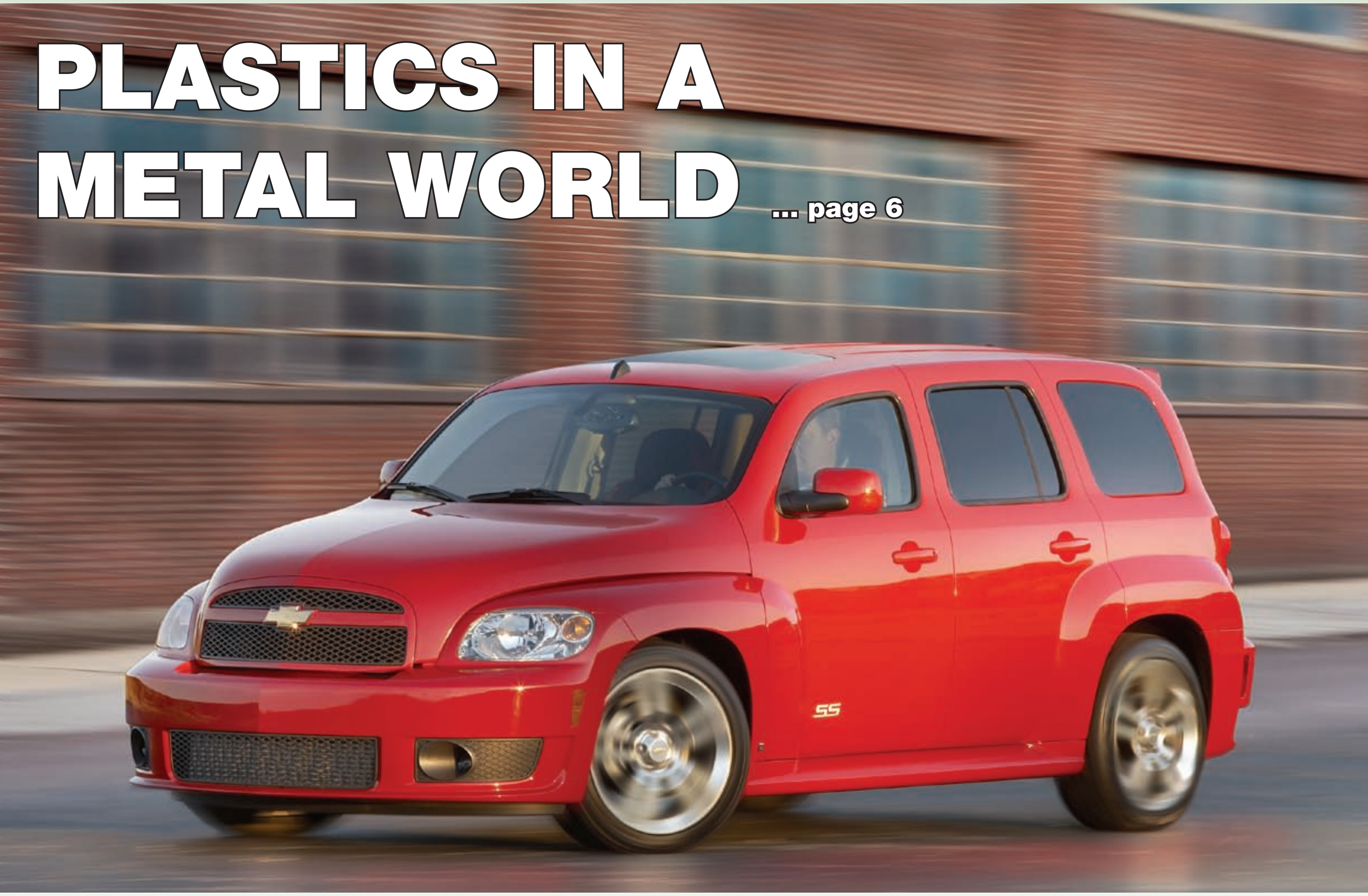
Thermoforming Quarterly®

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

SECOND QUARTER 2010 ■ VOLUME 29 ■ NUMBER 2



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

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Chairman's Corner

Ken Griep

Spring is here! First and foremost, I would like to thank Brian Ray and the Thermoforming Board of Directors for electing me Chairman for the next two years. It is both an honor and a challenge to lead the division during current difficult economic times.

Our annual conference in Milwaukee, WI (September 18th – 21st) is shaping up to be a huge success. The technical program is receiving great responses for content and the exhibitor hall sponsors are lining up and signing up to participate.

In the current economy, we are all struggling with work shortages, reduced hours and a lack of projects. This is a change for our industry and one to which we are not accustomed. Now is not the time to dig ourselves into a deep hole and wait for a better day to arrive at the door step. I want to create a challenge to our sponsors, exhibitors, attendees and all of our partners in the thermoforming industry: today is the day we need to get creative and push into high gear. My challenge is for our industry to create a new level of customer confidence and involvement. We need new materials and process techniques to accelerate our current technologies. We need new, innovative developments to take us beyond the current realm of thinking and processing.

The thermoforming industry is here to stay. Our challenge is to show our customers that we are a dynamic industry. We must show renewed interest in their needs and desires. We need to be their solution partners! Educating our clients to the fact that thermoforming is stronger, lighter and more functional than other plastic processes cannot be delayed. Price is not the only criteria. Developments in new materials are required to compete with other plastic processing while value-added services will provide new competitive advantages. We need to show our customers that thermoforming can and will exceed their needs.

To achieve this goal, we will all need to work together to create a vibrant industry. Competition creates new products. The current practice of buying business to keep your staff busy is hurting our growth and is discouraging new development. This practice most often shows the client an inferior process. They will not know or understand all that we can offer if we chase business to the bottom.

Our industry is about more than plastic forming. We are innovative and creative. We can and should find new areas in which to develop products. One such need is in disaster relief. We have had recent devastating earthquakes in Haiti and in Chile as well as continual eruptions of volcanoes in Iceland. A product line that should be created by our industry is an emergency relief shelter. These should be thermoformed and be deployable at a reasonable cost that provides aid to those in need.

Markets and clients need to see that thermoforming is a thriving industry that fully understands the cost of manufacturing. It is an industry that is driving to provide the best solutions possible while continually improving for new and unmet needs. We must continue to push our industry forward. We need to collectively alter our course of business practices by increasing the benefits of thermoforming to the end user. It is time to step up and show the world that thermoforming is here for the long haul!

Thank you for your continued support and I look forward to meeting you in Milwaukee.

If you have any comments or questions, please feel free to contact me. I would like to hear from you!

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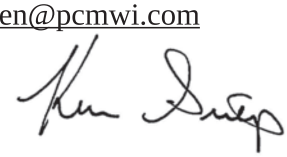

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Plastics Packaging: Pactiv takes over PWP

By Matt Defosse

Published: February 25th, 2010

Consumer and foodservice packaging major Pactiv has acquired thermoformer PWP Industries from holding company HPC Industries for $200 million. HPC is the holding company run by Leon Farahnik, who just two years ago sold his stake in the world's largest shopping bag processor, Hilex Poly, another company he founded.

For Pactiv (Lake Forest, IL), the acquisition especially strengthens its position in the baked goods and foodservice markets. PWP's 2009 sales were about $149 million. The company has three processing facilities: one in Texas, West Virginia and its headquarters site in Vernon, CA. It employs approximately 600, and extrudes much of the film it processes.

PWP has scored well many times at SPE thermoforming competitions, indicative of the company's design and thermoforming skills. Also attractive about PWP are its polyethylene terephthalate (PET) recycling facilities in West Virginia and one to be built in California, as these can provide lower-cost feedstock to PWP for its extrusion and subsequent thermoforming. The West Virginia PET recycling site is located only three miles from a PWP processing facility in that state.

According to Pactiv, the acquisition is expected to be modestly accretive to earnings per share and free cash flow in 2010 and generate a return in excess of Pactiv's cost of capital within two to three years. The transaction is expected to close in the first quarter.

Pactiv runs 46 production facilities and employs some 12,000, with annual sales of $3.4 billion. Its Hefty-brand bags and disposable plates accounted for 38% of its 2009 sales, with sales into food service and food packaging branches accounting for the remainder of sales. The processor is now the sole supplier of store-brand trash bags to Wal-Mart.

In a presentation on February 24 at the Credit Suisse annual global paper and packaging conference, a day after Pactiv announced the purchase, Pactiv officials claimed compound annual growth rates of 6.6% in the last five years for the Hefty products and 5.2% CAGR for its other product lines in the same period, with profit CAGR even higher. In 2009 Pactiv saw its volume of sales grow by 3.2% and its earnings per share hit $2.31, the highest ever for the NYSE-listed company. **(Reprinted with permission from Plastics Today.)**

Twin-sheet thermoformed TPU deployed to Iraq and Afghanistan

By Tony Deligio

Published: March 18th, 2010

A technology initially developed to absorb impact in running shoes now protects soldiers, seeing use in everything from helmets and kneepads to blast-limiting sheets and seat cushions, with development of ballistic grades for vests currently under way.

How much protection? During an interview with Mike Buchen, president and CEO of Skydex, at its Centennial, CO headquarters, he covered one hand with the company's new thermoplastic polyurethane (TPU) sheet padding and used the other to repeatedly slam a ballistic helmet into the material. This reporter was convinced.

The key to its innovation is what Skydex calls twin hemispheres. Supplied in sheet form, the product is made by forming small cups, or hemispheres, in a TPU sheet, and then joining two still-warm sheets of the structures in a twin-sheet thermoforming process, so that the cups are bonded together, bottom to bottom, to form an hourglass shape.

By changing the hemisphere's composition, thickness, and spacing, Skydex can tune them to a specific function, with current applications covering blast limiting, cushioning, impact mitigation, vibration absorption, and sound dampening. The product also uses various additive packages to boost functionality and performance in the field, including the addition of flame-retardant, anti-mildew, anti-fungus, and anti-static systems.

At the company's headquarters, Buchen and Peter Foley, chief technology officer, walked through the numerous applications the unique geometry has found a niche in, pulling product samples off the wall of their conference room, and occasionally demonstrating their effectiveness. With the ability to target foam currently used for cushioning and protection, the potential volume of applications for the technology seems limitless, but

Foley said Skydex has maintained strict focus in the products it targets.

"We're not packaging foam," Foley explains. "We have to protect things that matter, because if it's something that can be broken and replaced, you're probably going to protect it with polystyrene or something like that. For now, there are so many different ways we can tune this to protect brains and limbs, that that's really the focus."

Part of that immediate winnowing of development is blast-limiting panels that will be included in more than 6,000 military vehicles headed to Iraq and Afghanistan. Force Protection's Cougar and Buffalo vehicles, as well as Oshkosh's M-ATV, will feature large sheets, up to 60 by 90 inches, to help mitigate the impact caused by improvised explosive devices (IEDs).

Using independent studies, Skydex determined that its protective material reduces blast force transmitted through the floor by 71%. Those results were for vehicles headed to Afghanistan, where roadside bombs cause 75% of the casualties to coalition forces, and more than 50% of the troops will be exposed to a blast wave in one form or a another.

"We really started focusing on the military in 2004," Foley says, "and re-engineered the technology from dealing with the impact of a foot hitting the ground, which is a very known thing, to protecting brains from bullets, protecting brains from overpressure, shockwaves, IEDs."

Building better helmet padding. Before it was placed on the floors and walls of the next generation of vehicles to be deployed in Iraq and Afghanistan, Skydex's first tour came in ballistic helmets, replacing leather headbands. The older-generation PASGT system, which used leather or Kevlar to hold a helmet on, had proven uncomfortable, and the next-generation foam pads failed to perform under all the conditions soldiers can face. Buchen recalls a sales call in which, after storing the foam pads in a small cooler so they came down to 35-40°F, he broke them in half at a National Guard base. Because of this lack of low-temperature performance, troops were instructed to remove the pads from their helmet at night in cold environs and store them in a warm place.

After adopting Skydex's twin hemispheres, the Army has more than doubled the impact standards for its helmet pads because of their properties, taking them from absorbing 10 ft/sec of impact velocity to now striving for 17 ft/sec.

A duty to their customers.
The choice to protect soldiers in the field as opposed to flat-screen TVs during shipping has had numerous impacts on Skydex, including how it deals with certain customers. "We are committed to protecting things that matter and in this business, I don't know of anything that matters more than the safety of our men and women in uniform," says Buchen. **(Reprinted with permission from Plastics Today.)**

Leading UK Thermoformer Acquired by France Multinational

By Rory Harrington, FoodProductionDaily.com

The takeover of UK plastics packaging company Sharp Interpack by French multinational firm Groupe Guillin was announced on April 15.

The deal to acquire 100 percent of Sharp Interpack's shares and assets was signed on April 9 and means Groupe Guillin will now carry out more than 60 percent of its business outside France. No financial details were disclosed.

Sharp Interpack is a UK manufacturer and distributor of thermoformed rigid plastic packaging for the fruit and vegetable packers, meat and fish processors as well as retail and bespoke packaging. The company, which is forecast to post a turnover of £86m in 2009/10, has three facilities in southern England in Ayelsham, Bridgwater and Yate.

"The combination of Groupe Guillin's expertise alongside Sharp Interpack's UK market experience allows Guillin to strengthen its leading position on the European market for fruit and vegetables, and expand its strategic position in the industry and develop new industrial and commercial relationships for meat products," said a joint statement from the firms.

European reach
Andrew Copson, deputy managing director for Sharp Interpack, told FoodProductionDaily.com: *"The takeover will now give our company European reach and means we will be able to offer customers in excess of 3,000 packaging products."*

He added that discussions with Groupe Guillin had given every indication it was committed to growing the UK business through *"sustained investment."*

"This is great news both for our company and our customers," said Copson.

The French firm, which also has operations in Spain, Italy and Poland, said negotiations had been ongoing since 21 December, 2009.

Groupe Guillin already owns three other UK packaging companies Premier Packaging, GPI and Socamel. The firm was founded in 1972 and since then has pursued a strategy of growth through acquisitions.

Plastics in a Metal World

Don Mebius, Value Engineering Manager, McClarin Plastics, Inc.

With the technological advances seen over the past few years in the realm of plastic and composite materials, traditional metal products are being replaced in innovative applications. Many plastic base chemistries exist now that were not even contemplated a short while ago and have been developed for specific applications, from protecting the Space Shuttle during re-entry to designing the hand-held gadgets that we all take for granted today.

One particular field where these materials have been widely applied is in the trucking world. Where once metal was the material of choice, plastics are now becoming more prevalent. With careful material selection and component designations, many advantages can be conferred on the manufacturers:

- **The elimination of corrosion – plastics can't rust.** This maintains the "like new" appearance of a vehicle for much longer and contributes to a positive opinion of the product over an extended period of time.
- **Weight reduction which translates to fuel economy.** With the fuel cost fluctuations seen over the past year, fuel expense becomes a greater issue than ever before.
- **Aerodynamics as a large factor in truck design for added fuel economy.** Another advantage to this potential is that the manufacturer is free to emphasize their brand characteristics. Greater design flexibility is now possible to create an individual and distinctive appearance.
- **Color that is a part of the component, not applied later.** This advantage becomes obvious over time where normally a small scratch can become an embarrassing eyesore. Corrosion can give the appearance of a much larger flaw because the scratch has induced the appearance of a major defect. With the plastic material, the operator has a rig that continues to look good, year after year, and doesn't depend on the coating to double as a protective barrier to the base metal.
- **Better impact resistance and reduced maintenance.**

The front bumper fascias of many newer rigs are much more aerodynamic, with smoother shapes, as can be seen in Figure 1.

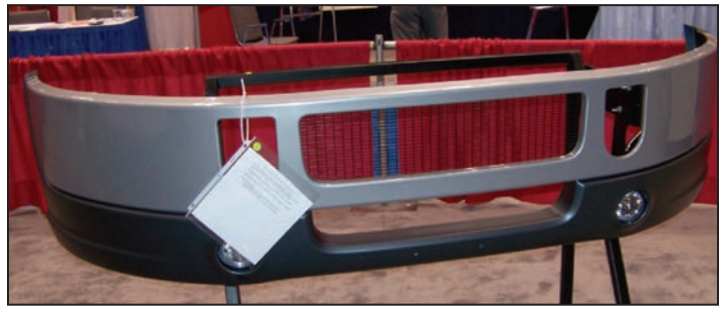

Figure 1. Automotive front bumper fascia.

An end result of using plastics is part reduction – this can be dramatic in many cases, because part integration plays a vital role if the design is done using one of the basic advantages of the material from the outset. To simply replace a steel component with an identical plastic part is not cost-effective. It is important to use the full advantages of the material and process. You can also see from the photo that the running lights have been incorporated due to the processing advantages of thermoforming. This part can also absorb much greater impacts than its steel counterpart. Other examples include side cladding and air foils. These many shapes are not economically produced in metal.

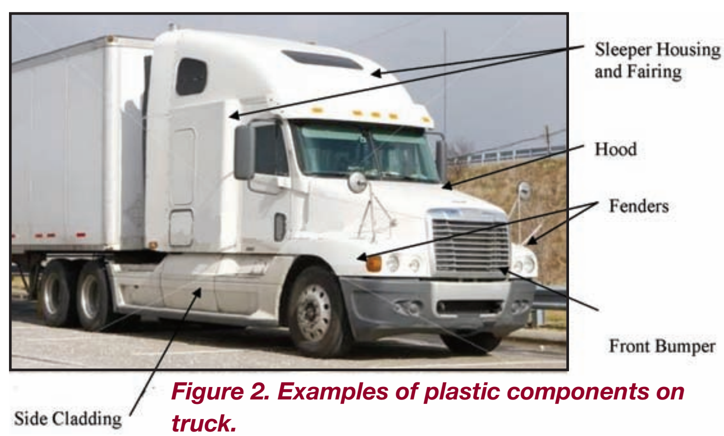

Figure 2. Examples of plastic components on truck.

Other components include side panels in heavy-duty tow rigs. (See Figure 3.)

TPO (Thermoplastic Olefin) is a highly beneficial material. This material is finding widespread use in many automotive applications, such as bumper cladding, front fender protection and air deflectors. The Chevrolet HHR retro car (see Figure 4) utilizes this material on the rear fender to protect the leading edge from gravel coming from the front tires.

Figure 3. Examples of plastic components on truck.

An inherent advantage of this material is that it is flexible, can take heavy impact loads, and is forgiving in that it does not show this abuse. It can also handle the type of temperature extremes most vehicles are subject to.

Figure 4. Chevrolet HHR with rear fender made from TPO.

TPO is a blend of polypropylene with various fillers, including various grades of rubber. The advantage this blend yields is a formable thermoplastic sheet that can take impacts and be very flexible. These properties are highly advantageous in the automotive and truck environment. Additionally, it is resistant to the sun's rays, and does not suffer from UV degradation. Typical physical properties are noted below:

Property	Test Method	Units	Result
Gardner Impact	Gardner	In-lbs	85
Specific Gravity	D-792		1.08 – 1.13
Tensile Strength	D-638	(psi)	3100
Flexural Modulus	D-790	(psi)	270,000
Flexural Strength	D-790	(psi)	9,600
Izod Impact	D-256	(ft-lbs/in) @ 73°	6.5
Deflection Temperature Under Load (DTUL)	D-648	°F	240

Table 1. Physical properties of TPO.

As can be seen in Table 1, the high flexural properties and impact strength make this material ideal for many of these automotive and truck applications Another example of the use of this material is in a wind fairing for a medium-duty cargo truck. A customer was introducing a new product line and wanted to include a wind fairing on the front of the cargo box above the cab. Additionally, the customer required a high-gloss finish to match the finish of the truck cab. A custom design was provided to include a shaped detail for the marker lights, and an added profile to match the truck cabs being used. The photo below is an excellent example of the application:

Figure 3. Examples of wind fairing component.

Being involved from the beginning of a project adds significant value to the final product that makes it more durable and appealing. Additionally, the customer's warranty requirements can more easily be met. These are a few examples of plastics / composites use in this rigorous environment. Perhaps these ideas can generate other ideas to replace a metal component with plastic.

REDUCE!
REUSE!
RECYCLE!

REDUCE!
REUSE!
RECYCLE!

Reinforced Thermoplastics Basics

Domasius Nwabunma, Ph.D., Senior Development Engineer, Spartech Corporation, Warsaw, IN 46580 and
Randall T. Myers, Ph.D., Commercial Development Manager, Spartech Corporation, Clayton, MO 63105

Introduction

Reinforced thermoplastics or reinforced plastics are a subclass of reinforced polymer composites, the two other classes being reinforced thermosets and self reinforced polymers. Since the reinforcing material is normally a fiber, reinforced thermoplastics can be regarded as fiber reinforced thermoplastics. Figure 1 shows the classification of reinforced polymers based on this convention. A second classification of reinforced polymers is based on the type of fibers: glass fiber reinforced polymers, carbon fiber reinforced polymers, aramid fiber reinforced polymers, and natural fiber reinforced polymers. A third classification is based on the specific resin or polymer used in the composite: reinforced polypropylene, reinforced polycarbonate, reinforced thermoplastic polyester, reinforced unsaturated polyester, reinforced nylon, reinforced epoxy, reinforced styrenics, reinforced PVC, reinforced phenolics, reinforced ABS, etc.

Figure 2 shows methods used to formulate reinforced polymers as well as fabricate parts from them. If a reinforced polymer is designed and fabricated correctly, it leads to material with a combination of desirable properties not available in any single conventional material. Reinforced polymer composite processing technologies are often capital and/or labor intensive. For example, sheet molding compound (SMC) tools are more expensive than corresponding thermoforming tools, fiberglass "chopper gun" is very labor intensive, autoclaving is a time and energy intensive process. Composite companies may be vertically integrated throughout the composite value chain. For example, a company who manufactures SMC parts may also be involved in the formulating of the same material.

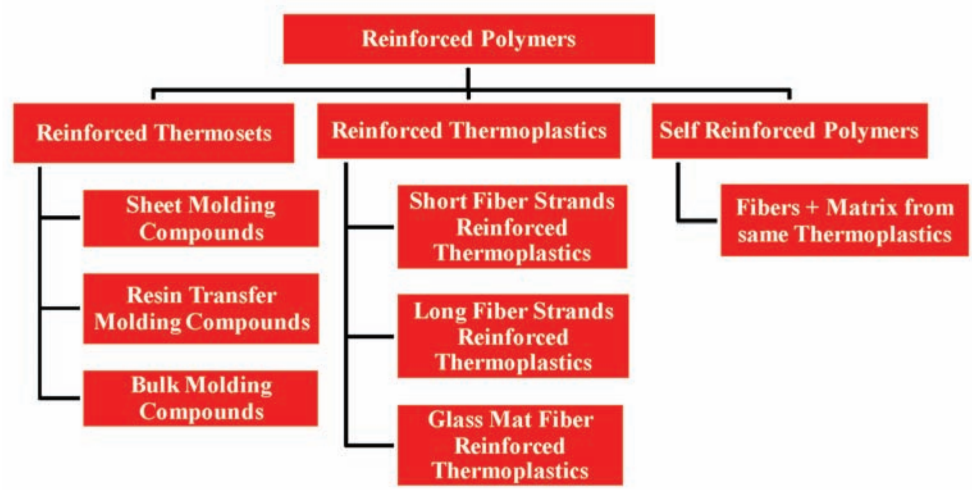

Figure 1. A Classification of Reinforced Polymer Composites.

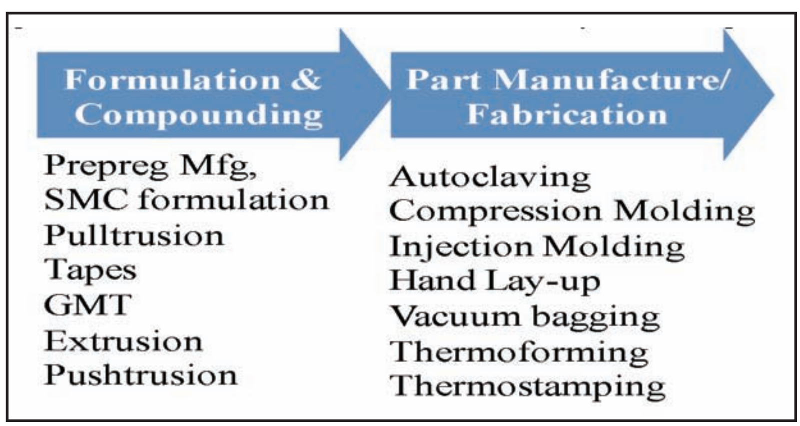

Figure 2. Formulation and Manufacturing Methods for Reinforced Polymer Composites.

Thermoplastic Matrix

One of the main components of reinforced thermoplastic composites is the thermoplastic polymer. The function of the thermoplastic polymer, which is also called the matrix, is to bind the reinforcing filler, provide compressive strength, and chemical resistance of the composite. Thermoplastics are either amorphous or semi crystalline and in terms of performance can be classified as commodity polymers, engineering polymers, and high/ultra high performance polymers as shown in Table 1. The commodity and engineering thermoplastic matrices offer lower processing temperatures and cost but have limited use temperatures. The high and ultra high performance thermoplastics tend to be designed for higher temperature environments and when reinforced with fibers, they exhibit long shelf life without refrigeration and possess exceptional impact resistance and vibration-damping properties. Their drawback is that they tend to be more expensive and can present composites manufacturers with some processing challenges because of their high viscosities. This is especially true with amorphous materials as they lack the sharp transition desirable for good fiber wet-out.

Reinforcing Fibers

The reinforcing fibers are another important constituent in reinforced thermoplastic composites. They can be long or short in length in the form of single strands or twisted, woven, stitched, knitted, or braided strands. Reinforced fibers can occupy up to 70% of matrix volume in the composites. The function of the reinforcing fibers is to increase stiffness, tensile strength, fatigue/creep resistance, and heat deflection temperature and shrinkage reduction. The mechanical properties of the composites are thus dominated by the reinforcing fibers. The mechanical properties depend on many fiber properties such as fiber types, loading level, orientation, and architecture. The fiber architecture denotes the pre-design fiber configuration such as mats, tape, roving, and fabrics obtained through braiding, knitting, or weaving. The reinforcing fibers may be treated with sizes such as starch, gelatin, oil, wax, and binders to improve bonding, and handling. Table 2 shows different kinds of fibers used to reinforce thermoplastics. Of these fibers, the most commonly used reinforced thermoplastics for structural applications are glass fibers, aramid fibers, and carbon fibers. Glass fibers are less expensive and carbon fibers are generally more expensive. The cost of aramid fibers is typically between the cost of glass fibers and carbon fibers.

Fillers and Other Additives

Fillers are added to reinforced thermoplastics to either reduce cost or to produce a composite with superior properties. Fillers commonly used in the formulation of reinforced thermoplastics include calcium carbonate, clay minerals (mica, kaolin, talc, vermiculite, smectite (bentonite, hectorite), silica, talc, wollastonite, carbon black, glass bubbles. When one or more of these fillers are added to reinforced thermoplastic composites, the improvement in performance may include fire and chemical resistance, low shrinkage and thermal expansion,

Table 2. Fibers Used in Reinforcing Thermoplastics.

Glass Fibers
Carbon Fibers:
- Fibers from PAN and Mesophase Pitch
- Graphite Fibers
- Carbon Nanotubes (Single and Multi-wall)
- Ceramic Fibers
- Boron Fibers

Natural Fibers:
- Bast (Skin Fibers): Flax Jute, Hemp, Bamboo, Wood
- Fruit/Seed Fibers: Cotton, Coir (Coconut), Kapok
- Leaf Fibers: Sisal, Henequen, Pineapple, Banana

Polymeric Fibers: Rayon, Aramid Fibers (Kevlar, Nomex)

Table 1. Amorphous and Semi Crystalline Thermoplastic Matrices by Performance.

Category	Amorphous Examples	Semi Crystalline Examples
Commodity	PS, HIPS, PVC	PP, HDPE, LDPE, LLDPE
Engineering	PC, PMMA, ABS, COC, PPC, TPE	PET, PBT, POM, PA6,6, PA6
High Performance	MDX6, PA11, PA9T, PA6T, PA4,6, PSU, PEI, PESU, PPSU	PPA, PPS, LCP, PTFE, HPN
Ultra High Performance	PI, PAI, TPI, SRP, HTS	PEEK, PFSA

(continued on next page)

fatigue resistance, and mechanical strength. There are other additives that are added to reinforced thermoplastics to improve processability, aesthetics, surface properties, etc. These additives can be catalyst, promoters, inhibitors, colorant, and release agents.

Markets for Reinforced Thermoplastics

Reinforced thermoplastics are increasingly finding applications in many areas owing to their superior performance characteristics over their metal and ceramic counterparts. This characteristics include weight reduction, corrosion resistance, paint elimination (color can be added in situ), cost reduction, impact resistance, and softness. As shown in Figure 3, end-use markets for reinforced thermoplastics include transportation, construction, marine, electrical & electronics, consumer products, aircraft/defense. North America and Europe are the largest markets for reinforced thermoplastics closely followed by Asia-Pacific. The U.S. represents the second largest market for reinforced plastics worldwide. The transportation section represents the largest and fastest growing end-use market for reinforced plastics worldwide followed by the electrical and electronics and construction industry.

Glass Mat and Long Glass Fiber Reinforced Thermoplastics

Glass mat fiber reinforced thermoplastics (GMFRT) and long glass fiber reinforced thermoplastics (LGFRT) are two most common, oldest, and commercially successful reinforced thermoplastics.

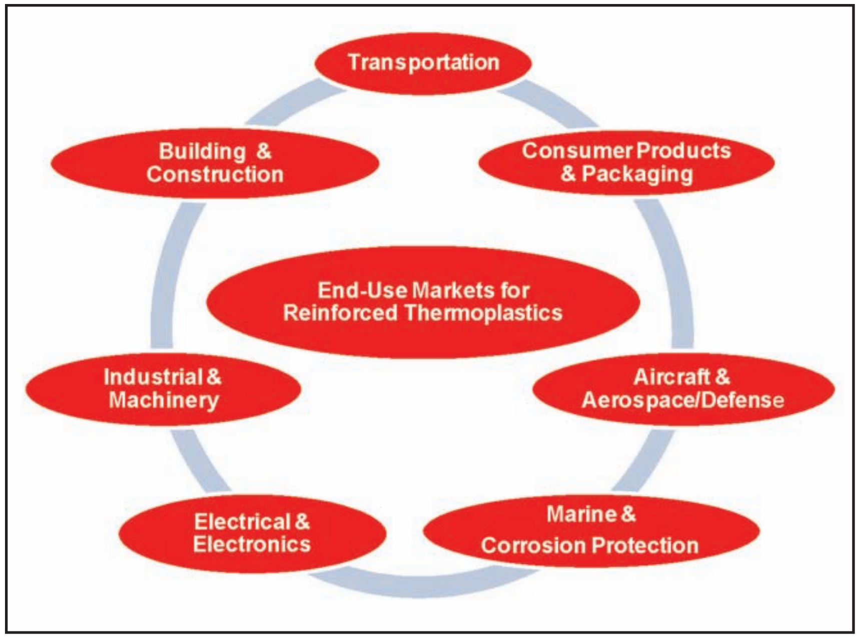

Figure 3. Applications of Reinforced Thermoplastics by Markets.

GMFRT was developed in mid-1960s for increased stiffness, strength, toughness (impact) in melt-processable polymer matrices. They provide superior fatigue and creep resistance at moderate costs. Industrial scale production capabilities are available. GMFRT sheet is typically converted to final part via compression molding, but parts have been successfully converted via matched tool thermoforming. Early GMT featured PP with continuous/randomly oriented glass mat reinforcement. GMFRT has been in existence for over 30 years. Types of GMFRT include long glass GMFRT, chopped glass GMFRT, aerated glass mat GMFRT, and textile reinforced GMFRT. On the other hand, LGFRT was commercialized in mid-to-late 1990s. LGFRT performance is intermediate between that of GMT and short glass fiber reinforced thermoplastics (SGFRT). LGFRT is historically compounded into pellets. These compounded pellets are typically injection molded into a final part, though there is nothing preventing using this technology as the basis for thermoforming.

Recently, a new type of LFRT has been developed, using in-line compounding. Fiberglass is compounded with the plastic matrix directly at the press via either a compression or injection molding operation. In the last decade, LGFRT has enjoyed significant growth (20-30% per year). Thermoplastic matrices for LGFRT includes PP, HDPE, PA6, PA6,6, PET, PBT, PC, TPU, ABS, PC/ABS, PPS, POM, PPA, and ASA copolymer.

Self Reinforced Thermoplastics

Self-reinforced plastics are a new family of composite materials, where the polymer matrix is reinforced by highly oriented polymer fibers derived from the same or similar polymer. Two techniques for producing self-reinforced PP materials are hot-compaction or co-extrusion. Compared to other reinforced thermoplastics, self-reinforced plastic typically offer significant performance advantages at similar or reduced costs. For example, a self reinforced thermoplastic may offer the following advantages: weight reduction, corrosion resistance, ease of recycling, high impact strength, resistance to hydraulic fluids and fuel, lower toxicity, improved surface, and cost to mass-produce. Possible applications for a self reinforced thermoplastic include: automotive (body panels, parcel shelves, under-shields, load floors); off-road vehicles (high-impact exterior panels); marine (personal watercraft); sports (helmets, pads, guards); leisure (suitcases, loudspeaker cones); personnel protective equipment (safety helmets, anti-ballistic shields); medical (orthoses, temporary supports); construction (shuttering, formwork).

Business and Market Trends

Reinforced thermoplastics are forecast to outpace reinforced thermosets according to Fredonia Group's 2009 Report on Reinforced Plastic. Demand is predicted to increase 2.8% annually to 3.6 billion lbs in 2013. Glass fibers will continue to be the dominant reinforcement material through 2013. Carbon fiber is expected to increase nearly 10% annually through 2013. Polypropylene will remain the leading thermoplastic. Growth is also forecasted for nylon and thermoplastic polyester. Construction & motor vehicles is predicted to account for 60% of total reinforced plastics demand in 2013.

Processing of Reinforced Thermoplastics

Historically, reinforced thermoplastics are converted to a final part via either an injection or compression molding operation. These methods are still viable, especially in high volumes and complex geometries. Thermoforming, however, is becoming a viable option to convert reinforced thermoplastics for similar reasons that thermoforming has taken hold for unreinforced materials: the ability to form large, flat parts of moderate volume.

Since the reinforcing material is often inorganic in nature, certain factors should be taken into account when forming a reinforced material. It may be that the material requires less heat to get to forming temperature. This could result in either lower energy requirements, faster cycle times or both. Conversely, the reinforcing material may act like a heat sink when forming against a thermoforming tool, possibly negating the cycle time advantage observed during the heating step.

Additionally, both the loading percentage and the aspect ratio of the reinforcing material are important when considering thermoforming composite materials. Since an inorganic reinforcing material, will not draw or form when heated, both the draw ratio and the sharpness of the radii will become limited as the reinforcement levels increase. Fiber reinforcement possessing a high aspect ratio may cause a sheet to "loft" when heating. When this happens, the sheet could become porous, rendering the material not formable using traditional vacuum forming methods. Often, this is the case with GMFRT. When this is the case, the material may need to be thermoformed using matched tooling.

Technology and Performance Trends

There is an increasing requirement of exceptional mechanical performance with respect to rigidity, strength, toughness (impact), and creep/fatigue resistance. In automotive, there is a strong desire to achieve the stiffness and other performance benefits of reinforced plastics at a lower cost. The desire to be able to incorporate both aesthetics and functional surface laminated to reinforced thermoplastic is increasingly becoming important. Long fiber reinforced thermoplastics can be over-molded on, co-molded with or bonded to metals, glass, paint films, carpeting, fabric and other decorative materials allowing cost-effective manufacture of intricate finished parts that are light weight, durable, and aesthetically pleasing. There is a growing interest in both nano-reinforced and natural fiber-reinforced thermoplastic composites motivated by the concern to conserve dwindling resources and to reduce environmental impact. There is also strong interest to use renewable (bio-based) polymers as matrices. These matrices when coupled with natural fibers form what has been regarded as "Green Composites."

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Some Acronyms Used in Reinforced Thermoplastics

RTP-reinforced thermoplastic
LGF-long glass fiber
SGF-short glass fiber
GMT-glass mat thermoplastic
GRP-glass reinforced plastic
GFRP-glass fiber reinforced plastic or polymer
LFT-long fiber thermoplastic
LFRT-long fiber reinforced thermoplastic
LRP-long fiber reinforced plastic
SRP-short reinforced plastic
SFRT-short fiber reinforced thermoplastic
D-LFT-direct long fiber thermoplastic or inline compounded LGF
CFRT-Continuous fiber reinforced thermoplastic
NFRT-Natural fiber reinforced thermoplastics
LWRT-light-weight reinforced thermoplastic

Investigation into the Effect of Extrusion and Thermoforming Parameters on the Properties of Polypropylene Containers

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Abstract

Extruded polypropylene (PP) sheet is widely used in the production of thin gauge containers for the food and beverage industry using the thermoforming process. In industry there is not a clear understanding of the relationship between the effect of varying extrusion and thermoforming parameters and the resultant changes in end product properties. This paper investigates the effect of parameters such as chill roll temperature and haul off speed during extrusion, and plug speed and sheet temperature during thermoforming on end product properties such as wall thickness distribution, weight and compressive strength. Test results show several parameters have a large effect on end product properties, with greatest variations between different material grades.

Introduction

Extruded polypropylene sheet is widely used in the production of thin gauge tubs and containers for the food and beverage industry using the thermoforming process. As thermoforming is always preceded by extrusion many of the properties exhibited by the material during thermoforming result directly from the extrusion conditions, consequently the production of high quality thermoformed parts is critically dependent on the standard of extruded sheet used.

Polypropylene is a very versatile packaging material that exhibits good mechanical properties such as low density, high melting point, stiffness, clarity and excellent barrier properties to water, which is useful in the food packaging industry. However, PP exhibits low melt strength which can result in prounced sag and inconsistent sheet thinning during thermoforming. This coupled with a very narrow processing window within which sheet material may be successfully formed into parts making PP a more difficult material for processors to work with [1,2].

In an increasingly competitive market, with rising raw material, energy and transport costs, and mounting pressure to reduce waste both during production and in materials to landfill, companies need to respond if they are to survive. In industry there is not a clear understanding of the relationship between the effect of varying extrusion and thermoforming parameters and the resultant changes in PP material mechanical properties.

For companies to respond and optimise process and product settings there is a need to determine the effect of changes in settings and gain more control over material properties during and after production. This is particularly important in the case of PP which can pose real problems for processors who must cut costs (e.g. decreasing cycle and set up times and reducing material weight in product) while ensuring the product stays fit for purpose. Investigations in the past have determined the extrusion and thermoforming parameters which have the greatest effect on the end properties of thermoformed PP containers [3, 4]. In this paper an investigation was carried out using laboratory based experiments to determine the effects of variations in material, chill roll temperature and line speed during extrusion; and sheet temperature, plug temperature and plug speed during the thermoforming of different polypropylene material grades.

Experimental

A full factorial experimental design was used with a small number of parameters, as investigations in the past have shown which parameters have the greatest effect on the end properties of thermoformed polypropylene containers. The parameter levels were chosen based on process knowledge and designed to be large enough to change the properties but not so large that the extrusion process or subsequent forming of the sheet fails.

Scree plots are used to determine the degree to which parameters are influencing properties. A Scree Plot is a simple line segment plot that shows the fraction of total variance in the data represented by each parameter or interaction [5]. The % of Variance due to each parameter and interaction is calculated and plotted from highest to lowest, so the plot looks like the side of a mountain.

"Scree" refers to the debris fallen from a mountain and lying at its base, so the Scree test proposes that points after the mountain ends are due to error.

Three commercial grades of polypropylene (PP) polymer have been investigated: 540J, 840K and 210G, all produced by Basell; with melt flow index (MFI) of 3.2, 1.8 and 3.5 g/min and referred to as M1, M2, and M3 (540J, 210G and 840K, respectively) with in the paper. With material referred to as parameter A.

1.4mm sheets were produced using a 38mm diameter Killion extruder with a sheet die of width 610mm and die gap 1.8mm. To produce sheet material at different line speeds, it was necessary to adjust the machine output accordingly to maintain the sheet thickness. Sheet with the ability to be thermoformed was produced with both a high and low chill roll temperature and a high and low line speed. The settings used are shown in Table 1, different chill roll temperatures of 45 and 55°C where used for M2 to enable viable sheet to be formed. With chill roll temperature and line speed referred to as parameter B and C, respectively.

Table 1. Extruder settings

Material	Chill Roll Temperature (°C)		Line Speed (m/min)	
	High	Low	High	Low
M1	95	85	1.53	0.27
M2	55	45	1.53	0.27
M3	95	85	1.53	0.27

Crystallinity results were obtained using Differential Scanning Calorimetry (DSC), with tests conducted on a Perkin-Elmer Version 6 DSC. Small fragments of between 7-9mg of each sample were placed in an aluminium pan and heated to 200°C at a rate of 10°C per minute. The crystallinity was determined from the area under the peak in the thermograms.

Specimens for tensile testing were cut from the polypropylene sheet using a standard die made to ISO 527 specifications. Force/deflection data was obtained using an Instron 5564 Universal Tester at room temperature and a rate of 100mm/min.

DMTA testing was carried out using a Triton 2000 DMTA testing machine. Samples cut from the extruded sheet were approximately 5mm x 40 mm. The samples were tested in dual cantilever mode from room temperature to 160°C at a frequency of 1Hz, displacement of 0.01mm and a heating rate of 2 °C/min.

Biaxial stretching was carried out using a laboratory based biaxial stretching machine at Queen's University [6]. Test specimens of 76 x 76mm were cut from the extruded sheet and stretched using a simultaneous equal biaxial (EB) mode. The true stress, (α_T) and the nominal strain, (ε_n) were calculated to show the deformation behaviour of the materials. Sheet samples were biaxially tested at $4s^{-1}$ strain and a stretch ratio of 2.

Thermoforming was carried out using a laboratory based single shot thermoformer [4]. During the plugging step of thermoforming the plug force was recorded. Sheet samples were thermoformed at high and low sheet temperatures, plug speeds and plug temperatures, as shown in Table 2. With sheet temperature, plug speed and plug temperature referred to as parameters D, E and F.

Table 2. Thermoforming test settings

Material	Sheet Temp (°C)		Plug Speed (mm/sec)		Plug Temp (°C)	
	High	Low	High	Low	High	Low
M1	155	150	900	500	100	Room
M2	145	140	900	500	100	Room
M3	155	150	900	500	100	Room

Results and Discussion

Effect of extrusion parameters settings on extruded sheet properties

Onset, peak and end temperatures for the different material grades did not vary with changes in extrusion parameters. However, the percentage (%) crystallinity and peak melting temperatures changed with material grade and to a small degree within each of the different material grades. The % crystallinity results from DSC testing of the sheet samples, of the three material grades, at high and low chill roll temperature and line speed are shown in Figure 1. From Figure 1 it can be seen that the highest crystallinity for all material grades was the sheet produced with high chill roll temperature and low line speed. Variation in peak melting temperature and % crystallinity between the PP material grades is to be expected as M3 is a high crystalline PP and M2 is a copolymer.

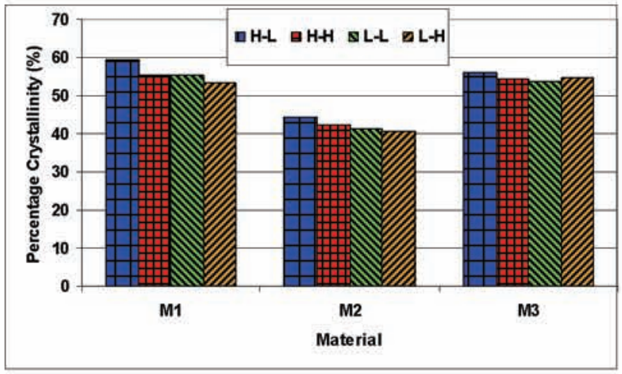

Figure 1. DSC testing percentage crystallinity results.

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A Scree plot comparing the percentage of variance in the % crystallinity results is shown in Figure 2, with a comparison of Scree plot results for the testing of extruded sheet shown in Figure 4. From Figure 2 it can be seen the major influence on the % crystallinity of the samples was material grade (A).

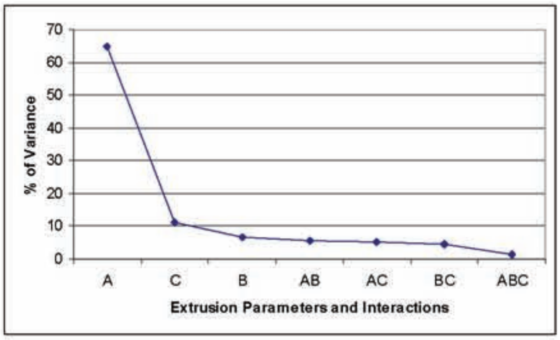

Figure 2. Scree plot for the effect of extrusion parameters and interactions on the % crystallinity of extruded sheet.

Average tensile results are shown in Table 3 for samples cut form the machine direction. For each material grade here was no significant difference in the tensile results with different extruder settings, but there was a significant difference between the results for the different material grades.

Table 3. Average tensile test results (machine direction)

Sheet Settings			Max	Elongation	Modulus
A	B	C	Load(N)	(mm)	(MPa)
M1	H	L	276.53	13.85	1289.78
M1	H	H	282.76	7.13	1484.05
M1	L	L	284.00	14.09	1289.46
M1	L	H	281.21	9.18	1302.59
M2	H	L	228.85	360.65	564.75
M2	H	H	230.98	365.85	586.12
M2	L	L	246.19	379.79	580.87
M2	L	H	230.71	364.46	598.17
M3	H	L	289.42	4.72	1384.04
M3	H	H	290.51	5.04	1477.72
M3	L	L	290.66	3.89	1354.84
M3	L	H	290.45	3.77	1372.26

The tensile results in Table 3 showed as with the crystallinity results there was a large change in properties with material grade but no clear pattern of the same extrusion settings giving the highest or lowest tensile result values. The Scree plot for the tensile modulus is shown in a comparison of Scree plot results for the testing of extruded sheet shown in Figure 4. The main influence was A (material), with slight effects from C (line speed). However, the Scree plot results for elongation at break also shown in Figure 4 showed the only significant effect on it was A (material).

Figure 3 shows DMTA results for the extruded sheet samples. With the different material grades causing more of a difference in results than any variation in extruder settings. For all the material grades as with other semi-crystalline materials the DMTA trace shows a narrow softening range and a sharp melting point.

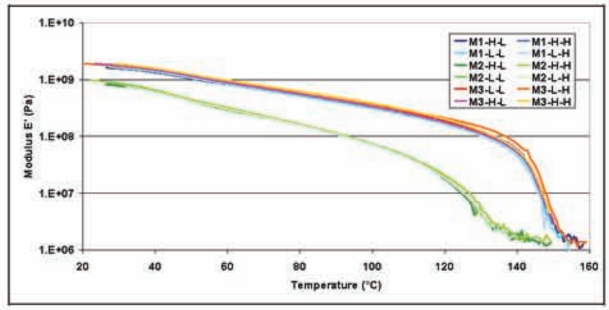

Figure 3. DMTA results for extruded sheet samples.

DMTA results show a higher storage modulus for M1 and M3, which along with a higher tensile modulus during tensile testing implies greater potential self-supporting properties (sag resistance) of the sheet in the heating step prior to forming compared to M2. This in turn may help to promote homogeneous stretching and improve wall thickness distribution in thermoforming [3]. The Scree plot results for the storage modulus at 130 °C, are shown in Figure 4 a comparison of Scree plot results for the testing of extruded sheet, the main effect is shown from A (material), but there is a significant effect from B (chill roll temperature).

Figure 4 shows a summary of the effects on the extruded sheet mechanical properties. It can be seen that A (material) has the greatest influence and for some properties is the only significant influence, with some other properties there is an influence from parameters B and C (chill roll temperature and line speed).

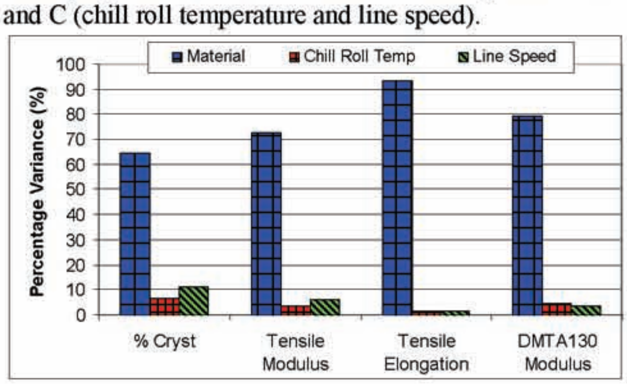

Figure 4. Comparison of Scree plot % of variation results for mechanical tests on extruded sheet.

Figure 5 shows biaxial results for M3 at 4 s^{-1} strain and a stretch ratio of 2. For all biaxial stretching tests the stress level of M2 did not rise as sharply initially compared to M1 and M3 this is probably due to the lower crystallinity of the M2. As crystals required more force to initiate the stretching. The biaxial graphs showed the result corresponding to a high chill roll temperature and low line speed consistently had a higher stress level over all material grades.

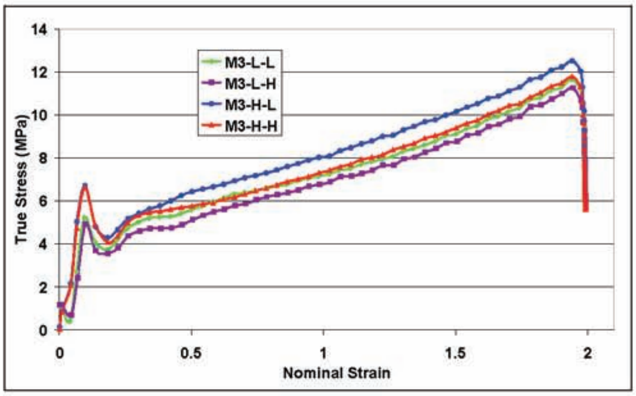

Figure 5. Biaxial stretching results for M3 at 4 s^{-1} strain.

A summary of Scree plot results for extrusion parameters on biaxial stretching properties is shown in Figure 6. Figure 6 shows parameter A (material) is not the only significant influence on the biaxial stretching properties, parameter B (chill roll temperature) has a significant effect on the elastic modulus in sheet temperature, strain, and stretch tests; and stress at 0.5 strain in strain, and stretch tests. Scree plots for biaxial stretching tests show C (line speed) has a significant effect on elastic modulus and stress at 0.5 strain in sheet temperature, strain, and stretch tests; and plastic modulus and peak stress in strain tests. Comparing the Scree plots for DSC, tensile and DMTA testing in which parameter A was the main influence with biaxial stretching Scree plots where it was not suggests biaxial stretching is a more effective method for observing small differences in sheet properties due to variations in processing parameters, compared to DSC and tensile testing

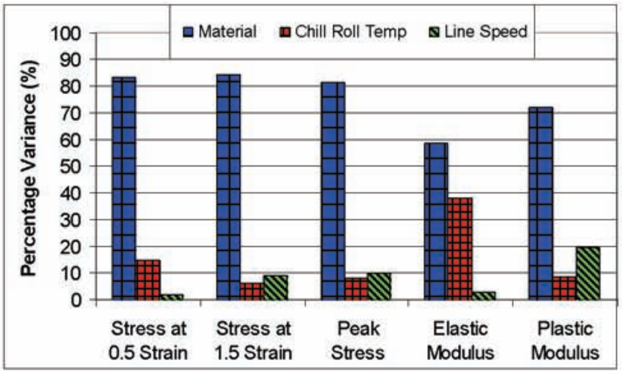

Figure 6. Comparison of Scree plot % of variation results for biaxial stretching of extruded sheet.

Effect of extrusion parameters on thermoformed containers

Results for plug force during thermoforming, container weight, average container wall thickness, Compression modulus and load at 2mm compression shown in Figures 7, 8, 9, 10 and 11, respectively, showed no clear trend for all material grades of containers made from sheet with the same extruder settings giving the highest or lowest properties. However, Figure 12 showing a comparison of Scree plot results for effect of extruder settings on thermoformed container properties, show parameter A (material) is not the only parameter that has a significant effect on container properties.

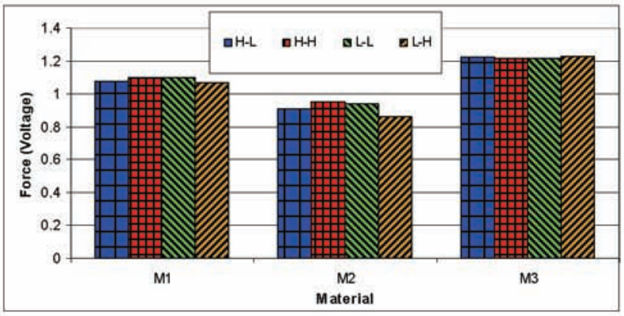

Figure 7. Plug force results from thermoforming of sheet produced with different extruder settings.

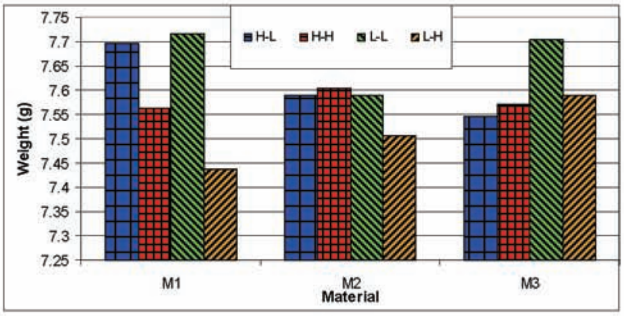

Figure 8. Container weight results from thermoformed containers made with sheet of different extruder settings.

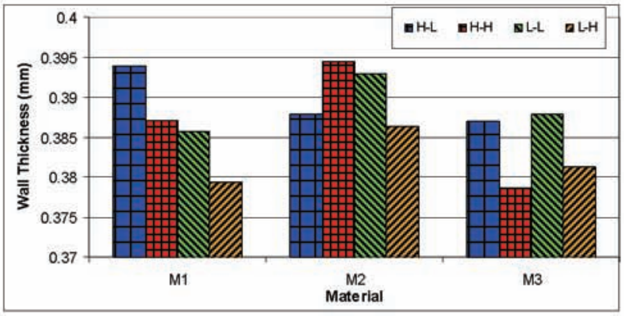

Figure 9. Average wall thickness results from thermoformed containers made with sheet of different extruder settings.

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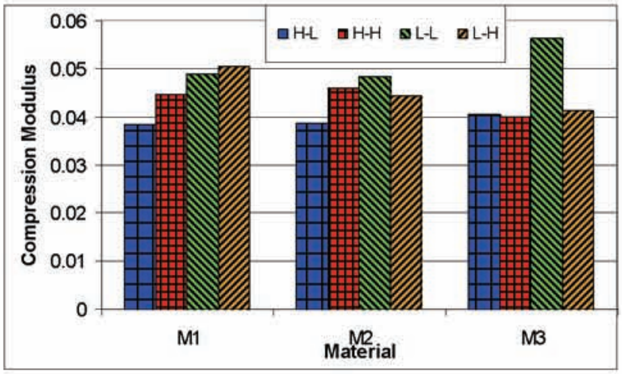

Figure 10. Compression modulus results from thermoformed containers made with sheet of different extruder settings.

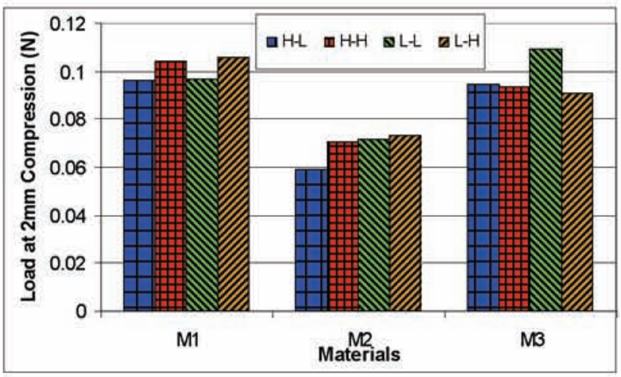

Figure 11. Load at 2mm compression results from thermoformed containers made with sheet of different extruder settings

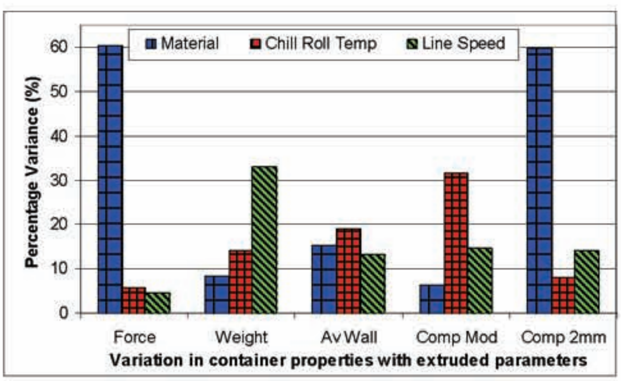

Figure 12. Comparison of Scree plot results for effect of extruder settings on thermoformed container properties.

Effect of thermoforming settings on container properties

The variation of plug force during thermoforming with changes in thermoforming settings is shown in Figure 13. Figure 13 shows that for all material grades with increased sheet temperature (D), the plug force decreases; with increased plug speed (E) the plug force increases; and with increased plug temperature (F) the plug force decreases.

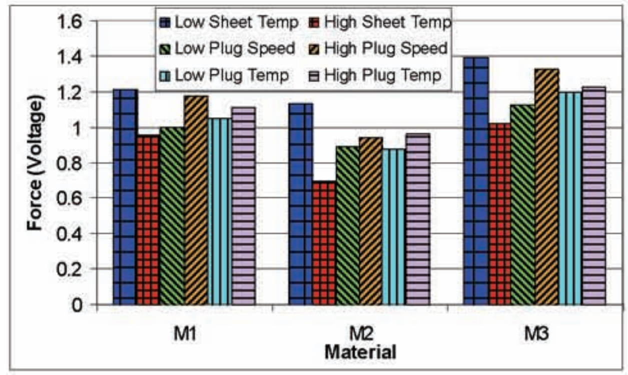

Figure 13. The variation of plug force during thermoforming with changes in thermoforming settings.

The Scree plot for the variation of plug force during thermoforming with changes in thermoforming settings is shown in Figure 14, with a comparison of Scree plot results for the % of variance of the effect of thermoforming parameters on thermoforming container properties shown in Figure 19. Figure14 shows D (sheet temperature) is the main influence on plug force during thermoforming, with significant influences from E (plug speed) and F (plug temperature).

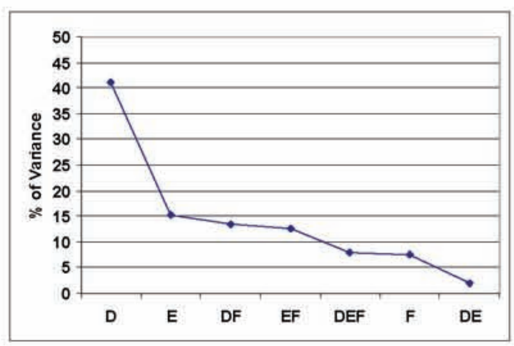

Figure 14. Scree plot for the effect of thermoforming parameters on thermoformed container properties.

The variation of container weight with changes in thermoforming settings is shown in Figure 15. Figure 15 shows that for all material grades with increased sheet temperature (D), the weight decreases; with increased plug speed (E) the weight increases; and with increased plug temperature (F) the weight decreases. A comparison of Scree plot results for the % of variance of the effect of thermoforming parameters on thermoforming container properties shown in Figure 19, shows the parameter with the greatest influence on container weight is D (sheet temperature), with significant influences from E (plug speed) and F (plug temperature).

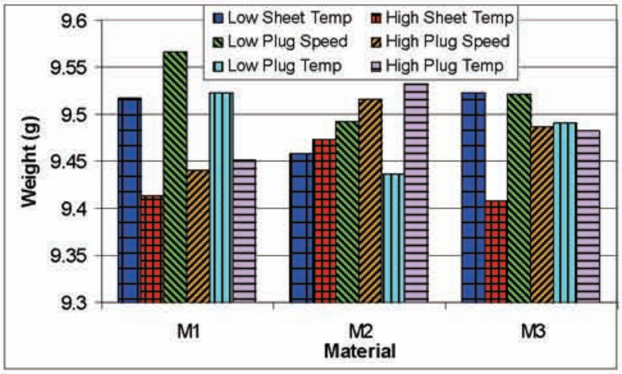

Figure 15. Results for container weight with changes in thermoforming settings.

The variation of container average wall thickness with changes in thermoforming settings is shown in Figure 16. Figure 16 shows that for all material grades with increased sheet temperature (D), the average wall thickness increases also; with increased plug speed (E) the average wall thickness increases; and with increased plug temperature (F) the average wall thickness decreases. A comparison of Scree plot results for the % of variance of the effect of thermoforming parameters on thermoforming container properties shown in Figure 19, shows the parameter with the greatest influence on container average wall thickness is E (plug speed), with significant influences from D (sheet temperature) and F (plug temperature).

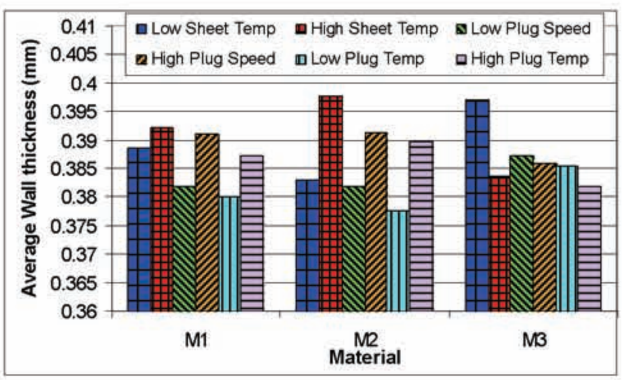

Figure 16. Results for container average wall thickness with changes in thermoforming settings.

The variation in compression modulus with changes in thermoforming settings is shown in Figure 17. Figure 17 shows that for all material grades with increased sheet temperature (D), the compression modulus increases also; with increased plug speed (E) the compression modulus increases; and with increased plug temperature (F) the compression modulus increases. A comparison of Scree plot results for the % of variance of the effect of thermoforming parameters on thermoforming container properties shown in Figure 19, shows the parameter with the greatest influence on compression modulus is E (plug speed), with significant influence also from D (sheet temperature) and a smaller influence from F (plug temperature).

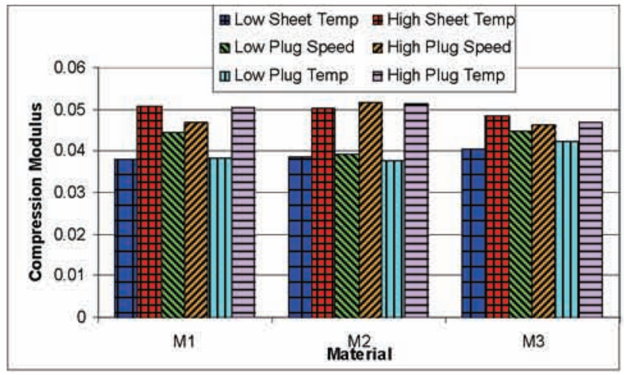

Figure 17. Results for variation in compression modulus with changes in thermoforming settings.

The variation in load at 2mm compression with changes in thermoforming settings is shown in Figure 18. Figure 18 shows that for all material grades with increased sheet temperature (D), the load at 2mm compression increases also; with increased plug speed (E) the load at 2mm compression increases; and with increased plug temperature (F) the load at 2mm compression increases. A comparison of Scree plot results for the % of variance of the effect of thermoforming parameters on thermoforming container properties shown in Figure 19, shows the parameter with the greatest influence on load at 2mm compression is E (plug speed), with significant influence also from D (sheet temperature) and a smaller influence from F (plug temperature)

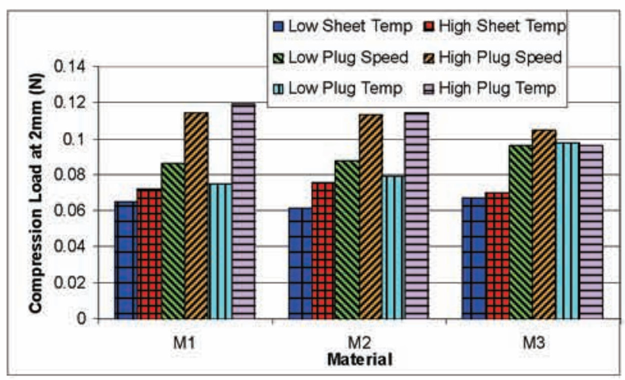

Figure 18. Results for variation in load at 2mm compression with changes in thermoforming settings.

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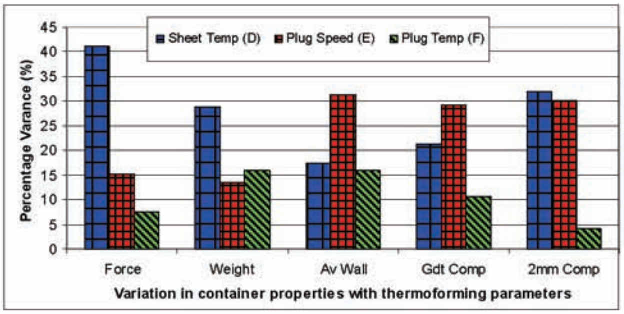

Figure 19. Comparison of Scree plot results for the % of variance of the effect of thermoforming parameters on thermoforming container properties.

Conclusions

Extruded sheet material with high chill roll temperature and low line speed consistently had a higher % crystallinity DSC results and a higher stress level over all material grades during biaxial stretching.

Biaxial stretching is a more effective method for observing small differences in extruded sheet properties due to variations in processing parameters, compared to DSC, tensile and DMTA testing.

Material grade influences the properties of extruded sheet to a greater degree than chill roll temperature and line speed.

Thermoformed container properties are mainly influence by sheet temperature and or plug speed, with a lesser influence from plug temperature.

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Key Words: Thermoforming, Extrusion, Polypropylene, PP, Biaxial.

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Roger C. Kipp
Vice President of Marketing & Engineering
McClarin Plastics, Inc.
Hanover, PA

An innovator and visionary helping to expand an industry, Roger C. Kipp's contributions to the plastics industry include hands-on development of processes and procedures, furthering education initiatives, and developing successful business models.

Roger C. Kipp's passion, contributions and innovations for the plastics industry began in 1967 during his first job out of college as the assistant plant manager of a small non-ferrous foundry in Cincinnati, OH. During this time, he saw an opportunity to become a one-stop source for plastic process tooling by combining pattern making with foundry skills. In 1968, he developed the first cast to form an aluminum injection mold for a major Cincinnati toy manufacturer. This venture was soon expanded to include tooling for heavy-gauge sheet thermoforming and rotational molding.

From 1967 to 1983, Kipp partnered with his father and brother to grow their pattern and foundry business in Cincinnati. As Operations Manager and Treasurer, he focused on business development with expansion of a permanent mold division and creation of the plastics tooling division.

In 1983, Kipp spun off the plastics tooling division from the family foundry.

For over 25 years, Kipp devoted his attention to the construction of aluminum tooling, developing innovative processes which improved heat transfer, created new techniques for forming undercuts, part ejection, molding inserts and improving overall cast tooling quality.

As the industry evolved, so did Kipp's focus. After many years of working with captive forming and molding operations, he developed an interest in developing new plastic components, an interest that extended beyond tooling. Kipp's knowledge of the values and limitations of metals, along with tooling engineering expertise, provided a technical advantage to allow him to expand into large part thermoforming applications and markets.

In 1987, Kipp directed the start-up of a vacuum forming and rotational molding facility in Sidney, OH. While he continued to oversee tooling construction, this position was Kipp's first foray into the sales and marketing aspects of the industry. He subsequently developed millions of dollars of new applications by introducing plastics innovation to various industries, including waste management, agricultural and construction equipment, sound systems, air handling, and playground equipment.

In 1994, Kipp joined McClarin Plastics in Hanover, Pennsylvania as Vice President of Marketing & Engineering. In this position, he has made it a priority to be involved in strategic and functional initiatives to further the company as well as to promote the plastics industry through affiliation with various professional organizations.

Kipp has been a member of the Society of Plastics Engineers Thermoforming Division Board since 1992. During his tenure on the Board, he has served as Conference Chairman (1996), Conference Treasurer, Division Treasurer and Chairman. As a member of the Society, he has served as the Communications Committee Chair and on the Foundation Executive Committee. The Society has honored Kipp with the 2002 Outstanding Achievement Award and a Lifetime Achievement Award in 2003.

With an interest toward the future of the plastics industry, Kipp has always had an affinity for education. He is Associate Professor teaching manufacturing processes part time at his alma mater, Miami University in Oxford, OH. Since then, he has assisted in the development of numerous industry-wide educational programs as well as a comprehensive in-house program at McClarin Plastics. The McClarin program offers its 200 employees about 40 classes that cover such topics as blueprint reading, lean certification, metrology and economics.

Kipp is also instrumental in supporting McClarin's aggressive programs focused on local high school students. These programs, which include job fairs, internships and hands-on projects are designed to spark interest in the industry and expose students to opportunities in the field of plastics manufacturing and engineering.

Kipp serves as a member of the Advisory Board of the Plastics Manufacturing Center at the Pennsylvania College of Technology, an affiliate of Penn State University. Through them, he is active with the Pennsylvania Plastics Initiative.

He and his wife Sandy now reside in Hanover, PA. They have three children and five grandchildren. Mr. Kipp is an alumnus of Miami University and is active with their Alumni Recruiter Organization.

An Alliance with Education

Roger C. Kipp, Vice President of Marketing & Engineering, McClarin Plastics, Inc., and Councilor, SPE Thermoforming Division

In this rapidly changing business environment, the growth and future of the plastics industry is connected directly to the development and creativity of new technologies. No less important is the communication and education required to promote such new technologies. These new technologies will involve all phases of our industry including materials, processing and equipment. In order for industry to participate and accelerate the application of these technology advancements, an alliance with education is essential.

The educational alliance provides companies with well-educated technicians and polymer engineers with strong academic credentials supplemented through valuable industry input. This alliance will enhance corporate training programs while developing a more competitive and knowledgeable workforce with improved quality and production performance.

Stiffer global competition and the increased performance demand required of our resources as we emerge from this recession further drive the need for change. Meeting these demands will require the application of carefully selected new technologies while maintaining a well-trained workforce.

The Plastics Manufacturing Center (PMC) at Pennsylvania College of Technology implements this alliance. The PMC combines academic, government and industry resources to facilitate technology and processing advancements throughout the plastics industry.

In 2008, the PMC Advisory Board recommended that the directors move forward to launch a National Thermoforming Center of Excellence and to undertake a seed money funding project. The Thermoforming Division of the Society of Plastics Engineers was proud to participate as a charter member providing a substantial donation toward the seed monies as well as in-kind service from members and their companies. Grants from Northeastern, Northern and Central PA Ben Franklin Technology partners along with many other corporate and government sponsors and grants provided further foundation for our industries alliance with education.

This Center of Excellence will be the nucleus of opportunity for all companies in any aspect of thermoforming to further research and development. The services and capabilities of the Center as well as an application for project submission are detailed in the following article. |

Research and Development Assistance

"Thermoforming Center of Excellence"

Charles (Hank) White, Director of PMC, Pennsylvania College of Technology

The Thermoforming Center of Excellence at Pennsylvania College of Technology in Williamsport, PA, is a 1,800-square-foot dedicated support facility (including classroom space), research and development facility, and educational facility to be utilized by thermoformers, sheet extruders, resin suppliers, mold builders, and equipment manufacturers. This center operates under the umbrella of the Plastics Manufacturing Center (PMC). The PMC is one of the top plastics-technology centers in the country, with extensive material-testing laboratories, industrial-scale process equipment, world-class training facilities, and highly skilled consulting staff.

The Thermoforming Center will also provide credit and noncredit courses aimed at preparing students for entering the workforce as well as furthering the knowledge of the current workforce within the thermoforming industry. A very significant issue facing the plastics industry is the need for employee understanding of plastics technology to capitalize on the latest material and technological advances.

The Thermoforming Center is equipped with industrial-scale, state-of-the-art process equipment and training facilities capable of demonstrating a wide variety of forming techniques.

Project Services

The Thermoforming Center will provide member- and client-driven R&D services focused on specific opportunities and issued related to the business of developing, manufacturing and improving of thermoformed sheet products, for both thick-gauge and thin-gauge rigid sheet forming. This Center will conduct specific programs suggested by industry to advance manufacturing technology, develop products and processes, and lower costs.

The Thermoforming Center will assist with the following: new product development; material selection, testing, and analysis; custom compounding; process improvement and development; and workforce training. Plastics professionals will provide the customized on-site training programs, as well as the on-campus course. Services from qualified consultants will be tailored to plastics product and process needs.

Potential projects include: (1) Reduction of material usage through tooling design advancements and processing control; (2) Advanced theory development of mold temperature control and its effects; (3) Optimization of vacuum/air to allow faster forming, better part definition, and faster cycles;

(4) Documentation and evaluation of the impact of recycling material properties, as well as processing to optimize material recycling capability; and (5) Bio-materials development research.

Educational Services

The Center will also provide credit and noncredit courses aimed at preparing students for entering the workforce, as well as furthering the knowledge of the current workforce within the thermoforming industry. Academic curriculum will be developed and thermoforming courses will be offered within the Plastics and Polymer Technology program at Penn College, utilizing the newly renovated process equipment and lab facilities located in the Advanced Technology & Health Sciences Center. Further, the Center will develop and deliver general and custom tailored noncredit courses and seminars to meet the needs of industry members and client companies. Seminars will be held at the Center, and specific training will be delivered on-site as requested by member companies.

Plastics Consulting, Testing, Training, and Product Development

Materials Testing and Analysis

- Competitive product analysis
- Mechanical testing
- Melt flow and rheology
- Impact testing
- Failure analysis
- Quality testing
- Materials identification
- Materials deformulation

Technical Support Services

- Material recommendations and sourcing
- Custom compound development
- Polymer processing
- Manufacturing process recommendations
- Mold design
- Literature search

Product Development

- Design services
- Product models
- Prototyping
- Mold design/construction
- Product molding trials

Thermoforming Equipment

The thermoforming machine on-site is an industrial scale machine with capability for twin-sheet forming and pressure forming for both thin-gauge and heavy-gauge material. The equipment includes the following features:

- Upper and lower moving platens
- Capable of forming 36" x 48" molds with a depth of 10"
- Upper and lower heating ovens with multiple heating zones
- Sheet clamp frame capable of holding sheet thicknesses from 0-0.5"
- Mold temperature control unit capable of heating & cooling of molds
- Forming press capable of up to 100psi of form pressure (40" x 40" mold)
- Servo driven 3rd motion actuators on upper press platen for accurate plug assisting and additional mold platen movements
- Quick change features
- 1-ton capacity crane mounted to top of form press

Forming Functions

The thermoforming machine is capable of performing the following "forming" functions:

- Standard drape forming using male (positive) and female (negative) molds and combinations thereof with the use of vacuum (25 InHg)
- Standard drape forming using male (positive) and female (negative) molds and combinations thereof with the use of vacuum & form air pressure (50-80psi)
- Plug assisted vacuum & pressure forming using third motion plug drive mechanism
- Fixed Plug with moving clamp vacuum and pressure forming
- Matched metal forming
- Vacuum snap-back forming
- Vacuum bleed techniques
- Light gauge twin-sheet forming

Control Functions

- PLC and operator touch screen interface
- Recipe screens – specific tool and product forming parameters
- Timing screens – for precise control of each forming process
- Timing history screen
- Heater control screen – individually and precisely controlled heater elements, each with thermocouple feedback to controller
- Heater history screen
- Error screen – showing real time e-stop, safety gates, heater and servo errors, etc.
- Manual settings screen
- Forming sequence indicator lamps for vacuum, vacuum bleed, form air, eject air, and plug bottom position
- Additional pneumatic solenoids and timers for clamp frames, stripper bars, and mold undercut devices
- Trimming 5-Axis CNC machine with 17.5' x 8.5' x 30" capacity

Other Processing Equipment Available On-Site

Injection Molding

- Cincinnati Milacron Injection Molder, VT110 110 ton, 7 oz. shot size
- Battenfeld Austria Injection Molder, BA 200 CD: 20 ton, 20 g shot size
- ASTM Mold Retrofitted with RJG Associates Data Acquisition System
- Boy 22 D Injection Molder (2) 20 Ton
- Nissei ES30000 All Electric Injection Molder

Blow Molding

- Bronco 888 Two-Stage Blow Molder
- Hesta Extrusion Blow Molder

Extrusion/Compounding

- Killion Single Screw Extruder, 24/1 L/D 1 lb./hr
- Film Blowing Tower
- 6" Sheet Die
- Leistritz 27 mm Twin Screw Extruder
- Gala Underwater Pelletizer
- Goodman Vacuum Sizer

(continued on next page)

Rotational Molding

- Med Keff-Nye Shuttle PDTM 42" Offset Arm Rotomolder
- Wedco Grinder (75 lbs/hour)
- Sweco Classifier
- Datapaq Acquisition System

Auxiliary Equipment

- Formech 300x Vacuum Former
- Carver Press Compression Molder
- Annelaing Oven
- Pelletizer
- Plasmec High Intensity Mixer (101)

Testing Equipment Available On-Site

Analytical

- Bio Rad FTS 3000 Excalibur Series Infrared
- Spectrophotometer
- Perkin Elmer Pyris 1 Differential Scranning
  - • Calorimeter/Thermal Gravimetric
  - • Analysis (TGA 6) System
- Arizona Instrument Computrax Moisture
  - • Analyzer Max® 2000 XL

Rheological

- Haake PK 100 Rotational Viscometer
- Tinius Olsen Plastometer
- Tinius Olsen Melt Indexers (2)
- Rosand RH 2000 Capillary Rheometer

Physical

- Weatherometers: Xenon Arc and QUV
- Heat Deflection Temperature Tester
- Izod/Charpy/Tensile Impact Tester
- Gardner Impact
- Bulk Density
- ARM Impact Tester
- Tinius Olsen H25KS Universal Testing
- Machine (UTM) with Environmental Chamber
- Load Cells – 25 kN, 5kN, 250N & 50
- 20% Extensometer & Laser Extensometer
- Tinius Olsen 1000 UTM (2) with Tensile and Flexural Fixtures
- 1000 & 50 lb. load cells
- 20% Extensometer
- Rotap Sieve Particle Size Analyzer (PSA)
- Density Gradient Columns
- Electronic Densimeter MD 200S

Membership Benefits

- Member directed technical initatives
- Access to Center research
- Technical support from Penn College faculty and staff
- Access to Penn College plastics processing and testing labs
- Networking with member companies
- Quarterly newsletter |

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SPE Thermo Forming Division

Our mission is to facilitate the advancement of thermoforming technologies through education, application, promotion and research.

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Visit Our Website at:
www.thermoformingdivision.com

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.

SPE ThermoForming Division

2010 SPE Thermo Forming

"Embrace the Challenge"

Sept. 18-21, 2010 Milwaukee, WI

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Join us at the 19th Annual Thermoforming Conference
Sept. 18-21, 2010
Milwaukee, WI

The SPE Thermoforming Division invites you to join our 19th Annual Conference exclusively created for the Thermoforming Industry. Our conference is your opportunity to network with clients, prospective partners, colleagues, vendors, and industry leaders. With meeting everyone in one location, you will save precious time and travel expenses.

Sessions and Events

Learn how to take advantage of new technical developments to maintain and grow your business in the current economy. Our comprehensive conference program includes technical presentations by recognized industry experts highlighting new and exciting developments in the industry as well as extensive and detailed industry assessments and a market outlook. We also offer full day workshops with respected industry experts to help your technical staff gain more practical insight into the thermoforming processes. Newly introduced expert panel discussions allow our audience to interact with industry specialists and discuss topics related to Tooling, Machinery, Materials and Processing. Our conference registration also includes 2 Breakfasts, Lunches and our traditional "Thermoformer of the Year" Grand Reception and Dinner.

Sponsors and Exhibitors

The conference offers an array of sponsorship, exhibiting and advertising options that provide your organization with a cost-effective way to promote your products and services, establish your brand, build new business relationships and secure your position as a leader in the industry. Our Sponsors and Exhibitors will have the unique opportunity to introduce their new and exciting products and technologies to a target audience during our newly introduced "Innovation Brief" Presentations located directly on the exhibit floor. Exhibiting at our conference is the perfect opportunity to reach industry decision makers.

Parts Competition

We invite you to enter your unique packaging or industrial parts in our annual parts competition. Winners will be selected during our conference and honored during our "Thermformer of the Year" dinner. We will also showcase the winning parts in various print media and on our website.

Register Early and Save

Register today and receive the early registration rate of $395 for SPE Members. Registration includes two continental breakfasts, two lunches, refreshment breaks, conference packet and admission to all conference sessions, the tradeshow, and evening reception & dinner. Registration does not include lodging. Download the registration form or register online **www.thermoformingdivision.com**

2010

Thermo Forming

"Embrace the Challenge"

Sept. 18-21, 2010 Milwaukee, WI

WHO SHOULD ATTEND

- Thermoformers
- OEM's
- Equipment Producers
- Tooling Suppliers
- Film and Sheet Suppliers
- Resin Producers
- Recyclers
- Potential Investors

HIGHLIGHTS

- Hands-on Workshops
- Technical Sessions
- Expert Panel Discussions
- Market Outlook
- Exhibit
- Parts Competition
- Networking Receptions/Dinner

2010 Parts Competition Announcement

Coming off a very successful 2008 Parts Competition, we look forward to our 2010 Competition and what it may yield. The quality of the parts submitted was exceptional two years ago with pieces ranging from complex food packaging parts to very large Twin-Sheeted and Pressure Formed parts. As advancement in the industry continues, we can only imagine what the parts competition will yield this year regarding innovation in design and manufacturing.

The industry considers the parts competition a key element in the educational efforts of the SPE Thermoforming Division, due directly to the state of the art components submitted by manufacturers. This year's conference again offers the opportunity to showcase your most recent innovations and advancements.

We made a concerted effort two years ago to provide greater media coverage and access to all of the parts submitted. This made it easier for highlights of each part to be understood and showcased throughout multiple trade publications. Every part that is received and entered is due their recognition, but unfortunately every part does not receive an award. In light of this, each submittal will receive a "Certificate of Acknowledgment" from the SPE Thermoforming Division.

Take Advantage of this Opportunity

We encourage all interested parties to start thinking now about how to take advantage of this opportunity to showcase their talents and introduce your firm through the press. We welcome all Thermoforming related businesses to submit a piece to our prestigious competition. This includes all material suppliers, tool builders, designers, and proprietary product manufacturers.

Drawing upon a more simplified entry process that we implemented two years ago, we have decided to continue on in this same vein and have simplified the categories even further. The product fields will remain the same as Roll-Fed and Heavy Gauge. The categories within Roll-Fed include Industrial Parts, Food Packaging, and Medical Packaging. The categories within Heavy Gauge will include Vacuum Form, Pressure Form, and Twin Sheet.

Download Entry Form

We encourage you to take a few moments and access the SPE Thermoforming Division website and download the entry form at www.thermoformingdivision.com. Along with the entry form, participants will be required to submit a product image in jpeg format (1MB or smaller) plus a product description in MS Word explaining critical elements of design, intended use, materials used, and innovative aspects.

All submissions or questions regarding the competition can be directed to bret@joslyn-mfg.com. Early submissions to the parts competition may also have the opportunity to be showcased in one of our pre-conference newsletters. We look forward to seeing you in Milwaukee in September.

FIRST CALL FOR SPONSORS/EXHIBITORS

19th Annual Thermoforming Conference & Exhibition

September 18 - 21, 2010

MIDWEST AIRLINES CONVENTION CENTER

Milwaukee, Wisconsin

2010 Thermo Forming

“Embrace the Challenge”

The 19th Annual Thermoforming Conference and Exhibition – Thermoforming 2010: “Embrace the Challenge” – plans are beginning to take shape. This show will be a forum for the newest techniques, latest equipment, materials, auxiliary equipment and current industry news. As an Exhibitor, this event will enable you to showcase your products and services at a show geared just to **THERMOFORMERS**! If your company is a player in the **THERMOFORMING INDUSTRY**, then this is the place for you to be in 2010. This industry event is a prime opportunity for you to reach the decision makers in the field and create a brighter future for your business as well.

Full exhibits will be offered. Our machinery section continues to grow each year. If you are not yet participating in our machinery section, you are encouraged to do so. Each 10' x 10' booth is fully piped, draped, carpeted and a sign will be provided. As an extra value, one comp full registration is included with every booth sold. This gives your attendees access to all **Technical Sessions, Workshops, Special Events, Expert Panel Discussions and all meals. A great bargain at $2,250.00**.

We are also offering our sponsors and exhibitors a forum to present their newest innovations through presentations at our newly introduced commercial sessions. Your **SPONSORSHIP** or participation as an **EXHIBITOR** has demonstrated its potential to help your sales and it is contributing to the strength and success of our industry as a whole.

We urge you to join us at **THERMOFORMING 2010 in Milwaukee**! Reserve your space early to avoid disappointment. Booth assignments and commerciaal presentation opportunities are made on a first come, first serve basis.

Should you have questions, please call (706) 235-9298, fax (706) 295-4276
or e-mail to gmathis224@aol.com.

2010 THERMOFORMING CONFERENCE
September 18 - 21, 2010

SPONSOR & EXHIBITOR REGISTRATION FORM

(Please complete and return with your check today.)

_______ YES, we want to apply as a 2010 Thermoforming Conference **SPONSOR**. Enclosed is our non-refundable deposit check for $2,500. We understand that if our firm is selected through a "Sponsor Lottery" we will have 14 days after notification to submit our payment of the additional $2,500 to confirm our Sponsor status. Those firms not meeting this deadline will relinquish their sponsor position and will be reclassified as an **EXHIBITOR**. Additional spaces available at discounted rates. 2nd Booth $2,250, 3rd Booth $2,000, 4 or more, $1,750 each.

WE WILL REQUIRE __________ Booths.
Initial Sponsor Cost … $5,000 **– Signup Deadline: December 1, 2009**.

_______ YES, we want to be a **2010 THERMOFORMING EXHIBITOR**. Enclosed is our check for $2,250. Additional 10' x 10' booths as needed will be 2nd $2,000, 3 or more $1,750 each. We will require _________ Booths. We understand that space assignments will be assigned after **SPONSORS** have been selected. Cancellations will be accepted up to June 1, 2010.

COMPANY NAME: ____

CONTACT: ______________________________ SIGNATURE: __________________________

ADDRESS: ____

CITY/STATE/ZIP: ____

PHONE: ________________________ FAX: ______________________

E-MAIL: ____

You get one (1) **FULL COMP REGISTRATION** for each 10' x 10' booth space. Please list the person who will be using your comp registration (subject to change):

____

MAKE CHECKS PAYABLE TO:

2010 SPE THERMOFORMING CONFERENCE

MAIL TO:

GWEN MATHIS, CONFERENCE COORDINATOR
SPE THERMOFORMING DIVISION
P. O. BOX 471, 6 SOUTH SECOND STREET, SE
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FAX (706) 295-4276

Please inform us if you wish to pay by credit card and we will arrange for the transaction with SPE. E-mail to gmathis224@aol.com.

The GPEC 2010 Environmental Sustainability Awards

Dr. P.M. (Subu) Subramanian, Awards Chair

The GPEC 2010 Awards program was a phenomenal success. Over the short time since the Awards program was created, its reputation has spread globally and the number of nominations has increased significantly. This year, we had 35 nominations, including some from China, Japan and other countries. All of the submissions represented unique innovations in plastics: recycling, biobased polymers, process solutions and other innovations for greater environmental sustainability.

All of these participants are winners and it is unfortunate that the judges had the job of picking only one winner in each category. The winners represent excellence in the pursuit of environmental sustainability in their respective categories. In recycling, Associated Packaging (post-consumer PET recycled to make food-grade crystallizable, thermoformed trays), Mannington (vinyl floorings), and Nicos Polymers for recovering PVC from fiber reinforced vinyl tubings, were recognized. The elastomeric polyamide PEBAX made from naturally derived intermediates from Arkema won recognition in the bio-derived polymers category. The polypropylene filled with a unique cellulose powder made from newspaper by Eco Research in Japan was another winner. The "Design for Sustainability" awards were won by Amway for their "e-spring" home water purifiers, and Vast for their unique tire and plastic based paving tiles. The prestigious Dan Eberhardt Environmental Sustainability Award went to **Delta Plastics of the South** (Little Rock, AR) who achieved an extraordinary goal of reclaiming and recycling nearly 100% of its used LLDPE irrigation tubings. The company is now recycling a large portion of competitors' tubing as well. In addition, 1,436,000 pounds (650 metric tons) per month of miscellaneous LDPE products were recycled into certified post-consumer resin. In these efforts they not only created the required infrastructure but also worked cooperatively with the communities, organizations, and local governments in doing so. These innovations are inspiring.

Competition Sponsored by Battelle at GPEC® 2010 is a Showcase for Emerging Companies with Technologies for Use of Renewable Material and Energy Resources

BROOKFIELD, CT, U.S.A, March 8, 2010

A new monomer platform technology developed by Avantium for creating biopolymers and biofuels from biomass through the creation of furanic chemical building blocks received the top award in the third annual Clean Technology Business Forum and Competition, as announced today by the Society of Plastics Engineers (SPE). Organized by SPE's Environmental Division, the event took place at the recent Global Plastics Environmental Conference (GPEC) in Orlando, FL. The second-place honor went to VAST Enterprises LLC, for a new composite masonry product made of post-consumer rubber and plastics. The winners came from more than twenty companies participating in the competition, including the top six finalists which presented at GPEC. Sponsor of the competition was Battelle, the international non-profit R&D organization. The competition was judged by representatives from Battelle, Cascadia Capital, Emerald Technology Ventures, *Modern Plastics Worldwide* magazine, SPM Technologies, and the winner of the 2009 competition, FRX Polymers. Eric Koester, an attorney with the law firm Cooley Godward Kronish LLP, served as coordinator of the Clean Technology Forum. "SPE's Clean Technology competition is an opportunity for inventors, emerging companies, and established firms with revenues under $5-million to present innovations that make possible the use of materials and energy from renewable sources, substantially reduce resource consumption, or dramatically reduce or eliminate emissions and waste," said Environmental Division chairperson Susan M. Kozora, engineering manager of International Automotive Components (IAC).

Award Winners Open New Possibilities for New Monomer and Green Building Technologies

First place winner ***Avantium*** is involved in the development and commercialization of furanics biopolymers and biofuels. The company is developing an efficient and low cost process to convert carbohydrates into furanics on the basis of novel chemical catalytic technology. Already covered by 15 patents, the technology could be used to create a biobased route to polyesters, polyamides, and polyurethane, with the technology applying polycondensation for polymerization that could allow it to run on retrofitted reactors. The company has developed a technology for the economic production of furanics from biomass. Furanics are building blocks to produce a wide range of green plastics, chemicals and materials, as well as for green fuels. Avantium's furanic technology offers the potential to enhance and change the global plastics industry, as these green building blocks can now be produced economically for a wide range of materials and applications. The Chief Executive Officer of the Amsterdam-based company is Tom van Aken. *www.avantium.com*

Runner-up ***VAST Enterprises LLC*** has developed patented material science technology to turn postconsumer recycled rubber and plastics into a new green building material: composite masonry. VAST develops and manufactures composite products that offer an engineered, green alternative to molded concrete and clay brick. VAST's injection-molded product, which consists of post-consumer rubber and plastics combined into composite masonry. Molded into pavers and other products, the product is pitched as an alternative to molded concrete or clay bricks. Launched in 2007, the bricks, which are supplied with a molded sub-structure to ease installation and alignment, are made from 95% recycled materials, and compared to the concrete they're aiming to replace, use 82% less energy and 89% less carbon dioxide in their manufacture. Available in different colors, the company supplies the bricks with a 10-year warranty, but offers a lifetime warranty against cracking and expects a product life of 25-30 years. At GPEC 2010, the company was also awarded the SPE Environmental Division: Design for Sustainability award. The Chief Executive Officer of the Minneapolis-based company is Andy Vander Woude. *www.vastpavers.com*

SAVE THE DATE!!

MILWAUKEE, WISCONSIN

SEPTEMBER 19th - 21st, 2010

SIGN UP TODAY FOR EXHIBITOR SPACE.

Contact Gwen Mathis, Conference Coordinator, at gmathis224@aol.com, 706.235.9298 (ph), or 706.295.4276 (fx).

Thermo Forming Division

2010 EDITORIAL CALENDAR

Quarterly Deadlines for Copy and Sponsorships

ALL FINAL COPY FOR EDITORIAL APPROVAL

30-JAN Spring	**15-APR** Summer
31-JUL Fall	**30-OCT** Winter *Post-Conference Edition*

All artwork to be sent in .eps or .jpg format with minimum 300dpi resolution.

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2010 - 2012

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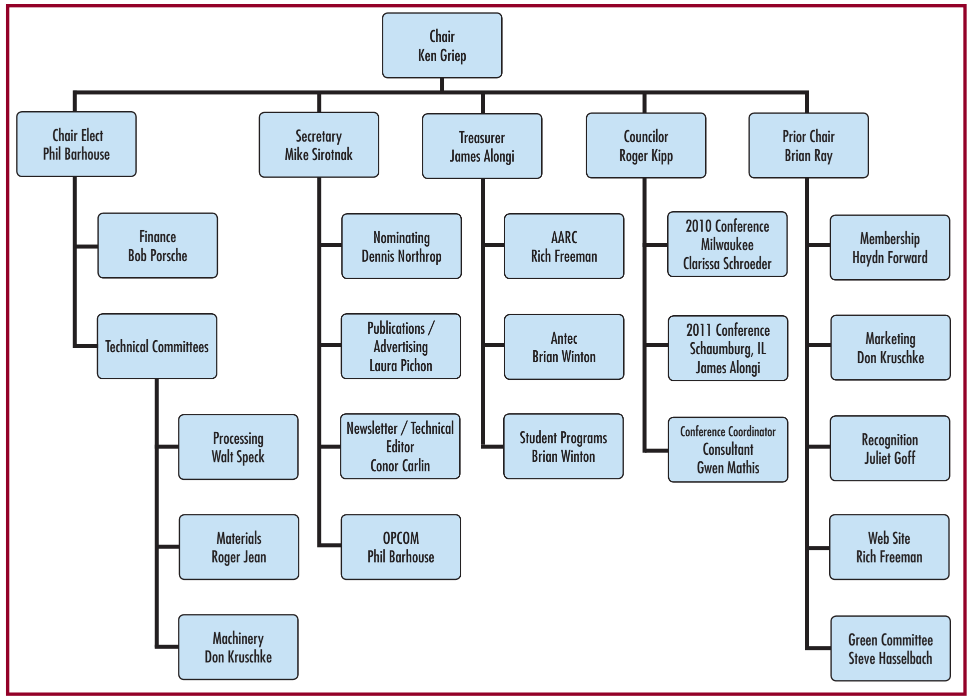
2010 - 2012 THERMOFORMING DIVISION ORGANIZATIONAL CHART



UPCOMING CONFERENCES

MILWAUKEE, WISCONSIN

SEPTEMBER 19 - 21, 2010

SCHAUMBURG, ILLINOIS

SEPTEMBER 17 - 20, 2011

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