Finetuning Process Performance

SPE conference speakers share techniques for achieving and maintaining peak polymer throughput

By Geoff Giordano

The inaugural Plastics Processing Conference of the Lehigh Valley and Palisades-New Jersey sections of SPE focused on ways of achieving and maintaining polymer performance and productivity during extrusion, injection molding and compounding.

GreenMantra recycling technology converts plastics with short life cycles in their original applications to specialty polymers that act as process aids in products with long service lives. Courtesy of GreenMantra Technologies

Topics presented at the virtual event, April 6 to 7, included GreenMantra's advanced recycling technology, which involves the partial depolymerization of waste plastics to create specialty polymers that function as additives in processing and in applications like asphalt roofing and roads. In another area, Leistritz discussed how to marry downstream processing lines directly to twin-screw extruders to efficiently produce 3D printing filaments without sacrificing dimensional precision.

In a keynote address, SPE Vice President of Sustainability Conor Carlin provided a perspective on the industry's best path forward to sustainability. The "triple bottom line" of people, planet and profits will best be achieved by creating a network of small, well-functioning regional circular economies, he asserts. Amid the efforts underway, he notes that industry must accept that sometimes "solutions to complex problems are difficult, messy and incomplete. We cannot let the perfect be the enemy of the good when it comes to environmental impact. Sometimes the least-worst option is simply the best choice." A well-managed landfill, for instance, is not an undesirable disposal option given that the plastics therein remain inert, with no degradation or emissions. (See also Carlin's article, "In Pursuit of Effective and Equitable Sustainability," in the March issue, p. 40.)

Bridging Recycling Methods

Finding a niche between mechanical and chemical recycling processes, GreenMantra Technologies of Brantford, Ontario, Canada, has created and fully scaled a recycling technology platform that takes plastics with lifespans of six months to one year in their original applications and transforms them into specialty polymers that function as processing aids in applications with long service lives—up to 50 years in some cases.

Using high-density polyethylene, low-density PE and polypropylene as feedstocks, GreenMantra converts millions of pounds of discarded plastics into specialty waxes and polymers, explains Domenic Di Mondo, vice president of technology and business development. The specialty waxes are used as processing aids for end-uses like composites and drainpipes and to enhance asphalt applications like shingles and roads.

GreenMantra, founded in 2011, launched capacity and geographic expansion in 2020. The company has been "able to significantly increase the demand for collection, and as a result reduce the plastics that end up in our environment and oceans," he says.

The company's business model is to "upcycle undervalued plastics streams into value-creating polymer additives that can be used inside and outside the plastics industry," Di Mondo notes. "We intercept underutilized materials that have a low value and are destined for landfills and transform them into specialty waxes and polymers of tangible value. Tangible value often translates into improved profitably for customers—for example, by providing increased manufacturing efficiency and higher throughput in an extrusion process or enabling a plastics product producer to use lower-cost recycled resin streams, which can reduce formulation cost."

GreenMantra employs "a proprietary process to perform a selective partial depolymerization of a plastic molecule into very precise smaller polymer segments," he says.

Part of the company's portfolio is its Ceranovus range of PE- and PP-based products, each derived from 100 percent recycled plastics. These materials do not migrate or bloom out of parts, Di Mondo says, and exhibit functionality as internal lubricants.

In extrusion studies with HDPE, GreenMantra achieved up to a 25 percent throughput increase by boosting melt flow as much as 40 percent with additions of 2 to 4 percent of its materials, while maintaining properties such as elongation and strength.

Another study, using a high-molecular-weight HDPE resin for pipes, GreenMantra's Ceranovus PN20 wax was dry blended with the resin at loadings of 2, 3 and 4 percent. The blends were fed into a corotating twin-screw extruder to produce pellets that were compression molded. The wax increased resin melt flow 19 percent with loadings of 2 percent and 3 percent and 40 percent at a loading of 4 percent. Additionally, extruder output increased by up to 25 percent, due to a decrease in load on the extruder motor ranging from 6 percent to 13 percent. Physical properties like flexural modulus and tensile strength were maintained, with elongation at break exceeding 300 percent.

Di Mondo says that GreenMantra is conducting in-depth testing with external labs to validate results in different recycled resin streams, and that its additives can be added anywhere in the plastics value chain.

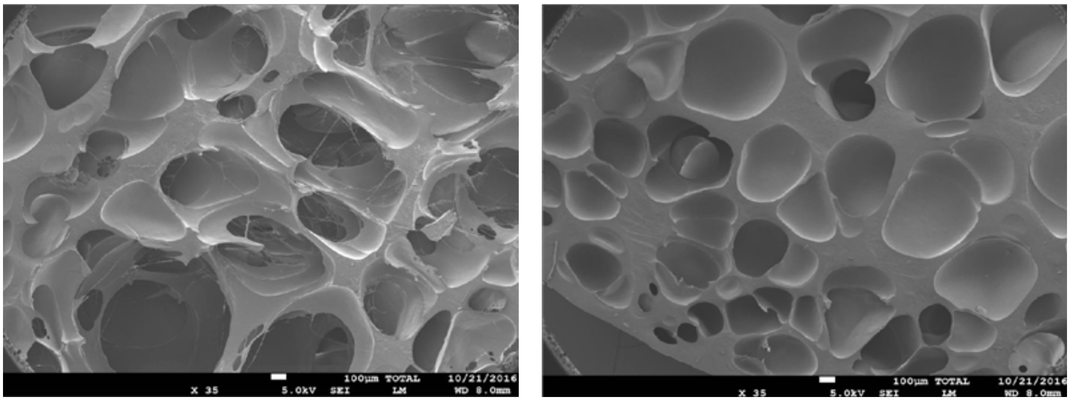
Tailoring PP Melt Strength

To increase the ability to incorporate regrind into PP and expand applications for post-industrial and post-consumer recycled PP, Brett Robb of Total Petrochemicals & Refining USA in Houston demonstrated how the company's Dymalink 9200 additive increases the polyolefin's inherently low melt strength.

Robb, an application chemist for Total's Cray Valley division, discussed how using the company's ionic additive to increase PP melt strength creates an ionic network.

"Adding Dymalink 9200 into polypropylene creates a unique dynamic network leading to unusually high-melt-strength behavior, even at very low loadings," Robb notes. "This allows for a tailored approach to high melt strength in PP-based homopolymers, copolymers and elastomers that are used in extrusion and foaming applications." The resulting recycled PP can be thermoformed or foamed.

Total's Dymalink technology has been used in the rubber industry for decades, Robb says, generally as an agent to



SEM image of conventional PP processed with 0.6mL/min CO_2 at 130 bar die pressure (100μm)

SEM image of conventional PP modified with 1% Dymalink 9200 processed with 0.6mL/min CO_2 at 130 bar die pressure (100μm)

Total researchers found that ionic domains produced by addition of 1 percent of the company's Dymalink 9200 additive foams homopolymer PP that's not otherwise suited to foaming. Courtesy of Total Petrochemicals & Refining improve the crosslink density of ethylene propylene monomer (EPM) and EPM rubber, and generally used with a peroxide to improve the crosslink density of rubbers. Dymalink 9200 is an off-white powder, while Dymalink 9202 is an off-white pellet version in an LDPE carrier masterbatch.

Total compounds its metallic monomers into polyolefins at more than 210°C, Robb explains, producing radicals that lead to the formation of ionic domains within the PP. Above 190°C, "the ionic bonds disassociate, and we have free-flowing chains. This allows for reprocessing these materials and for molding without affecting too much viscosity." Total can take this material or scraps, regrind it and still retain the ionic domains. As the material cools, the domains reform, creating higher-melt-strength material.

Robb cites two studies that illustrate the improvements achieved by adding Dymalink 9200. One involved a customer who approached Total to improve the amount of scrap that could be put through his lines. At the time, the customer could achieve no more than 5 percent regrind after adding impact modifier to high-melt-strength PP, foaming it and thermoforming it. Running the customer's homopolymer through a twin-screw extruder three to four times to simulate degradation at elevated temperatures, Robb and his team added 0.5 percent to 2 percent of Dymalink 9200, determining that scrap produced with 1.5 percent of the additive was well improved. After two extruder passes, "we're getting close to that elongational viscosity of the virgin material," he says.

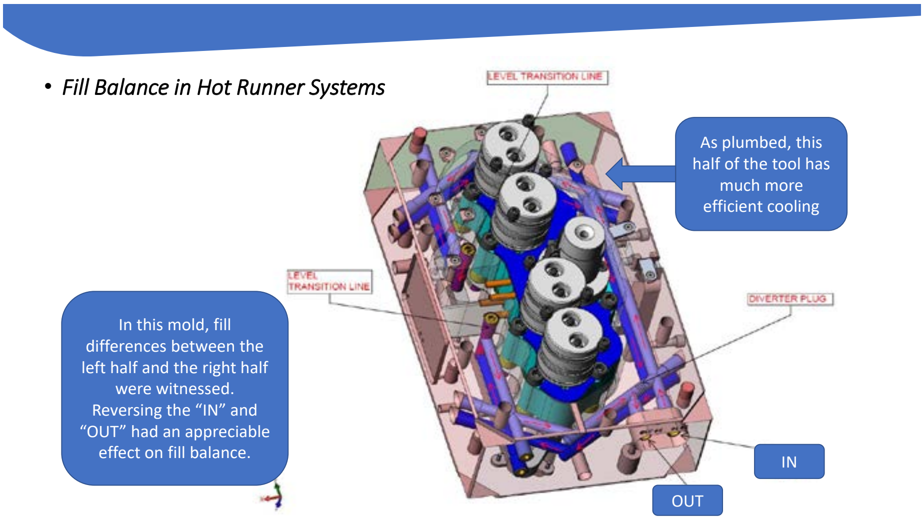
Total was able to load that modified material in 5 percent to 25 percent increments to the overall new material mixture to improve melt strength. While the customer was achieving 500,000 to 600,000 pascal seconds of elongational viscosity with 5 percent regrind material, Total achieved more than that while using 20 percent of its Dymalink-modified scrap.

Robb and his team also studied the ability of the ionic domains produced by Dymalink 9200 to foam PP that is not by itself suited to foaming. By adding 1 percent Dymalink to an off-the-shelf PP homopolymer, they achieve a "nice homogenous foam with very little work" and did not resort to a high-melt-strength material. The resulting extruded foam shows mostly closed cells, as opposed to the open cell structure of an unmodified foam.

Harnessing Hot Runners

Noting that hot runner systems, like any thermal process, are a source of variation, Matt Carnovale, staff engineer at molder Teleflex of Wyomissing, Pa., detailed how the application of Scientific Injection Molding analysis to common hot runner system problems is necessary to ensure part quality.

Computer aided engineering (CAE) helps Teleflex identify and eliminate "multiprocess disease" (a term coined by Rod Groleau, founder of training and consulting company RJG Inc.) in its valve gated hot runner systems, which are relatively new to the company.


- *Fill Balance in Hot Runner Systems*

As plumbed, this half of the tool has much more efficient cooling

In this mold, fill differences between the left half and the right half were witnessed. Reversing the "IN" and "OUT" had an appreciable effect on fill balance.

When water affected mold cooling performance unevenly, Teleflex reversed the lines and found an appreciable difference in fill balance. Courtesy of Teleflex

A hot runner system is "not a black box that you just apply to your injection molding process," Carnovale notes. "There are things that need to be done very early on" in the way of CAE work to achieve proper mold cavity fill balance and avoid shear imbalance. Such optimization is key to realizing the full benefits of hot runner systems, including:

» Sustainability: Achieved by eliminating or reducing runner waste by ensuring that all melt is delivered from the injection molding machine to the gate of each part.

» Versatility: Ability to gate into hard-to-reach zones or areas of parts.

» Cosmetics: Improved with enhanced gate quality.

» Improved cycle times: Cold runners and sprues often dictate cycle times, especially with small parts.

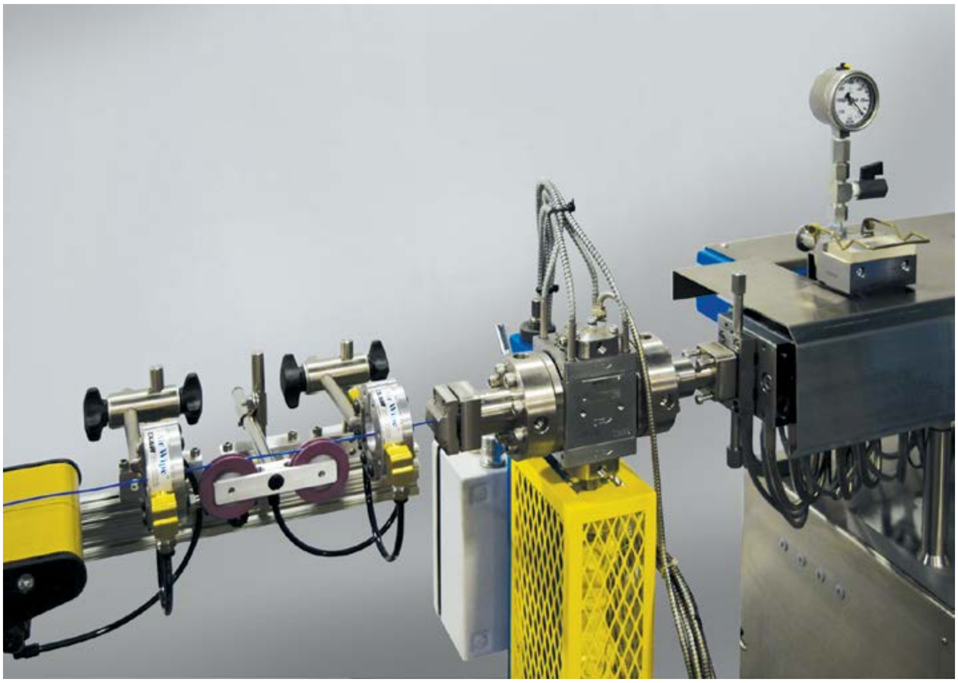
» Enhanced properties: HRS can achieve proper molecular spacing throughout parts when filling, packing and cooling. "We can be more confident that we're not freezing-in internal stress."

System suppliers are reliable in the operation parameters they provide, but Carnovale cautions that pre-installation analysis is often conducted just once and "not iterative enough to give the customer options for good, better and best." In assessing the hot runner process, he identifies issues Teleflex experienced.

In achieving fill balance, Teleflex found that in one hot runner system, the pneumatic delivery system was undersized for the application. Carnovale and his team had to optimize piston speed and consistency in the mold, where tenths of a second can be critical when producing small parts. In another instance, cooling water affected mold performance, with one half of a mold cooled much more efficiently than the other. With the incoming and outgoing water lines situated on the same part of the mold, Teleflex reversed the lines and found an appreciable difference in fill balance. "It highlights the need that as we look at the design of a hot runner system, even the cooling behavior needs to be taken into consideration."

He also says that managing shear imbalance is of particular importance, given that most of the company's work is overmolding small parts. In the case of overmolding plastic over stainless steel cannulas on an eight-cavity system, shear differences were detected across the flow channel. The plastic molecules closest to the mold wall shear more, and because of the laminar nature of melt flow, that material stayed to the outside when the melt was divided—leaving half the cavities to fill so slowly that the situation became "problematic to the point where we had to compromise our optimized injection molding process to create less shear, which means we had to slow down the fill rate."

Ultimately, "We need to be working with suppliers to help facilitate the instructions of use. The end customer and hot runner supplier need to determine what a reasonable method is to assess the process balance." To that end, Carnovale remarked after the conference, "It is of importance to us and something we are actively discussing with the hot runner supplier at the start of each project."



Direct precision compounding of 3D filament with the twin-screw Leistritz ZSE-18 system eliminates one heat and one shear history from these materials and from other heat- and shear-sensitive polymers. Courtesy of Leistritz

Filament in Less Steps

Typically, filament for 3D printing with fused deposition modeling is produced in a two-step process involving twin- and single-screw extruders. With process control, however, downstream processing equipment can be joined with a twin-screw extruder.

The keys to this efficiency, explained Leistritz president Charlie Martin, include carefully controlling extruder screw speeds, melting zones and gear pump pressures to achieve better diameter precision of the final filament.

In illustrating precision compounding with the Leistritz ZSE-18 3D filament direct extrusion system, Martin explains that the ability to eliminate one heat and one shear history from filament is ideal for some polylactic acid grades, biodegradable PLGAs (polylactic-co-glycolic acid), and heat- and shear-sensitive medical polymers. Also, during rapid prototyping: "During the development phase, we may want to … produce four to six samples per hour," he notes, with feeders adjustable to introduce additives at different formulation loads.

Essential to such production is building and stabilizing pressure with the gear pump. Running the extruder at 400 psi to the gear pump inlet keeps melt temperature down; a positive displacement device builds discharge pressure to the die with up to a 4,000-psi pressure differential. The gear pump, Martin explains, dampens out pressure fluctuations to maintain tight tolerance of the filament.

"When you're running a direct filament line, you're going to need to run closed-loop pressure control to maintain the gear pump inlet pressure," he notes. Eliminating process interrupts is the goal. If gear pump pressure shoots up, melt temperature of the material increases, die pressure decreases and the material often falls out of spec.

To access on-demand recordings from this conference, visit www.4spe.org/PlasticsProcessing.

ABOUT THE AUTHOR

Geoff Giordano has been a contributor to *Plastics Engineering* since 2009, covering a range of topics, including additives, infrastructure, flexible electronics, design software, 3D printing and nanotechnology. He has served as editor-in-chief of numerous industry magazines and is founder and chief creative officer of content marketing firm Driven Inbound. He can be reached at geoff@driveninbound.com.