
Providien Thermoforming grabbed silver for an enclosure assembly that serves as the fascia and door front to an automated microbiology system. The assembly is a mix of single-sheet and twin-sheet pressure formed parts, formed from custom-colored PVC blend, on textured and smooth, multi-cavity tools.

The design gives a snap-fit interface been the front and

Tower soft drink dispenser, Associated Thermoforming Inc.

Koala display, Electro-General Plastics Corp.



Surgical cover set and body protection plates, Profile Plastics

Automated microbiology system, Providien Thermoforming


Calf-Tel housing system, Hampel Corp.


Floor pan and ramp for shower, Associated Thermoforming

rear fascia parts, and formed-in threaded inserts.

The door has CNC-routed slots on a curved plane to accept a clear polycarbonate viewing window on the medical product.

Heavy-gauge innovation, silver
Hampel Corp. of Germantown, Wis., won for its work on the Calf-Tel housing system for dairy calves, which replaces wood.

The climate-controlled, elevated unit is formed from high molecular weight polyethylene, to withstand the most brutal weather conditions. The sheet has a pigment to block ultraviolet light.

A sliding roof cover can be opened or closed, depending on the weather.

Hampel forms the hutch on a large, male cast aluminum tool, multiple zoned temperature with a deep draw to match the cover. The front is formed on a large twin-sheet cast aluminum tool, also multiple zoned and deep draw, with vertical twin-sheet edges, and curved to match the hutch.

Twin-sheet, gold
Associated Thermoforming got gold for its large twin-sheet parts creating the floor pan and ramp for a wheelchair-compatible temporary shower.

The bottom surface has ribbing to give it the necessary strength. the top surface has molded-in features to facilitate draining, and the attachment of walls and doors.

Both parts are formed from ABS sheet on aluminum tooling.

Twin-sheet, silver
Corvac Composites LLC, based in Kentwood, Mich., won for its lightweight panel assembly for an underbody automotive engine compartment closeout, with an integrated service door.

The customer wanted low cost, light weight, rigidity, a smooth lower aerodynamic surface and the ability to withstand rigorous automotive exterior part validation.

Corvac used high density polyethylene, made from at least 50 percent reclaimed material. The parts were molded in a five-cavity water cooled aluminum tool.

Heavy-gauge, value added, gold
Medallion Plastics Inc. of Elkhart, Ind., snagged gold for a complete interior dashboard for a Class A motorhome.

The assembled dash, along with driver and passenger consoles have automotive-style stitching, making the part a set up from the current ABS/vinyl wrapped style of dashboard tops.

Medallion uses ceramic tooling that is non-water cooled, using innovative design techniques to allow for negative drafts in the tooling. The post-assembly process of the process of the parts, along with custom hardware and brackets, reduced the amount of time required to install the dashboard, and also do service if needed, according to the company.

Heavy-gauge, value added, silver
Allied Plastics Inc. of Twin Lakes, Wis., won for a case assembly for a marine propeller — so it needs to be very tough to pass drop tests, the company said.

The project started out as a single-sheet case, but it became clear than a twin-sheet case was need to protect the propeller. The prop is secured by a nylon dowel and receiver. High density foam, mounted on the dowel, fits between the pro hub and the top cover. Four steel locking caps secure the top and bottom of the case.

Allied formed the case of two sheets of high molecular weight polyethylene, on a two-cavity, water-cooled aluminum mold.

Heavy-gauge TPO, gold
Brentwood Industries Inc. of Reading, Pa., won gold for a dashboard assembly for a low-entry heavy truck, made of 20 components — six thermoformed, two machined and 12 injection molded louvers.

The top surface of the dash is pressure formed while the other thermoformed duct work components are vacuum formed out of TPO, which is custom color matched by for LyondellBassel, and extruded by Primex Plastics Corp.

Automotive engine compartment, Corvac Composites LLC

Motorhome dashboard, Medallion Plastics Inc.

Marine propeller, Allied Plastics Inc.

Truck dashboard assembly, Brentwood Industries Inc.

School bus baggage door, Plastitel Products

Decorative wall panel, Valley Industrial Products

The assembly, which is ready to be installed directly into the truck cab, replaces multiple subassemblies that had been installed by the customer.

Heavy-gauge TPO, silver

Plastitel Products of Laval, Quebec, Canada, won silver for its twin-sheet thermoformed baggage door for a e-Lion school bus. Company officials said Lion Bus is only North American manufacturer of all-electric type C school bus manufacturer.

Lion Bus has started delivering the e-Lion to Quebec and California.

The bus manufacturer has always used fiber-reinforced composites for many of its exterior parts. All of the side skirts and baggage doors were converted from traditional fiber-reinforced plastics to a TPO using Plastitel's twin-sheet thermoforming process, which gives quicker production time, reduced manual labor, removes the need for painting, cuts weight and improves esthetics.

PMC supplied the sheet in a custom school bus orange color.

Sheet-fed recycled, gold

Valley Industrial Products of Fort Valley, Ga., won for a laminated, vacuum formed front face of a decorative wall protection system.

The film is prelaminated onto extruded polyester from 100 percent postindustrial regrind, produced on a twin-screw dryerless extruder. The front face of the film is screen printed, then the total assembly is vacuum formed using an array of frosted, incandescent reflective bulbs.

PET Thermoform Recycling: A Case Study in Packaging Recyclability Claims and Realities

By Resa Dimino, National Association for PET Container Resources (NAPCOR)

Earlier this year, the Sustainable Packaging Coalition's Centralized Study on the Availability of Recycling found that a substantial majority of Americans have recycling programs available to them that accept all PET packaging. Included in this designation were not only bottles and jugs, but also non-bottle PET packages: the clamshells, cups, tubs, lids, boxes, trays, egg cartons and similar rigid, non-bottle packaging made of PET (#1) plastic resin that are increasingly common on retailer shelves.

"We were very pleased to see that most Americans can put PET thermoforms in their recycling bins according to the guidelines provided to them by their communities, but we know that this doesn't tell the whole story of what happens to those containers," said Michael Westerfield, Corporate Director of Recycling Programs for Dart Container and a National Association for PET Container Resources (NAPCOR) Board Member.

How do we look beyond collection to determine whether a material placed in a recycling bin actually makes it to market? NAPCOR set out to answer this question in the spring of 2016, seeing it as a good time to benchmark progress toward our ongoing efforts to open markets to PET thermoform materials, and as an opportunity to assess whether PET thermoforms meet Federal Trade Commission (FTC) requirements for recyclability claims.

The methodology was straightforward: ask those who handle the PET material along the way, from bin through to reclamation. To that end, NAPCOR surveyed the major operators of Material Recovery Facilities (MRFs) and Plastics Recovery Facilities (PRFs), as well as PET reclaimers, to determine how they handle the PET thermoforms that flow through their systems. We found that, for the most part, PET thermoforms collected at curbside are being sent to PET markets in bottle bales, and most reclaimers who handle curbside materials generally recycle them along with PET bottles.

"We have worked closely with PET reclaimers to analyze the impacts of thermoforms on the recycling stream and wanted to do our due diligence with the other parts of the value chain to ensure real recyclability before we put messages into the marketplace," Westerfield added. He and the NAPCOR leadership recommend that other resins and materials work to the same standard as they assess recyclability.

Do PET thermoforms meet the FTC's Green Guide's requirements for unqualified claims of recyclability? The answer is pretty clearly yes. Recycling programs are available to more than 60 percent of the US population, and once collected, PET thermoforms can be separated and recovered through the existing PET recovery infrastructure.

So, they are recyclable, but are they a preferred material for reclaimers? Not yet, for the reasons explored below.

Identifying the Issues

Over the last decade, NAPCOR has worked with stakeholders to facilitate the collection and recycling of PET thermoform packaging. The effort has involved the full value chain: PET thermoform package manufacturers; retailers; recycling collectors; MRF operators; PET reclaimers; and recycled PET end users.

Initial work included lab trials aimed at determining whether PET thermoforms would be compatible with the bottle stream, and what technical or practical issues would need to be mitigated. Through these early-stage initiatives, NAPCOR and its partners identified the following key issues that could inhibit the growth of PET thermoform recycling: look-alike packages; labels/adhesives/inks; intrinsic viscosity (IV); and mechanical issues related to package size, shape and configuration.

At the end of the day, these early trials found no overwhelming issues that precluded PET thermoforms from being recycled and processed. Nonetheless, the incorporation of PET thermoforms in the bottle recycling infrastructure has not been seamless, and further study and analysis was identified as a critical step to maximizing recovery of this growing package in a manner that does not harm the existing bottle recycling infrastructure.

Delving in Deep

"Through NAPCOR's early work, we knew that PET thermoforms could be effectively collected, sorted and marketed," said Dan Kuehn, General Counsel for Plastic Ingenuity and Chair of NAPCOR's Thermoform Committee. "Even though reclaimers were becoming more comfortable with buying PET bottle bales that contain some PET thermoforms, there were clearly key questions that were holding back the broad acceptance of PET thermoforms in the recycling stream, so we set out to answer those," he added.

Guided by a committee including both thermoformer and reclaimer members, NAPCOR identified five technical trials as critical to building the information base that would help open the rPET market more broadly to PET thermoforms. Those trials included:

• The effects of thermoform IV and orientation on the performance and yield of the PET reclaiming process: trials found no show-stopper issues relate to IV and orientation
• The impact of aggressive adhesives on the PET thermoform reclaiming process: identified some impact of labels, adhesives and inks, but readings within the Association of Plastic Recyclers' (APR) acceptable design guideline range; despite these bench-scale trial results, thermoform labels, particularly those using paper substrates, are still problematic in reclaimer operations
• The effectiveness of standard PET reclaimer sorting systems to identify non-PET thermoforms: some reclaimer systems did not effectively sort OPS and PETG, but this was largely resolved with adjustments to auto sort equipment
• The impact of varying levels of silicone slip agents on rPET color and haze: documented that low- to- medium-levels of silicone application do not materially negatively impact haze, but high levels do
• The potential increase in generation of fines when processing thermoforms, and related impacts on yield rates: issues related to the supply stream used rendered the results of this trial unreliable; NAPCOR will continue to work to better understand and quantify the relationship between thermoform processing and fines generation

Reclaimer Perspectives: Context and Trends

The growing prevalence of PET thermoforms in curbside PET bottle bales is unmistakable (see Figure 1). As such, reclaimers have had to adapt to a stream containing these materials, but as the reclaiming industry struggles with

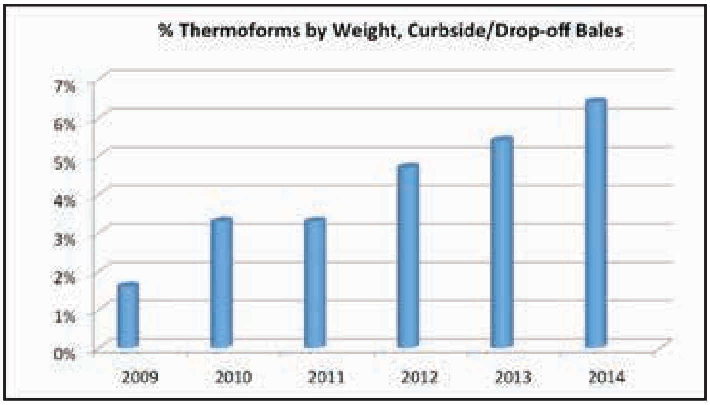


Figure 1: Percentage of PET thermoforms in curbside PET bottle bales (by weight) (source: NAPCOR)

increased contamination and yield loss, this comes at a difficult time.

Along with increasing thermoforms, reclaimers are faced with the impact of lighter weight containers, full wrap shrink labels, metal components, and other design elements that impede recyclability and negatively impact PET yield. At the same time, they are facing tight operating margins that result from competition with extremely low virgin materials prices. The result: reclaimers need to buy more bales to produce the same amount of salable rPET flake, and often sell that flake for less. It doesn't take an MBA to see that this is a tough business.

"It feels a bit like death by a thousand cuts," explains Byron Geiger, President of Custom Polymers PET and member of the NAPCOR Board of Directors. "There are a lot of packages coming through our facilities that add costs to the system, and thermoforms are among them. We need to understand how they impact our operations, and we need to be sure they don't bring along more contaminants."

Yet, despite concerns about contamination and yield, reclaimers need more PET material. Even in today's difficult economic conditions, there is still far more capacity to recycle PET than there are bottles collected in the US. Reclaimers routinely supplement domestic supply with imported bales and other non-bottle materials. PET thermoforms offer the potential to increase domestic supply.

The drive to develop new sources of supply keeps reclaimers engaged in working through their issues with thermoforms. And they are making progress. Reclaimers generally fall into three categories with regard to thermoforms. The first group routinely accepts a certain percentage of thermoforms, as identified in their specifications. The second does not officially acknowledge acceptance of thermoforms in their specs, but does accept them from suppliers that have a good track record with regard to contamination. The third category does not accept thermoforms at all. Most of the reclaimers in this last category typically rely on materials collected through deposit programs.

"As we have learned more about thermoforms through the NAPCOR trials, we've become more comfortable with running them in our system," adds Geiger. And it appears he is not alone. The market is moving toward greater inclusion of thermoforms, with reclaimers representing the majority of the US capacity reporting that they routinely process PET thermoforms with bottles. The trend has been for reclaimers to move from the "do not accept" to the unofficial acceptance category; and from unofficial acceptance to inclusion of thermoforms in specifications. However, the allowable percentages of thermoforms for some reclaimers is still quite low and MRF operators remain hesitant to open the floodgates and invite all of their suppliers to include PET thermoforms in the stream.

Where do we go from here?

"We have made serious progress toward the goal of making recycling of PET thermoform packages as easy as recycling bottles," notes Kuehn, "but we are not quite there yet." Important work remains to ensure that MRFs and the PET reclaiming industry can effectively sort, process and reap value from this new material stream. NAPCOR will continue its efforts to work through the design, technical and mechanical challenges to increase acceptance of PET thermoforms in domestic recycling programs and markets. At the same time, we need to ensure consistent and accurate messages to the marketplace about the status of PET thermoform recycling.

Communities and MRF operators interested in marketing their PET thermoforms domestically should talk with their PET buyers about including PET thermoforms in PET bottle bales. And, packaging and consumer product companies can help in this process through incorporating APR design for recyclability principles when setting specifications and selecting labels for their PET thermoforms.

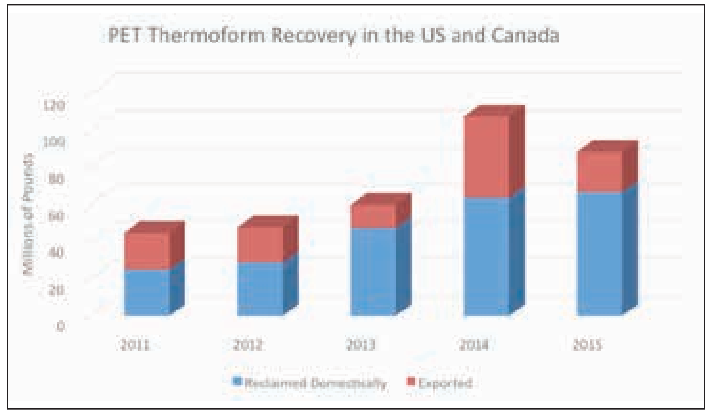


Figure 2: PET thermoform recovery in US & Canada (source: NAPCOR)

2007
NAPCOR expands its membership to include PET thermoform and sheet manufacturers

Initial lab trials aimed at identifying potential issues with thermoform recycling

2009
The Canadian retail initiative

2009
<2% thermoform content in curbside PET bales

2011
Pet thermoform recycling is at 45 million pounds

2012
Three grant programs to test collection, sorting and marketing strategies

2013
~6% thermoform content in curbside PET bales

2013
PET thermoform recycling is at 60 million pounds

2014-2015
Technical trials to evaluate the impact of rPET quality and the PET bottle reclaiming infrastructure

2016 & Beyond
Continued work on design, technical, and mechanical challenges; ensuring consistent and accurate messaging; and promoting collection volume increases and tracking

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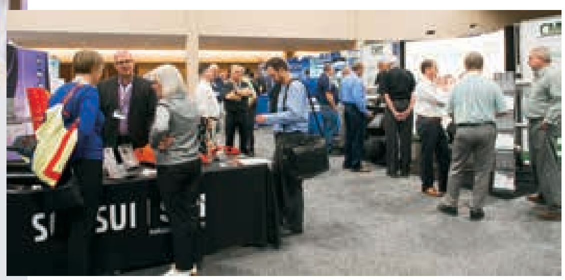
The Division celebrated its 25th anniversary in style!

All photography provided by Dallager Photography

The Board kicks off the tradeshow in Schaumburg.

Brisk exhibit hall traffic as attendees visit with sponsors and exhibitors.



Exhibitors throughout the supply chain participate in the Conference.

Paul Alongi, 2016 Conference Co-Chair, spends time with two student attendees.

Machinery on the show floor drew interested visitors.

Attendees check out new innovations in the Parts Competition area.

Ian Strachan, 2016 SPE Thermoformer of the Year, with Bret Joslyn, Division Chair, and Barry Shepherd, 2015 SPE Thermoformer of the Year.

The PlastiVan hosted two visits from local schools.

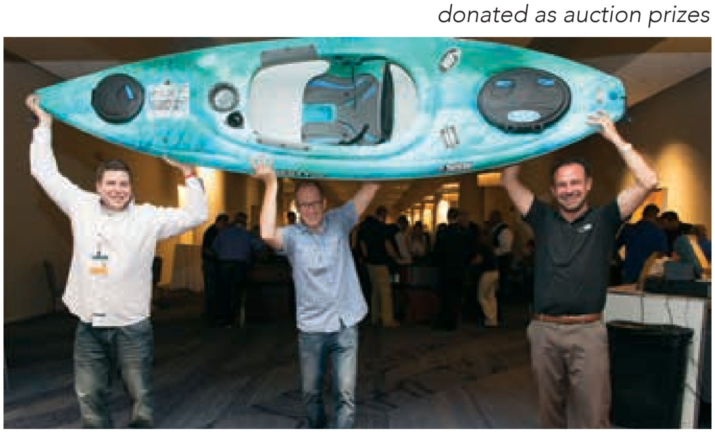
Fourteen heavy and thin gauge technical sessions were presented in parallel tracks.

Friendships were renewed during the Welcome Reception.

Dr. Jim Throne returned to lead the thin gauge workshop.

2016 SPE Thermoformer of the Year, Ian Strachan, delivers his speech.

Thermoformed kayaks were donated as auction prizes



Noel Tessier of CMT Materials receives the 2016 Lifetime Achievement Award.

Casino Night proceeds benefit the Division's scholarship fund.

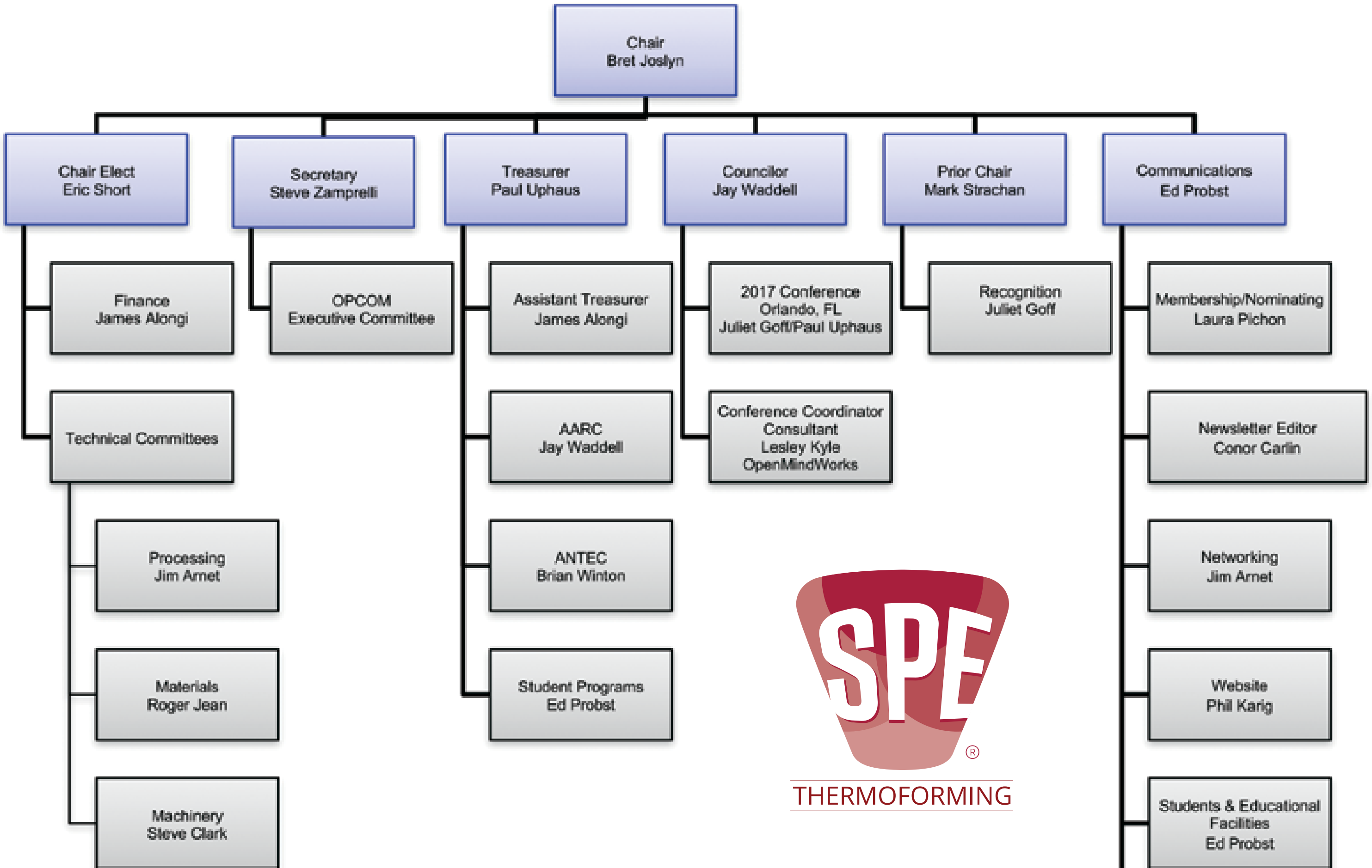
The changing of the guard! Ian Strachan of ToolVu with Conor Carlin, CMT Materials.

The Parts Competition is always a main attraction.

Over 100 people participated in the heavy gauge workshop.

Make plans now to attend next year's conference in Orlando, FL, Sept. 11-13!

2016 THERMOFORMING DIVISION ORGANIZATIONAL CHART



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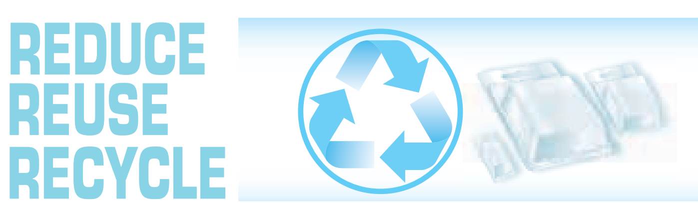

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