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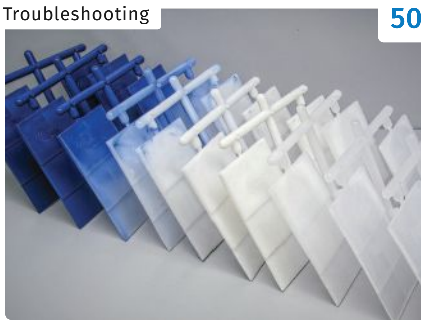

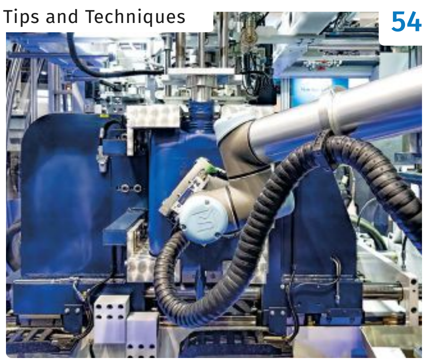

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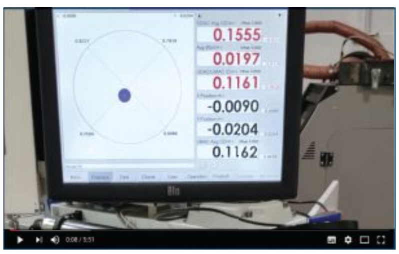
BLOG: Recycle Sourcing: Industry's Challenge & Opportunity

Senior Editor Heather Caliendo reports from the Plastics Recycling Conference (Feb. 17-19 in Nashville, Tenn.) where Eastman's Holli Alexander discussed the risks and rewards the plastics industry faces as it finds its spot in the circular economy. Carbon renewal technology, chemical recycling and more are addressed. ***short.ptonline.com/recy***

Stay Centered



At Plastec West 2020 (Feb. 11-13 in Anaheim, Calif.), Novatec unveiled its Ultrasonic Centering Gauge, a system that reportedly allows operators to easily center the tube in the tank during startup (see p. 14). See the system in action, paired with a Zumbach OD/ID wall system, ensuring that a microbore tube is centered in the tank. ***youtu.be/QBXNDWQpBk0***

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BLOG: Granulation Gets Smarter

On its face, size reduction is a brute-force activity, focused more on muscle than finesse, and presumably without the need for nuance or intelligence. Executive Editor Matt Naitove checks in with Hellweg Maschinenbau, which promoted a "smart" granulator at the K show last October in Germany, breaking down how the machine can "learn" as it breaks down plastic scrap. ***short.ptonline.com/gran***


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Time to Learn More About the Real World of Recycling

Next month, *Plastics Technology* will cover the challenges of recycling with a targeted print and electronic supplement—and a focused webinar—highlighting best practices in processing with high levels of PCR.

Sustainability. The Circular Economy. All Green. Cradle to Cradle. Yesterday's buzzwords have become today's reality for plastics processors. Pledges from brand owners and OEMs to produce products—or package them—in previously used materials will be forcing dramatic changes across the entire plastics processing supply chain. Simply, if you've been molding or extruding products from all-virgin materials—because that's what your customer and the application demanded—you will most likely be asked to change things up in the near future.

Jim Callari
Editorial Director

Think of all the far-flung obstacles that have to be overcome before this becomes a reality. If you are making, for example, a sophisticated packaging film for a high-end application, are you going to be able to change that to one containing 10-50% post-consumer reclaim at a flip of the switch? Heck no. For starters, from where are you going to source this material? And if and when you get it—even if it's in pristine condition—will you be able to drop it into an existing process and go about the rest of your day? I doubt it.

We seen some indications from your suppliers that they are bracing for change. Some resin companies have grades on the street containing quantities of post-consumer material, or are looking at chemical recycling as an option. And even machine builders are designing new features into blenders and conveying systems to accommodate higher usage of PCR.

We at *Plastics Technology* are trying to give you some guidance as you navigate this rocky road. Next month, packaged with your May issue, you'll be receiving a supplement looking at recycling that will contain these elements:

- A summary of the pledges made by some major brand owners to include specific amounts of PCR in the packaging within a specific time frame, pledges that will change the way you manufacture products for them.
- A look at the steps major processors in injection molding, extrusion, blow molding and compounding are taking to meet these demands, focusing mostly on the new supply channels and processing techniques that are being utilized.
- An examination of the role chemical recycling will play in the way in which you will specify materials in the year ahead.

How will plastics processors deal with brand owners' demands for more recycle content? That's the theme of a special supplement and webinar next month.

This supplement will be available in print and electronically (it will be on our website, of course, and will be delivered via email as an e-newsletter). And on May 6, we will be holding a no-charge, one-hour webinar focusing on recycling best practices that will hone in on what you need to do differently at your plant—from handling to drying to conveying to blending to processing—to meet these escalating demands for PCR use while still producing a high-quality product.

We hope you will find the content in these products useful, and that you will be able to learn from the experiences of experts in the field to ease your transition into this challenging territory. PT

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Arburg Acquires 3D Printer Maker German RepRap

Arburg has signed an agreement to acquire industrial 3D printer manufacturer German RepRap (*3hti.com*). Founded in 2010, German RepRap will continue to operate as a separate company at its location in Feldkirchen, Germany. Founder and managing director Florian Bautz will continue to run the business

Arburg considers additive manufacturing to be an important complementary production method for plastics processing that holds significant promise for the future. At K 2013, Arburg introduced its Freeformer additive manufacturing system.

German RepRap makes 3D systems based on FFF technology (fused filament fabrication). Its new model x500pro processes engineering plastics such as polycarbonate. In 2016, the company added Liquid Additive Manufacturing technology (LAM) to its portfolio, which allows processing of materials such as liquid silicone rubber (LSR). Arburg's Freeformer works with droplet discharge from an infeed of standard molding pellets.

Conair & Partners Run TPE Tubing, ABS 3D Filament at Medical Show

At the Plastec West/MD&M Show in February in Anaheim, Calif., Conair Group teamed with Davis-Standard and Zumbach Electronics to process 4.5-mm (0.18-in.) TPE medical tubing and 1.7-mm ABS 3D-printing filament, switching back and forth throughout the show.

The demonstration marked the first MD&M appearance of Conair's space-saving HTMP multi-pass vacuum-sizing/cooling tank and the new ATC Series coiler. With HTMP, instead of making a single pass through a long tank, the extrudate follows a Z-shaped path so that the compact, 12-ft-long HTMP tank provides cooling time equivalent to a 30-ft tank—a feature especially valuable in cleanrooms, where floor-space is at a premium. The new ATC Series coiler (photo) provides tensionless winding of extruded tubing and filament to prevent damage, and is equipped with an automatic coil-isolation safety feature that prevents user access to moving coils.

At the show, a Davis-Standard 2-in. Super Blue extruder was supported by Conair upstream and downstream equipment, with downstream measurement and monitoring provided by Zumbach Electronics. The extruder's touchscreen integrates all these downstream inputs for complete line control. The demonstration line can deliver output rates up to 400 ft/min.

On the medical tubing runs, TPE was fed to the extruder through a self-contained Conair Access Series AL-2 mini-loader. Downstream, the Conair HTMP multi-pass tank was served by a MedLine Thermolator TCU and a Conair EP1A-02 (2-ton) portable air-cooled chiller to maintain precise temperature control, necessary for proper extrudate drawdown and sizing.

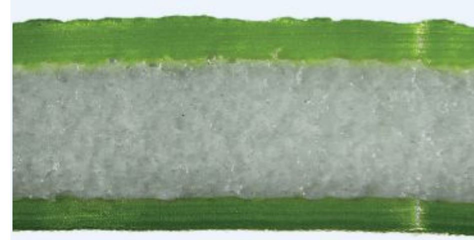
A pair of Zumbach ultrasonic gauges—one each near the tank entrance and exit—continuously monitored changes in tube wall thickness on a control screen as the tubing cooled. Further downstream, a Zumbach 3-axis O.D. laser gauge provided closed-loop dimensional control and also displayed the tube profile for concentricity adjustments. Together, data from the ultrasonic and laser gauges were used to regulate puller speed and cooling-tank vacuum to maintain critical tube dimensions.

The finished extrudate (tube or filament) then moved through a Conair MedLine Pinch Roll puller. The programmable, dual-servo precision puller fed the new MedLine ATC Series coiler. Its ultrasonic loop sensor automatically adjusted coil speed and traverse motion to wind product smoothly into a military wrap, without the friction or tension that can distort delicate products.

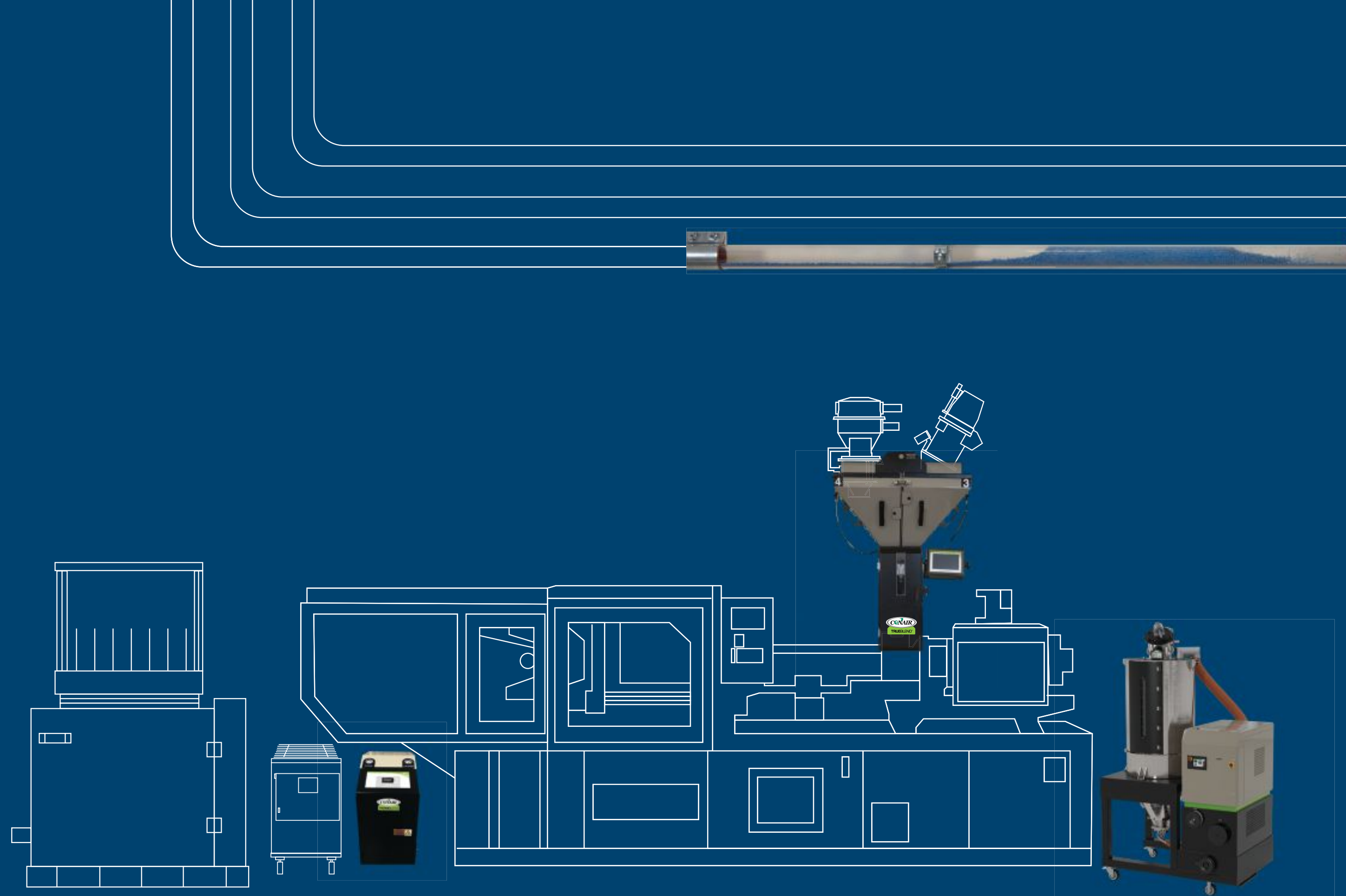
Changing the line over to 3D filament production was straightforward: the only hardware changes involved installing a filament extrusion die and a "pre-skinner" (non-contact sizing chamber) at the entrance of the HTMP multi-pass vacuum-sizing tank. The Conair pre-skinner is a water-filled chamber used to pre-cool and "skin" the surface of the filament before it comes in contact with calibration sleeves in the cooling tank. Without pre-skinning, the hot filament could stick and release on the calibration sleeves, resulting in "chatter" marks. (More details at ***ptonline.com***.)

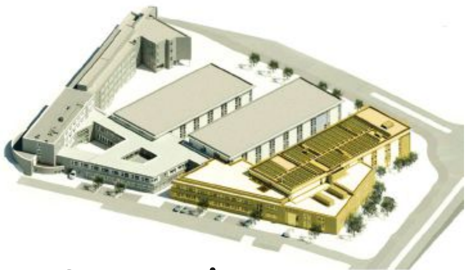
Kautex Shifts Focus from Automotive to Packaging and Recycled Plastics

Kautex Maschinenbau in Germany reported recently on its continuing restructuring and reorganization, begun last year, which involves a "shifting of focus" from its historical concentration on automotive applications to a new emphasis on packaging—especially sustainable packaging. The company is reallocating personnel from its automotive division and making "double-digit millions of Euros" investment in its Packaging, Pharmaceuticals and Healthcare Packaging businesses this year. Kautex said this shift is necessitated by "the sudden drop in new orders in the automotive business" and "a noticeable, worldwide reluctance of automotive suppliers to invest." Nonetheless, "Kautex expects that demand in the automotive market will recover over time. The company will, therefore, "remain committed to developing composite applications in this business as well."



Kautex also stated, "The dominant issues that affect the future direction of the company are waste prevention and processing of recycled materials." This was apparent at last October's K 2019 show in Düsseldorf, where Kautex's main exhibit was an all-electric KBB evo shuttle machine molding HDPE bottles with a center layer of foamed material containing 70% post-consumer recycle (photo).





Germany's IKV to Build 'Smart Factory' R&D Center

Germany's Institute for Plastics Processing (IKV) has announced plans to build a new complex as part of a $21 million project to develop the "smart factory" concept, also known as Industry 4.0. The new 45,000-ft^2 Plastics Innovation Center 4.0 will be erected adjacent to the IKV's home at the RWTH University Aachen and should be completed by 2022. The center will pursue both R&D and training of companies and employees in digitization of plastics processing. The IKV says it aims "to become a world-leading Industry 4.0 center for the plastics industry."

Pascal Bibow, team leader of process control and mold technology at the IKV, has been tapped to run the center. He told *Plastics Technology* that although injection molding will play an important role, "We want to enable cross-domain analytics and process interconnection; we will also focus on correlations from other directly related technologies. There are plenty of possible use cases for process interconnection that cannot be represented and analyzed anywhere yet for scientific research on digitized value chains."

Bibow said the IKV plans to relocate its injection molding department to the new building. The project will also focus on a range of ancillary processing steps, including material testing, drying and conveying, along with compounding and final quality assurance. He noted that research could also encompass production of injection molded bottle preforms and stretch-blow molding.

Equipment suppliers and plastics processers will be included on the center's advisory board, Bibow explained, noting that the names of participants will be released in the coming months. The German state of North-Rhine Westphalia and the European Union are funding the project.

Wide Spectrum of Medical-Grade Resins & Compounds Debut at MD&M West 2020

Here's a rundown of new medical materials at at February's MD&M show in Anaheim, Calif. (more details at ***ptonline.com***):

- New custom colors with USP Class V or VI and ISO 10993 compliance for BASF's Ultrason S, P and E (PSU, PPSU and PESU) sulfone polymers, used to make medical devices such as sterilization trays, research cages and diagnostic equipment, resulted from a collaboration between BASF and Techmer PM.
- Clariant unveiled Mevopur medical compounds and concentrates for laser welding.
- Also from Clariant, modified Mevopur PEBA and TPU medical compounds resist hydrolytic degradation even with high loadings of radiopaque metals for applications such as catheters.
- Two new medical-grade families of Makrolon PC from Covestro are aimed at autoinjectors and injection pens and surgical and drug-delivery applications (photo).

- Covestro also featured three new Texin Rx TPU grades for medical devices, component housings, connectors, tubing, film and sheet.
- DuPont's low-friction Delrin SC698 acetal with internal lubrication reportedly ensures smooth actuation of high-load drug-delivery devices like inhalers, injectors and pumps.
- Eastman expanded its Tritan MXF specialty copolyester line with flame-retardant grades for housings and hardware of electronic medical devices.
- Elkem's LSR system with low-temperature cure boasts productivity improvements without damaging heat-sensitive components such as thermoplastics, electronics and batteries in two-shot overmolding.
- RTP Co. launched a broad range of specialty engineering thermoplastic compounds for surgical robotic systems and housings, monitor components, and reusable instruments such as medical staplers, cannulas and grasper tips.
- SABIC's LNP Elcres CRX PC copolymers resist stress-cracking in healthcare equipment housings ranging from portable ultrasound and x-ray machines to hand-held diagnostics and infusion pumps exposed to aggressive healthcare disinfectants.
- Solvay Specialty Polymers' Xencor long-fiber thermoplastic (LFT) compounds reportedly deliver high strength and enhanced impact resistance for structural applications like vehicle chassis, gear systems and other components.
- Trinseo's new wear-resistant, high-lubricity Calibre PC, designed for drug-delivery components and surgical tools provides a solution for low-friction movement.

Tomra Reports Strong Polystyrene Sorting Test Results

Tomra Group of Norway recently completed tests on sortation of post-consumer PS waste with Tomra's near-infrared (NIR) sensor technology. The multi-step process included initial sorting, grinding into smaller flakes, washing, drying and flake sorting. The resulting purity of PS was reported to be be higher than 99.9%.

Jürgen Priesters, sr. v.p. for Circular Economy at Tomra, says one reason for the good results is that "styrenic compounds have a unique signal that enables easy and very precise sorting, an advantage which some of the other polymers do not have."

Tomra recently joined the Styrenics Circular Solutions (SCS) value-chain initiative to increase the circularity of styrenic polymer. Another member of SCS that participated in the PS sortation tests at Tomra is Ineos Styrolution, which is investing in multiple projects in Europe and in the Americas to set up PS chemical recycling facilities based on the depolymerization process.

"These findings on polystyrene sorting make styrenics a material of choice for a circular economy and confirm our statement that styrenics are made for recycling like no other," says Sven Riechers, v.p. of business management for Standard Products EMEA at Ineos Styrolution.

Nordson Opens Pelletizing Lab in N.C.

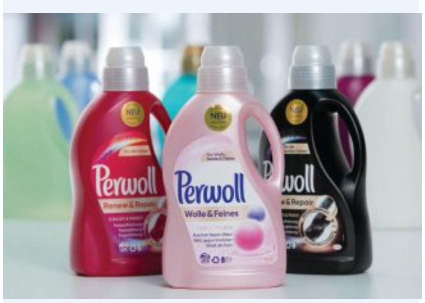
Nordson Corp. has cut the ribbon on an "extensively equipped" process laboratory to serve the Americas market for pelletizing systems and melt-delivery equipment. Installed at Nordson's facility in Hickory, N.C., the new laboratory has a pelletizing line with throughput capacity up to 1000 lb/hr available for training and application development. The line includes a twin-screw extruder, BKG pelletizer, Optigon self-cleaning process-water and pellet-drying system, and jet cleaner for removing polymer residue from die plates. Both underwater and water-ring pelletizers are available for testing. Melt-delivery components include three HiCon screen changers (backflush, continuous, and discontinuous types), a BlueFlow gear pump, and a HyFlex diverter valve. For evaluating materials to be processed, the facility also provides rheological analysis.

Nordson operates BKG process laboratories in Germany, China and Thailand. The new BKG lab in Hickory is Nordson's first in the Americas.

Henkel Launches Recyclable Black Detergent Bottles

Henkel AG of Germany announced last month that from now on, all HDPE bottles for its Perwoll line of laundry detergents in Western Europe will be fully recyclable and also contain 25% post-consumer recycle (PCR). The bottles are molded by Alpla of Austria.

Of particular interest, the "fully recyclable" label applies also to Perwoll's "Renew & Repair" variant, which comes in a black bottle. Historically, black-pigmented bottles have presented a challenge to recycling because the carbon



black pigment defeats sorting by near-infrared (NIR) detection technology. Working together with masterbatch supplier Ampacet, Henkel last year introduced its first recyclable black HDPE bottles using Ampacet's carbon-black-free Rec-NIR-Black concentrate, which is said to be compatible with NIR scanning. These bottles were for Henkel's Bref brand of toilet cleaners. Besides being fully recyclable, the new black Perwoll bottles also contain 25% PCR.

New Concepts in PET Wine & Vitamin Bottles

New shapes and PCR content have recently been introduced to two very different PET bottle markets by Amcor Rigid Packaging. For wine bottles, Amcor showed off its most recent design concepts at the Unified Wine and Grape Symposium at Cal Expo in February in Sacramento, Calif. One example, shown here, is a concept pairing a stock cylindrical 375-ml bottle with an overcap, in this case adhered to the twist-off closure beneath it. Another example is the "flat" 750-ml wide bottle commercialized two years ago in Europe by UK company Garçon Wines, which is just now bringing it to the U.S. Its shape saves space, and it also contains post-consumer recycled PET, though Amcor won't reveal the amount.

Amcor also unveiled what's said to be the first PET multivitamin container made of 100% PCR. Made for L.A.-based Ritual, it comes in two sizes, 100 and 150 cm^3. Ritual is an environmentally conscious firm started in 2015.

Borealis is Now Producing Renewable PP

Borealis officials confirm that the Austrian company has been producing PP based on renewable feedstock from Neste of Finland at two Borealis facilities in Belgium. Borealis considers this another milestone for furthering its ambition to make 100% of its products recyclable, reusable, or produced from renewable sources by 2025. It can use up to 100% renewable feedstock from Neste in PP production.

Neste produces renewable propane using its proprietary Nexbtl technology, which converts vegetable oils and animal fats. Neste then sells the renewable propane to the Borealis propane dehydrogenation plant in Belgium. Here it is converted to renewable propylene, then subsequently to renewable PP at the two Belgian plants.

The first-ever production of biobased PP at commercial scale occurred in a trial run about a year ago at a LyondellBasell plant in Germany, using over 30% renewable hydrocarbons from Neste's Nextbtl process.

Borealis is working with its partners to expand availability of renewable PP. One such partner is Henkel, known for its strong brands in laundry detergents, home care and beauty care. Henkel has made the use of sustainable materials a key pillar in its packaging strategy. Including renewable PP content in the packaging of a major Henkel brand over the course of the year marks another step in its efforts to cut its use of fossil-fuel-based virgin plastics in half by 2025.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New Method Boosts Medical-Tubing Efficiency

At Plastec West, Novatec unveiled an ultrasonic centering gauge to all but eliminate concentricity issues while decreasing startup time and slashing material waste.

Novatec's Ultrasonic Centering Gauge features a real-time display to facilitate centering the medical tube in the tank's tooling.

By Jim Callari
Editorial Director

Novatec has devised a novel method aimed at improving the processing of precision medical tubing. At February's Plastec West show in Anaheim, Calif., the Baltimore-based machine builder took the wraps off its Ultrasonic Centering Gauge, a system that reportedly will allow operators to very easily center the tube in the tank during startup, avoiding troublesome processing issues, decreasing setup time and wasted material.

The new Novatec Ultrasonic Centering Gauge ensures a microbore tube is quickly centered in the tank tooling before processing. According to Bob Bessemer, Novatec's v.p. of extrusion technology, this is critical because it solves concentricity issues due to the tube rubbing against the entry tooling. He explains, "When processing microbore tubing, the crosshead die is typically in very close proximity to the water or vacuum-tank tooling, making it almost impossible to see whether the tube is centered in the tooling and not rubbing against it, which leads to hard-to-solve concentricity issues and product defects."

Ultrasonic Centering Gauge ensures a microbore tube is quickly centered in the tank tooling before processing.

When Novatec developed its MVT Vacuum Tank Series, it found the vacuum was so stable it could be used to control water drool at the entrance to the vacuum tank. "This allowed the tube to enter a wall of water, which greatly enhanced concentricity over older systems using an iris or precise water-level control to minimize water exiting the tank in an uncontrolled manner," Bessemer explains.

With this in mind, Novatec created a water-level-controlled vacuum chamber in combination with an open-to-atmosphere pre-skinning chamber to house ultrasonic transducers located at the entrance to the water or vacuum tank. The ultra-precise vacuum and water-level control allow the transducers to be maintained underwater even while located only 1 to 2 in. from the die face.

At Plastec West, Novatec displayed this unit in combination with a Zumbach Electronics O.D., I.D., Wall System, showing wall thickness/concentricity and the position of the tube within the housing. Crosshairs similar to a gunsight visually display the tube-centering process to assist the operator in using the tank up/down and side-to-side adjustments to center the tube. Bessemer also notes, "Because the transducers are so close to the die, the die acts as support for the tube, and thus no rollers or guides are necessary, further simplifying the string-up process and eliminating the potential for the tube to touch and/or stick to any surfaces, making it a truly non-contact solution."

Another advantage of the Ultrasonic Centering Gauge is the distance to the ultrasonic transducers from the hot die, according to Bessemer. "With traditional laser-gauge/cold control, the laser gauge is the control point, as this is the final tube measurement of the O.D. The distance from the laser gauge to the hot face of the die is the distance the control waits before making a change to either the internal air unit, vacuum level, or puller speed to control the dimensions of the tube being processed. But, generally, due to control-loop delays, it is typical for this distance to be 10 to 15 times longer."

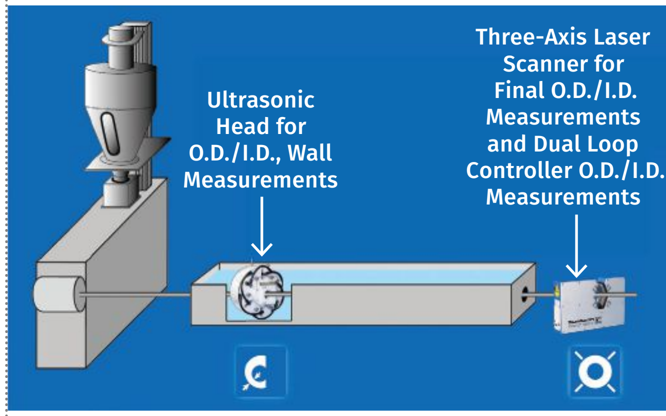
As an example, if the distance on a high-speed flexible PVC line from the hot die to the puller is 50 ft, then the control loop is every 500-750 ft. This means that small diameter or wall-thickness variations will not be corrected within this distance, leading to ►

diminished Cpk quality values and thus not being able to run on the thin side of wall tolerances, notes Bessemer.

"For the last five to 10 years, the ultrasonic units have been enhanced to not only measure the wall thickness but also the outside 'hot' diameter, as the distance can now be measured from the individual transducer face to the outside of the tube," Bessemer explains. "The typical ultrasonic transducer holder is mounted 18 to 20 in. inside the cooling or vacuum tank, which can accommodate a control distance of approximately 24 in. Within the software of these units, the 'hot/ultrasonic' diameter is compared with the 'laser-gauge/cold' diameter reading and then used as a dynamic offset for control. As with the previous example, if we now use, say, 24 in. from the hot die face to the ultrasonic transducer, and apply a 10-15X factor, we end up with a control loop of 20-30 ft. Dramatic improvements have been seen with the ultrasonic control and the associated tube tolerances and Cpks. This has allowed typical tolerances of ±0.001-in. diameter control of tubing with 0.125-in. O.D. at line speeds of 800 to 1000 ft/min or more."

Novatec's Ultrasonic Centering Gauge will also have the potential to take this "hot" control approach one step further, according to Bessemer. "With the holder mounted to the entrance of the water or vacuum tank, the transducers will be within 2-3 in. of the hot die face, which will further reduce the control point to 20-30 in. That will allow even further improvements in tube O.D. and wall-thickness tolerances and precision," Bessemer explains.

Line Layout of Measurement Locations



The position of the ultrasonic transducers can make dramatic improvements in tubing tolerances. Novatec utilizes a dual-loop controller for O.D. and I.D. measurement on both hot and cooled ends. Because O.D. and I.D. can change after the first measurement point due to cooling, etc., the second control loop continually monitors and adjusts the offset in values between the two points.

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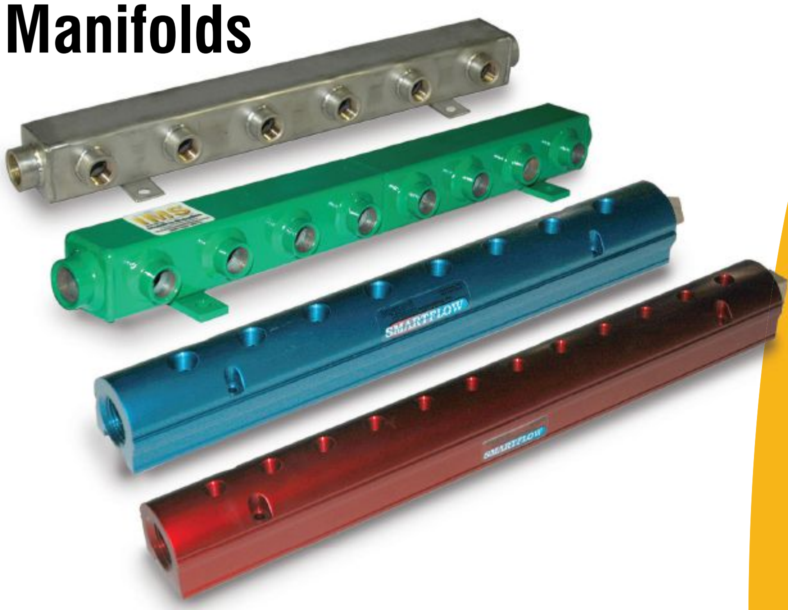

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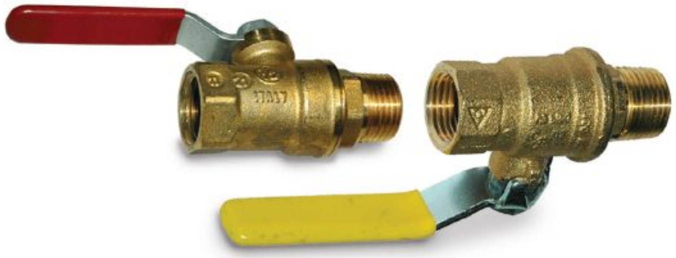

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MATERIALS

PART 1 What Annealing Can Do for Your Process

Relatively rapid cooling rates in processing introduce internal stress. If functional problems in use result, annealing may draw down the stress to levels that may not be achievable during processing.

By Mike Sepe

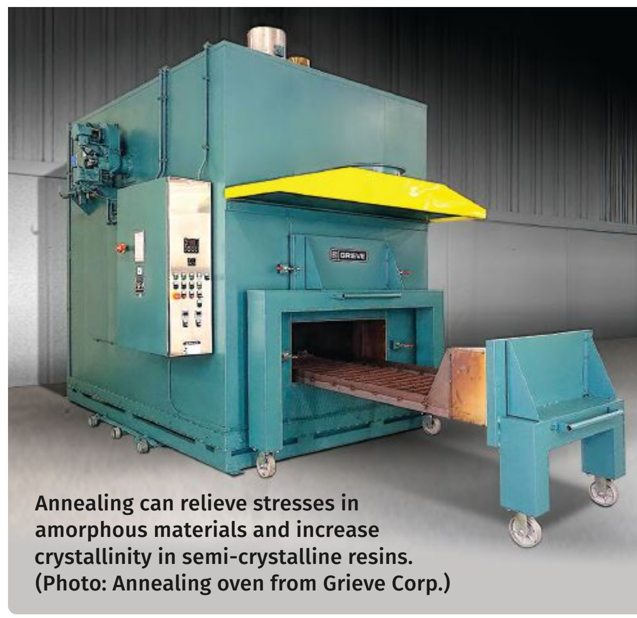
Long before there were plastics there was the process of annealing. The metals industry, and more specifically the steel industry, has known for a long time that conducting a follow-up process that exposes materials to controlled heating and cooling will reduce the hardness of the material, increase ductility, and reduce internal stresses. The microstructure of the material is also changed. Other metallic materials such as copper and brass can also benefit.

Annealing of plastics is not performed as part of most manufacturing processes. There are exceptions. Products of significant thickness such as solid rod, thick-walled tubing and sheet are often annealed as a preparatory step for machining. This is done to stabilize the structure of the material and reduce internal stress, much the same reasons that the process is performed on metallic materials.

Products of significant thickness such as solid rod, thick-walled tubing and sheet are often annealed as a preparatory step in machining.

In all products fabricated by melt processing, the relatively rapid cooling rates that are associated with these processes introduce some level of internal stress and a departure from an equilibrium state. In cases where this produces a level of internal stress that creates functional problems in use, annealing may be performed to draw down the stress to levels that may not be achievable during processing.

The rationale for annealing, and the effect that it has on the material, will depend greatly upon the polymer being annealed. In amorphous polymers, the objective is to reduce internal stress. Parts that are produced in a well-controlled process that gives appropriate attention to the importance of cooling rate may contain internal stresses below 1000 psi. But parts that are rapidly cooled may display internal stresses two to three times higher. The higher the internal stress is, the less capable the product will be of managing external stresses without failing. In addition, failures in parts that contain a high level of internal stress are more likely to be brittle.



Annealing can relieve stresses in amorphous materials and increase crystallinity in semi-crystalline resins. (Photo: Annealing oven from Grieve Corp.)

Even if the application is not expected to involve an elevated level of external stress, high internal stresses can increase susceptibility to environmental stress cracking (ESC). Amorphous polymers are particularly likely to exhibit ESC if they are exposed to certain chemical agents. These chemical agents may be present as solvents, plasticizers, cleaning agents, rust preventatives and adhesives, and prolonged contact of an amorphous polymer with these fluids can result in ESC failures. In these types of environments, annealing can be the difference between success and failure.

In semi-crystalline polymers, the purpose for annealing is fundamentally different. Semi-crystalline polymers are used because of the mechanical and thermal attributes that arise from their crystallinity. The degree of crystallinity governs properties such as strength, modulus, retention of mechanical properties above the glass-transition temperature, chemical resistance,

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fatigue and creep resistance, and tribological properties. Just as internal stresses in amorphous polymers are minimized by slower cooling rates, crystallinity in a semi-crystalline polymer is *maximized* by slowing the rate at which the material is cooled.

But even in the best of circumstances, the cooling rates associated with melt processing result in a part that possesses approximately 90% of the achievable crystallinity. In most cases, this is sufficient. But in those instances where it is not, annealing is performed to provide that additional 10%.

The opportunity for crystal formation occurs in a temperature window below the melting point of the polymer and above its glass-transition temperature (T_g). Consequently, the annealing temperature must be above the T_g in order to achieve the desired result. Optimal crystallization rates are usually obtained near the midpoint between the melting point and the T_g. As an example, nylon 66, with a T_g of 60 C (140 F) and a melting point of 260 C (500 F), anneals most efficiently at around 160 C (320 F).

In crosslinked materials, the annealing process is performed for reasons similar to those that govern semi-crystalline thermoplastics. Just as molding processes struggle to achieve the highest level of crystallization possible, they also do not typically achieve the optimal level of crosslinking. While this may be accomplished by extending the cycle time, the economics often do not favor such an approach and it is more efficient to reheat a large number of parts after molding. In the thermoset industry this is typically referred to as post-baking and it is most often performed on polymers such as phenolics and polyimides.

However, many practitioners in the industry have also found benefits in performing this operation on unsaturated polyesters, epoxies, and silicones. In order for the post-baking process to effectively advance the crosslink density of the material, the temperature of the baking process must exceed the T_g of the polymer in the molded part. As we will see in a later article, there are some thermoplastics that also require post-baking in order to achieve optimal properties.

Some elastomers also benefit from a post-baking or annealing process. As with semi-crystalline thermoplastics and rigid crosslinked polymers, the objective is not reduction of internal stress, but instead a structural rearrangement that improves mechanical and thermal performance. This process can be useful in thermoplastic elastomers such as polyurethanes, and it has also been shown to improve performance in crosslinked systems such as silicone rubber. The process is particularly useful in providing optimal performance in applications where prolonged exposure to elevated temperatures are involved.

In order for these processes to achieve the desired result, the specific conditions of annealing or post-baking temperature and time are critical. Of equal importance in some of these cases is the rate of cooling after the heating process is concluded. Failure to manage this cooling process is often the reason that annealing does not achieve the desired result. This is a parameter that is often overlooked.

In subsequent articles in this series, we will discuss the different requirements that pertain to amorphous thermoplastics, semi-crystalline thermoplastics, crosslinked materials, and elastomers. We will also discuss the limits of this process to achieve positive outcomes without introducing unintended negative consequences. PT

ABOUT THE AUTHOR Mike Sepe is an independent, global materials and processing consultant whose company, Michael P. Sepe, LLC, is based in Sedona, Ariz. He has more than 40 years of experience in the plastics industry and assists clients with material selection, designing for manufacturability, process optimization, troubleshooting, and failure analysis. Contact: *(928) 203-0408 • mike@thematerialanalyst.com*.

INJECTION MOLDING

The Cosmetic Process Window: Key to a No-Tweak, Robust Process

Establishing a process with the widest possible cosmetic window can help put your injection molding on cruise control.

By Suhas Kulkarni

You've just finished molding parts from a tool hung in the press this morning, and you have submitted first shots to the quality inspector for dimensional verification. What is the first thing that the inspector is going do? Is she going to pick up a pair of calipers and start measuring the parts right away, or is she going to first inspect the parts for any cosmetic defects? If the parts are short or if they have flash, there is no chance you are going to convince the inspector to measure the parts.

How about another scenario: You'd like to drive your car in cruise control at 80 mph for 4 hr at a stretch. Given a choice between a narrow and winding road at the edge of a cliff and a straight road with a wide lane, which would be your choice? The answer is obvious! If you choose the edge-of-the-cliff road, it's very likely that at some point you will fall off the cliff. Even if you do manage to finish this journey, that doesn't mean you'll be successful during future journeys. Also important: the cliff journey is stressful. You have to pay constant attention to the road, with no room for any deviation from the settings. You can never take your eyes off the road and will have to monitor the drive constantly .

In injection molding, we often find ourselves in similar situations. If the parts are short at a pack-and-hold pressure of 3750 psi (plastic) and cosmetically acceptable at 4000 psi but will flash at 4500 psi, the window to mold parts with acceptable cosmetics is very small. The window inside which cosmetically acceptable parts can be molded is defined as the Cosmetic Process Window (CPW). In this case, if the job is a week-long run of a 100,000 parts, there is a very high probability of molding short shots or parts with flash. The frequency of parts inspection will need to be higher.

Unfortunately, "100% inspection" is more common than we think. Processes with smaller cosmetic windows require constant attention by process engineers, equivalent to driving a car at 80 mph at the edge of the cliff. Just as driving a car 80 mph along a cliff's edge for 5 min does not guarantee you can do it for 4 hr and all future journeys, similarly, successfully molding 10 parts and assuming that you can then run 100,000 parts with no issues is also a myth. We have to understand short-term variation and long-term shifts. The molding process must be robust enough to capture these variations and shifts.

FIG 1 Parts Molded with Varying Pack-and-Hold Pressures

Short Shot/Sink | **Acceptable** | **Flash**

Parts from the same mold, molded at three different pack-and-hold pressures, yield parts that are short with sinks, parts that are cosmetically acceptable, and parts that have flash.

Figure 1 shows parts from the same tool molded at three different pack-and-hold pressures, yielding parts that are short with sink, or are cosmetically acceptable, or have flash. The pres-


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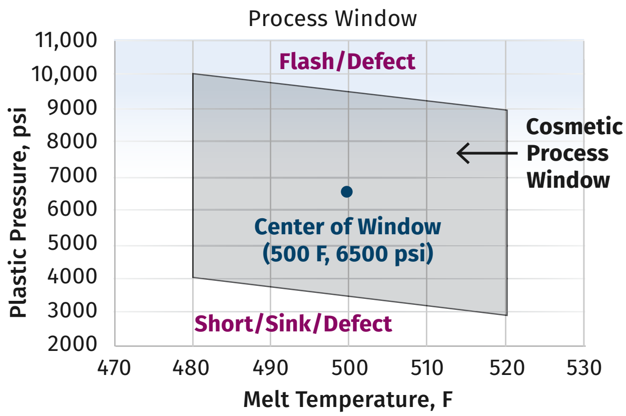
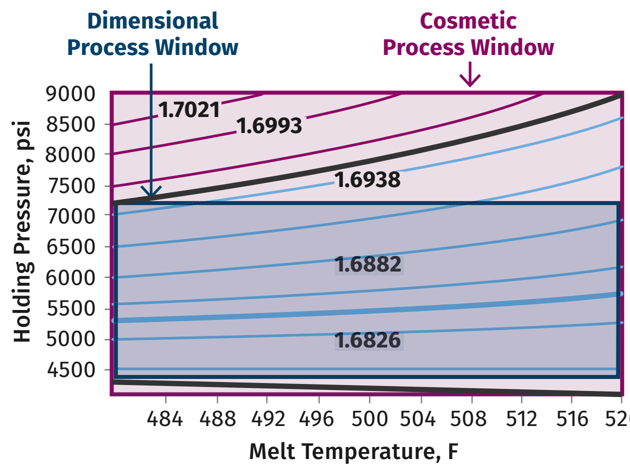
FIG 2 The Cosmetic Process Window



Process window study was done at melt temperatures of 480 F and 520 F, the high and low recommended on the plastic (ABS) data sheet. At 480 F, parts molded below 4000 psi yielded shorts and sinks, and parts molded above 10,000 psi yielded parts with flash. Parts molded between 4000 psi and 10,000 psi were free of sink, flash or short shots.

FIG 3 Cosmetic Process Window & Dimensional Process Window



Molding at the center of the dimensional process window will yield a robust process. On each side of this setting there is plenty of room for variation and shift.

sures mentioned in this article are plastic pressure values (not hydraulic pressures). A Process Window Study was done at melt temperatures of 480 F and 520 F—the high and low recommended by the data sheet for this ABS. At 480 F, parts molded below 4000 psi yielded shorts and sinks, and parts molded above 10,000 psi yielded parts with flash. Parts molded between 4000 and 10,000 psi (inclusive) yielded parts that were free of sink, flash or short shots. The same study was repeated at 520 F, and the pressure limits were found to be 3000 and 9000 psi. These four data points form the Cosmetic Process Window (CPW). Parts molded within the CPW are cosmetically acceptable (Fig. 2). We are not considering dimensions when performing this study.

Successfully molding 10 parts and assuming you can then run 100,000 parts with no issues is a myth.

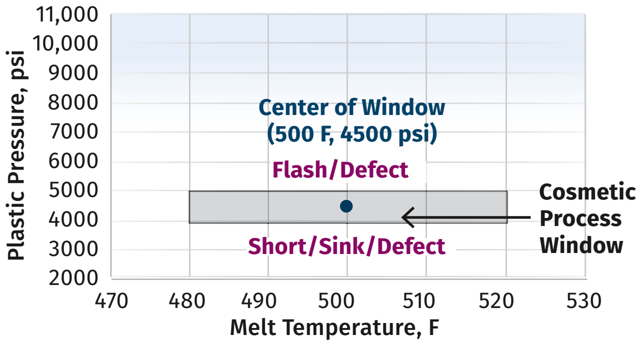
Going back to the analogy of choosing the road to drive on and looking at the CPW, it becomes clear that the choice of molding conditions would be the center of the window. In this case, that results in a melt temperature of 500 F and 6500 psi of pressure. Setting the process at these conditions and having a wide process window will ensure that the molded parts will always be cosmetically acceptable. Any natural variations and shifts around these settings will get cushioned in not requiring any tweaking by the process engineer. A wide process window is key to process robustness.

Only after this study is done should a molder look at part dimensions. Part dimensions are a function of shrinkage, which is based on the Pressure-Volume-Temperature (PVT) relationship for the given plastic. Shrinkage here is related to volume, and the given volume is dependent on pressure and temperature. Therefore, pack and hold pressures and melt and/or mold temperatures are the main factors that affect the part dimensions. There are several other factors that affect the dimensions, which will be discussed in a later article. The technique of Design of Experiments (DOE) is used to evaluate the dimensions. During a DOE, parts are molded at the four corners and the dimensions are plotted as contour plots inside an inscribed rectangular window.

In Fig. 3, the diameter of the wheel considered for the CPW study is plotted from the DOE results. The nominal value is 1.685 in. with a tolerance of 0.006 in. on the lower side and 0.009 in. on the upper side. The outside box is the CPW, and the inside box that was drawn based on the blue contours is the Dimensional Process Window (DPW). The heavy blue line is the nominal value, and clicking anywhere on the line will give the combination settings of the pack-and-hold pressure and the melt temperature to produce parts at the nominal value. For the DPW, the lows and highs for the pressure are 4250 and 7250 psi and 480 F and 520 F for the temperature. The center of the window is 5750 psi and 500 F. Molding at the center of the window will again give us a robust process, since on either side of this setting there is plenty of room for any variation and shift.

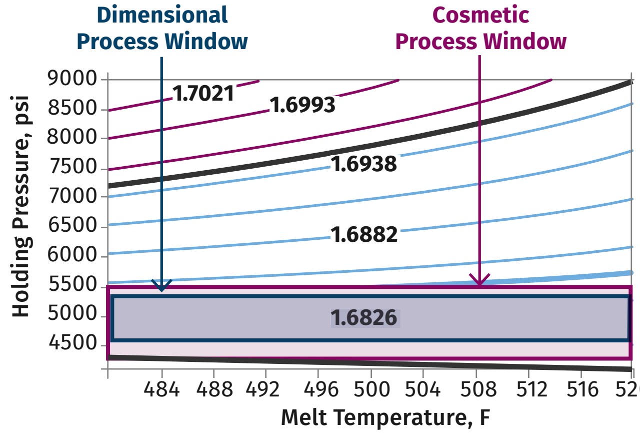
Now consider this same mold but with a small cosmetic process window. The temperatures used and the low pressure of 4000 psi are still the same, but the mold starts to flash at 5000 psi (Fig. 4). Since the DPW is a subset of the CPW, the DPW is now very small, as far as the pressure is concerned (Fig. 5). The center would be 4500 psi, and we could mold acceptable parts for a short time, but over

FIG 4 The Pack-and-Hold Phase: The Cosmetic Process Window



Parts here are molded in a hypothetically narrow cosmetic process window. The temperatures used, and the low pressure of 4000 psi are still the same, but the mold starts to flash at 5000 psi.

FIG 5 Narrow DPW Resulting from Narrow CPW



A narrow dimensional process window results from a narrow cosmetic process window.

a week-long run—because of natural variations in the machine, material, environment (including personnel)—it is very likely that parts could be molded that are short, out of spec on the lower side, or have flash. If the parts are cosmetically acceptable but have dimensions below the lower spec limit, increasing the pressure could cause flash. We are once again driving the car on the edge of the cliff, and 100% inspection is now required.

The discussion above therefore mandates a wide DPW for a robust process. Since the DPW is a subset of the CPW, the CPW also must be wide. The natural variation will get cushioned in a production run. Over time, the mold components will wear, the gates will wear, the vents will start getting crushed, the material lots will vary, and the part quality can shift. Results from the DOE will let you make data-driven decisions to change the process and still mold parts within the specifications.

It is therefore the area of the CPW that is the critical first step to achieving a robust process, zero defects, reduced inspection and no process tweaking.

ABOUT THE AUTHOR: Suhas Kulkarni is president of Fimmtech Inc., which specializes in services and training related to plastic injection molding. He earned his Masters in Plastics Engineering from the University of Massachusetts, Lowell, as well as a Bachelors in Polymer Engineering from the University of Poona, India. He has 27 years' experience as a process engineer and is the author of *Robust Process Development and Scientific Molding,* published by Hanser Publications, now in its second edition. He also works as a contract faculty member at U.Mass.-Lowell. Contact: *suhas@fimmtech.com*; *fimmtech.com*.

EXTRUSION

Important Polymer Melting Equations for Extrusion Processors

The more you know about what happens in a screw, the more you'll be able to work with your supplier to optimize design.

By Jim Frankland

A major step in the history of the design of extrusion screws took place in the early 1960s as a result of research work done by Western Electric Co., the former manufacturing side of the Bell System and later AT&T. Some aspects of single-screw extrusion—such as output, polymer flow properties and power calculations—had already been well developed by a number of other researchers, but a complete analysis of the extrusion process, particularly melting, was still needed.

I worked for a major polymer producer at that time and remember doing multiple "push-outs" of full screws in the lab to explore early theories of melting. But even when the basic principles could be seen, the complexity and amount of calculations involved for a complete screw analysis were so complicated that it was completely impractical to execute them without a computer. The wider availability of computers at that time allowed for a more complete analysis as polymer progressed down the screw channels. Formulas for the computer programs were adjusted, readjusted, and then readjusted again by Western Electric researchers until they closely matched actual lab results. This then evolved into a full length computer analysis. Today's analysis is still very similar to that developed by the Western Electric researchers.

The melting rate is directly proportional to the square root of the width of the solid in contact with the barrel wall.

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Equations for many aspects of extrusion screws were developed and later published by Imrich Klein and Zehev Tadmor, two of the principle researchers at Western Electric, in their book *Engineering Principles of Plasticating Extrusion*. I used the programs developed by Klein and Tadmor for a number of years before developing some approximation techniques.

As an example of how their formulas can help explain many things, the melting-rate equation shows the importance of the solid-bed width (X) against the barrel wall as well as the effect of other variables necessary for the melting calculation.

Melting rate (ω) = $\{ V_{bx}\, \rho_m\, [\, K_m(T_b\text{-}T_m) + (\mu/2)\, V_j^{2})\,] \div 2\, [\, (C_s\, (T_m\text{-}T_s) + \lambda\,]\, X \}^{1/2}$

If we let $\Phi = \{ V_{bx}\, \rho_m\, [\, K_m(T_b\text{-}T_m) + (\mu/2)\, V_j^{2})\,] \div 2\, [\, (C_s\, (T_m\text{-}T_s) + \lambda \}$, or all of the melting equation inside the brackets, then:

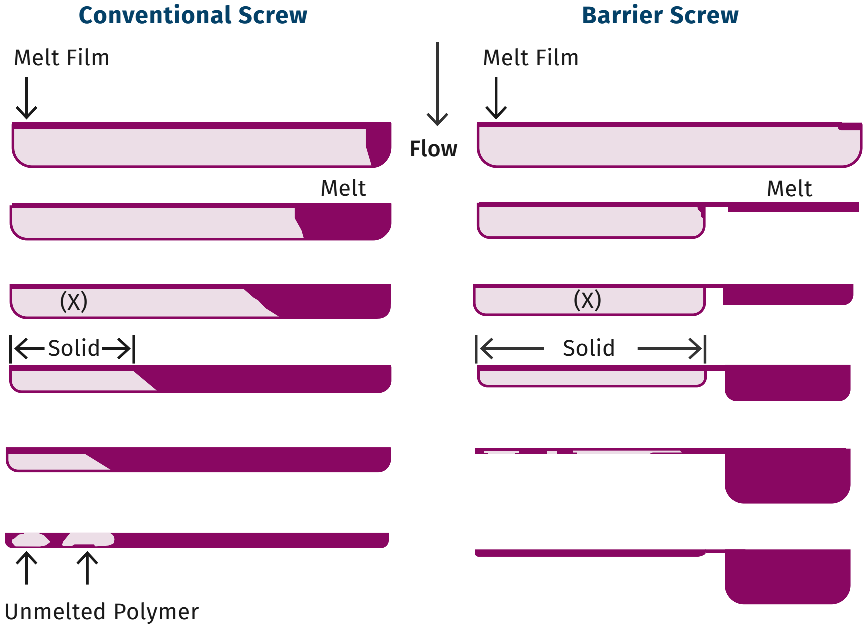
$\omega = \Phi X^{1/2}$ where X is the width of the solids in the channel

That says, for a given screw geometry, screw speed, location and specific polymer, the melting rate at any point is directly proportional to the square root of the width of the solid in contact with the barrel wall.

Other parts of the equation offer more explanation of the melting process:

V_{bx} = Velocity parallel to the screw
ρ_m = Density of the melt
K_m = Thermal conductivity of the melt
T_b, T_m and T_s = Temperature of the barrel, melt and solid respectively
μ = Viscosity at shear rate and temperature of the melt film over the solid bed
V_j^2 = Velocity difference through the melt film
C_s = Specific heat of solid polymer
λ = Heat of fusion (only for crystalline polymers)

Melt Flow Patterns in Conventional vs. Barrier Screws



In a conventional screw, the "melt pool" width increases as it moves down the barrel. Barrier-type screws allow the melted polymer to flow over the increased clearance of the barrier flight and accumulate in a separate channel, thereby keeping the area that the unmelted polymer is in contact with the barrel wall quite constant. As a result, the melting rate is also quite constant throughout the barrier section, unlike in a conventional screw design.

By substituting actual values into this equation you can see for yourself the relative effectiveness of each variable. For example, $K_m(T_b-T_m)$ and $C_s(T_m-T_s)$, which define the heat transferred into or out of the polymer from the barrel and screw, are usually very small because the melt transfers heat to the barrel and it quickly approaches the melt temperature. That's due to the poor thermal conductivity of the polymers and the short time the polymer is typically in the barrel under production conditions.

The melting rate is constant throughout the barrier-section length, unlike a conventional screw design.

For example, the thermal conductivity of steel is 54 (BTU/ft-hr-°F) and of polypropylene is 0.57 (BTU/ft-hr-°F), or about 1/100 that of steel. As a result, the polymer does not absorb much heat from the barrel or give up much heat to it. Many operating personnel think they control melting rate with the barrel temperatures. However, the viscosity at the appropriate shear rate and approximate temperature (μ), as well as the screw-channel velocity terms (V_{bx} and V_j^2), are usually the predominant factors. That says that polymers with highest viscosity at the operating shear rates (screw speed) have the greatest energy input per unit surface area during melting.

Such design estimates necessitate the availability of shear-rate/viscosity curves, as well as density and thermal data, for the particular polymer being processed. But even without a computer simulation system, a great deal can be learned from the formulas developed for the computer programs.

To illustrate how knowledge of the basic formulas helps, we know that barrier-type screws have proven to have greater melting capability than conventional screws. In a conventional screw the melted and unmelted polymer coexist in the same channel. Melting occurs primarily at the barrel wall due to shear between the solids in the rotating screw and the stationary barrel wall. Again, transferred heat from the barrel constitutes a relatively small part of the necessary energy once the screw is in operation.

As seen in the illustration above, a conventional screw has the melt or "melt pool" width increasing as material moves down the barrel, and eventually melt fills most of the channel as melting progresses. One of the principles of barrier-type screws is they allow the melted polymer to flow over the increased flight clearance of the barrier flight and accumulate in a separate channel, thereby keeping constant the area that the unmelted polymer is in contact with the barrel wall. As a result, the melting rate is also quite constant throughout the barrier section, while the conventional screw has a generally decreasing melting rate due to the enlarging melt pool as material moves down the screw.

This explains why barrier screws are considered high-performance designs for melting, compared with conventional designs, and why understanding of the basic equations is very helpful in screw design with or without a computer simulation program.

ABOUT THE AUTHOR: Jim Frankland is a mechanical engineer who has been involved in all types of extrusion processing for more than 40 years. He is now president of Frankland Plastics Consulting, LLC. Contact *jim.frankland@comcast.net* or *(724)651-9196*.

COMPOUNDING

PART 2

Demystifying Devolatilization

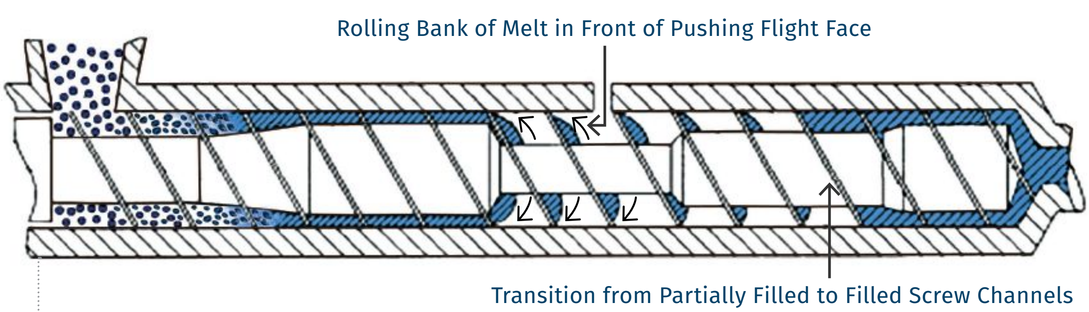
Here are some simple tools to help monitor and optimize your devolatilization process.

It is instructive to break apart the controlling variables for devolatilization into machine-design parameters and thermodynamic variables. This helps deconvolute the problems and makes the controlling mechanisms a bit clearer in the mind of the designer and operator.

By Robert Jerman

MACHINE PARAMETERS

Devolatilization is the process by which solvents or dissolved gases are stripped from a polymer solution or melt. Devices employed for devolatilization are wide ranging in design, from falling-film evaporators to multi-screw extruders, but the guiding principles remain the same. One must create a vapor space above the polymer melt or solution and provide mechanical means for regenerating surface area. In that vapor space, one needs to create conditions that favor movement of volatiles from the melt to the vapor.



Single-screw devolatilizing extruder with rolling banks of polymer.

While quantification of the devolatilization process is very challenging, the nature of the process lends itself to grouping two sets of parameters: mechanical and thermodynamic. The mechanical variables are equipment design parameters that link the geometry with three key process metrics:

- Surface area and rate of regeneration;
- Residence time;
- Distributive mixing.

Why is surface area so important? Imagine two cups of water of equal volume, taken from the same tap at the same temperature, and placed on a table in a room. Now, one of those cups is spilled out over the table while the other is left in the cup. We all know that if we return to that room after several hours, that water poured on the table will be largely gone, while the water in the cup will still be largely as we left it. The difference is surface area. A gallon of paint in a can be left open for hours and remain fluid and serviceable. Spread that same paint over a wall, and within a few hours it is dry and ready for pictures and curtains. Again, the difference is surface area.

A volatile species will leave a solution only at a gas/liquid (or gas/melt) interface. The larger the interface, the faster the loss of the volatiles. In the example of water on the table, it need not be above its boiling point and in that case is only at room temperature. It need only have sufficient area and a concentration gradient—the water on the table dries faster on a dry day than on a humid day, the difference being concentration of water vapor in the air.

So, if surface area is so important, why do we need distributive mixing and surface-area regeneration? The accompanying image shows a profile view of a venting zone in an extruder screw. The channels are partially filled with melt, and it is easy to imagine that the surface of the melt is continually refreshed as the screw rotates. Arrows indicate the direction of the refreshed surfaces on the rolling banks of melt in the partially filled screw channels. Because of the relatively slow rates of diffusion of the volatiles through the melt, only the molecules very near the surface will escape to the vapor phase. If one were to rely on diffusion of the volatiles through the melt, devolatilization (DV) would take weeks or months rather than seconds.

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Instead, we help mother nature along by continually bringing fresh material to the surface of the channel via surface-area regeneration, and by ensuring a homogenous mixture in the channel itself by optimizing distributive mixing.

The focus on distributive mixing may seem a bit misplaced at first, but it is important to remember that as the layer immediately at the surface of the melt is depleted of the volatile components, the devolatilization process shuts down unless that surface is replaced with fresh melt. The diffusion rate of volatiles in the melt relative to the short time in a DV zone is such that a high degree of mechanical mixing needs to occur, coupled with surface-area regeneration to keep the stripping process at its highest rate.

Unfortunately, options for mixing are limited, because one cannot simply put in kneading or other non-conveying elements, as that would risk material backing up into the vent. Instead, we optimize the turnover in the channel, exchange between screws in a twin-screw extruder, and the time in the DV zone. Screws in typical DV sections, whether single- or twin-screw, are partially filled and experience laminar flow, meaning that bringing fresh material to the surface of the rolling bank can be accomplished only through high rates of laminar mixing. Multiple flights, more steeply pitched screws, and interruptions in flights all contribute to maximizing the rate of bringing fresh material to the surface.

What is important to note is that these are all predictable parameters, without having to model bubble nucleation, growth, and rupture. One knows that surface area is important and that the rate of generation of surface area is important. Regardless of bubbles or no bubbles, nothing leaves the melt unless it is at a melt/gas interface.

A volatile species will leave a solution only at a gas/liquid (or melt) interface. The larger the interface, the faster the loss of the volatiles.

For example, one can write a simple relationship for generation of surface area per unit time as a function of the number of channels, the geometry, and the screw speed. It is important to remember that the total surface area is the film deposited on the barrel wall, along with the face of the rolling bank of polymer.

These simple relationships show that the rate of surface-area generation increases with the number of channels, screw speed, and decreased degree of channel fill. The pitch of the screw, generally set as a square pitch (one turn of the flight in one diameter of the screw) can be altered to a steeper pitch to improve surface-area generation. This is embedded in the helical length of the zone Z as shown here:

$SA_c = (V_y) \times (nZH)$ (surface area/unit time in channel)
$SA_b = (1-f)W \times nZ \times N$ (surface area/unit time on barrel surface)
W = channel width
f = fill fraction
Z = helical length of zone
N = screw speed
n = number of channels
H = channel depth
V_y = rolling-bank face velocity

Similar relationships may be developed for residence time in the zone, which contributes to both mixing and surface-area generation. It stands to reason that the longer the polymer is in the vented section, the more volatiles will be removed.

THERMODYNAMIC VARIABLES

The thermodynamic variables (the mere word strikes fear into the hearts of many of us) come down to maximizing the driving force for volatiles to leave the melt or solution and enter the vapor space above the melt.

While thermal energy is one of the primary drivers for devolatilization, too high a temperature for too long a time will harm the polymer in other ways, leading to oxidative degradation, etc.

The controlling thermodynamic mechanisms change as the concentration of the volatile component changes. Very high concentrations of solvent or monomer behave much like a boiling process. Here the controlling mechanism is driving heat into the melt or solution and allowing a rapid decompression. The elements of the screw design have little impact on this, other than to knock down the foam and prevent flying polymer in the vents.

As the concentration of volatiles diminishes, the mechanism moves to a diffusion-controlled mechanism. There is lots of discussion about superheat in the literature and while sufficient energy must be applied to overcome the heat of vaporization etc., this is seldom the limiting step other than in the initial venting operation for a low-solids feed. Instead, the controlling mechanisms are the aforementioned surface-area generation coupled with the partial pressure of the volatilizing species.

Partial pressure is a critical variable in predicting the separation of a gas from a polymer melt. Gases will want to equalize their pressure between two phases that are open to one another. A gas will move from an area where its partial pressure is higher to an area where its partial pressure is lower. In addition, the greater the partial-pressure difference between the two areas, the more rapid is the movement of gases.

The movement from the melt to the vapor space above the melt is dictated by the solubility of the gas in the melt and the partial pressure of that component above the melt. This is the fundamental relationship spelled out in Henry's law, which one may remember from high school or college physics. Henry's law states that the concentration of gas in a liquid is directly proportional to the solubility and partial pressure of that gas. The greater the partial pressure of the gas, the greater the number of gas molecules that will dissolve in the liquid. The concentration of a gas in a liquid also depends on the solubility of the gas in the liquid.

The Flory-Huggins equation shows the relationship between how much of a volatile component wants to stay in the melt and the vapor pressure above the melt. While neither the Flory-Huggins equation nor Henry's law are directly applicable to a DV vent, qualitatively they can teach a lot:

$$\log(P_1/P_{01}) = \log(1-V_2) + V_2 + XV_2^2$$

P_1 = vapor pressure above the melt
P_{01} = vapor pressure of pure substance at the temperature under consideration
V_2 = volume of polymer in binary mixture
X = Chi or Flory-Huggins parameter

Very high concentrations of solvent or monomer behave much like a boiling process.

From the thermodynamics side, one simply wants to eliminate as much of the volatile component from the vapor space above the melt as possible. This translates into:

- As high a vacuum level as conditions will permit;
- Use of inert sweep gases (nitrogen) to further reduce the concentration of the stripping species above the melt;
- Put energy into the melt to compensate for cooling created by the stripping action.

One can condense all the math into some simple rules of thumb:

- Maximize surface area and regeneration of surface area.
- Ensure the highest degree of distributive mixing in the partially filled channels.
- Reduce the concentration of the volatile species above the melt by employing high vacuum levels and possible sweep gases.
- Stage the stripping (multiple vents) to reflect the changes in controlling mechanisms.
- Keep the viscosity low to minimize degradation.
- Keep oxygen out of the system to minimize degradation.

PRACTICAL MATTERS MATTER

There are a variety of practical aspects for good devolatilization performance, including having the proper number of stages, preventing polymer buildup in vents, flying polymer, and cooling of the melt as a result of too rapid a stripping action. There are several continually recurring themes for poor devolatilization. These include:

- **Flying polymer:** When the rate of volatile removal is high, devolatilization is more of a boiling process, generating significant amounts of foam and bubbles. As the solution decompresses, gases escape, bubbles are formed and rupture, and there is significant loss of temperature due to the cooling effects of the heat of vaporization of the volatilizing species. This often results in the foam solidifying and coming off the screws and being entrained in the venting system, with all the expected undesirable consequences. Allow sufficient screw length after the upstream seal prior to the vent opening to allow the screws to break down the foam and reheat the melt.

- **Polymer backing up into the vent:** This is a result of too long a filled length (or too short a pumping section) downstream of the vent prior to the downstream seal. Increase the screw speed, improve the pumping efficiency of this section (shallower screw channel), or simply increase the length of screw between the vent opening and the downstream seal. Decrease the pressure drop over the downstream seal so there is less of a ΔP to pump against.

- **Thermal regeneration:** Stripping large masses of volatiles will significantly cool the melt, perhaps not to the point of solidification, but certainly to the point where further volatilization is impaired. The pumping section and the melt seal downstream of a venting section can be designed to impart more viscous heating to

Leaking systems, inadequate vacuum levels, or the wrong types of vacuum pumps can all dramatically reduce the performance of a vent.

the melt so that the subsequent DV zone operates more efficiently.

- **Poor vacuum:** Leaking systems, inadequate vacuum levels, or the wrong types of vacuum pumps can all dramatically reduce the performance of a vent. We focus on the extruder while often ignoring the ancillary components that are equally important to this stripping operation.

- **Too much in one step:** There are practical limits to the reduction in volatiles that can be accomplished in one zone. The beauty of an extruder, especially a twin-screw, is that you can stage the devolatilization vents and optimize the performance of each one. It is not realistic to expect to remove much more than an order of magnitude in concentration per vent—and not necessary, either. Stage the stripping, because it allows the greatest process flexibility and greatest turn-up and turn-down ratios for the extruder.

- **Creating new volatiles:** Understand the degradation mechanisms for your polymer. Be careful not to subject the melt to conditions that will cause it to unzip, as it is a battle you will not win. Avoid oxygen, and design the stripping stages so that the last vent before discharge is operating at close to capacity. This maintains a lower viscosity throughout the machine and minimizes degradation in the extruder.

WHAT DEVOLATILIZATION DOES *NOT* DO

We have discussed how DV works and how to improve DV performance, but it is worth noting that there are limits to what DV can remove.

What devolatilization will *not* do is remove non-volatile contaminants from a polymer melt. Larger molecules, dimers, and trimers that have a high boiling point and/or low vapor pressure will not be extracted by devolatilization and must be removed via extraction or reactive processes. The higher the boiling point of a contaminant, the higher the melt temperature and rates of surface-area regeneration, and the lower the partial pressure must be to strip those materials. PT

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TOOLING

PART 2

How to Properly Size Gates, Runners and Sprues

Get the sprue, runner and gate sizes close to ideal the first time around.

Last month, I discussed the importance of proper gate depths and gate widths. This month, I will focus on two types of gates, as well as gate land length and gate-freeze time.

By Jim Fattori

SUB-GATES

There are several different types of sub-gate shapes, as mentioned in my January 2018 article, "Tunnel Gates for Mold Designers." The most common ones are conical because they are the least expensive to machine. "D"-shaped and chisel-shaped sub-gates are also very common.

To determine the size of a conical sub-gate, start by assuming the part was going to be edge gated. Using the guidelines discussed in last month's column, estimate the gate depth and width. Multiply the depth times the width to get the flow area. Then convert this area into a diameter. That way, the sub-gate diameter has an area equivalent to an edge gate. The formula is:

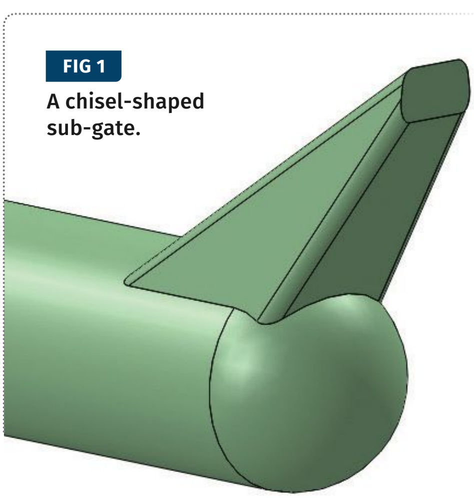
Sub-Gate Diameter= $\sqrt{(\text{Edge Gate Depth} \times \text{Width} \div \pi)} \times 2$

For conical or "D"-shaped gates, this diameter is the size of a gauge pin that can fit through the hole. It is the minor diameter of the elliptical sub-gate scar. It is not the major diameter of the ellipse, nor the entire area of the ellipse, or "D" shape. If you think about it, this is similar to comparing the flow area of a full-round runner to a trapezoidal, parabolic, or any other runner shape.

While conical and "D"-shaped sub-gates are the most common, they are the least desirable. You cannot control the gate-freeze time and material flow rate through the gate independently. If you have a long flow length, the sub-gate would need to be larger to fill the cavity. This causes the gate-freeze time to be needlessly longer. The preferred type of sub-gate is chisel shaped, as in Fig. 1. The gate depth and width you want for a chisel-shaped sub-gate are the same dimensions you would use for an edge gate. This allows you to control the gate-freeze time and the flow length independently without having to extend the cycle time. Another advantage to the chisel sub-gate is that it leaves a smaller gate vestige than a conical sub-gate, especially when the gate is located on a wall that has a steep taper or a radiused surface. It also has less chance of producing mold-damaging flakes.

FIG 1

A chisel-shaped sub-gate.



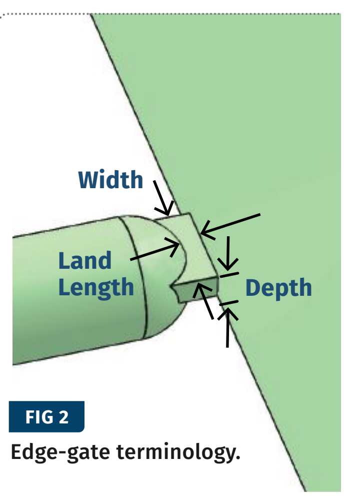


FIG 2

Edge-gate terminology.

DIRECT SPRUE GATES

Direct sprue gating is used in single-cavity molds. There is no runner or a conventional gate. The sprue-bushing orifice on a direct-gated part is effectively the gate. The sprue-bushing orifice size is one of the least understood dimensions in mold designs—especially with direct-gated parts.

Sizing a direct sprue-gated part can be a difficult challenge. Ideally, you want the outlet diameter of the sprue bushing where it meets the part to be about 1.5 times the wall thickness of the part. For example, if the part had a wall thickness of 0.100 in., the outlet diameter of the sprue bushing would be about 0.150 in. If it is much larger than that, it will cause the cycle time to be extended, because the pack pressure and hold time must be

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high enough and long enough to prevent a sink mark on the opposing surface of the part. It can also be a challenge to prevent blush on the surface—especially since direct-gated parts usually don't have a cold well to catch and retain a cold slug from the machine-nozzle tip.

When considering what the inlet, or "O"-orifice diameter should be, I start by considering what size would I use if the part were edge gated, just like I did in the previous sub-gate example. That makes it easy to determine what the minimum orifice size should be. Let's assume that if the part were edge gated the gate would be 0.050 in. deep × 0.200 in. wide. The flow area is therefore equal to 0.050 in. × 0.200 in. = 0.100 in^2. An equivalent diameter would therefore be the square root of $(0.100 \div \pi) \times 2 = 0.113$ in.

The sprue-bushing orifice on a direct-gated part is effectively the gate.

So now we know the "ideal" inlet and outlet diameters of the sprue bushing for this direct sprue-gated part. Achieving these values is going to be based on the length and internal taper of the sprue bushing—and that's where things get challenging, if not impossible. In this example, to have an inlet or "O" diameter of 0.113 in. and an outlet diameter of 0.150 in., a sprue bushing with an industry-standard internal taper of ½ in./ft (2.386° included) would only be about 0.89-in. long. That's probably not going to be long enough to go from the face of the injection clamp plate all the way down to the part. You can often minimize the overall length of the sprue bushing by counter-boring the clamp plate and sometimes a portion of the cavity plate.

I once mounted the underside of the head of a sprue bushing directly against the back of a cavity insert. The nozzle contact pressure from the machine's barrel was strong enough to snap the bolts and push the cavity insert out of its pocket and onto the floor. The larger the machine, the larger the nozzle contact force. Therefore, if you go this route, select the size and quantity of bolts retaining the insert with this in mind.

You can also make a custom sprue bushing and reduce the internal taper from the standard 2.38° included, to just 1° to 2° included. Base your decision on what angle you think you can get away with on the thickness of the sprue and the shrinkage rate of the material. The best way to make a custom sprue bushing is to buy a stock sprue bushing with a smaller "O" dimension. The smaller orifice becomes the starter hole for wire EDM-ing the bore to the desired size and taper.

You don't want to reduce or increase the sprue's estimated "O" dimension, which controls the required injection pressure and the gate-freeze time. If the length is a problem, the only thing you can do is live with a larger outlet diameter. In order to minimize the increase in cycle time, the sprue bushing needs direct cooling. Indirect cooling via water channels near the sprue bushing is usually not very effective—unless the sprue is cut directly into the cavity insert, meaning there is no separate sprue bushing. Using a sprue bushing made of a copper alloy, or one that is conformally cooled, will be very helpful.

Gate land length has a direct effect on material viscosity.

Unfortunately, many direct sprue-gated parts are inject/eject on the same side (reverse ejected), and the sprue bushing is extremely long. The best solution in a case like this is to consider using a hot bushing. If you think that the cost of a hot sprue bushing is prohibitive, the accompanying table details the number of cycles it takes to recoup their average cost. The ROI is based on the hourly machine rate and the expected cycle-time savings. Once you reach the ROI cycle quantity, the profit on the molded part increases from there on in.

These are conservative numbers because they do not factor in the material saved and the possibility of reducing the labor requirements. It also doesn't factor in the reduced scrap rate. Try to order hot sprue bushings that leave a small cold sprue and have a replaceable tip. That way you can buy tips of different length to put the same bushing in different molds for even more savings. Lastly, whether you have a cold sprue or a hot sprue bushing, add a 0.005-in. to 0.025-in. radius at the outlet of the bushing. Thermoplastics don't like sharp corners of any kind.

EDGE-GATE LAND LENGTH

In order to discuss edge gates, we need to first discuss land length. The land length for an edge gate is a short straight section connecting the outer surface of the part to the runner, as shown in Fig. 2. A gate's land length has a direct effect on the viscosity of the material. Longer lands impart more shear on the material, which in turn reduces the material viscosity. That can be beneficial, if not necessary, to help improve the flow length into the cavity. Long land lengths can also be detrimental and create burns with shear-sensitive materials, such as PVC.

The longer the land length, the greater the pressure required to push the material through the gate—like breathing through a long straw versus a short straw. However, since long lands reduce the viscosity of the material, it takes less pressure to fill the cavities—especially at high injection velocities.

There is an old rule of thumb that says the gate land length should be half the depth of the gate. This is yet another "rule" that you would be wise to forget. I have seen molds with zero gate land, and I have seen molds with lands over 1½ in. long. Both worked just fine for their particular application. The general consensus among industry experts is that a gate's land length should be between 0.020 in. and 0.045 in. That's a pretty good general rule, but rules always have some exceptions, which unfortunately are rarely mentioned.

Your decision on how long to make the gate land should be based on the expected injection velocity. If you are going to inject extremely fast, such as with a thin-walled part having a shallow gate depth, a short land length is usually necessary. If you are going to inject extremely slowly, such as with a thick-walled part having a very deep gate, the land length can be considerably longer, because there is very little pressure loss going through that gate. The ideal land length is also somewhat material dependent. Always review the material manufacturer's design guidelines, but keep in mind that most design guides are general in nature.

It is always best to start with a slightly longer gate land. If there is an issue with either high shear or high injection pressure going through the gate, it is steel-safe and you can reduce it. Don't make the molder have to process around an incorrectly sized gate. The resulting processing window will be narrow and the likelihood of rejects will increase exponentially. Whatever you do, just make sure all of the gates in a multi-cavity mold have the exact same gate depth, width and land length. Otherwise, you will get a cavity imbalance.

ROI Cycles for a Typical Hot Sprue Bushing

	Hot Sprue Bushing Cost Installed				$1000
	Machine Rate with One Operator, $/hr				
Seconds Saved	$40	$60	$80	$100	$120
	Cycles to ROI				
1	90,000	60,000	45,000	36,000	30,000
2	45,000	30,000	22,500	18,000	15,000
3	30,000	20,000	15,000	12,000	10,000
4	22,500	15,000	11,250	9000	7500
5	18,000	12,000	9000	7200	6000

GATE FREEZE

In May 2000, Bill Fierens (now sr. technical development engineer at M. Holland Co.) and Sean Mertes (now application development engineer at Amco Polymer) presented a paper at the SPE ANTEC on "Gate Land and its Effects on Gate/Cavity Pressure Loss." The paper briefly asserted that short lands can increase the gate-freeze time. I spoke with both authors, and while there is no empirical data to support this statement, we all believe it to be true for two primary reasons. First, short lands have less steel in the gate area, and area is a primary variable in the mathematical equation for calculating the rate of heat transfer by conduction. Second, the shorter the land length, the closer the runner is to the gate—putting additional heat into this critical area. Additionally, if the wall of the molded part is

thick, it also puts additional heat into the critical area. As mentioned before, thick-walled parts or parts with large round runners can require longer lands.

While I am certain that a gate with a 1-in. land will solidify faster than a gate with a 0.100-in. land, I find it difficult to believe that there would be much of a difference in the solidification time between a gate with, say, a 0.020-in. land and one with 0.045-in. land. Additionally, since shorter lands develop less shear, there will be less temperature rise in both the material and the steel. If the gate-freeze time is in fact extending the molding cycle, I think it is more likely that it's not because the land is too short—it's because the gate is too deep. Without empirical data, we will never know for sure.

This brings up another point worth mentioning. Companies that have adopted scientific molding methods perform gate-freeze studies on their molds. John Bozzelli's November 2015 column, entitled "Gate-Seal Testing Done Right," is a thorough guide on how to perform this study. Basically, you start with a very short second-stage hold time—about 1 sec, and then weigh the part(s). You then incrementally increase the hold time while maintaining the cycle time, until the part weight no longer increases. Now you know how long it takes for the gate to freeze, which prevents material from flowing backward into the runner, causing the part to be underpacked. If you want to use a "gate unfreeze" condition, you still need to perform this study in order to know how much less hold time to use. Either way, you know how long the hold time needs to be before starting screw rotation.

Always perform a gate-freeze study.

What a gate freeze-study doesn't tell you is whether the gate is too shallow or too deep. It also doesn't tell you if the land is too long or too short. The part, the molding machine, and physical testing will tell you those things. If the part still has visible sink marks or internal voids, or is dimensionally undersized after the gate has frozen, the gate depth probably needs to be increased. This will increase the gate-freeze time, which is necessary in order to pack more plastic into the cavity.

As I just mentioned, if it takes a long time for the gate to freeze, the gate is probably too deep. But it is also possible that the hold pressure is too high and semi-solidified material in the gate is continually pushed into the cavity. If the pressure loss going through the gate is extremely high or the material is jetting into the cavity, the gate could be too shallow or the land too long. PT

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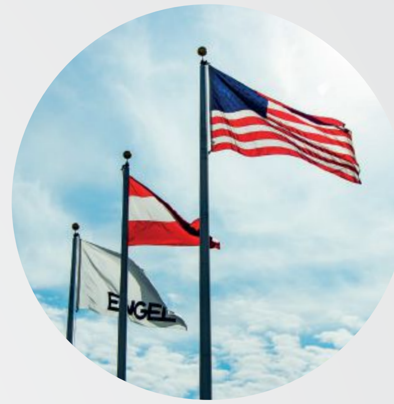

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PT On-Site

Lindar Corp. • Baxter, Minn.

By Lilli Manolis Sherman
Senior Editor

Lindar pioneered the Simply Secure Tamper Obvious Hinged Package, now offered in both PET and PLA.

Award-Winning Package Boosts Lindar's Thermoforming Credentials

Custom thermoformer Lindar has experienced years of steady growth, with numerous technical advances to its credit, as it continues to expand its capabilities in packaging and industrial markets.

"We are really good in helping our customers find solutions, both in terms of new product development and for existing products that need upgrading. We are a 'can-do' thermoformer with the best team to make your product a success." So says Dave Fosse, director of marketing at Lindar Corp., Baxter, Minn. Lindar is AIB and ISO 9001:2015 certified and prides itself in creating precisely designed, highly efficient thermoformed products ranging from food packaging to paint trays and tray liners.

Last year, the processor was recognized twice by the Thermoforming Division of the Society of Plastics Engineers (SPE). Lindar won a gold medal award in the roll-fed, thin-gauge food-packaging category for its Simply Secure Tamper Obvious Hinged Package, while company owner and CEO Tom Haglin was named SPE's 2019 Thermoformer of the Year. Haglin's career in the thermoforming industry is noteworthy for business growth, job creation, innovation and community impact. In accepting the award, Haglin attributed the success that Lindar has experienced in its 26-yr evolution to his company's motivated and capable team that continues to drive the business forward.

Since Haglin bought the company in 1993, Lindar has grown from 21 to 175 employees, with annual revenues exceeding $35 million. The company's 165,000-ft² manufacturing facility houses nine roll-fed machines, eight sheet-fed formers, six CNC routers, two robotic routers, one label line, and one extrusion line.

Lindar's owner and CEO Tom Haglin was named SPE's Thermoformer of the Year in 2019.

Attesting to Haglin's commitment to innovation are a number of patented products and technological breakthroughs in packaging. Also, he aligned with Dave and Daniel Fosse of Innovative Packaging to create Intec Alliance, which has been fully absorbed into the Lindar business.

ENTRÉE INTO PACKAGING

Prior to that partnership, Lindar was primarily involved in industrial custom and sheet-fed thermoforming for OEMs. The Intec Alliance team, says Fosse, brought a new market opportunity to Lindar—a proprietary, thin-gauge, roll-fed food-packaging line that is now marketed under the Lindar brand name.

Lindar also acquired Lakeland Mold in 2012 and rebranded it to Avantech, with Haglin as CEO. A producer of tooling for rotational molding and thermoforming, Avantech was relocated to a new facility in Baxter in 2016 and has expanded its CNC machining capacity and added personnel.

In addition to the captive tool-building and maintenance, the company has made significant investments in secondary operations such as robotic part trimming and product assembly, as well as product design capability, inventory-management software, and complete supply-chain solutions.

Thermoforming paint trays and paint-tray liners for a large retailer is a stable part of Lindar's business.

Lindar is comprised of two main divisions—consumer and commercial. Accounting for about 60% of the company's business, the consumer division includes paint trays and tray liners and food packaging. Included are quite a few stock parts, such as different-sized cupcake and cake containers and paint trays and liners. In addition, Lindar manufactures many custom-sized containers for food manufacturers or national retailers, ranging from fresh produce and baked goods to to deli containers.

Materials used in food packaging are primarily PET and PLA, as clarity is key on retail shelves. "We were one of the first companies to thermoform PLA containers, about 18 years ago," says Fosse. He says Lindar has used post-industrial recycle content for several years but they are also now working with some suppliers of post-consumer recycled materials. "We recently made custom and stock products that are 100% post-consumer PET, and we expect to see this trend grow. Requests for post-consumer PET are coming primarily from retailers as well as food manufacturers. It costs more to get post-consumer PET, but this is becoming a mainstream reality—the critical mass is nearly there."

Lindar's commercial and cut-sheet division does primarily custom thermoforming of cut sheet up to ½-in. thick and heavy- ►

Roll-fed, thin-gauge thermoformed food packaging boosted Lindar's capabilities and offerings.

gauge parts up to 4 × 8 ft for tractor hoods and fan covers to filter casings for construction equipment. Materials used include PC, ABS, HDPE, LLDPE, TPO, and Kydex acrylic/PVC sheet from Sekisui SPI, used for medical equipment such as housings for sterilization units, wash basins, and electronics housings.

Last year, this division purchased two dual-arm robotic trim cells. Says Fosse, "There's a learning process, but people love them, and there are significant productivity improvements on all parts, the extent depending on part complexity."

Also installed last year was new MAAC four-station rotary thermoformer, which can produce 2.8 times the throughput of standard shuttle machines. This investment allows the company to be competitive while also being more sustainable, using less energy to produce more parts. This machine, combined with the new robotic trim cells, is expected to dramatically increase the company's throughput.

Custom thermoforming makes up the commercial and cut-sheet division, ranging from cut sheet up to ½-in. thick to heavy-gauge 4 x 8 ft parts.

INNOVATIVE PRODUCT PIONEER

The company's commitment to innovation has fueled its exponential growth, with sales having soared by 83% in the last five years, according to Fosse. Pioneering technology and patented products include last-year's award-winning Simply Secure "tamper-obvious" containers made of clear PET. Lindar pioneered tamper-obvious, two-piece pie and cake containers, launching this intuitive design of easy-to-handle packaging in the fall of 2018. It features tabs that snap into place to secure products on store shelves; the tabs can be simply torn off by the consumer, making Simply Secure user-friendly and readily identifiable as opened. Other innovations include the following:

- *Single-serve cupcake and dessert packaging:* Lindar reportedly was the first to produce individual cupcake containers and single-serve muffin packaging, which catalyzed a market trend for individually packaged food items. Single-serve containers are available in traditional and large sizes, include a built-in freshness seal, and are manufactured with recycled and renewable materials

- *Biobased products*: Lindar's single-serve and Simply Secure packaging are also offered in Good Natured bioplastic (PLA) materials, which are biodegradable, reduce carbon emissions and minimize the release of hazardous chemicals into the environment. Says Fosse, "PLA posed some processing challenges but we overcame them."

- *Lenticular lens extrusion:* Extrusion of lenticular optical lenses in plastic sheet creates a parallax—making an object's appearance change when seen from different positions. Optica-brand products reportedly provide vivid, 3D-motion graphic images, creating eye-catching labels for use on salad containers, cereal boxes and other consumer products.

RETAINING AND EXPANDING WORKFORCE

Lindar prides itself on the retention of its workforce, with several veterans from the company's beginnings still on board and flourishing. Training is an ongoing process as new equipment and/or materials are brought in.

Fosse concedes, however, that finding good people has been a problem for quite some time, as attested by others in the industry. "We try to make this a better place to work and help people step up through training, particularly in automation. We also work with local technical schools, where we aim to get across that today's manufacturing is not the manufacturing of our parents, with technology that makes it a more exciting venture worth exploring."

Be Proactive in Your Purging Program

True, it can be tough to take a machine out of production, but a purging maintenance program should be thought of as a direct line to cost savings.

Color chips illustrating purge cycle.

By Brian K. Cochran
Britec Solutions Inc.

Plastics processors realize that purging is a necessary evil and that every moment of downtime translates into lost profits. This raises the obvious question of "how to be proactive" in eliminating black specks, carbon buildup and degraded resin, and minimizing the need to stop production. Understandably, it is difficult to convince any processor to break into a production run to perform a purge cycle. However, controlling the issues is the ultimate goal and requires a program that is proactive rather than defensive.

Creating resin degradation or carbon buildup is directly related to process conditions, equipment and materials that determine the approximate time in the process that degradation takes place. Scheduling a purge to break that cycle prior to the event is the most logical approach to a successful purge program.

PRIMARY CAUSE OF CARBON BUILDUP

Most often, the course of purging begins with an existing issue that has manifested in a specific area of the screw. Contamination is the result of layers of resin degradation that develop into a buildup in dead spots or negative-flow areas of the screw. As the process continues, the degradation forms layers that become a black or discolored, glass-like substrate that grows more solid, collects and retains heat, and attaches more securely to the metal.

Despite the common perception that purging with resin or continuing through production will remove or dislodge such accumulations, this approach only multiplies the buildup process. Typically, this creates a situation where the degradation area swells into the positive-flow area and releases the contamination into the resin flow, creating black or discolored particles that begin to appear in the part.

Pits or cavities on the screw or grooves in the barrel, no matter how small, become gathering points for resin degradation.

Color and additives may be a contributing factor, as well. Color introduced to the resin contains pigment particles, each with individual characteristics that respond to temperature, shear, and melt flow. These pigments are typically selected by the color supplier for their compatibility with a resin system, process and part application.

QUESTIONS ABOUT PURGING?
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However, pigments are free-flowing particles, and although they are stable for the specific process temperature, once these pigments get entangled in the negative-flow area of the screw, they become exposed to continuous elevated temperatures that may change their actual color appearance. As they break loose and travel into the melt stream of the polymer and blend with unaltered pigment particles, they create an obvious distortion of the intended color, generating part rejects.

Other contributing factors to degradation buildup are screw and barrel wear. Pits or cavities on the screw or grooves in the barrel—no matter how small—become gathering points for resin degradation. Once resin is deposited and becomes idle, it is exposed to resident heat and begins the degradation cycle that results in carbon buildup. Once these deposits swell outside of the void area, they release into the melt stream as a contaminant, polluting the aesthetic appearance of the plastic.

A PPMP begins with determining what tool to use and more importantly when to apply it in the process.

This process then develops into a progression of incalculable conditions that chronicle something like what is shown in Fig. 1.

This scenario relates to two-thirds of the cycle being associated with cost and only one-third generating profits. Although these ratios may vary, this situation most often relates to unpredictable production downtime, impulsive resin losses (since the common perception is to run more resin in attempt to remove or release contamination), and idle production resources.

Obviously, the most rational approach to reducing downtime associated with carbon buildup is to interrupt the process and break the cycle of degradation. The next question is, "When is the right time to break into production?" Unfortunately, there is no one answer for all situations. Because there are so many process variables involved in injection molding, extrusion and blow molding, it is difficult to employ a generic program.

For this reason, it is important for the processor to communicate with their purge product supplier to develop a pilot program that sets the foundation for an efficient preventive-maintenance program for purging related to the process, equipment and culture of the facility. Most manufacturers or distributors of commercial purging products have the technical resources gathered by testing, past experience or case studies to pass along to plastics processors.

Implementing a planned preventive-maintenance program (PPMP) requires discovery; due to the many variables involved, there is some degree of trial and error. Determining the frequency of breaking into production to eliminate contamination buildup can typically be implemented on a weekly basis, evaluated, then adjusted based on results. This can be done concurrently on multiple machines for a trial period, then adjusted based on the results of that process. Building an effective PPMP will require continuous improvement, an understanding of what purge products to use, collecting and analyzing data, and making adjustments accordingly.

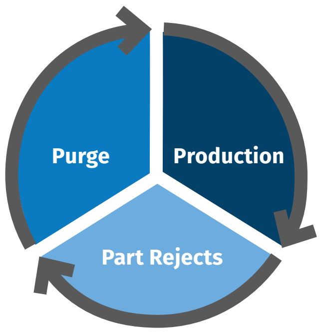
Understand that the types of purging compounds—chemical, mechanical and hybrids—are just like tools in a toolbox. It is highly unlikely that a screwdriver would be used as a hammer or a wrench used to remove a nail. The same is true with purging compounds: Each product has an intended and best-use application. A PPMP begins with determining what tool to use and—more importantly—when to apply it in the process.

A typical PPMP for injection molding most often begins with the plasticating unit of the equipment and transitions into the mold/hot runner. A mechanical purge compound is used to scrub or scour the barrel and screw, followed by incorporating a chemical or synergistic purge compound into any manifolds or hot-runner systems. Integrating a purge into shutdown and startup of production to maintain a clean screw and barrel is a large part of a PPMP and is highly recommended. This practice most often produces an immediate reduction in the contamination buildup cycle and generates a positive starting point for the PPMP.

Avoid the common impulse to just keep running more resin through the machine to remove or release contamination.

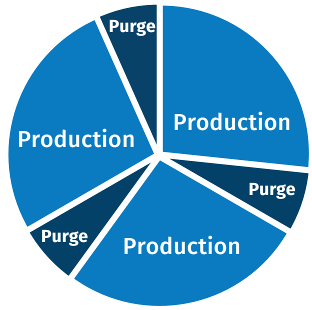
Figure 2 demonstrates a vast reduction in downtime associated with contamination issues related to degradation and carbon buildup with a PPMP in place.

FIG 1 **Unscheduled Purges Cost Money**



Cases in which purging is not planned on a preventive basis often results in only one-third of the cycle generating profit.

FIG 2 **Preventive Purging Cuts Downtime**



A vast reduction in downtime associated with contamination issues related to degradation and carbon buildup can result with a PPMP in place.

In a recent case study completed by Britec Solutions, an injection molder in Ohio was experiencing excessive downtime due to black specks and other contamination issues on a PP food-storage container. Color concentrate was used to tint the containers in a variety of translucent colors on a 750-ton press with a multi-cavity hot-runner mold. Resin usage was 40% higher than required—representing a waste of 13,360 lb through futile attempts at purging with natural resin—and part rejection was reaching levels of 12%.

A PPMP that consisted of an initial purge cycle on the barrel and screw using a mechanical purge compound designed to scrub and remove stubborn carbon buildup was performed at the onset. After three 24-hr shifts, production was interrupted for a 16-min purge cycle using a different grade—a hybrid purge compound that combines the key features of both mechanical and chemical agents. The purge began with the screw and barrel, then transitioned to the hot-runner mold system before returning to production.

Another purge cycle was implemented for each color change, using both purging grades.

In addition, a purge cycle was employed each Friday at the end of shift to seal the barrel and screw, again using the hybrid grade. After implementing this PPMP with these two compounds, part rejects were reduced to less than 1%, resin consumption was reduced by 56% and machine downtime was cut by over 67%.

This and other case studies show that a PPMP produces significant reductions in downtime, cost savings in resin and color consumption, increased production numbers, and improved efficiencies for plastics processors. PT

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What 'Cobots' Can Do for Blow Molders

Low-cost and easy-to-program collaborative robots are a new solution to bottle handling, trimming and packing automation.

By Joe Campbell
Universal Robots, USA

Collaborative robots are providing new opportunities to free workers from repetitive tasks in blow molding operations, while also allowing manufacturers to increase output and quality. "Cobots" offer the versatility of a traditional six-axis robot, but bring additional advantages in terms of significantly lower cost and complexity as well as the ability to work safely in proximity to humans without guarding. New blow molding systems are using cobots in production equipment as well as in finishing, packaging and palletizing applications.

Proco Machinery has developed packaging systems for blow molding, like this Half Cube Palletizer, with Universal Robots cobot arms to reduce the handling of containers, simplify operation, and enhance efficiency with a small footprint and fast ROI.

WHY COLLABORATIVE ROBOTS?

Collaborative robots are named for their ability to work safely in close proximity to humans (with a proper risk assessment) and other equipment. This collaborative nature allows humans to share the cobot's work area for upstream or downstream operations, such as quality inspection or other tasks that require human dexterity or decision making. Because cobots can easily interact with other machinery and robots, they are often more productive than using either conventional robots or human operators alone. In fact, a study completed by MIT for the *Financial Times* of London concluded that the combination of cobots and human operators delivers 85% more productivity.

Blow molders are now looking into cobot automation to take over manual tasks they simply can't staff. With record-low unemployment rates, we're seeing companies consider automation more than ever before. The National Association of Manufacturers' (NAM) latest Outlook Survey confirmed that finding skilled workers remains one of the top challenges for manufacturing executives today. And the Society of Manufacturing Engineers (SME) reports that 89% of manufacturers are having difficulty finding skilled workers.

This situation does not appear likely to improve anytime soon, with 10,000 baby boomers retiring every day and younger generations skeptical about

At K 2019, BBM demonstrated a new all-electric shuttle blow molder for stackable jerrycans. Inside the machine, a Universal Robots six-axis cobot transfers parts from the mold to a trim station, laying them down for a vertical punch, which makes flash easier to collect than if containers were left upright with a standard horizontal deflasher.

jobs in manufacturing. Asked how they were addressing the skills shortage, manufacturing executives' responses to the NAM survey ranged from assigning more overtime (70.3%), relying more on temporary staffing services (57.7%), and encouraging possible retirees to stay longer in their roles (30.7%)—all strategies that adversely impact the bottom line. An additional 28.8% reported they had to turn away new business or had lost revenue opportunities because of workforce constraints—ones that cobots can help address.

When properly implemented after a risk assessment, cobots typically don't require the heavy, expensive, and bulky safety guarding that is associated with conventional robots. Lightweight and easy to set up and program, cobots are often treated as a manufacturing tool, moved from machine to machine as the production mix and schedules demand. Cobots have been mounted on rolling bases or carts and wheeled into position for short runs.

Other installations use magnetic bases or a high-precision collet mounting to enable cobots to be moved from machine to machine. With a small footprint and no bulky safety guarding, even floor- or pedestal-mounted installations can free up floorspace. Cobots are also being incorporated directly into blow molding equipment cells because of their compact size and flexibility.

Ease of programming is another key reason for incorporating cobots, with easy setup and interfacing to molding machines and other peripherals, as well as easy redeployment for new production needs. With no special software language to learn, employees with no prior robotics experience are successfully implementing cobots. That makes operating costs low enough that collaborative automation is within reach for small and medium-sized operations. In addition, "libraries" of pre-certified peripherals such as grippers and vision systems dramatically simplify what until now could be a complex automation initiative.

Blow molders are now looking into cobot automation to take over manual tasks they simply can't staff.

COBOTS IN BLOW MOLDING

BBM of Germany recently demonstrated at the K 2019 show a new all-electric, shuttle-type extrusion blow molding machine for stackable jerrycans (see Jan. '20 show report). Installed inside the machine is an integrated six-axis collaborative takeout robot. The cobot (from Universal Robots) transfers parts to a trim station, laying them down for a vertical punch, which makes the flash easier to collect than if containers were left upright with a standard horizontal deflasher. Afterward, the cobot places containers upright on a conveyor. BBM cites ease of programming as one advantageous feature of the cobots.

Collaborative robotic systems are also seeing strong growth in blow molding due to the need for greater efficiency and automation downstream within the packaging line. Proco Machinery Inc. has developed packaging systems with collaborative robot arms to reduce the handling of containers, simplify operation, and enhance efficiency, all with a small footprint and fast ROI. The compact Proco Case Packers and Proco Half-cube Palletizers handle ►

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blow-molded containers at a significantly lower cost than conventional automation. By using collaborative robots, these systems can be placed alongside workers in constrained spaces such as assembly lines. Once again, these cobots require minimal training and are flexible and easy to redeploy for short runs.

Proco Machinery's Robo Packer for bottles has an integrated UR10 cobot. The case packer is an integrated packaging module that also includes infeed conveyor and box conveyor mounted onto a movable sub-frame.

Proco's Half-Cube Palletizer system, powered by a six-axis Universal Robots UR10 collaborative robot arm automatically palletizes blow molded containers with minimal operator involvement at half the cost of conventional automation. With a reach of 51.2 in. and a payload of 22 lb, the UR10 cobot is well suited to palletizing containers.

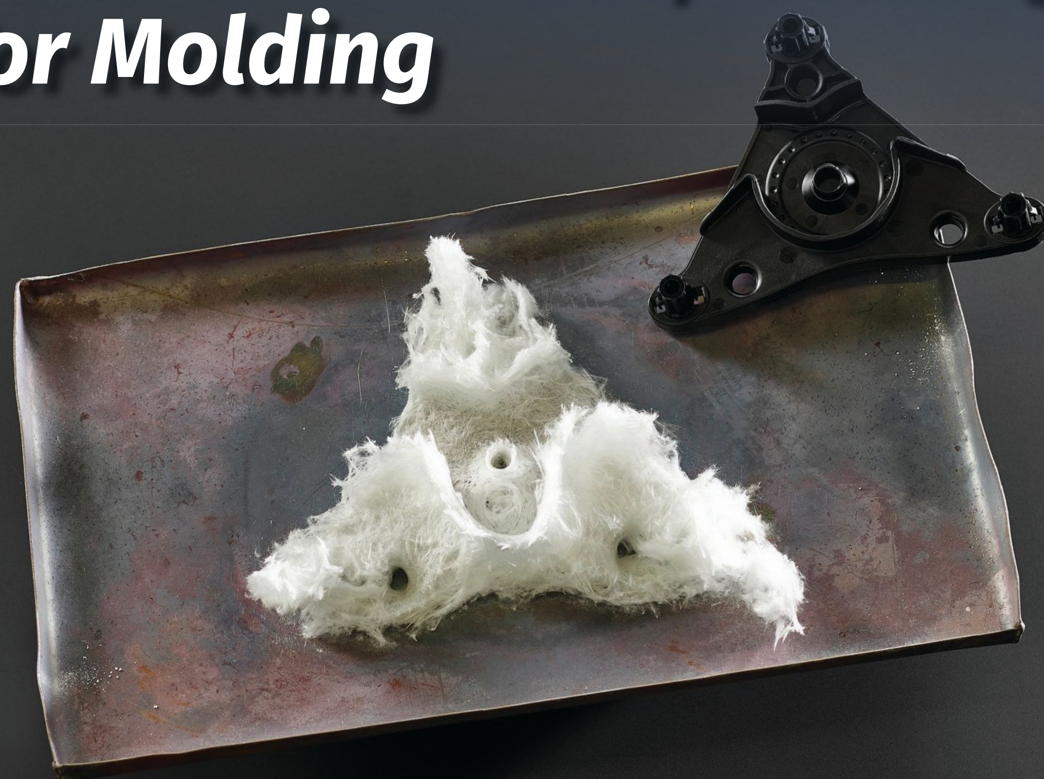
The UR10 also powers Proco's Robo Packer case packer, which is an integrated packaging module that also includes infeed conveyor and box conveyor, all mounted onto a sub-frame that can be quickly moved into position, set up, and put into production. The compact unit fits between blow molding lines for pick-and-place, assembly and packaging applications. The cobot can package bottles inside a box or on trays in configurations such as necks up, necks down, alternating rows of necks up and down, or layflat of bottles inside the box.

ADVANTAGES OF AUTOMATION, WITHOUT THE COSTS

Collaborative automation offers all the expected advantages of traditional robots, including increased output through round-the-clock operation, improved consistency and quality, and reduced scrap. But with reduced or eliminated costs for safety guarding and programming and implementation, and project schedules measured in weeks not months, cobots bring those automation advantages to blow molding at about half the cost of conventional robots, and routinely deliver ROI of less than 12 months.

Joe Campbell is senior manager of applications development for Universal Robots North America. He has 35+ years' experience in robotics and factory automation. Prior to joining Universal, Joe was v.p. sales & marketing for Swiss-based gantry-robot and track manufacturer Gudel. Previous assignments included executive roles in sales, marketing, operations and customer service with industry leaders such as ABB, Kuka, AMT and Adept Robotics. Contact: *joca@universal-robots.com*; *universal-robots.com*.

Time for Another Look at Fiber-Direct Compounding for Molding



Deller plastics cable-drive housing component (top right) and the ashed part showing glass fibers.

Despite its benefits in cost, performance and lightweighting, fiber-direct compounding (FDC) has seen relatively limited adoption—is that changing?

By Manuel Woehrle
Arburg

It's a relatively simple idea: take strands of glass fiber, cut them to length and feed them into the barrel of an injection molding machine, where they mix with neat resin before the resulting compound is injected into a mold. Fiber-direct compounding (FDC) has been a recognized alternative to molding pre-compounded long-glass-filled materials since at least 2012—one that can lead to better properties and cut costs. So why hasn't it caught on?

Well, to begin with, it's not like a molder can just buy the necessary equipment and easily start competing for long-glass-fiber applications. The process is designed to make tough, tech-

FDC side feeder with cutter mounted on a modified barrel.

Brose cable-drive housing component (right) and the ashed part showing glass fibers.

nical parts—automotive is the primary target market—often as a replacement for metal, so these components must be designed with the process in mind. This means key decisions need to be made in the design stage and must involve collaboration up and down the supply chain. Despite this challenge, there are commercial FDC applications in Europe, and several U.S. companies are looking seriously at the technology.

Consider deller plastics of Breckerfeld, Germany. This injection molder and moldmaker used FDC to make housings for a cable-drive unit used in automotive power windows (see photo opposite). Deller plastics had been using pre-compounded polypropylene (PP) with 30% glass but switched to Arburg's FDC system in February 2018. It immediately reduced its material costs by almost 40%. Then, by feeding 11.2-mm glass to the process, deller was able to increase the length of the glass fibers in the molded part by about 50% compared with the compounded material. This precisely matched product strength and stability requirements. With the higher strength, the customer was able to design thinner wall sections, reducing total material use and cutting weight—a critical objective for automakers.

> ***With the higher strength, the customer was able to design thinner wall sections, reducing total material use and cutting weight,a critical objective for automakers.***

Nils Braselmann, along with his brother, Jann, and father, Uwe, runs the deller plastics family business, founded in 1959. Application of FDC helped keep the German company competitive in the global arena. "Following implementation of the FDC process, we were able to continue production in Germany, while remaining internationally competitive," Braselman says. "We reduced our product and manufacturing costs to such an extent that we were able to offset our global logistics expenses."

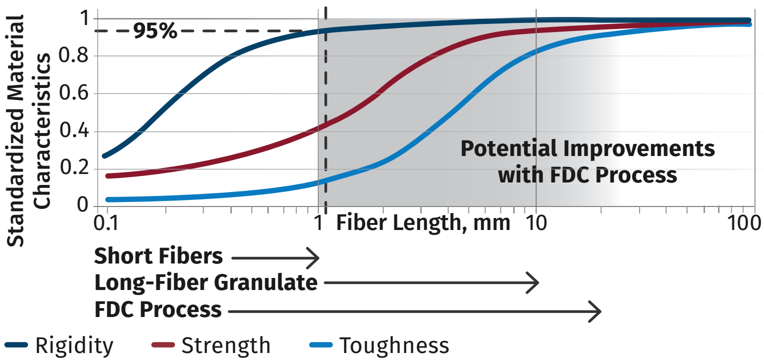
An FDC system involves an otherwise standard injection molding machine fitted with a modified barrel and a special two-stage screw, plus a servo-electric side feeder with integrated cutting device.

Cost of Molding an Actual Part Using FDC vs. Compounded PP

Process	Material	% of Part Weight	Material Cost/lb	Part Cost/lb
Pre-compounded resin	PP LGF 30	100%	$1.25	$1.25
FDC	PP	67%	$0.75	$0.50
	Glass roving	30%	$0.64	$0.19
	Bonding agent	3%	$1.80	$0.05
			Total	$0.74
			Cost benefit/lb	$0.51
				40%

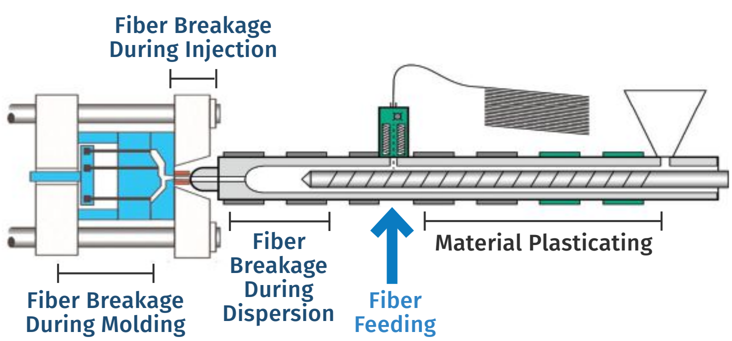
In operation, continuous glass rovings are fed to the cutter, with the number of blades determining the length of the reinforcements. Fibers can be cut up to 50 mm long in theory, but 33.6 mm has been the maximum used so far. Cut fibers are fed through a port in the machine's barrel, where they are incorporated into the melt. The first stage of the screw plasticates the resin while the second stage mixes in the glass and homogenizes the compound before injection.

FIG 1 Fiber Length Impact on Mechanical Properties



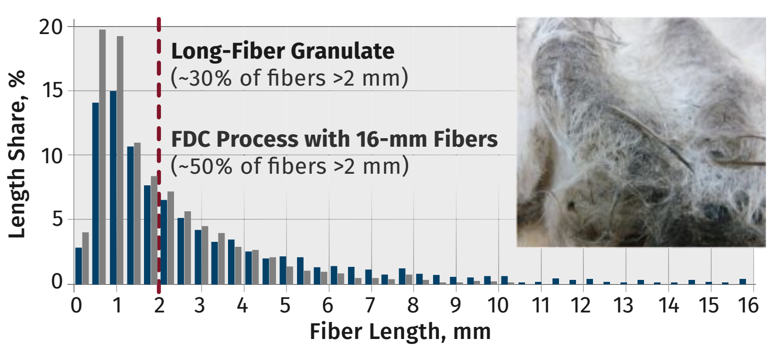
Rigidity, strength and toughness all increase dramatically when fiber length exceeds 1 mm in the finished component.

FIG 2 Fiber Damage Points in Injection Molding



Fibers can be shortened at various points during molding.

FIG 3 Final Fiber Length in FDC vs. Long-Fiber Granulate for PP Airbag Housing



FDC ensures that longer fibers find their way into the finished part.

IMPROVED MECHANICAL PROPERTIES

The most important reason for using fiber-reinforced plastics is their greater mechanical load-bearing capacity, which is not temperature-dependent. Distortion, creep and energy absorption are similar to those of metals, but with the benefits of thermoplastics.

The most significant factor in increasing strength and toughness is the length of glass fibers (Fig. 1). While almost any glass reinforcement will deliver an immediate increase in rigidity, a truly noticeable effect on strength and toughness is achieved only when fibers in the finished part reach and exceed a length of 1 mm.

In reality, it is extremely difficult to predict the length of fibers in the final part because the length will depend on several factors (Fig. 2). Material characteristics such as melt-flow rate and process parameters like screw speed and backpressure during plasticating are especially important, but so is injection speed. The hot-runner system also has a big influence on the fiber length. In fact, the part, mold and hot-runner system should all be designed with long fibers in mind. This means, for example, that large-diameter hot runners, smooth transitions and large gates are all very important. Depending on application requirements, each of these elements must be considered carefully.

The part, the mold and the hot-runner system should all be designed with long fibers in mind.

In the end, the advantages of the side-feeding FDC approach are especially evident when examining the length of the fibers that can be incorporated in the final part. Figure 3 compares the final fiber length using FDC versus long-fiber granulate in a PP airbag housing. When a conventional pre-compounded long-fiber material is used, only about 30% of the fibers are longer than 2 mm. With FDC, feeding 16-mm fibers, the percentage of fibers that are at least 2-mm long increases to about 50%.

Clearly, when there is less damage to the fibers during melt preparation, the strength of the components increases significantly. Properties can be controlled in a more targeted way through custom adjustment of fiber length, fiber content and material combinations. For instance, if a glass loading of 23% meets performance requirements, then that exact loading can be achieved simply by adjusting the glass feeder settings. It is not necessary to buy custom compounded pellets or choose between standard 20% or 30% glass-filled materials.

LOWER COST

As deller plastics discovered, FDC can dramatically reduce material costs in glass-filled parts. Neat polymer is considerably less costly than reinforced pre-compounded resin, and bulk glass roving is quite inexpensive too. Only a small amount of a bonding agent is needed to ensure the plastic adheres to the glass fibers. In some cases, a colorant can be added to the bonding agent, simplifying the feeding process. Of course, actual costs will depend on the region in which the purchases are made and the amount of material purchased, but the table on p. 59 compares the cost of molding an actual part using FDC versus compounded PP.

The ready-to-use composite part is produced in just 50 sec, while it takes several days to produce the same part in metal.

LIGHTER WEIGHT

Another one of the first adopters of the FDC process was ROS GmbH of Coburg, Germany. In 2012, the company was also molding a cable-drive housing for Brose, a global automotive supplier. This component, however, was molded in glass-reinforced PBT, a relatively expensive material. "At that time," recalls Steffen Tetzlaff, ROS's managing director, "we were thinking about potential ways of lowering our manufacturing costs. Because we had already exploited most of the mold technology possibilities, we examined the material costs in greater detail and recognized that FDC would offer us significant benefits."

ROS began evaluating the idea of replacing the PBT with PP and 30% glass fiber. The quality requirements were high. In addition to dimensional stability, strength was an especially important factor, requiring 50% of the glass fibers to be at least 1 mm long.

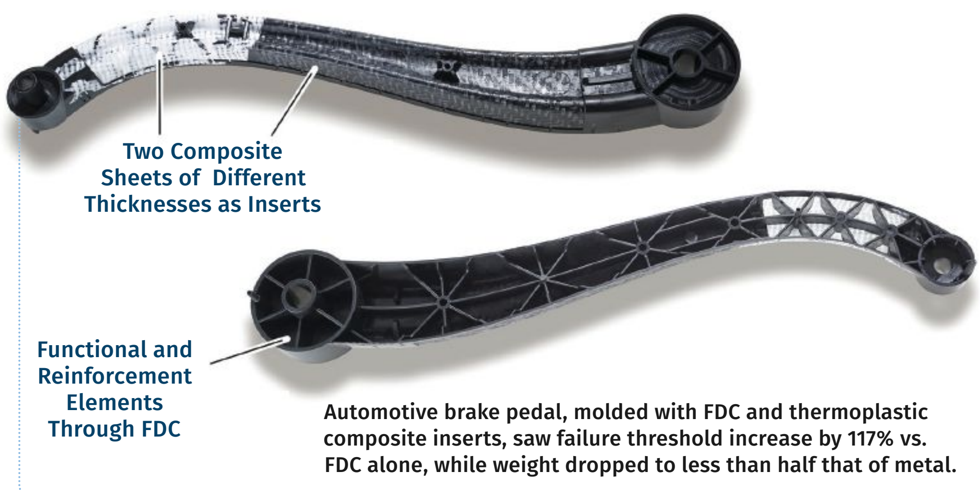
The results speak for themselves. The cable-drive housings, which measure 7.87 × 3.9 in. and weigh 1¾ oz, were made of 30% glass-reinforced PP. They exhibit toughness, strength and rigidity comparable to the PBT version, but they are up to 30% lighter and can be produced with a shorter cycle time of just 33 sec. In recognition of this achievement, Brose awarded ROS for implementation of innovative ideas in 2017. ROS produces about 1.5 million fiber-reinforced parts each year on its FDC machine.

HYBRID PROCESSING WITH FDC

Fiber direct compounding was developed for use on conventional injection machines. However, it can also be used in combination with thermoplastic composite sheet to achieve exceptional strength-to-weight ratios.

One such high-strength, lightweight composite application is an automobile brake pedal (photo below). In order to increase the strength and rigidity of the component, two thermoplastic composite sheet sections of different thicknesses are inserted into a single-cavity mold, where they are formed and overmolded using FDC to add reinforcing ribs and other functional details. The whole process is automated using a six-axis articulated-arm robot to insert the sheet and remove the finished part.

The composite sheets raised the failure threshold when a load is applied by 117%, compared with FDC alone. A comparison with metal parts indicates a significant weight benefit too. The same part made from metal weighs 533 g, while the composite pedal weighs only 202 g. The differences become even more pronounced in the production process. The tested, ready-to-use composite part is produced in just 50 sec, while it takes several days to produce the same part in metal.



Automotive brake pedal, molded with FDC and thermoplastic composite inserts, saw failure threshold increase by 117% vs. FDC alone, while weight dropped to less than half that of metal.

Better physical properties, lower costs and the flexibility to tailor glass length and content to exactly match application requirements—these are just some of the reasons why fiber-direct compounding deserves a closer look.

ABOUT THE AUTHOR: Manuel Wöhrle, Arburg senior sales manager, Lightweight, has worked for Arburg in Germany since 2003. As part of the Turnkey department, he was initially responsible for designing and coordinating complex automation projects. Since 2015, he is the central point of contact for lightweight construction and is leads the sales team in that department. Contact: *contact@arburg.com*; *arburg.com*.

Keeping Up With Technology

PRODUCT FOCUS **Recycling**

RECYCLING

New Software Allows Real-Time Remote Access

Starlinger has introduced software that allows the operator to centrally monitor the complete recycling plant in real time—via a computer, the smartView app, or on a monitor in the production shop. New GRAFiT 4.0 presents the data of all connected machines in real time for early detection, analysis and correction of errors. Starlinger says that in the future, the GRAFiT software will be geared towards machine learning, so that the system can be trained to detect errors at an early stage.

The system is available for the complete Starlinger product range, but machines of other manufacturers can be integrated as well by means of standardized interfaces. Features include push notifications, recipe storage, and export of data to an ERP system. Online tutorials are available for operator training.

RECYCLING

New Developments in PP Labels Containing PCR

Avery Dennison is working with Sabic on supplying a recycled polypropylene label film. PP labels are widely used in food, cosmetics, and a variety of other segments, so improvements in this area can make a major contribution to sustainability, Avery Dennison states. The new material is food-contact approved, and reportedly offers the same properties as standard PP film.

The new material is made via pyrolysis chemical recycling of mixed post-consumer plastics waste (PCR). The joint pilot project will make this material available during 2020.

In a related development, Finland-based UPM Raflatac recently released its PE PCR white TC 85 label material, made with 30% PCR from household waste and a minimum of 55% post-industrial (PIR) plastic. PE PCR white TC 85 is available in Europe for home-care and personal-care markets.

As one of the signatories to the Ellen MacArthur Foundation's New Plastic Economy Global Commitment, UPM Raflatac is committed to offering labeling solutions with recycled content. Legislation in the European Union sets goals to increase recycling to cover more than 50% of the EU's plastic waste and make all plastic packaging reusable or recyclable by 2030.

RECYCLING

New Free-Fall Metal Separator

Sesotec extends its range of free-fall metal separators with the Rapid Pro-Sense 6. This system is optimized for plastics applications, especially for pellet and compound producers. The model reportedly features a high detection accuracy and provides protection against metal particles, and the logbook function allows full traceability. It also is suitable for applications involving abrasive material.

Rapid Pro-Sense 6 is characterized by an aperture size ranging from 50 to 250 mm that can be adapted to customer requirements, and features a wear-resistant design—for example,it does not contain any product-contacting seals that might come loose.

Rapid Pro-Sense 6 allows tool-free cleaning. The metal separator is suited for compound producers who need frequent color changes and/or short cleaning intervals. Optional washing nozzles allow water cleaning of the interior. Short cleaning time is said to increase uptime. The unit is equipped with an Ethernet interface and is "IoT-ready."

RECYCLING

New PE Grades Made With PCR

Ineos Olefins & Polymers and Italian recycler Forever Plast SpA have developed a range of new polyethylene grades made with 50% post-consumer bottle caps. Ineos claims that this Recycl-IN line mirrors virgin bottle-cap PE grades and works with injection molding and compression molding machines.

In October 2019, Ineos introduced Recycl-IN compounds containing recycled plastics for rigid and flexible non-food-contact applications. Now, Ineos is expanding the line into the PE non-food caps market. Over the next five years, an estimated 6.5 billion bottle caps will be diverted from the waste stream for use in this new line.

INJECTION MOLDING

Two-Platen Line with Wider Platens

Yizumi-HPM Corp. has launched the DP-N-WP wide-platen series of two-platen servo-hydraulic injection machines. The series initially includes five models of 770, 990, 1200, 1650 and 2000 tons with 15 available injection units. For the 770-ton machine, the platens measure 61.4 × 59.8 in., while for the 2000, they are 105.6 × 100.1 in.

The series also offers larger tiebar spacing, longer clamp strokes, bigger maximum mold heights and increased mold weights.

RECYCLING

Continuous-Fiber TP Composites from Recycled Polycarbonate

Lanxess subsidiary Bond-Laminates is developing a new version of its Tepex continuous-fiber reinforced thermoplastic composite sheets. Half of the resin matrix for the new semi-finished products consists of recycled large, reusable polycarbonate water bottles. Primary target applications include laptop covers and housings for smartphones, tablets, e-books and cellphones. The company also foresees these new composites being used in sporting goods and automotive components.

RECYCLING

Advances in Direct PET Decontamination

Kreyenborg of Germany (represented here by eFactor3) says its IR-Clean system offers an alternative for cleaning post-consumer materials and direct decontamination of PET—without use of vacuum. The system is a further development of the company's Infrared Rotary Drum (IRD) used in crystallization and drying of post-consumer PET bottle flakes.

Good decontamination results reportedly have been shown in tests together with the Fraunhofer Institute for Process Engineering and Packaging IVV. The U.S. FDA has issued a Letter of Non-Objection on the basis of these values. Depending on use, this technology can also be used for processing up to 100% PCR under regulations of the European Food Safety Authority (EFSA).

The functional principle of the IRD is based on the low mass of material in the process and continuous movement of the material, which ensures a continuous surface exchange of the material to be treated. With direct heat input from infrared light, which generates high temperatures in a few minutes, the IR-Clean reportedly doesn't require expensive and high-maintenance vacuum systems. IR-Clean, combined with a downstream desiccant air drier, gives final moisture values <50ppm.

INJECTION MOLDING

Magnetized Elevation Pads Simplify Support of Molds & Machinery

Rhino Feet are a new offering from Molders Choice to support heavy objects such as molds, machines, toolboxes, cabinets, benches and tables. Produced by Rhino Products, these magnetized elevation pads are plastic with a molded-in magnet to stick to ferrous-metal objects. The bottom side has a molded steel insert to allow the feet to stack for easy storage.

Rhino Feet come in sizes from 2 in. to 4 in. tall, and a mini version is coming soon. Safe workloads range from 630 lb to 7000 lb. Uniform size eliminates the need to match the height of random wood blocks or pallets from around the shop. In addition to making it convenient for forklifts to access objects, Rhino Feet facilitate assembly and disassembly of injection molds by keeping ejector pins organized and protected.

INJECTION MOLDING

Free Customer Portal Offers Parts Ordering & Service Assistance

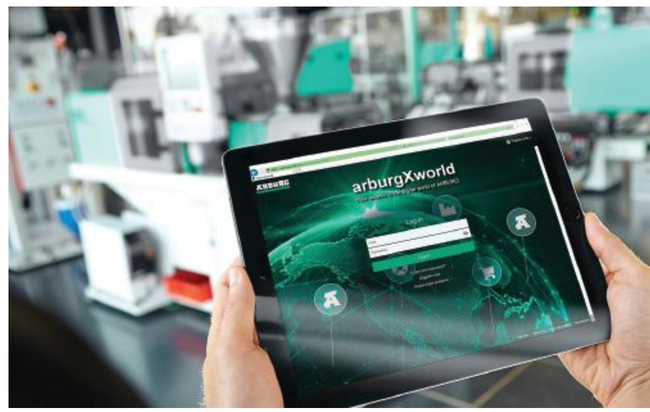
The K 2019 show last October marked the global availability in 18 languages of the arburgXworld customer portal to all owners of Arburg injection machines (see Sept. '19 show preview and Jan. '20 post-show report). This new digital service had been available in Germany since March 2019. It allows users to order spare parts, schedule and manage technical service, and access other features that address a wide range of plant operations and other tasks.

The basic arburgXworld (pronounced "Arburg's world") portal includes four free apps:

- *Machine Center* maintains machine-specific data (model, machine number and delivery date) for a molder's entire fleet of Arburg machines. Users also have easy, centralized access to operating instructions and a spare-parts list for machines built since 2017.
- *Service Center* makes communicating with Arburg quicker and easier when support or service is needed. Customers can open a service ticket, submit supporting information and photos, check ticket status, and access documented service history.
- *Calendar* helps manage scheduled service and download appointments to the user's personal calendar.
- *Shop* gives molders access to spare-parts catalogs, including exploded-view and 3D drawings; allows users to review pricing and availability; and instantly places orders 24/7.
- *Self Service* allows users to analyze machine errors themselves simply by entering a problem description or error code, for which the system suggests causes and solutions.

A U.S. molder involved in beta testing the new portal reports that he especially appreciates the online parts-ordering function in the Shop app. "What used to require some research and a phone call or two now can be completed in about 5 minutes. We used to have to call or email to get availability and pricing, then get a quote and cut a purchase order. But now it takes just a few mouse clicks to order parts."

Besides the free Basic package, the portal offers additional fee-based functionality in Premium, Premium Plus, and Connect packages. For instance, the enhanced Machine Center app includes extended documentation for each machine—digital records of



machine features, service reports, acceptance protocols, etc.—all stored under customizable machine designations. The enhanced Self Service app includes assisted problem analysis with Arburg expert guidance to lead the user through a problem-solving process and links to machine manuals.

Other apps available in the fee-based packages include Virtual Control, which simulates the Arburg machine controller so that users can create setup programs and optimize processes without taking a machine out of service. It also facilitates offline training of employees.

Machine Finder is a configuration app that helps molders determine the appropriate machine size and features for a particular product, material and process conditions.

Machine Dashboard displays key performance indicators (KPIs) for connected molding machines.

COOLING

Portable Chiller Line Expands with 30-Ton Unit

Thermal Care has extended its range of Accuchiller NQV portable chillers with variable-speed compressors to include 30-ton units. The NQV monitors the heat load and adjusts the compressor speed so that the chiller only works as hard as the job requires. Thermal Care says this design has resulted in energy savings of up to 51% compared with a conventional portable chiller. According to Thermal Care, based on $0.10/kWh power cost, ROI ranges from less than 6 mo (8400 hr at a process load of 50%) to 2.1 yr (4000 hr at 85% load).

INJECTION MOLDING

Flexible Automation for Packaging

Muller Technology Colorado, the former CBW Automation, has launched the M-Line integrated robot and automation system, which offers greater flexibility for users, a departure from past systems that were highly application/tool specific.

The M-Line, which was jointly developed by Muller Technology Colorado and its sister company, Muller Technology Conthey of Switzerland, can accommodate various mold types with differing cavitation and pitch between those cavities, ranging from one to 48 cavities. Instead of more rigid automation systems that are designed for certain molds with specified cavitation, the M-Line can adapt to market changes and shifting production volumes.

The M-Line has three models suited for various injection press sizes—small (300 to 500 tons), medium (600 to 850 tons), and large (850 to 1000 tons). Muller says the M-Line features low-cost, flexible end-of-arm-tooling that can be changed quickly. Built on a single frame that doesn't require assembly and has a small footprint, the M-Line replaces pneumatics with servomotors, reducing energy consumption. Servomotors, which can have a lifespan that's 10 times that of pneumatics, also reduce maintenance. Muller notes that using servomotors also creates an extended period of accumulation time on the conveyor of up to 1 hr, which can reduce the number of packers needed.

Muller designed the M-Line to eliminate vibration of the arm and beam. A wireless WiFi-enabled tablet is included for setup and troubleshooting. Muller reports that seven units have already been sold in North America. Applications currently utilizing the systems range from specialty closures to thinwall containers and lids.

INJECTION MOLDING

Updated All-Electric Machines for Caps

Engel is updating its e-cap line of all-electric machines for closure molding. Originally launched at K 2010, the new e-cap series will feature four sizes—220, 280, 380 and 420 metric tons. Hydraulic ejectors are standard; optional servo-electric drives use around 10% less energy.

To demonstrate the machine's capabilities, Engel set up a 380-m.t. press molding HDPE 29/25 caps from a 96-cavity mold. With a shot weight of 1.3 g per cavity, the machine achieved a cycle time less than 2 sec.

Engel says the e-cap line was updated in response to new demand requirements from the market, with still-water caps now weighing less than 1 g, while cycle times have dropped from 2.5 sec in 2010 to 2 sec or less today. To make this possible, the new e-cap offers faster mold opening and closing and a more stable machine bed with a beefed-up frame and platens.

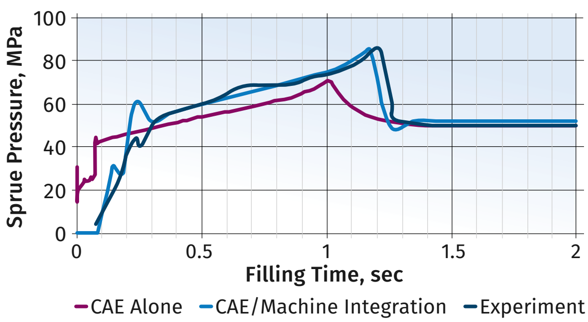
The e-cap 380 has a dry-cycle time of 1.3 sec, thanks in part to parallel movements for ejection and mold opening. Ability to amplify ejectors on demand via a switchable hydraulic booster is new. This applies to situations where the machine has stopped and the ejectors have to apply more force to remove caps that have cooled down in the mold.

Engel completely redesigned the plasticating unit to handle preferred cap materials, including HDPE grades with MFI of 0.8 to 1.4 g/10 min. To achieve fast cycles, Engel increased the screw torque and created a new barrier-screw design and wear-resistant sliding-ring nonreturn valve. Engel says the new screw can process high-viscosity HDPE in a gentle way. Braking energy is recuperated, increasing energy efficiency. The e-cap 380 boasts specific energy consumption of 0.37 kWh/kg.

INJECTION MOLDING

Simulation Factors in Material Compression and Machine Response During Injection

The latest version of Moldex3D injection molding simulation from CoreTech System in Taiwan includes two factors intended to increase the accuracy of mold-filling predictions. First, Moldex3D R17, released last year, takes into account the compressibility of the melt during screw recovery and injection. Since the melt acts somewhat like a spring, disregarding this factor will result in a gap between the simulated and actual flow rates through the nozzle, runner and mold.



Second, conventional CAE predicts melt flow through the tooling based on settings for injection speeds, without considering the machine response—i.e., the response speed of the control loop to attempt to satisfy the speed settings throughout the injection profile. CoreTech offers instructions on how to set up and conduct experiments to quantify the machine response, and the new version of Moldex3D lets users set the filling speed and pressure response as part of the simulation parameters.

The accompanying graph shows the difference in simulation based on standard CAE inputs alone vs. the results of actual experiments and Moldex3D with melt compression and machine response ("machine integration") included.

EXTRUSION

New Extruder Line for Medical Applications

US Extruders has introduced a new series of extruders for the medical market. The new Med-Ex line was introduced at the Plastec West show in February in Anaheim, Calif. The line comes in four iterations:

Med-Ex Elite: Key features (photo, far left) include easy-to-swap barrels (0.5 to 1 in.); stainless-steel surfaces that can be easily wiped down; easy-open and -close toggle clamps; temperature range to 900 F; precision servomotor; corrosion-resistant design option; clean wire management; and virtual pressure measurement.

Med-Ex Elite Flex: In addition to the above, it features (photo, second from l.) swappable barrels (0.5 to 1 in. or 0.75 to 1.25 in.) and low-profile casters with integral jacking pads.

Med-Ex Compact: Special features (photo second right) include a slim panel design, gearless direct drive; and clear-covered plug plate.

Med-Ex Classic: Key features (photo right) include an economical design; easy open and close toggle clamp; base-mounted cabinet; and air or water cooling.

Extruders can be equipped with the firm's ProControl Medical touchscreen control offering recipe management, data acquisition, reporting, and alarm analytics.

ADDITIVES

Flow Enhancers for Semi-Aromatic Nylon

What is said to be the first flow enhancer for semi-aromatic nylons is commercially available from Germany's Bruggemann (U.S. office in Newton Park, Pa.). Bruggolen TP-P1810 joins the company's Bruggolen TP-P1507, which is already used worldwide for aliphatic nylons 6, 66 and 12.

Both Bruggolen TP-P1810 and TP-P1507 reportedly demonstrate very significant improvements in melt flow while retaining the mechanical properties of finished components. Supplied in pellet form, they are reportedly easy to dose and disperse during injection molding and compounding.

Trials carried out with well-known independent testing laboratory RJG Technologies revealed that Bruggolen TP-P1810 enabled more than 20% cycle-time reduction during molding and allowed filled compounds containing 50% or more glass fiber to be injection molded into very intricate and complex shapes. For example, during molding tests, spiral flow of a semi-aromatic nylon reinforced with 50% glass was lengthened by 70% with addition of only 1.5% TP-P1810.

Much-improved color and appearance of the resultant molded parts are also claimed. Alternatively, by allowing a 30° C/54° F reduction in melt temperature, the additives allow for gentler processing and reduced energy consumption.

ADDITIVE MANUFACTURING

New Mid-Range 3D Printer

Stratasys has launched the J826 3D printer, the latest in the J8-series PolyJet printers. The J826 is a lower cost alternative and features full Pantone-validated color and multi-material 3D printing.

The J826 is suited to mid-volume requirements in industries such as consumer goods and electronics and automotive. It provides the same resolution and detail as other J8-series 3D printers and uses the same PolyJet materials as the J850.

The J826 has a max. build volume of 10 x 9.9 x 7.9 in., (255 x 252 x 200 mm). Its seven-material capacity means operators can load their most frequently used resins and avoid downtime for material changeovers.

MIXING

Enhanced Multi-Shaft Mixer

Ross has improved the dual-post hydraulic lift and seal design of its 1500-gal Multi-Shaft Mixer (Model PVM-1500). The new lifting mechanism is a double-acting, fully hydraulic cylinder operating at a much higher pressure, allowing for a smaller cylinder and significantly less oil for operation. The result is a lifting system that operates at lower cost, requires less maintenance, and provides faster raising and lowering of the agitators. In addition, the new seal arrangement allows seal replacement without removing agitator shafts. Unlike the historical design, seal replacement no longer requires removal of the mixer from the tank nor tank entry to access the seal.

The pictured PVM-1500 features three independently driven agitators: a screw auger, a high-speed disperser and a three-wing anchor agitator. The sides and bottom of the changeable mixing vessel are insulated and jacketed for up to 50 psig. This vacuum-rated machine comes with rugged touch-screen controls showing digital readouts for speed, cycle time, vacuum level and batch temperature.

FEEDING

Controller Comes with Configuration 'Wizard'

Movacolor says it has made the configuration of feeders easier by adding a software "wizard" to its touchscreen controller. The wizard guides operators through the configuration process step by step. This is said to eliminate the possibility they will forget to configure loaders, select the right dosing tool, or perform the initial loadcell calibration.

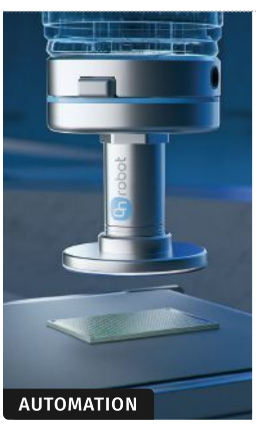
Movacolor controllers are delivered preconfigured to "plug-and-play" out of the box. With Movacolor's modular dosing equipment, processors can combine the different dosing systems to customize their own dosing system.

AUTOMATION

Vacuum Gripper Now Compatible with Wider Range of Cobots

Piab's piCobot vacuum-cup gripper is now available with a generic electrical interface and several options for mechanical mounting-plate dimensions in accordance with the ISO 9409-1 standard. These changes make the piCobot, originally designed to work with collaborative automation from Universal Robots, now compatible with a wide range of cobots and smaller industrial robots.

The PiCobot consists of a proprietary vacuum pump and a gripper with suction cups. Piab's customers can now configure the gripper online, choosing between a generic electrical interface with a standard cable or an interface specified by Universal Robots. Customers also can choose various mechanical interfaces. PiCobot weighs only 1.59 lb and can lift objects weighing up to 15.4 lb.



AUTOMATION

Smaller Non-Marking Gripper For Smooth, Shiny or Perforated Surfaces

OnRobot, the Danish maker of end-of-arm tooling for collaborative robots (cobots), came out with a smaller version of its novel Gecko adhesive gripper for smooth, shiny or perforated surfaces. The Gecko gripper utilizes millions of micro-scale fibrillar stalks that adhere to surfaces by means of van der Waals forces—the same way that gecko lizards are able to climb vertical walls. Because this silicone-based technology doesn't mark even high-shine surfaces, OnRobot claims, it eliminates the need for a cleaning step in some manufacturing processes. And the Gecko grip also can grip even perforated workpieces, like printed circuit boards, aluminum mesh, or head gaskets. No wires or air supply are required.

The new Gecko SP (single pad) gripper brings this capability to smaller applications and lighter payloads. It comes in three sizes for payloads of 1, 3, and 5 kg, vs. 5.5 to 6.5 kg for the larger, four-pad Gecko gripper. The gripper is said to offer "plug-and-play" compatibility with a wide variety of cobot brands.

FEEDING

New Line Comes in Two Configurations

Acrison Inc. is now offering its high-capacity, heavy-duty Model 260 Weigh Belt Weighers/Feeders in two styles: 1) to weigh and/or totalize the flow of dry materials in a "wild-flow" configuration; or 2) to meter dry solid materials in a controlled, "closed-loop" configuration as a weigh feeder.

The Model 260(WF), operating as a weigher and/or totalizer, continuously weighs material passing across the belt. Belt speed is constant and the rate of flow is not controlled, only weighed. The controller, which continuously monitors and totalizes the flow of material, displays the flow rate and produces an output signal that can be used for various process functions. The Model 260(WF) Weigher is also capable of batching to a preset total.

When operating as a weigh feeder, the Model 260(F) continuously controls the feed rate (or rate of product discharge off the belt) in relation to a setpoint via modulation of the belt speed.

MATERIALS

Innovative PC Copolymers for Medical Equipment & More

Launched at MD&M West 2020, a new family of PC copolymers from Sabic boasts excellent resistance to highly aggressive chemical disinfectants used to prevent hospital-acquired infections. LNP Elcres CRX copolymers are said to be a drop-in alternative to incumbent resins used in healthcare equipment housings for portable ultrasound and x-ray machines to hand-held diagnostics and infusion pumps.

Repeated cleanings with highly aggressive chemical disinfectants such as quaternary ammonium compounds have been shown to cause environmental stress-cracking (ESC) that can lead to part failure in conventionally used materials such as PC/ABS and PC/PBT blends.

These opaque PC copolymers have shown excellent property retention after exposure to PDI Healthcare's Sani-Cloth AF3 wipes and other aggressive healthcare cleaners, combined with excellent impact performance (ductile notched Izod) and mitigation of crack propagation. To measure a polymer's potential compatibility with chemical disinfectants, SABIC devised a quantitative ESC test that evaluates retention of tensile stress at yield and tensile elongation at break.

The three initial grades are an amorphous blend of PC copolymer and PC resin for non-powered equipment and devices; a flame-retardant amorphous blend for powered devices; and a flame-retardant PC/PBT blend for powered devices.

Flame-retardant versions meet UL 94V-0 at 1.5 mm. Sabic is exploring additional grades for consumer electronics, mass transportation and industrial uses.

MATERIAL HANDLING

Bulk-Bag Discharger Features 'Clean' Construction

Flexicon's new Bulk-Out bulk-bag discharger features stainless-steel, open-channel construction for applications in which contamination of the product or equipment cannot be tolerated. Unlike hollow-steel frame members, the open-channel frame is devoid of cavities or recesses where bacteria, mold and other contaminants can breed, allowing rapid, thorough washdown with water, steam or cleaning solution, reducing the risk of cross-contamination between changeovers and providing unobstructed inspection for verifying cleanliness.

The discharger has a cantilevered I-beam with electric hoist and trolley for loading and unloading bulk bags without a forklift. Its Flow-Flexer bag activators promote complete discharge of even non-free-flowing materials.

The bag spout interface features a clamp ring that makes a high-integrity connection between the bag spout and the equipment, and a telescoping tube that maintains downward tension on the spout as the bag empties and elongates, promoting total evacuation. Together, the devices prevent the escape of dust throughout the entire discharging process.

MATERIALS

New Biodegradable Bioplastics for Fruit & Vegetable Bags

Spain's Kompuestos (Plasticos Compuestos S.A.), a manufacturer of sustainable compounds, has developed a new bioplastic made entirely from potato starch that is reportedly degradable on the ground in four weeks. This addition Kompuestos' Biokomp range is targeted as a replacement for traditional supermarket plastic bags for fruit or vegetables. The new bioplastic, and three other products in the Biokomp product line, have obtained the "OK Compost" label from the world leader in certification of bioplastics, Agency TÜV Austria, which certifies that they are 100% biodegradable in a specific period.

The Biocomp portfolio is all based on biodegradable resins made from different starches derived from corn, potato and various types of cereals, among other polymers of renewable origin. These resins reportedly can be processed in standard processing equipment. The company has obtained certificates for materials compostable at home or in industrial composting facilities. Depending on the product, they can require four to 14 months for composting.

MATERIALS

Long-Fiber Engineered Compounds for Medical Equipment

Continuous and highly aligned long-glass reinforced compounds from Solvay Specialty Polymers reportedly deliver high strength and enhanced impact resistance for structural applications like chassis, gear systems and components needing high mechanical properties and load-bearing capabilities. These new Xencor LFT thermoplastics offer healthcare designers and OEMs new opportunities to replace metal and conventional short-fiber thermoplastics used in structural medical components.

Featured at MD&M West 2020, the Xencor LFT portfolio comprises grades based on Solvay semi-crystalline resins such as Ryton PPS, Amodel PPA and Ixef PARA. These compounds are produced with Solvay's pultrusion manufacturing process and can contain 30% to 60% long fibers.

MATERIALS

Low-COF Acetal for Medical Devices

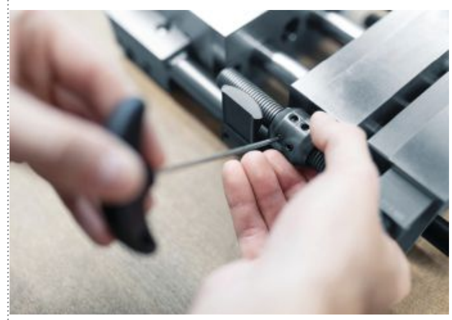
A new acetal resin launched at MD&M West 2020 reportedly features the lowest coefficient of friction (COF) in DuPont's Delrin line of materials for medical devices. Lubricated Delrin SC698 can help improve patient comfort and ease of use by ensuring smooth actuation of high-load drug-delivery devices like inhalers, injectors and pumps. Moreover, its strength, stiffness and dimensional stability can help increase the injection precision of wearables and inserter devices. Delrin SC698 resin can be custom colored.

TOOLING

Latch Lock for 3-Plate Molds

Meusburger says its new E 1817 latch lock can replace round or flat latch locks as a compact, reliable solution to control molds with two split lines. With this device, when the mold is opened at the first split line, it is done with a maximum pulling force of 14 kN (3.15 lbf) per latch lock. The puller inserted in the plate then pulls the floating plate to the desired stroke.

This stroke is determined by the position of the cam, which can be adjusted on the spindle in increments from 6 to 165 mm. The position is fixed by locking the two cam halves, which eliminate any play in the spindle.



As soon as the rocker lever makes contact with the cams, the latch arm is steered over the puller and the second split-line face is released and can be opened. The wear-resistant rocker lever is DLC coated. The integrated compression spring in the latch arm brings the lever back to the neutral position after each operation.

Prices of Volume Resins Flat to Down

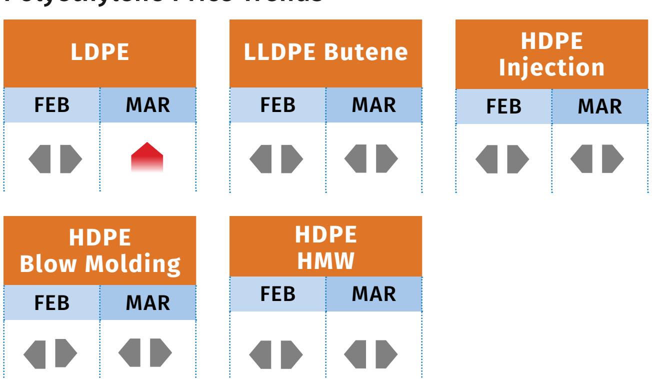
Key drivers for the trajectory of resin prices include supply outpacing demand, lower feedstock costs, and uncertainty about coronavirus effects.

By Lilli Manolis Sherman
Senior Editor

Prices of all volume commodity resins heading into April were expected to be mainly flat and in some cases lower. Factors for this softness include well-supplied markets, sluggish demand, lower global feedstock prices, and the effects of the coronavirus disrupting global production networks. The latter introduced a key element of uncertainty into industry sources' projections for commodity resin pricing going into the second quarter.

These are the views of purchasing consultants from Resin Technology, Inc. (RTi), senior editors from Houston-based *PetroChem Wire* (*PCW*), and Michael Greenberg, CEO of The Plastics Exchange.

Polyethylene Price Trends



Market Prices Effective Mid-March 2020

Resin Grade	¢/lb
POLYETHYLENE (railcar)	
LDPE, LINER	96-98
LLDPE BUTENE, FILM	79-81
NYMEX 'FINANCIAL' FUTURES	32
MARCH	32
HDPE, G-P INJECTION	101-103
HDPE, BLOW MOLDING	94-96
NYMEX 'FINANCIAL' FUTURES	32
MARCH	32
HDPE, HMW FILM	108-110
POLYPROPYLENE (railcar)	
G-P HOMOPOLYMER, INJECTION	57-59
NYMEX 'FINANCIAL' FUTURES	42
MARCH	42
IMPACT COPOLYMER	59-61
POLYSTYRENE (railcar)	
G-P CRYSTAL	108-110
HIPS	112-114
PVC RESIN (railcar)	
G-P HOMOPOLYMER	86-88
PIPE GRADE	85-87
PET (truckload)	
U.S. BOTTLE GRADE	45

PE PRICES FLAT—MOSTLY

Polyethylene prices were flat in February and were projected to remain flat in both March and April, after suppliers implemented a 4¢/lb January increase. Mike Burns, RTi's v.p. of PE markets, *PCW* senior editor David Barry, and The Plastic Exchange's Greenberg all noted that most suppliers had delayed their February 4¢ increases to March, while two suppliers—Dow and ExxonMobil—notified customers of an additional late-February increase of 2¢/lb for LDPE. According to these sources, spot LDPE availability has been tight for several months due to unplanned shutdowns and delays of new capacity coming on stream.

Still, these sources note that all key factors supporting an increase have reversed themselves—from lower global oil prices and feedstock costs to lower global PE prices and demand, and a significant drop in U.S. exports brought on by the uncertainty of the coronavirus. Greenberg reported that, given these developments, "Suppliers might be happy just to hang on to the 4¢/lb hike they achieved in January." Noting that domestic demand continues to be good, Burns said, "The duration of the impact of the coronavirus will continue to be the main demand driver. Without global demand and export opportunity, inventories will continue to grow and outpace demand." And Greenberg's projection of flat pricing in March and April is coupled by downward pressure from spot-market prices and lack of export opportunities (40% of U.S. PE production typically goes to exports).

Barry noted that suppliers will have to throttle back production and/or reduce PE export prices, which they had yet to do in early March, in order to get export markets moving again. He thought that planned maintenance turnarounds in March and April would help reduce the supply glut. Burns doubted suppliers would throttle back production and expected them to seek every reason to hold onto the unexpected January price increase.

PP PRICES DOWN

Polypropylene prices in February dropped 1¢/lb in step with propylene monomer and were expected to be flat or slightly lower in March and possibly into April, even though suppliers issued price increases. Those views were held by Scott Newell, RTi's v.p. of PP markets, *PCW*'s Barry, and The Plastic Exchange's Greenberg. Newell, for one, said an additional 1¢/lb drop was possible in March or April. All three noted that the coronavirus was creating uncertainty and supply disruptions and would likely impact global demand, in addition to existing lackluster domestic demand.

Polypropylene Price Trends

Homopolymer	
FEB	MAR
▼ 1¢/lb	◀▶

Copolymer	
FEB	MAR
▼ 1¢/lb	◀▶

Several suppliers had posted 3-4¢/lb hikes for March 1, on top of any change in monomer pricing. Missing was ExxonMobil, which later issued an April 1 increase of 3¢/lb for PP homopolymers and random copolymers such as clarified grades, with no change in impact copolymer pricing. While PP contract buyers have had no problems in getting material, there has been a shortage in the spot market (and rising prices), particularly for homopolymer raffia (low-MFI grades) and random copolymer clarified grades. Barry saw this as a relatively short-term tightness and ventured that suppliers might actually inch prices up by 1-2¢/lb in March and April. While Greenberg envisioned a similar scenario, he noted that these PP margin increases have been hard for suppliers to secure in the past.

Newell noted that PP plant operating rates were below 80% for four months through February, and that despite planned and unplanned production interruptions, supplier inventories stood at a healthy 35.5 days of supply. He did not see the market fundamentals supporting any non-monomer-related increase.

PS PRICES FLAT

Polystyrene prices in February were flat and were expected to remain so last month and possibly this month as well, owing to feedstock price cuts affected by the coronavirus, seasonally quiet demand and adequate supply, according to both *PCW*'s Barry and Robin Chesshier, RTi's v.p. of PE, PS and nylon 6 markets. Barry, in fact, ventured that a 1¢/lb price concession was possible for March. March benzene contract prices dropped 7¢/gal to $2.57¢/gal but spot prices, in step with crude-oil prices, dropped from $2.69/gal to as low as $2.20/gal going into March. Styrene monomer prices were at a record low of 34¢, dropping another 2¢/lb by February's end, and ethylene prices were also 2¢/lb lower, with further decreases likely last month. According to Barry, the implied styrene cost based on a 30/70 ratio of spot ethylene/benzene was at 25.7¢/lb, down 2.6¢ from the prior week and down 3.7¢ through February.

Polystyrene Price Trends

GPPS	
FEB	MAR
◀▶	◀▶

HIPS	
FEB	MAR
◀▶	◀▶

Chesshier indicated that buyers were asking suppliers to give back some of their January 3¢ increase, based on the same dynamics the suppliers had cited as justification for the increase—the price trajectories of benzene, ethylene and styrene. She said there was some potential for higher prices this month, as the traditional busy season for PS gets underway and plant production would likely be increased from the low 60% utilization rates through much of the first quarter. Said Barry, "I'm not sure that demand for PS, which is pretty static with no new applications developed, could swing prices upwards as there's ample supply, even at low operating rates."

PVC PRICES RISE, THEN LEVEL OFF

PVC prices moved up in February by 2¢ of the 3¢/lb sought by suppliers. This came after implementation of the January 3¢ hike, noted Mark Kallman, RTi's v.p. of PVC and engineering resins.

PVC Price Trends

Pipe	
FEB	MAR
▲ 2¢/lb	◀▶

Gen. Purpose	
FEB	MAR
▲ 2¢/lb	◀▶

PCW senior editor Donna Todd reported that the full implementation of the January increase was attributed by suppliers to PVC resin supply tightening up after planned and unplanned production shutdowns, which pushed export prices up and then pulled up domestic pricing as well. Still, both these sources noted that PVC processors had no difficulty getting the PVC they needed through February.

Kallman said PVC prices in March and April were likely to be flat, owing to lower ethylene costs and uncertainty over the coronavirus's impact. He noted that while two more plant turnarounds are scheduled for the April-May timeframe, expanded new capacity would nix any further tightening. Seasonal demand for construction could result in upward pressure on pricing through the second quarter.

PET PRICES FLAT

PET prices started March in the mid-40¢/lb range, delivered railcar to the Midwest, down 1¢/lb from the start of February. According to *PCW* senior editor Xavier Cronin, an abundant supply of imports from around the world has sustained a buyers' market. Cronin reported that March prices were expected to be mostly unchanged for monthly contract business for bottle resin delivered Midwest and U.S. South. ►

PET Price Trends

Bottle Grade	
FEB	MAR
1¢/lb	

He ventured that April could see an uptick of 2¢ to 5¢/lb for prime PET resin as the warm-weather season ushers in demand for single-use PET bottles and containers, especially for carbonated soft drinks and water.

Consumer brand companies are under pressure to use more recycled PET in single-use bottles and containers for their products. But, noted Cronin, cheap, abundant virgin PET resin, including wide-spec, is keeping demand for recycle steady, even as brands try to blend more food-grade rPET pellet and flake into their production.

ABS PRICES FLAT TO DOWN

ABS prices moved down 1-2¢/lb in January, remained flat in February, and were expected to drop another 1-2¢ in March, according to RTi's Kallman. Lower benzene and styrene monomer prices and a very well-supplied market, plus low-priced imports, are likely to keep prices flat this month and most likely beyond.

PC PRICES FLAT

Polycarbonate prices through most of the first quarter were generally flat, according to RTi's Kallman. He noted that January saw some 2020 contract concessions on the order of under 5¢/lb, reflecting similar discounts some contract buyers secured in last year's fourth quarter. He expected PC prices to remain flat into the second quarter, owing to a well-supplied market and attractively priced imports. A downward turn could come if domestic automotive production and sales are affected by the coronavirus, as has occurred in China and elsewhere.

PRICES OF NYLONS 6 & 66 FLAT TO DOWN

Nylon 6 prices through much of the first quarter were largely stable, despite suppliers' attempts to push through price hikes of 7¢/lb, according to RTi's Chesshier. Moreover, due to ample supply and weak demand, suppliers reportedly offered some volume discounts in order to retain and/or gain market share. Based on short-term market indicators, nylon 6 prices were expected to be largely flat through the second quarter. Still, uncertainty about the effect of the coronavirus during a time of an oversupplied market makes it hard to predict price trends. Companies like BASF, Lanxess and Evonik all have nylon 6 production in China, where plants were said to be operating, but at much reduced rates.

Nylon 66 prices were mostly flat through much of the first quarter, though some 2020 contract concessions under 5¢/lb were given in January, reflecting similar discounts given to some processors in the fourth quarter, according to RTi's Kallman. He saw the potential for price concessions in April. driven by low oil and feedstock prices globally, a well-supplied market, and the possibility of prolonged coronavirus fallout.

Expanding Production Bumps Index Above 50

Index expands for first time since June 2019.

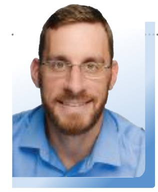
The Plastics Processing Index expanded for the first time since June 2019 with a February 2020 reading of 51.8. Most of the Index's components reported improved figures versus the prior month.

By Michael Guckes
Chief Economist/Director of Analytics

Gardner Intelligence's review of the underlying Index reveals that the Index—calculated as an average of its components—was supported by an eight-month high in production activity and a modest expansion in employment. The Index was pulled lower by a sharp contraction in export activity and a ninth consecutive month of contracting backlog activity.

The impact of COVID-19, widely known as the Coronavirus, is expected to have an adverse effect on the Index in the coming months. The necessary efforts of Asian governments in January and February—and by a widening collection of nations in February and March—will most immediately restrict the normal flow of upstream and sub-component goods necessary for the proper functioning of the manufacturing sector.

Our Indexes measure North American business conditions on a monthly basis. Moving forward, they will be able to quantify both the initial shock from the virus along with the timing and strength of the market's eventual recovery from the economic impact of the virus. The Index is based on responses to surveys conducted each month by subscribers to *Plastics Technology* magazine.



Michael Guckes is chief economist and director of analytics for Gardner Intelligence, a division of Gardner Business Media, Cincinnati. He has performed economic analysis, modeling, and forecasting work for more than 20 years among a wide range of industries. He received his BA in political science and economics from Kenyon College and his MBA from Ohio State University. Contact: *(513) 527-8800*; *mguckes@gardnerweb.com*. Learn more about the plastics processing Index at *gardnerintelligence.com*.

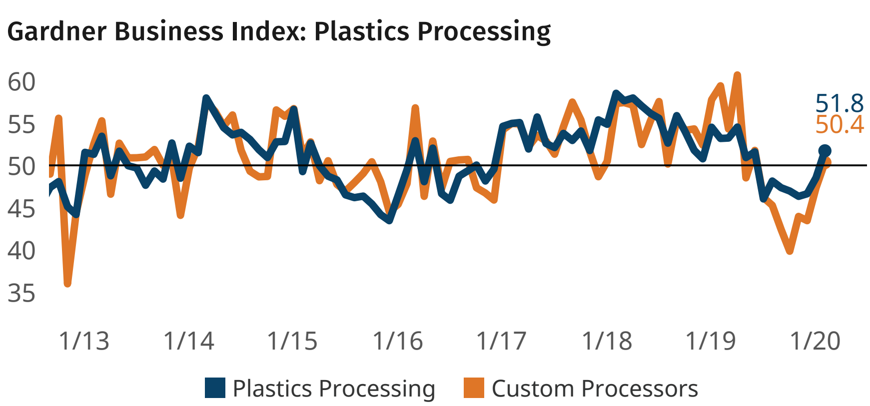


FIG 1

Both indexes expanded in February for the first time since June 2019. Plastics processors reported expanding production, new orders, supplier deliveries and employment activity. This positive news, however, will likely be soon overshadowed by COVID-19's mounting impact on the global economy.

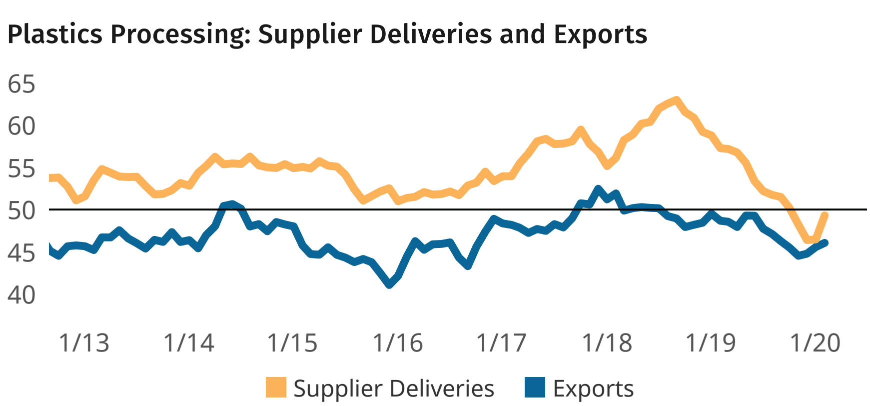


FIG 2

Gardner Intelligence expects that most—if if not all—of its indicators will be subjected to shocks from COVID-19. That the virus originated in Asia suggests that American manufacturers in the immediate future should pay particular attention to their supply chains and expect increased volatility in export orders and material prices.

infoNET

This is *Plastics Technology's* online listing for plastic processing equipment builders, material suppliers, auxillary manufacturers and more.

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Monthly Resource Guide

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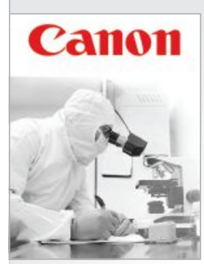

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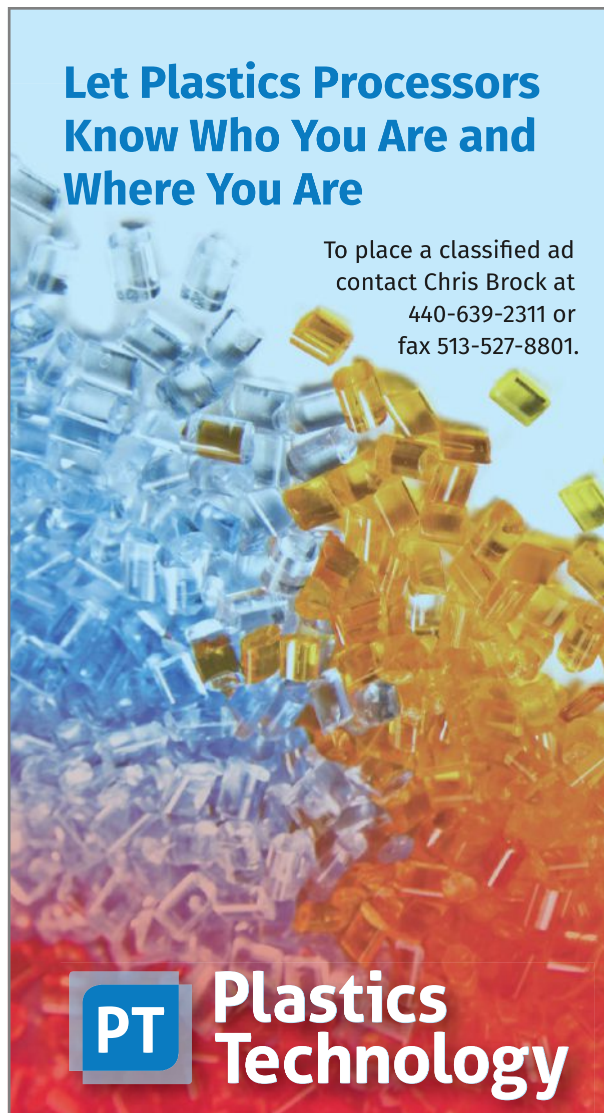

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T&M ENTERPRISES, INC. — SHAFTSBURY, VT.

Small, Family-Run Vermont Molder Pioneers in 'Lights-Out' & Industry 4.0

Going back 37 years, T&M Enterprises dared to push available technology far beyond the risk tolerance of much larger firms.

T&M founder and president Tom Paquin (rt.) with his son, T.R. Paquin, operations manager, in their all-Battenfeld plant.

By Matthew Naitove
Executive Editor

It doesn't take long to recognize that there's something different about T&M Enterprises. At first glance, the picture may not seem all that remarkable: small, family-owned custom molder with 16 injection machines from 27 to 200 tons in a 28,000-ft^2 plant in Shaftsbury, Vt. The "T" and "M" in the name stand for the founder, Tom Paquin, and his wife Marty. In business since 1983, the firm molds standard parts for electrical capacitors (its original specialty) as well as medical parts, plumbing components, handles for paint and pastry brushes, nylon handcuff ties, small automotive parts, and a proprietary line of votive candle cups in clear or colored PVC—11 million of them a year.

Tom and T.R. Paquin with samples of their production.

T&M keeps things simple: just molding—no decorating, painting or assembly. "We focus on consistent quality, fast delivery, and good pricing," says Paquin, company president. Sales are "north of a million, but we have extra capacity now and lots of plant space for expansion," adds his son, T.R. Paquin, operations manager.

A closer look reveals interesting details. All the electric, air and water lines are under-floor. The machines are organized into cells with interchangeable components—"so we're not limited to any certain product line or specialty," notes T.R. Paquin.

Still more interesting: The plant gets 70% of its electricity from solar panels. Soon, an off-site solar array will take T&M off the grid entirely.

Here's where it really gets intriguing: To run those 16 injection machines, T&M employs just *eight* people. The company runs half the second shift with just one worker to pack parts and fill hoppers, while the third shift is entirely "lights out"—and has been since the shop opened in 1983. Back then, machines could monitor positions of the screw and mold with limit switches and could shut themselves down, if necessary. Today, "Every action of the press is monitored by distance, time and even system pressure," observes T.R. Paquin. "The press can shut itself down for probably over 50 different faults. Today's presses can even sense a piece of bubble wrap that might get between the moving plates of the tool, and can shut down before the bubble pops. That means that if a molded part hangs up in the tool, the controls can prevent damage to the tool or press."

"Not many other molders trust their machines enough to do this," muses Tom Paquin. But he has had that trust ever since he started out with three Battenfeld presses. He has stuck with that brand exclusively, transitioning to the newer Wittmann Battenfeld models when the machine builder changed hands in 2008.

Wittmann Battenfeld today is a strong advocate of cell integration via its "Wittmann 4.0" technology. But T&M has had its own version of cell integration for the last five to 10 years. Recalls Tom Paquin, "We added contactors and pigtails to our presses. We would plug all our auxiliary equipment—dryers, conveyors, granulators, etc.—into the press. They were tied into the press motor, and if the motor stopped, so would our auxiliaries. I won't lie, we did come in some mornings to nice messes—like if a conveyor stopped working and hours' worth of parts piled up on the floor."

T.R. Paquin adds, "Today, everything, including auxiliary equipment, is monitored through Wittmann's software, and parameters for all equipment can be saved for the next time you run a specific tool. Press a few buttons, and all of those saved settings are recalled."

T&M also values the ability of the machines' B6 and B8 controls to allow Wittmann technicians remote access. "If we have a problem, they can look into the controls and see what the machine is doing and diagnose issues," says T.R. Paquin. "It's a very useful and time-saving technology." PT

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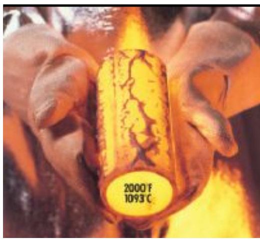

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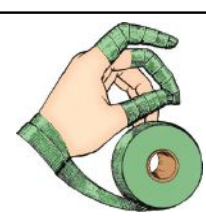
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