Thermoforming Quarterly®

A JOURNAL OF THE THERMOFORMING DIVISION OF THE SOCIETY OF PLASTIC ENGINEERS

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Conference Edition

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Thermoforming Quarterly®

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Thermoforming Quarterly®

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

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Cover Artwork courtesy of
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Phil Barhouse

Inspiration, Ideas and Innovation

As a Board, one of our goals is to find better and more efficient ways of reaching out to the thermoforming industry. The flagship annual conference is the most visible way that we accomplish this goal.

When I started in this industry almost 20 years ago, we communicated by telephone and by attending conferences. Of course, today's technology provides multiple ways of gathering the information we need, but I will argue that it is technical conferences that truly provide the most effective means of exchanging ideas for all of us in the thermoforming industry. No matter how advanced our communication gets, I believe that face-to-face discussions between suppliers, vendors, consultants, customers and students help keep our industry growing and competitive.

Michigan is a state renowned for expertise in thermoforming. Several large processers, toolmakers and machinery builders all call the Wolverine State home. Of course, no conversation about Michigan is complete without talking about the profound impact that the automotive industry continues to exert in U.S. manufacturing. Thermoforming touches on multiple aspects of automotive supply, including innovative new developments in material science, exciting part design and value-added service.

Grand Rapids offers us a unique view into the heart of this manufacturing mecca. While this region of the country still faces challenges, we can celebrate recent accomplishments such as the $700,000 National Science Foundation grant awarded to Mid Michigan Community College (see story on page 25). It is perhaps the most important topic in our industry – workforce development – and we are delighted to celebrate this award with the recipients in their home state. Given that Grand Rapids was named "Beer City USA" (well, tied with Asheville, NC), we will all be ready to raise a glass to this ambitious program and to future of the industry.

With experts in thermoforming processes, materials and sustainability, this year's technical program has something for everyone. Jim Throne will be covering advanced topics while Eric Shiffer from Tech II will explain how his company has brought the European in-mold labeling technology to the U.S. We will have our popular thermoforming workshops, full days of technical presentations and plant tours. Allen Extruders, Formed Solutions and Fabri-Kal will be opening their doors for you.

As always, I would like to hear your ideas, comments and feedback. Together we will continue to advance our industry through inspiration, ideas and innovation.

Phil Barhouse

Phil Barhouse

New Members

Chris Allen
Fabri-Kal Corp.
Duncan, SC

Ian Ashton
Lake Forest, IL

Joseph L. Blass
Fabri-Kal Corp.
Hazleton, PA

Randy Blin
Blin Management Co.
Independence, IA

Dave Bonadona
ITW Deltar
Frankfort, IL

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Mutual Industries Ltd.
Mumbai Maharashtra

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Daniel M. Hawkins, Sr.
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CCMI Inc.
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Solo Cup Co.
Lake Forest, IL

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Vitalo Industries
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Ralph Danny Quillen
D&W Fine Pack
Fort Wayne, IN

Dan J. Renn
CVG
New Albany, OH

Doug Ripley
Duo-Form Plastics
Edwardsburg, MI

Marco Roche
Plasticos Del Litoral S A
Guayaquil

Eduardo A. Rosales
Dart Container Corp.
Mason, MI

Javier Alejandro Sabena
Cordoba

Dipak Sen Gupta
Ridat Co.
London

Mohan Shanmugam
IAC
Rochester Hills, MI

David A. Shipman
Hampel Corp.
Germantown, WI

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Commercial Vehicle Group
Tigard, OR

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Subzero Freezer Co.
Madison, WI

Sonia Villamizar
Multipartes SA
Cali

Thermoforming in the News

Mid Michigan Community College Starting Two-Year Thermoforming Degree

By Bill Bregar, *Plastics News* Staff
Posted July 25, 2012 HARRISON, MI (12:55 p.m. ET)

Mid Michigan Community College is starting an associate's degree program in thermoforming plastics technology – the latest two-year plastics program designed to teach job skills.

The National Science Foundation has awarded a $717,000 grant over three years to fund the program at MMCC's campus in Harrison, MI, northwest of Midland.

"We're looking primarily to serve the local employment needs here, which are crying for people," said Scott Govitz, MMCC executive director of workforce and economic development.

Students can begin taking some of the classes this fall. The NSF grant will help the college buy equipment, Govitz said.

"We're advertising for a grant coordinator right now," he said in mid-July.

The associate's degree will be transferrable to Ferris State University's four-year bachelor's degree in plastics engineering technology. Govitz called it a "laddered approach." Ferris State is in Big Rapids, MI, about an hour away from MMCC in Harrison.

Govitz said that part of Michigan has several thermoforming companies, and they need employees with skills.

MMCC students can get shorter certificate programs.

The college is also going to create programs to teach skills in welding and computer numerical controlled machining.

A Mid-Michigan Plastics Industry Alliance is forming to serve as an advisory board.

Govitz said community colleges can play a key role in helping industry compete. MMCC officials say Michigan has more than two thousand skilled-trade job openings, the most of any state.

"It's a national issue and there's this huge mismatch that's occurring out in the world between people who are job-skill ready. And it's at every level," he said.

Thermoformer CW Thomas Buys Local Rival Analytic Plastics

By Jessica Holbrook, *Plastics News* Staff
Posted July 30, 2012 PHILADELPHIA, PA (3:55 p.m. ET)

CW Thomas Inc., a thermoformer based in Philadelphia, has acquired custom thermoformer Analytic Plastics Inc.

CW will move tools and some equipment from Analytic's plant in nearby Bensalem, PA, to its own 80,000-square-foot facility, and take over Analytic's orders and inventory.

The two plants are located about 10 miles apart. Three of Analytic's six employees will move to CW, said Bob Brennan, vice president of operations.

"It's a very small company, but for us, it's a nice little expansion," he said by phone.

Brennan would not disclose terms of the deal.

The acquisition will allow CW to expand its customer base and offer Analytic's products at a lower cost, he said.

Analytic vacuum forms parts, mainly for commercial customers, in contrast to CW who uses both vacuum and pressure forming to make specialized and technical parts, he said.

CW also offers in-house tooling, engineering and assembly. It largely serves the transportation, aerospace, industrial and medial markets.

CW is more focused on using the expansion to broaden its customer base rather than its product offerings, and plans to "use our technologies to get to a broader range of customers," Brennan said.

CW, a privately owned company, does not disclose financial information. It currently has 45 employees.

Analytics reported sales of $1 million in 2012, according to the most recent *Plastics News* survey of North American thermoformers.

Faurecia Launches 2nd Fraser Site

By Rhoda Miel, *Plastics News* Staff
Posted August 2, 2012 FRASER, MI (4:30 p.m. ET)

Auto supplier Faurecia SA has launched production at its second plant in Fraser, and already has space set aside for future expansion.

Faurecia, with North American operations based in Auburn Hills, MI, began renovating an empty 160,000-square-foot building in January and is now producing key interior parts for General Motors Co.'s Cadillac ATS and Ford Motor Co.'s Focus.

It has one injection molding machine in use now and space for up to 14, said plant manager Damien Duclair during an interview at the plant's August 2 opening ceremony.

An overhead crane system covers the entire molding area, which is a key to the company's rapid tooling changeover system, Single Minute Exchange of Dies, or SMED, practiced in Fraser and elsewhere globally. The name points to the company's target, not its current tooling change pace, Duclair added.

In addition to injection molding, the plant thermoforms thermoplastic olefin skins used on center consoles and doors and has in-house welding and assembly. It makes 10 different components for the Cadillac interiors, among them the glove box, knee bolster, defroster grille and front and rear door panels.

The door panels use a natural fiber thermoplastic composite, which helps to reduce weight and resin content, Faurecia North America President Mike Heneka noted.

It takes in parts from its sister plant on nearby 14 Mile Road in Fraser, another Faurecia site in Mexico and coordinates final assembly on some parts with sequencing specialists. The Masonic plant is working with recyclers who can separate multilayer scrap and allow the site to reuse the material, Duclair said.

Faurecia entered the North American market less than 10 years ago and has been growing steadily since then. It is now the eighth largest auto supplier in North America, Heneka said. In addition to its interiors business, the company – with global headquarters in Nanterre, France – supplies seats, exterior systems including front-end modules and exhaust systems.

Michigan Governor Rick Snyder joined a contingent of city, county and state officials to mark the opening ceremony, with Snyder noting Faurecia's growing employment base in the state. |

See Excerpt on Pages 10-13

Randy A. Blin
Executive Vice President
Blin Management Co./Triangle Plastics
Independence, IA

Randy A. Blin has contributed dedicated service over an extended period of time to the Thermoforming Industry and to the SPE Thermoforming Division. Randy continues to carry that dedication and focused organizational structure in numerous endeavors. It is clear from Randy's career that if you have a plan and the desire to do whatever is necessary to act on that plan you will make a difference.

Randy Blin has a lifetime of making a difference.

Randy became an Eagle Scout at the age of 16. This is the same year he entered into the business world as a dishwasher at Kentucky Fried Chicken. Within a year, as a high school senior, he was the store manager and he was just getting started. From that early introduction Randy has honed an extensive and diversified business career built on hard work and initiative.

As the Executive Vice President of Blin Management Co., Randy directs the business activities of the Blin family enterprises. BMC serves as the conduit for legal, accounting, and financial advising for managing the day to day activities of over 50 entities. These operations include; Blin Farms Limited Partnership, Star Lake Cattle Ranch, Independence BancShares, Inc., and Heartland Acres Agribition Center, as well as numerous business consulting initiatives.

As for community activities Randy is making a difference. Randy has volunteered as a Founding Director and served as the initial president of the Independence Area Dollars for Scholars. Every student that applies is awarded at least one scholarship. Randy is active in the leadership at the First Presbyterian Church of Independence, Iowa serving as an elder, president of the congregation and chairman of the property & finance committee. Randy also served on the Board of the Hereford Youth Foundation of America where they have worked to build a 2 million dollar endowment fund for youth activities.

Randy continued to make a difference.

In the Thermoforming community, Randy really made a difference. As a manager and corporate officer in the areas of sales, accounting, manufacturing and administration covering a 20 year career at Triangle Plastics Randy was a dynamic leader. Triangle operated as a family owned thermoforming business and grew from a basement operation in 1965 to the largest heavy gauge thermoforming company in North America by 1998. Randy was closely involved in that growth, providing creativity and innovation with an emphasis on customer relationships, process optimization, materials development and strategic acquisition management.

Randy has a keen ability to analyze a situation and effectively formulate a successful action plan. He was a pioneer in the Thermoforming Industry leading the way in the transformation to CNC automated trimming and cellular manufacturing. His visions created the benchmark for the sheet fed Thermoforming industry to effectively form and finish parts with repeatable accuracy at a very competitive price. At Triangle Plastics, he led the acquisition team that successfully integrated eight acquisitions in just eight years.

Randy became an SPE Thermoforming Division Board member and made a difference.

After serving 2 years as treasurer he became the Thermoforming Division Chairman serving a two year term, 1997 and 1998. He continued as Past Chairman serving on the Executive Committee in 1999 and 2000. As Chairman, Randy stayed focused and committed to establishing a committee format that improved the efficiency of Board meetings. It was under Randy's leadership that the organization developed a structure for continuity and sustainability within the SPE. Many of the changes that SPE has made over the last decade to remain viable have can trace their beginnings to actions begun by the Thermoforming Division in this timeframe. Randy's leadership was paramount in developing much of the respect thermoforming has earned within the engineering and plastics processing community.

In 1996, as Co-Chairman of the Conference in Northern Kentucky, Randy's passion for success was contagious. Randy expanded the exhibit format and introduced a sponsor level for added value opportunity to exhibitors. Those changes and that passion were instrumental in developing the trade show environment of the conference model today. Randy clearly communicated that the conference is presented to provide a service to the Thermoforming Industry with a mission to provide an educational event that broadens the exposure of thermoforming technology.

With the vision of communicating the value of the Thermoforming Industry as a quality, engineering based process Randy provided the leadership to further change the Division newsletter from the traditional to a high quality technical / industry publication.

In 2004 Randy received the Thermoforming Division Lifetime Achievement Award in recognition of his impact to the success of the SPE Thermoforming Division. The advancements of the SPE Thermoforming Division over the last 15 years, and with many aspects of the thermoforming industry, are the result of Randy's take charge strength, contagious energy and inspiring leadership.

Experience and leadership in the Thermoforming Industry as a business owner and innovator, service to the professional society leading to the growth of resources to further thermoforming education, continuing corporate success with strategy development and dedicated community service, and his ability to be there as a friend and confidant are the true attributes of Randy Blin's career.

There is little doubt that Randy Blin has made and continues to make a difference.

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.

Within this past year alone, our organization has awarded multiple scholarships! Get involved and take advantage of available support from your plastic industry!

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

- UMASS Lowell
- San Jose State
- Pittsburg State
- Penn State Erie
- University of Wisconsin
- Michigan State
- Ferris State
- Madison Technical College
- Clemson University
- Illinois State
- Penn College

Start by completing the application forms at www.thermoformingdivision.com or at www.4spe.com.

Thermo Forming Division

Thermoformers Market Review and Outlook 2012

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Plastics News Reports

(Editor's Note: Thermoforming Quarterly *is pleased to provide our members with this exclusive excerpt from* Plastics News' *recent publication, "Thermoformers Market Review and Outlook 2012." We invite our readers to visit www.plasticsnews.com for details on downloading the complete report. Thanks to Crain Communications for licensing rights.)*

Thermoforming Market & Process Overview

As a process for forming plastics, thermoforming represents one of six categories. In those categories covered by *Plastics News*, $97.6 billion were recorded in sales for companies ranked during 2011. Thermoforming represented 9.7 percent of the total market. Though it's a relatively smaller category in plastics processing, thermoforming is poised for growth. Advancements in tooling, machinery and materials make the process a viable choice in many cases where it wouldn't have been considered in the past. Essentially, the thermoforming process can be broken down into two categories: pressure forming and vacuum forming. During the thermoforming process, a heated sheet of plastic is placed onto a mold (male or female) where it is shaped or formed. It is cooled, trimmed, finished and fabricated into its final part.

Thermoforming can be separated into thin gauge (0.005" to 0.030") and heavy gauge (0.031" to 0.310"), based on the thickness of the sheet that is being formed. As a general rule, thin-gauge material is used for packaging applications in a roll-fed process and heavy-gauge is used for industrial applications in a cut sheet process. Companies covered here serve 22 separate end markets, 18 of which fall into the industrial category.

The packaging industry is seeing substantial growth, especially for sustainable packaging alternatives that will bolster recycling efforts and cradle-to-cradle sustainability initiatives. Global packaging industry revenues will increase to $530 billion by 2014.[1] That is an increase of roughly 24 percent over 2009. Plastics packaging will be the largest segment of that. As a percentage of total sales, the industrial sector decreased from 18.4 percent of the total pie in 2007's ranking to 13.3 percent in 2012's ranking. That does not necessarily mean that industrial has shrunk, however. Packaging has grown at a very rapid pace. Industrial applications are finding their home in other markets like medical, for example, where advances in equipment and material have translated into advances in aesthetic and physical properties. Thermoforming increasingly is taking market share in lower-quantity applications, officials reported. Those sectors include medical; signage & displays; lawn & garden; electrical/electronics; building and construction; swimming pools and spas; marine; aerospace; agricultural; automotive/transportation; appliances; and pallets. Smaller manufacturers will maintain their positions by creating niche markets.

This report focuses on the North American thermoforming market, which has undergone significant change over the past five years. Thermoformers, material suppliers,and equipment makers had a sizeable presence during the International Plastics Exposition 2012, held April 1-5 in Orlando. Officials interviewed there reported that both heavy-gauge and thin-gauge sectors are growing nicely, and companies across the supply chain appeared busy at the start of 2012.

Plastics News has been tracking and ranking companies involved in thermoforming since the publication of its first ranking in 1995. This analysis is based on 227 companies with operations in the North American market for the 2011 business year.

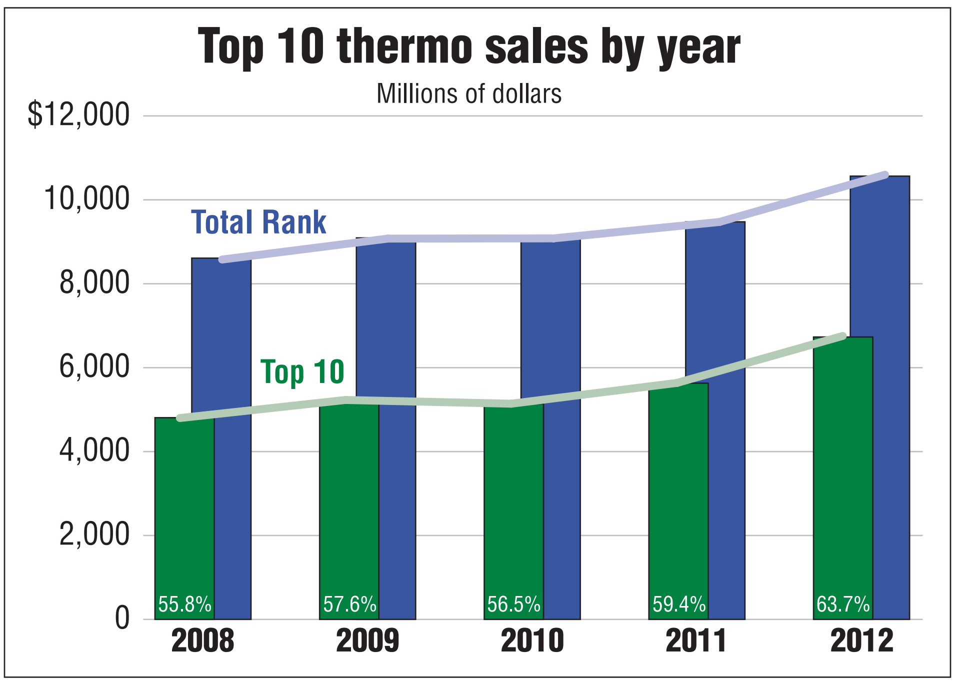
[1] *http://www.pikeresearch.com/newsroom/sustainable-packaging-market-to-reach-170-billion-worldwide-by-2014*

Thermoformers Mergers & Acquisitions Analysis

Consolidation is occurring through all parts of the plastics supply chain, including resin suppliers, machinery makers, mold makers and processors, and thermoforming is no exception. As globalization continues, it behooves companies to have scale, technological leadership, marketing prowess and the ability to provide multiple materials solutions to compete effectively. Not surprisingly, more companies are moving toward varied models of vertical integration. In the world of thermoforming, this can take shape in many ways. Companies can vertically integrate in tool building and forming; companies can integrate in sheet extrusion and forming. The models that will take shape will depend on a company's market position and where and how it makes the most sense to take costs out of the business.

For an illustration of consolidation activity, one need only look at the numbers represented in the *Plastics News* North American Thermoformers Special Report, which has full data online for 227 companies. That is a decrease of roughly 4 percent from one year earlier, when the number was 236. That figure held steady in 2010's ranking. But since 2007, the number of companies reflected in the ranking decreased nearly 19 percent, from 270 companies in 2007's ranking to 227 in the 2012 ranking.

Interestingly, as the number of companies decreases, the total sales increase. In 2007's ranking, total sales were $8.2 billion for 270 total companies; in 2012, total sales reached $10.6 billion for 227 companies. But what provides better support to the consolidation trend is the market share of the Top 10. In 2008's ranking, the Top 10 companies represented 55.8 percent of the total market sales. It increased slightly to 57.6 percent in 2009's ranking, then took a very minor dip in 2010, to 56.5 percent. Into 2012's ranking, the Top 10 represented 63.7 percent of total sales in the thermoforming market.



This chart illustrates the continued impact of consolidation in the thermoforming market. Since 2008, the Top 10's total share of the market increased from 55.8 percent to 63.7 percent in 2012. For 2012, the Top 10 companies are: Pactiv Foodservice; Solo Cup Co.; Dart Container Corp.; Genpak LLC; Berry Plastics Corp.; Sonoco Plastics Thermoforming; D&W Fine Pack LLC; Fabri-Kal Corp.; Anchor Packaging Inc.; and Tekni-Plex Inc.

Sonoco Plastics Thermoforming, ranked No. 6 with sales of $330 million, has leaped its way into the Top 10. The firm snapped up thermoformer Tegrant Alloyd Brands Inc., which it acquired as part of its $550 million purchase of Tegrant Corp. from private equity firm Metalmark Capital LLC. According to its website, the company partners with the world's largest food brands in the consumer packaged goods and food-service industries. It processes CPET and polypropylene. Its technologies include monolayer, coated and barrier and non-barrier laminated tubs, cups, spools, consumer and institutional trays.

Through 2011, smaller deals were happening, too. Spara LLC acquired the assets of TriEnda LLC. Spara bought TriEnda in a distressed situation, acquiring the assets from Fifth Third Bank in a foreclosure sale. Officials at that time acknowledged revenue problems at TriEnda.[2]

At the beginning of 2012, the activity didn't seem to be slowing. In March, for example, No. 3 Dart Container Corp. ($480 million estimated thermoforming sales) announced it was buying No. 2 Solo Cup Co. ($790 million estimated thermoforming sales). This was a $1 billion transaction.[3]

[2] *http://www.plasticsnews.com/headlines2.html?id=11070400102&q=Spara+Logistics*
[3] *www.plasticsnews.com: "Dart buying Solo Cup for $1 billion," March 22, 2012.*

(continued on next page)

The M&A activity has been occurring from strategic and private equity purchasers, and often, there can be a mix of both, for example, with a strategic buyer that has private equity backing.

Smaller companies are gobbling up additional plants in bolt-on purchases. In January, Peninsula Packaging Co. LLC (No. 12 in the ranking) of Exeter, Calif., purchased two thermoforming plants from Berkley Operations LLC, which does business as Packaging Plus LLC.[4] The company announced in March that it would expand the acquired plant in Yakima, Wash., with a $20 million investment. In a deal between two thermoforming firms, Rohrer Corp. has purchased Buckell Plastic Co. Inc. for an undisclosed price. Acquiring Lewistown, Pa.-based Buckell will allow Rohrer to strengthen its position in the visual packaging market, officials said in a Jan. 4 news release. Buckell "is a well-run company with products and customers that complement our current book of business," Rohrer President and CEO Scot Adkins said in the release. Buckell has annual sales of about $3.5 million. Its 50,000-square-foot Lewistown plant – which makes custom thermoformed packaging for medical, food, retail and other markets – will join Rohrer plants in Wadsworth; Buford, Ga.; and Huntley, Ill. This marks the first deal for Wadsworth, Ohio-based Rohrer since private equity firm ShoreView Industries of Minneapolis bought controlling interest in the company in early 2010. Rohrer makes thermoformed blister packaging as well as paper cardstock for blisters and folding paper cartons. ShoreView owns four other plastics-related businesses.

Industry Mega Trend: Sustainability

Major players across the plastics industry have been increasing their sustainability initiatives. In a review by Plastics News of each website of the Top 15 thermoforming companies, each company had at least one mention of "sustainability," "environment," or "recycling" or related language placed prominently on its home page or within one click once on its home page.

Genpak LLC (No. 4 on the ranking) has its sustainability initiatives branded as "The Green Room" on its home page.

Berry Plastics (No. 5 in the ranking) outlines its areas of focus. On its website, officials let viewers know that sustainability touches every aspect of its business and the company has prioritized its activities by focusing on specific areas that have the greatest impact. Its goal is to reduce overall resin usage by 5 percent, increase use of recycled content in its products and continue to develop products that incorporate bio-based materials.[5]

This response has been due in part to mega-retailers like Wal-Mart Stores Inc. mandating supplier changes in its Sustainability Scorecard, and government mandates. Because the definition of sustainability is so broad, these initiatives vary in scope, size and approach.

Dart Container Corp., for example, has an entire website dedicated to "Environmental Information."[6] Dart is educating consumers through initiatives like, "Did you know …" where it lets views know that the company's sustainability efforts save enough energy each year to heat nearly 105,000 homes. The company also lets site visitors know that it recovers waste heat from its manufacturing processes and uses it to heat buildings and boiler feed water.

Sonoco markets itself as a leader in recycling services and as one of the nation's largest recyclers. The firm operates six material recovery facilities, an increase from three that it operated in 2010.[7]

Spartech Packaging Technologies of Portage, Wis., listed as No. 28 on the ranking with $66 million in thermoforming sales, is part of Spartech Corp., which launched its first corporate sustainability report in March. Vicki Holt, Spartech Corp.'s president and chief executive officer, said corporate sustainability has been part of Spartech for some time, but the company has broadened its communication efforts, increased awareness, raised its standards and started to monitor progress toward its goals.[8]

[4] www.plasticsnews.com: "Peninsula buys two thermoforming plants," January 9, 2012.
[5] www.berryplastics.com
[6] http://www.dart.biz/web/environ.nsf/pages/menu
[7] Sonoco 2011 annual report, pg. 10.
[8] Spartech Corp. Press Release, March 28, 2012

The company illustrates its manufacturing sustainability efforts through technologies such as EnviroAir. This is a foaming technology that allowed Spartech to reduce the amount of plastic used in a Danone yogurt cup by up to 20 percent. The materials require less energy to thermoform, are lighter in weight than solid sheet and provide improved thermal insulation.[9]

The efforts are not restricted to packaging applications. Spartech released its Reinforce product line of compounds, which allows the company to produce thinner wall designs that meet structural requirements for industrial applications.

Even among smaller firms, sustainability and recycling initiatives have become a way of doing business. Shepherd Thermoforming & Packaging Inc. of Brampton, Ontario, promotes the use of materials that come from recycled plastics wherever possible, according to its company website. In 2011, the company processed close to 2 million pounds of RPET, letting its customers know that activity is equivalent to diverting roughly 36 million water bottles from the landfill.[10]

At Dordan Manufacturing Co. Inc. of Woodstock, Ill., officials have a "Recycling in America" blog. The company offers a bioresin show and tell; Wal-Mart Scorecard Packaging Modeling; and a Four-Step Design for Sustainability Process. The company also presented at the Green Manufacturer's Zero-Waste-to-Landfill Workshop in Raleigh, N.C., in late 2011.

In early 2012, the Society of the Plastics Industry Inc. and the National Association for PET Container Resources (NAPCOR) announced that three United States recycling operators were selected to receive grants toward establishing model programs for collection and intermediate processing of PET thermoformed packaging.

Resin Pricing Impact

Companies have been struggling with raw material price increases, in addition to increases in prices for energy and freight costs. The most dominant resins used in the thermoforming process are polyethylene, polypropylene, polystyrene and PET. [11]

HDPE (extrusion sheet), has experienced a 13 percent increase in per-pound pricing since January 2011 and an increase of 6.5 percent since January 2012. PP (extrusion sheet) has experienced a 21 percent increase since January 2011, and a 20 percent increase since January 2012. PS (high-impact, extrusion) is up 25 percent on per-pound pricing since January 2012, and 13 percent since January 2012. All the data is for large-volume purchases of more than 20 million pounds per year.

Machinery makers serving this sector have been making adjustments in their equipment as well. Nowhere was this more apparent than NPE2012: The International Plastics Showcase. GN Thermoforming, for example, showcased its plug-assist thermoforming machinery and tooling technology. The cut-in-place machine is targeted for medium-to-low-volume runs. Officials touted its energy efficiency and minimal waste production.

Conclusion

Processors will continue dealing with the volatility in resin pricing and must maintain a cautious outlook for a moderately improving U.S. economy. At the writing of this report, the U.S. economy was experiencing moderate growth. The Federal Open Market Committee on April 25 released its decision to keep the federal funds rate at 0 to 0.25 percent at least through 2014. Global financial markets are experiencing their own problems, which can have significant impact on the performance of the U.S. economy.

Although the labor market has improved, unemployment does remain high in the U.S. Effective companies must consider all macro-economic factors when choosing how to deploy resources, especially in a sector such as thermoforming.

[9] *Sustainability Report*
[10] *www.shepherdthermoforming.com/materials-recycling.html*
[11] *Plastics News' Thermoforming & Packaging Special Report, March 5, 2012*

Thermoforming Quarterly® | ANTEC Paper

Influencing Thermoforming Properties of Polypropylene Films with Additives

By Prof. Dr.-Ing. Ch. Hopmann, Prof. Dr.-Ing. Dr. Ing. E. h. W. Michaeli, Dipl.-Ing. M. Begemann, Institute of Plastics Processing at RWTH Aachen University (IKV), Germany

Abstract

The processing and product characteristics of thermoformed polypropylene can be influenced by the additives added during the extrusion process. The Institute of Plastics Processing (IKV) at RWTH Aachen University, Germany, is conducting extensive tests with the different additives in extrusion and consecutive thermoforming. This paper deals with the influence of slip, antiblocking and antistatic agents on the thermoforming behavior of polypropylene.

Introduction

Thermoforming is the process of choice for manufacturing thin-gauge or large-area parts for packaging or technical applications [1]. The process allows low-weight parts to be produced very rapidly and economically.

The wall thickness distribution is an essential and often critical characteristic of thermoformed parts [2]. It influences the necessary part weight among other important properties. Beside mechanical properties like strength and rigidity the wall thickness distribution affects e.g. the permeation behavior. This criteria describes the sturdiness of the packaging and the shelf life of the packed victuals.

The semi-finished product is decisive for the quality of the thermoformed part. Thermoforming uses (co-) extruded films from amorphous and semi-crystalline thermoplastics. With the choice of the polymer the basic properties of the posterior part are fixed. Therefore many raw material producers offer optimized materials for the thermoforming process.

Beside the choice of the raw material the extrusion parameters widely influence the thermoforming behavior and the properties of the thermoformed part. For example a very fast cooling of the melt of semi-crystalline thermoplastics leads to a fine spherulite structure. The same effect can be achieved by the use of nucleating agents or colored pigments which act as initial nucleus. To validate the influence of additives on the product properties of thermoformed parts, it is necessary to examine and to analyze the entire process chain (Fig 1).

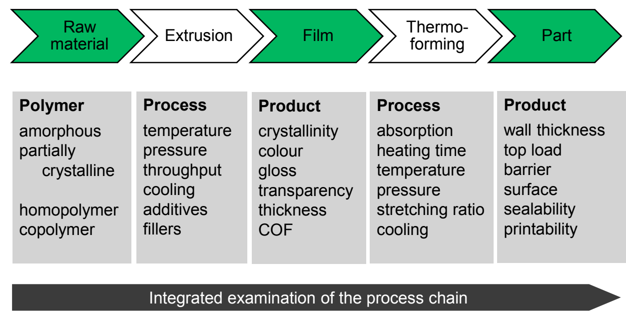


Figure 1. Effects on properties of thermoformed parts.

Many raw material producers have cut down their product portfolio. Therefore especially smaller film producers cannot get hands on customized materials for their applications anymore. Thereby, the addition of additives is increasingly relocated to the processors. The multiplicity of additives and the interaction among each other often do not allow an a priori assessment of the effectiveness. Many film producers tend to overdose the additives to achieve the required effect definitely. The precise composition of the raw materials and possible additives are often unknown. On that account it is hardly possible to create a specific additive range for a certain application.

A well-directed matching of the additives to the thermoforming application can avoid overdosing or the addition of unneeded additives. The saving of expensive additives and the optimization of the heating behavior can positively influence the productivity and the energy consumption. This paper shows the characteristics of polypropylene with additives.

Additives for Thermoforming Applications

The film production for thermoforming application uses a huge variety of additives:

- nucleating agents (metal oxides, talc, …)
- fillers (talc, chalk, …)
- colorants (TiO_2, carbon black, pigments, …)
- antistatic agents (fatty acid esters, …)
- antiblocking agents (polydimethyl siloxane, …)
- slip agents (internal & external)

There are processing aids that influence for example the flow characteristics of the melt or the surface friction of the film and additives that directly affect the mechanical and thermal properties of the film. If the fraction is less than 5 % it is named 'additive'. When it is between 10 and 70 % is usually called 'filler' [3]. The additives are typically added as masterbatch to the extrusion process. In the following the additives used in this paper are described.

Antistatic Agents

Plastics are electrical insulators and can build up high electrical charges. This can lead to handling problems during transportation, storage and packing [4]. Electrostatic charges e.g. can hinder the separation of packing units. In food packaging hygienic aspects like freedom of dust between thermoforming and filling are essential. Antistatic agents help to reduce the electrical surface resistance so far, that dust attraction and potential process disturbances through electrostatic charges are minimized [5]. Those charges also lead to dust enclosure and lacerated edges of printed images [6].

Internal antiblocking agents are added during film extrusion to influence the electrical surface resistance. This can be fatty acid ester or amide, ethoxylated amine, alkyl sulphonate and cyanophthalocyanine which are incorporated into the base material. Those agents are incompatible to the base material and migrate to the surface. The resulting hydrophilic layer attracts water from the surrounding which leads to conductivity [3]. The effect of antistatic agents is depending on the ambient conditions during storage as well as from the time between production and further processing.

Slip Agents

The friction properties of films are very important during film extrusion and the subsequent thermoforming. Films with high COF tend to wrinkle during winding. Sleek films with a low COF lead to shifting of the inner layers of the reel, the so called telescoping [7]. The friction behavior is greatly affected by the surface properties, which can be adjusted by the use of slip and antiblocking agents.

Slip agents are widely used in films for packaging applications. The literature differs between internal slip agents, which reduce the melt viscosity, and external slip agents, which act as lubricants between melt and metal cladding [3]. The last one should be finely dispersed in the melt and be incompatible with the polymer. During cooling the slip agent migrates to the surface. After a certain time there will be an equilibrium state between the slip agent remaining in the film and on the film surface. The measured COF stabilizes to a constant value [7].

Polyolefines mostly use fatty acid amides. The slip agent molecules migrate to the surface due to their weak compatibility to the polymer [8]. The amid molecules orient on the surface in a way, that the polar amide groups ($-CONH_2$) are in contact with polymer and themselves. The hydrocarbon chains are projected outwards and avoid contact with other surfaces.

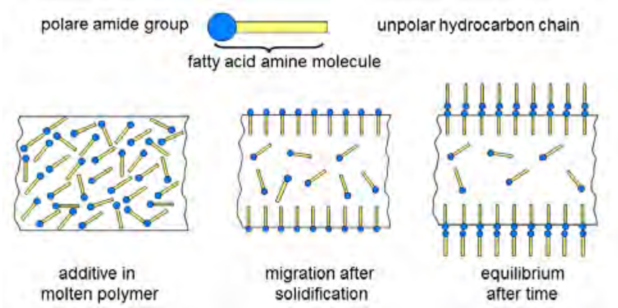


Figure 2. Migration behavior of fatty acid amines (according to [9].

Antiblocking Agents

Antiblocking agents inhibit the adhesive sticking of adjacent layers of film. This sticking, also called blocking, often occurs in tightly wound rolls and when sheets are stacked under pressure and heat [7]. The action mechanism of antiblocking agents differs from slip agents. The antiblocking agent obtrudes to the surface due to shrinkage of the film thickness during solidification. This creates a surface roughness that helps to minimize film-to-film contact and hence reduces blocking. Typical substances used are inorganic and synthetic silicates and talc.

Machinery

For the film extrusion the IKV is equipped with an extrusion line with 60 mm-extruder (L/D=27), gear pump and a slit die with an adjustable lip. Due to the local adjustability of the melt flow at the outlet of the die, a homogeneous distribution of the melt can be warranted.

The thermoforming tests are conducted on a single station thermoforming machine type LDFG 23 (Illig Maschinenbau GmbH & Co. KG, Heilbronn/ Germany). This machine is equipped with a both-sided quartz IR-heating. The parts are formed with negative plug-assist thermoforming into a cup-shape with an opening diameter of 60 mm and a drawing depth of 40 mm.

The wall thickness distribution of the formed cups is determined nondestructive using a MagnaMike 8000 from Panametrics GmbH, Hofheim/ Germany.

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Materials

For the tests a polypropylene (PP) HP400H of Basell Polyolefine GmbH, Wesseling/Germany, was used. This homopolymer is featured with a basic stabilization but no further additives or fillers. It is widely used for thermoformed cups and trays, blister packs and flower pots.

The additives were provided as masterbatches by A. Schulman GmbH, Kerpen/Germany and Clariant Masterbatches (Deutschland) GmbH, Ahrensburg/ Germany. Table 1 provides an overview of the deployed additive masterbatches. GM2 is based on polyethylene, all other masterbatches are based on polypropylene. The main active ingredient of the antistatic agents is ethoxylated amine. The slip agents are based on erucic acid amide and the antiblocking agents use synthetic silica.

Table 1. Additives used.

additive	abbr.	name	supplier
antistatic agent	AS1	ASB 20 G	A. Schulman
	AS2	ASPA 2446	A. Schulman
slip agent (external)	GM1	SPER 6	A. Schulman
	GM1	CESA-slip PEA 0025148	Clariant
antiblocking agent	AB1	ABPP 05	A. Schulman
	AB2	CESA-block 1102	Clariant

DOE

All parameters concerning the extruder are kept constant during film extrusion with different additives. This is necessary to differ between the influence of the extrusion parameters and the additives. Particularly the film thickness is kept constant to keep the films comparable.

- cylinder: 210/ 230 / 240/ 250/ 250 °C
- die: 250 °C
- chill roll: 20 °C
- speed melt pump: 20 min^{-1}
- feed pressure pump: 70 bar
- film thickness: 1.2 mm

The additive masterbatches are added individually with different dosages to characterize the influence on the thermoforming properties separately. The research concerning the combined adding of additives are not part of this paper. To depict possible saving potential the manufacturer recommendation is chosen as maximum dosage. The following dosages are chosen for the different additive masterbatches:

- antistatics: 1.0/ 1.5/ 2.0 weight-%
- slip agents: 1.0/ 1.5/ 2.0 weight-%
- antiblocking: 2.0/ 2.5/ 3.0 weight-%

To solely examine the additive influence, the thermoforming parameters are kept constant throughout the experiments.

- heating power: 500 W
- forming temperature: 163 °C
- plug displacement: 95 %
- forming pressure: 4 bar

Results

After film extrusion the analysis of the film, thermoforming and part properties is performed. The reference film without additives and the corresponding properties are indicated in the following with "Ref".

The results of the DSC show no definite dependency of the degree of crystallization on the additive dosage. The addition of the antistatic and slip agents result in a slightly lower degree of crystallization (Fig. 3). With exception of the antistatic AS1 the degree of crystallization increases slightly with increasing dosage of additive. This indicates a nucleating effect of the additives. Micrographs show a finer spherulite structure with increasing additive dosage. Evidently the additives act as additional crystal nucleus and lead to a finer crystalline structure.

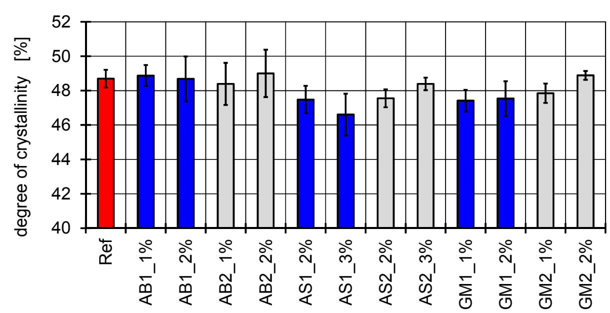

Figure 3. Degree of crystallization depending on additive type.

The use of additives influences the surface properties of the films. The coefficients of friction (COF) are measured using a self-construction. A test sled with a contact area of syntactic foam is pulled with a defined speed over the tempered film surface. The required force is measured and the COF is calculated.

Fig. 4 shows the average over the results of all dosages of one additive. The low standard deviations proves the assumption, that the influence of the dosage is very low. The exception is the slip agent GM1. The COF decreases from 0,189 at 1 % masterbatch to 0,108 at 1,5 % masterbatch. At high dosages it does not decrease further. Adding antistatic and slip agents leads to a reduction of the COF compared to the reference in the range of 33-73 %. Adding any antiblocking agent increases the COF around 22 %.

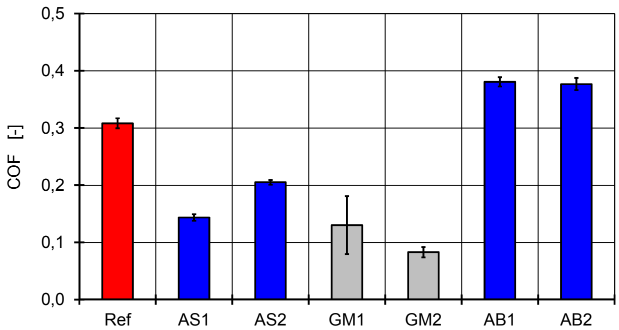

Figure 4. Influence of additives on COF at room temperature.

During thermoforming the heating times are measured. The influence of the additives on the heating time is already achieved by the lowest dosage used in this DOE. An increased dosage does not lead to a further influence on the heating time. This is proved again by the standard deviation in Fig. 5, which is formed over all three dosages of the same additive.

Both antistatics lead to reduction of heating time of about 12 % compared to the reference. The slip agent GM1 leads to a reduction of 18 %, whereas GM2 leads to an increasing of the heating time of 5 %. The same inconsistent scheme is observed for the antiblocking agent. AB1 increases the heating time by 17 %, AB2 does not influence the heating time. The conclusion from the examined additives is, that any antistatic reduces heating times. The effect of slip and antiblocking agent depend on the exact type of additive and cannot be generalized.

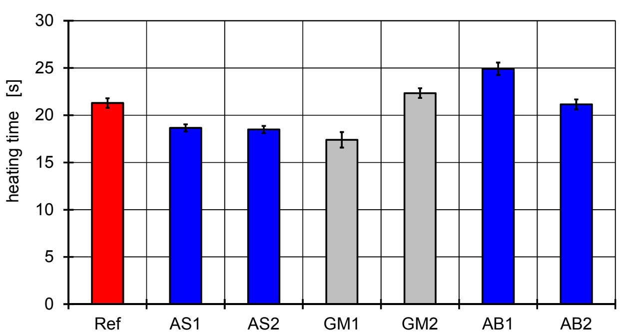

Figure 5. Influence of additives on heating time during thermoforming.

After thermoforming the wall thickness distribution of the cups is measured. Exemplarily the wall thickness distributions of the cups with antistatic agent films are shown in Fig. 6. The kind of additive influences the wall thickness distribution. The lower the COF of the film, the less the wall thickness at the bottom of the cup.

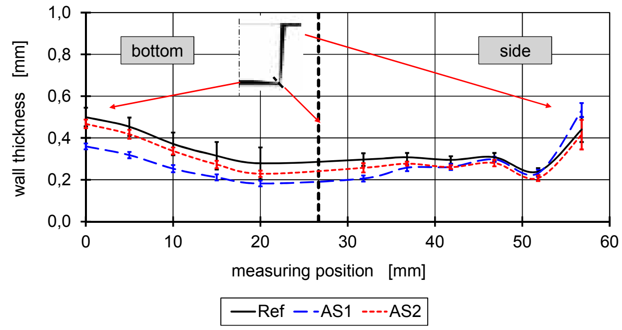

Figure 6. Influence of antistatic agents on wall thickness distribution.

The last examination presented in this paper is the top load behavior. The cups are pressed in a tensile testing machine. The force at failure (F_{max}) and the compression at failure (s_{max}) are recorded. Fig. 7 shows the results as an average over all dosages again. The additives mainly influence the force which the cups can withstand before failure. The corresponding compression alternates only 5 % around the value of the reference. The antistatic agents lead in both cases to a reduction of the maximum force. The effect of slip and antiblocking agents depend on the exact type of additive and again cannot be generalized.

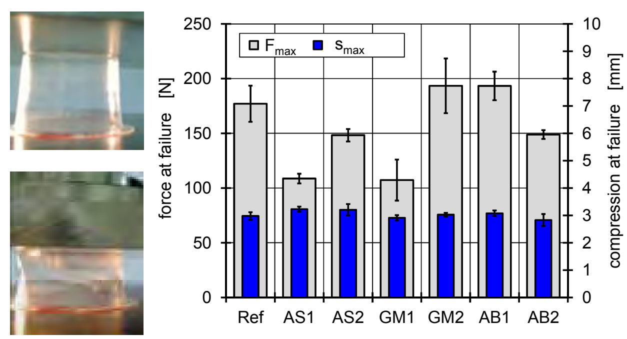

Figure 7. Influence of additives on product behavior.

Conclusion and Perspective

The quality of thermoformed parts is decisively influenced by the semi-finished product. With the choice of the polymer the basic properties of the posterior part are fixed. Beside the choice of the raw material the additives added during film extrusion widely influence the thermoforming behavior and the properties of the thermoformed part.

This paper did show the characteristics of polypropylene with slip, antiblocking and antistatic

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agents. The additives have no distinctive influence on the degree of crystallization. A higher dosage of additive leads to a finer crystalline structure.

Both antistatic and slip agents lead to a reduction of the COF. Antiblocking agents increase the COF. The COF directly influences the wall thickness distribution of thermoformed cups. A low COF leads to a low wall thickness at the bottom of the cup. The heating time during thermoforming can be reduced by the use of antistatic agents. But coincidental antistatic agents reduce the force the thermoformed part can withstand.

It was shown, that the lowest dosages used for the experiments are already sufficient to achieve the desired effects. These dosages were chosen lower than the manufacturers recommendation. The thoughtful use of additives has a huge economic potential. The heating time reduction attained by the use of antistatic agents allows possible energy savings in thermoforming production.

Acknowledgements

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Furthermore we would like to thank the companies A. Schulman GmbH, Kerpen/Germany, Basell Polyolefine GmbH, Wesseling/Germany and Clariant Masterbatches (Deutschland) GmbH, Ahrensburg/ Germany, for supplying materials for the experiments.

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Pressure Forming and Special Effects – A Game Changer for Designers

By Ronn Cort, President at KYDEX, LLC

In recent years, new advances and continuous innovation in the thermoforming industry have changed the playing field for designers. Previously considered much later in the process, thermoplastics were selected on the basis of price, quantity and compliance. Today, designers are considering thermoplastics at the beginning of the design process, which is paving the way for new design capabilities in industries like aviation, mass transit and medical devices. More accurate color matching, special effects and the ability to produce more acute details deliver stronger brand recognition and enhance customer experience.

Advances in thermoplastic materials development are providing designers with capabilities that were previously not widely available. Thermoforming processes, like pressure forming, and changes in how the industry uses molds also contribute to design innovations.

Pressure Forming

As pressure forming continues to deliver value-added components throughout modern industry, thermoformers are improving quality by delivering more detailed parts that have greater consistency across the batch. With traditional forming, wall thinning can be a challenge, caused by deviations in how the material is stretched over the tool. Furthermore, detail like reverse angles and undercuts cannot be achieved by traditional forming alone.

Conversely, pressure forming – a process that integrates design and forming – can deliver low-cost, highly aesthetic parts that rival the process of injection molding. The combination of air pressure and vacuum, as well as more sophisticated process controls that better monitor tool and sheet temperatures, enable the delivery of consistent parts, precise detail and intricate undercuts. With air pressure forcing the material into the minute crevices of a mold, features like small, tight corners, molded-in vents and ribs, and logo silhouettes can be formed more accurately.

Pressure forming gives processors the ability to selectively texture various surfaces on a single formed component. Instead of embossing a texture into the extruded sheet, thermoformers are now applying the texture directly to the mold andeliminating the risks of inconsistencies caused by stretched or distorted materials.

One airline took advantage of new design capabilities inherent in pressure forming when it created new cup holders for its business class seats. The designer wanted a cup holder that was selectively textured, with texture on the exterior of the cup holder and a smooth surface on the interior. Because pressure forming can create tight corners that more accurately fit together, the cup holder was created in two pieces that were snapped together, eliminating the need for an additional step of applying adhesive.

Changes in how thermoformers are using molds also deliver a higher quality product. Although temperature-controlled molds have been around for decades, in recent years we've seen more widespread adoption of them. Evenly cooling the formed part delivers a more stable product, aiding consistency and enhancing quality.

Special Effects

While advances in the process of thermoforming deliver more dynamic parts and new capabilities for designers, innovations impacting materials like thermoplastics also contribute to new design functionality. In the past, designers were limited by the availability of color in compliant materials. Special effects – like color and texture – were typically only used for high-end products due to cost. Now, some manufacturers can offer custom color matching capabilities and materials that are fully compliant with highly regulated industries, like aviation. For example, a designer that wants red for a retail fixture is no longer limited by the cherry red offered by a given thermoplastics manufacturer. Custom color matching enables the designer to choose from variations in red such as burgundy, crimson, brick red, or virtually any red in between.

Beyond color, thermoplastic manufacturers are pushing the boundaries in special effects capabilities. Metallic or pearlescent sheet, previously achieved through the application of a special metallic cap, can be created without additional processing. The use of monolithic sheet creates consistency of color or of effect through the entire sheet. For example, if the sheet becomes scratched or damaged in use, the color won't scratch off, increasing part longevity.

Translucent thermoplastics are another game-changer for designers. Now offered in color, and fully compliant within verticals like mass transit and aviation, translucents create a new aesthetic for cabin and rail interiors. Today, translucent thermoplastics are being used for partitions between cabin classes, or decoratively for fixtures like lighting or even fountains. While aviation interiors in Europe and in Asia tend to be more design-forward than in North America, we're starting to see color and translucents play a more prominent role across the industry. One airline, based in Eastern Asia, is taking advantage of new thermoplastic design offerings. The airline is evaluating the use of a fountain in its premier class cabin using a colored translucent thermoplastic to highlight the waterfall through backlighting.

Designers in the mass transit industry are also starting to look at new capabilities and how they might enhance the customer experience. While European mass transit is a true leader in this area, American designers are beginning to evaluate new possibilities. Thermoplastics manufacturers are working to proactively develop new palettes and capabilities to help guide design-forward progress for mass transit in the U.S.

The medical device industry is also experiencing changes based on new device and component capabilities presented through advances in thermoforming. The level of detail achieved through pressure forming allows for more articulately formed recesses, pulls and depressions where labels can be applied. While whites and blues have been the industry standard for medical equipment, designers are beginning to deviate from traditional colors. New thermoplastic special effects, like metallic finishes, are starting to be applied to give equipment a more "high end" appearance.

As designers start to turn to thermoformers earlier, they're becoming aware of new capabilities that can transform the design process. As these partnerships continue to evolve, thermoformers need to think proactively and understand the nuances of the industries they serve in order to continue delivering innovative solutions and high quality products.


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2012 Thermoforming Scholarship Recipients

SHARNA-KAY DOBNEY
The Segen Griep Memorial Scholarship - $5,000
Kettering University

Sharna-Kay Dobney is an international student from Jamaica pursuing a Bachelor's degree in Chemical Engineering at Kettering University. She is a senior and is looking forward to graduating in Spring 2013. In her spare time, she reads novels, travels, and enjoys swimming and socializing. She currently holds the position of vice president for Kettering University's SPE student chapter. She helped revitalize the chapter, which had been dormant for the past 5 years. The chapter currently has 13 national members, and is actively recruiting for the upcoming Fall 2012 term. Sharna-Kay is a co-op student at Inteva Products, a major producer of automotive interior systems, where she has been working with some of the leading advanced materials in the automotive industry including thermoplastic olefins (TPO). At Inteva Products, she has become familiar with numerous plastic processes, including injection molding, thermoforming and compression molding. It is Sharna-Kay's dream to make a difference in the plastic industry by contributing to the development of more eco-friendly plastic components. She is honored to be a recipient of the Segen Griep Memorial Scholarship, and is very thankful for SPE's generosity in providing her with this scholarship. "It well definitely propel me a step further in pursuing my dream," she stated.

HARRY KOSHULSKY
The Thermoforming Division Memorial Scholarship - $2,000
Pennsylvania College of Technology

Harry Koshulsky is a senior at the Pennsylvania College of Technology in Williamsport, Pennsylvania. Harry will graduate in May 2013 with a Bachelor of Science degree in Plastics and Polymer Engineering Technology. He started studying plastics as a junior in high school by taking Dual Enrollment College Courses in Thermoforming, Injection Molding, Extrusion Blow Molding, Rotational Molding and Basic Machining through the Pennsylvania College of Technology Now Program. During his senior year in high school, Harry received an Advanced on the NOCTI (National Occupational Competency Testing Institute) for the end of program assessment in the Computer Aided Drafting and Design Program in which he received the Pennsylvania Skills Certificate from the Pennsylvania Department of Education. Upon college graduation, Harry will be the first student to complete the Workforce Leadership Dual Enrollment 2+2+2 in the Plastics and Polymers Technology Program. During his summer break, Harry works at TE Connectivity, formerly Tyco Electronics, in the Injection Molding Department. His job responsibilities range from the basic operation of three molding presses, inspecting parts for quality assurance, to pulling and setting molds. Since his freshman year, Harry has been a member of the Society of Plastics Engineers Student Chapter at the Pennsylvania College of Technology and a member of the Society of Plastics Engineers National Chapter since his sophomore year. In his junior year, Harry was voted as the Fundraising Chairman of the Society of Plastics Engineers Student Chapter and Fundraising Co-Chairman for his senior year.

MMCC Receives Grant to Offer Training in Plastics Technology

Mid Michigan Community College (MMCC) has received a three-year grant through the National Science Foundation (NSF) for over $700,000 to support the creation of a Plastics Technology program on its Harrison Campus.

The new grant will provide for training in the plastics industry through a laddered approach. College students will be able to pursue non-credit training, academic certificates, or an associate's degree that will seamlessly integrate with Ferris State University's bachelor's in Plastics Engineering Technology program.

In order to educate K-12 students about high-tech and in-demand careers, manufacturing career awareness opportunities will be provided through classroom instruction, field work and apprenticeships.

The plastics program at MMCC represents a collaborative partnership between the college, the Clare-Gladwin Regional Educational Service District (CGRESD), and Ferris State University (FSU). Funding through the grant will support the creation of program curriculum, the purchase of new equipment for hands-on training prep, as well as a program director.

Building from the existing trade and technical classes that MMCC offers, a new level of classes that focus specifically on the plastics technology arena will be developed over the next two years. The grant also provides possibilities and opportunities for area manufacturers who seek qualified training in this emerging field.

Direct assessments of area employment opportunities in the plastics field prompted the college to procure the NSF grant and develop a plastics program. This initiative represents a deepening of the college's partnership with area manufacturers. Over the coming months, MMCC will work closely with other local manufacturing employers to identify their training and staffing needs and to build short-term training programs that specifically meet those needs.

"The plastics industry is stable and growing, and our local manufacturers are key to economic vitality in this region," notes Scott Govitz, Executive Director of Workforce and Economic Development. "This grant is aimed at supporting these manufacturers and putting people to work in the plastics sector. We're very excited about the possibilities it holds."

The grant serves as a powerful example of the importance of proactive and collaborative efforts to provide local opportunities that make significant local impacts. MMCC is enthusiastic about working with FSU and the CGRESD to increase the impact of the plastics program in both scope and reach.

MMCC's technical offerings are undergoing a number of changes. Over the last few years, technical facilities and programs have been upgraded and modernized. Included in these changes are roughly $2,000,000 in upgrades to both the MMCC welding lab and the Heating/Refrigeration/Air Conditioning facility, which included the addition of working geothermal fields for student study and research.

"MMCC has always remained flexible and adaptable so that it could meet the needs of area industry and employers," Govitz said. "Our new structure brings all of the college's technical offerings under one umbrella that offers students and employers one place to get the training they need."

To learn more about the Technology Center at MMCC or the technical and trade offerings, visit midmich.edu.

From the Editor

If you are an educator, student or advisor in a college or university with a plastics program, we want to hear from you! The SPE Thermoforming Division has a long and rich tradition of working with academic partners. From scholarships and grants to workforce development programs, the division seeks to promote a stronger bond between industry and academia.

Thermoforming Quarterly is proud to publish news and stories related to the science and business of thermoforming:

- New materials development
- New applications
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Trending Topics
(as of September 6th, 2012)

1. How to start a thermoforming plant

2. Applications for high dies and steel rule dies in PET

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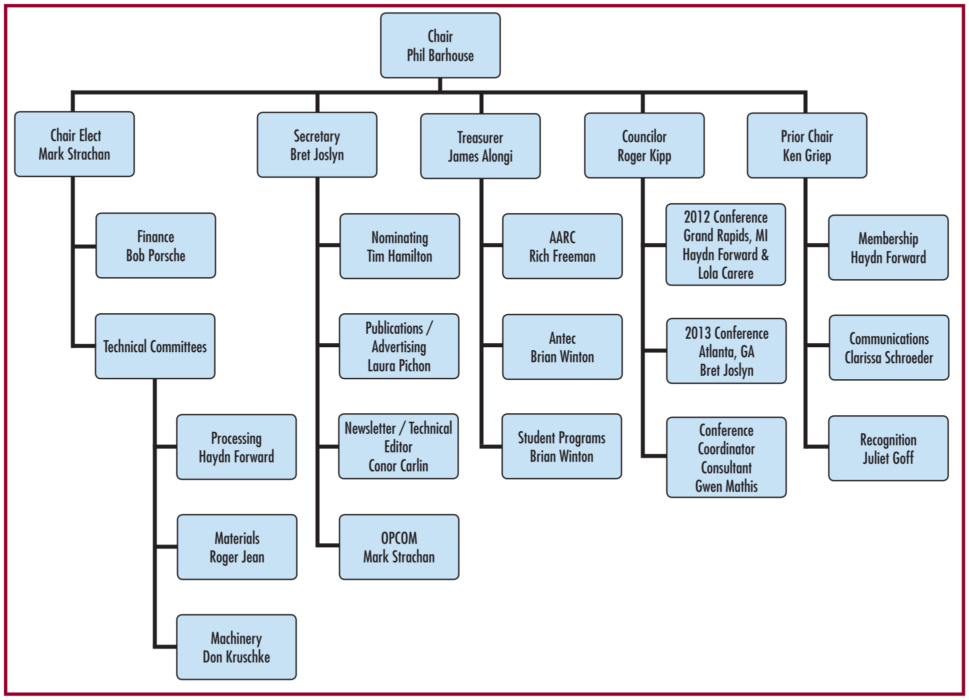

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