Greetings! As we go into this holiday season we hope all is well with you and your family. The Extrusion Division has had a busy and fruitful year and next year promises to be eventful as well.

In September we held an Extrusion Mini-Tech as the SPE Thermoforming Conference in Atlanta. Mini-Tech’s are one-day conferences focusing on the fundamentals of our discipline. They have been a very successful venue over the last 15 years or so. We move them around from place to place, partnering with local Sections, or in this case with another Division. By co-locating with Thermoforming this year, we were able to help thermoformers better understand the front end of their process.

We will continue our educational mission in March by presenting a Topcon on Continuous Compounding. This is a 2 and half day event co-sponsored with the Akron and Cleveland Sections. It will be held on the campus of Case Western Reserve University and promises to be a highly educational event. Look for more details in this newsletter.

Finally we would like to say a word about our future. Many professional societies are seeing a drop in membership: younger members are not joining as fast as older member retire. The SPE and the Extrusion Division are not exempt from this trend. To help us better understand how we can better fulfill our mission and attract and retain new members the Board of Directions has begun a strategic planning process. Modeled after what many of the companies we work for have gone through, the Board began the process at our fall board meeting with a critical assessment of where things stand now. In future meetings we will process the insights gained and develop strategies and tactics for strengthening our Division and mission. Stay tuned for future communications on this very important subject.

Barry Morris, Joe Golba, John Christiano and Tim Womer

Acting chairs for Michelle Curenton 2013-2014
Is this on your wishlist for next year?
ANTEC 2014
Las Vegas, Nevada
April 28 — April 30, 2014

- Would you like to meet with fascinating, informed and creative colleagues from around the world?

- Would you like to look for partners to collaborate on future projects?

- Would you like to broaden your understanding of the plastics industry?

- There will be 10 sessions from the Extrusion Division including single screw, twin screw, die design, film and sheet, special sessions on hot melt extrusion and tutorial sessions! Come be a part of the knowledge sharing!
We’ve listened to the feedback our younger SPE members have provided from previous ANTEC conferences. So we just wanted you to know we’re offering some new, fun and engaging activities at ANTEC 2014 (April 28-30), specifically for young plastics professionals:

- **Plastics Race** - See Las Vegas through the eyes of a plastics engineer as you team up and roam the Vegas Strip to compete for some awesome prizes!
- **Panel Discussion** - Participate in a lively discussion, ask your industry questions, and gain the knowledge you’ve been looking for including career tips and tricks relevant to you, not that generic advice you find online.
- **Celebration Dinner** - Network over an enjoyable dinner with your fellow peers, future associates and industry veterans. Prizes, awards and more!
- **Mission Possible 2.0** - Your chance to make ANTEC 2015 and SPE what you want it to be.
- **Speed Interviews** - Sharpen your skills at on-site screening visits with prospective employers.

*So come on out, and see the new and improved ANTEC!*
During the past year or so, we have been alerted to the fact that associations in general are struggling to maintain membership, generate and increase participation, attract volunteers, and compete with alternative service offerings. These realities have been addressed in recent books such as: Race for Relevance, The End of Membership as We Know It, and The New Recruit.

The reality is that demographics have changed and that with this change, the interest of the younger generations have too! So it is natural to think that after so many years of operation, we do not know or it may not be clear to all members of the Extrusion Division what our PVMs (Purpose, Vision and Mission) are and what we need to do to accomplish them.

We are indeed facing a large problem and our Division is responding to a call from SPE Headquarters to do whatever possible to analyze the situation and take measures. We will proceed to establish a process in which we place our BRAND (the Extrusion Division) in the middle and analyze all the forces that affect it. These forces have been identified as: 1) Governance, 2) Members Market, 3) Market Place Realities, 4) Programs, Services and Activities, and 5) Technology.

The Strategic Planning Process that we are following is depicted above. We have already started with the Situation Assessment. This is the part of the Strategic Planning Process that requires the most work. During this module we are analyzing all the forces that are affecting our brand and generating a list of “learnings”. We are looking at “what is happening and why?” and “how is it affecting the Extrusion Division”?

The key question is: “What do these learnings mean?” The insights generated are of maximum importance to the rest of the exercise. We need to grasp the inward or hidden nature of what is going on. This is not trivial and so, much time is being devoted to this stage.
The board had a productive 2-day meeting in Wilmington, Delaware on Nov. 7-8th. Many important issues were discussed such as the Extrusion Division branding efforts, and how to attract and retain young professionals to be more involved in the division. Do you have any ideas or would like to be more involved? Please contact any of the board members listed on the second last page of the newsletter!
Flow disturbances that emanate from the extruder can cause thickness variations in a cast sheet or film coating. However, the size of the disturbance that results in the sheet or film will be dampened by the delivery system between extruder and die. The delivery system would include pipes, filters, mixers, valves or any other things in the flow stream. Proper design of the delivery system will minimize the size of a disturbance that reaches the product.

A model of the transient flow is used to analyze the dampening of the delivery system[1]. It is based on the impedance method for calculating hydraulic transients[2]. The model is used to identify the important factors and the quantitative relative importance of each.

Figure 1 shows a very simple example of a delivery system, and it lists the factors that are important to system damping of flow disturbances. Flow rate is given for sinusoidal flow at the inlet and exit of the system. An amplitude ratio is defined as the ratio of the amplitude of the exit flow disturbance divided by the amplitude of the inlet flow disturbance at the extruder, and it will be less than one.

Figure 1. A simple example used to demonstrate the important factors to flow dampening in a polymer delivery system.
Figure 2 shows an example for LDPE with specified values of the factors, and the amplitude ratio of the flow is given for these alternative factors of the system. A base case is given by which to judge changes.

Of importance is the wave speed of the polymer. This is a measure of the compressibility of the polymer melt which includes the size and end constraints of the conduit. The wave speed determines the amount of flow disturbance that will be absorbed by the delivery system through bulk compression of the melt and stretching of the conduit.

![Example of System Damping](image)

**Example of System Damping**

Basic: LDPE, ID=5.08 cm, L= .610 m, 2 cps

Figure 2. The damping ratio resulting from changes in the system layout.

Several factors are shown that give an amplitude ratio of between 0.8 and 0.9. For comparison, the amplitude ratio for water is shown to be over 0.90 as water (wave speed =1440 m/s) is less compressible than LDPE melt (wave speed=1241 m/s).

The location of a filter is shown to be a significant factor. Locating the filter as near as possible to the die lowered the amplitude ratio to about 0.55. When near the extruder the amplitude ratio is nearly 0.9.

A cumulative effect for making the pipe longer, larger diameter and putting the filter near the die lowers the amplitude ratio to about 0.24.
The frequency of the oscillation of 20 cps is shown to be a major factor. Higher frequency will always lead to lower amplitude ratios.

Entrapped air or gas is shown to be a major factor. A value of 0.4% by volume dramatically lowers the wave speed to 168 m/s, and almost eliminated the transmission of the disturbance. Ironically, purging of the system to eliminate gas bubbles in the product will hinder damping and thickness uniformity.

Every system will react differently depending on the cited factors. The math model can be easily used to identify which factors are most effective in increasing damping and improving thickness uniformity for different systems.

References

On September 9-12, 2013, the annual SPE Thermoforming Conference was held at the Renaissance Atlanta Waverly Hotel and Convention Center in Atlanta, Georgia. This was the first time that the SPE Thermoforming and Extrusion Divisions had co-located and event together.

On Thursday, September 12th, the Extrusion Division held a Mini-Tech, “An Overview of the Extrusion Process for Thermoforming Sheet-Pellet to Product or Everything You Wanted to know about Extrusion and were afraid to ask”.

The Mini-Tech started with a keynote presentation by Roger Kipp, Past-President of the Thermoforming Division and also the 2010 “Thermoformer of the Year”. Roger’s presentation entitled, “Starting our Innovation Engine” was very motivating and very well received by the audience.

Following Roger’s presentation there were presentations with the following topics: Material handling primarily dealing with the drying of resins, Advances in material feeding and handling, the use of computer simulations for screw designs, high speed extrusion for sheet extrusion, the fundamentals of screen changers and melt filtration, the basics of sheet die design, computer simulations for die design, the basics of melt pumps and their usefulness and ending with the basics of heat transfer roll designs used for flat sheet extrusion. The program was setup just as the title of the event, from “Pellet to Product”.

The individuals who were gracious enough to give their time to speak at this event were: Roger Kipp, Keith Larson, Jaime Gomez, Karen Xiao, John Christiano, Monica Gnuess, Gary Oliver, Mahesh Gupta, Dan Smith and Tim Womer.
The Society of Plastics Engineers Extrusion Division and the Cleveland/Akron Sections will host a Continuous Compounding Topical Conference (CCT 2014) on March 11-13, 2014 at Case Western University in Cleveland, OH. This program will feature 20+ presentations by industry experts and will include a review of fundamental mixing technologies on Day 1, continuous compounding core technologies and case studies on Day 2, and advanced/cutting edge technologies on Day 3. A tour of the prestigious Case Western University laboratories will augment the technical program and provide 1st hand knowledge of extrusion and analytical equipment, techniques and practices.

In addition to the technical program, there will be a networking reception and tabletop display area to mix and meet with some of the top compounding companies in the world. A preliminary list of corporate sponsors includes: ACS Group, Brabender Technologie, Bay Plastics Machinery, Coperion-K-Tron, Gala Industries, Gneuss, Leistritz, Plastics Technology Magazine, and Schenck AccuRate.

A limited number of corporate sponsorships are still available for $1000. To become a CCT 2014 Corporate Sponsor, please contact Charlie Martin at cmartin@alec-usa.com or by phone, 908/685-2333, x616.
CONTINUOUS COMPOUNDING TOPICAL CONFERENCE

MARCH 11 – 13, 2014
PROPOSED PROGRAM

DAY 1 (Half Day) – FUNDAMENTALS—March 11, 2014 afternoon

- A Review of Extruder Types and the Unit Operations of Extrusion…Joe Golba (PolyOne Corporation)
- A Primer on Mixing for Melt Compounders…Prof. Ica Manas-Zloczower (Case Western Reserve University)
- The Feeding and Dosing of Raw Materials for Productivity and Profitability…Jaime Gomez (K-Tron International)
- Extruded Product Management for Customer Satisfaction…Chris Case (Reduction Engineering)

DAY 2 – CORE TECHNOLOGIES FOR CONTINUOUS COMPOUNDING & CASE STUDIES – March 12, 2014

The Melt Compounder’s Extruder Tool Kit (Morning)
- Mixing with Single Screw Extruders…Tim Womer (TWWomer and Associates, LLC)
- TriVolution™ in Single Screw Kneading…Michael Lazorchak (B&P Process Equipment)
- Co-Rotating, Intermeshing Twin Screw Extrusion…Paul Andersen (Coperion)
- Counter-Rotating, Non-Intermeshing Twin Screw Extrusion…Chris Tucker (NFM Welding Engineers)
- “Direct Extrusion” for Increased Profitability…Charlie Martin (Leistritz)
- Coupling Melt Compounding with Injection Molding for Increased Profitability…Matt Sieverding (Krauss-Maffei Berstorff)

Case Studies in Melt Compounding and Reactive Extrusion (Afternoon)
- Liquid Color and Additive Melt Injection…Andrew Overend (PolyOne/ColorMatrix)
- “Wood Plastic Composites”…TBD
- Latest Developments in Processing Biomaterials…Kim Young & Alex Utracki (Coperion)
- “Something Melt Compounding…TBD (TBD)…1/2 hr.
- “Something Reactive Extrusion”…TBD (TBD)…1/2 hr.
- Reactive Extrusion Based Chain Extension For Engineering Nanocomposite Rheology…Joe Golba (PolyOne Corporation)
CONTINUOUS COMPOUNDING TOPICAL CONFERENCE

MARCH 11 – 13, 2014
PROPOSED PROGRAM (Continued)

DAY 3 – TWENTY FIRST CENTURY TECHNOLOGIES FOR CONTINUOUS COMPOUNDING – March 13, 2014

Process Monitoring and Control for 21st Century Manufacturing (Morning)
- Keynote Speaker…Prof. Joao Maia (Case Western Reserve University)
- On-Line Viscometry…Monica Gneuss (Gneuss, Inc.)
- On-Line Color…Bob Furlan (Equitech International)
- On-Line FT-NIR…Herman He (Thermo Scientific)
- A New Paradigm in Process Control…Prof. Zhiqiang Gao (Cleveland State University)

Process Simulation for Design, Scale-Up, and Troubleshooting (Afternoon)
- One Dimensional Process Simulation for Twin-Screw Compounding – Limitations and Opportunities…Adam Dreiblatt (Century Extrusion)
- Applying Ludovic 1D Twin Screw Extrusion Simulation for the Analysis and Scale-Up of Melt Compounding and Reactive Extrusion Processes…Jane Spikowski (PolyOne Corporation)
- Ximex™ 3D Process Simulation…Philippe David (Sciences Computers Consultants)
- New Options for TSE Process Simulation…Prof. David Bigio (U. Maryland)
- “Simulation Applied to SSE and/or Die Design”…John Perdikoulis (Compuplast)
- Simulation via the Manufacturing and Polymer Portal…Rich Markham (PolymerOhio)
Twin Screw Extruder Developments to Produce Consistent/Repeatable Concentrates

Charlie Martin, Leistritz

Twin screw extrusion has been an established industrial technology to manufacture concentrates for decades. Prior to the use/acceptance of twin screw extruders (TSE’s), batch mixers and single screw extruders were the mixing devices of choice in the plastics industry. In the last dozen years an analog evolution has begun in the pharmaceutical industry, as twin screw extrusion has emerged as a viable platform to mix active pharmaceutical ingredients (API’s) with polymers and additives that serve as binders. Just like a color masterbatch application, the TSE is utilized as a continuous mixer to make a high-quality, consistent drug delivery mechanism.

Today, in the pharmaceutical industry, applications range from controlled release systems to oral bioavailability. Pioneering development activities in the late 1980’s and 1990’s spawned the generation of several commercial compositions. Driven by the FDA’s 2003 Process Analytical Technology (PAT) initiative, the use of twin screw extruders has been embraced by virtually every major worldwide pharmaceutical company.

It is without question that pharmaceutical companies have reaped the benefit of 50+ years of technological developments and process refinement. Now might be time for concentrate suppliers to implement, where practical, current Good Manufacturing Practices (cGMP) as utilized by pharmaceutical companies to improve manufacturing efficiencies and make a better product.

Historically, dosage forms have been manufactured via batch processes. The FDA’s 2004 Process analytical technology (PAT) initiative provided drug makers a framework for pharmaceutical development, manufacturing and quality assurance through in-line monitoring. In a nutshell, the PAT initiative strongly encouraged that new dosage forms be manufactured by continuous processing with in-line monitoring of key parameters- it literally could have been written by an extruder supplier.

Twin screw extruders process materials in channels bounded by screw flights and barrel walls, and are therefore referred to as small mass continuous mixers. The motor inputs energy into the process for mixing via rotating screws. Process control parameters include screw speed (rpm), feed rate, temperatures along the barrel and die, and vacuum level. Typical parameters that are monitored for in-line quality measurement include melt pressure, melt temperature, motor amperage and in-line IR valves. Programmable Logic Controllers (PLC’s) and touch-screen Human Machine Interface (HMI) are now common, as compared to discrete controls/readouts.
Twin Screw Extruder Developments to Produce Consistent/Repeatable Concentrates
(continued)

Pharmaceutical class TSE with loss-in-weight feeders

Additional Platinum Sponsor
Twin Screw Extruder Developments to Produce Consistent/Repeatable Concentrates
(continued)

As an example of a key process parameter to monitor, whether a concentrate or drug, it is imperative to monitor the Specific Energy (SE) that is being input by the motor into each KG of material being processed. If the SE suddenly changes, this indicates the equipment, process conditions or raw materials has changed, and the end product may be different. SE is calculated in 2 steps:

\[
\text{KW (applied)} = \text{KW (motor rating)} \times \% \text{torque} \times \text{RPM running/Max. RPM} \times 0.97 \text{ (gearbox efficiency)}
\]

Specific Energy = KW (applied) / KG per hour

Units:
SE is denoted in KW per KG/HR
KW = Kilowatts (the motor rating, KW = HP \times 0.746)
% Torque = % used of the maximum allowable torque
RPM = Screws rotations per minute

TSE’s utilize segmented screws that are assembled on high torque shafts. Barrels are also modular and integrate internal bores for cooling. Segmented screws/barrels, in combination with the controlled pumping and wiping characteristics of co-rotating, self wiping screws, allows screw/barrel geometries to be matched to the unit operations being performed in the TSE. The counterrotating intermeshing twin screw mode is also utilized for masterbatch and pharmaceutical mixing applications.

Co-rotating, intermeshing TSE screw set
Twin Screw Extruder Developments to Produce Consistent/Repeatable Concentrates
(continued)

The intense mixing associated with the short inter-screw mass transfer characteristics inherent with a TSE facilitates highly efficient distributive and/or dispersive, as compared to comparative large mass batch mixers. Entrapped air, moisture and volatiles are also removed by vacuum venting in the extrusion process. The relatively short residence times (10 seconds to 2+ minutes) associated with a TSE is beneficial for many heat/shear sensitive materials, as the TSE can be designed to limit exposure to elevated temperatures to just a few seconds.

TSE’s are starve fed, with the output rate determined by the feeder(s), which meter pellets, liquids, powders and fibers into the process section. The TSE screw rpm is independent from the feed rate and is used to optimize compounding efficiencies. Because the pressure gradient in the extruder process section is zero for much of the process, materials can be introduced into downstream barrel sections to facilitate sequential feeding. Just like pigments, some API’s require dispersive mixing in the TSE, and some benefit from distributive mixing. For instance, a shear sensitive API or pearlescent pigment can be metered in the latter stages of the process section.

Pressure profile in a starve-fed TSE
Co-rotating TSE’s currently represent 90% of the TSE’s utilized to produce masterbatch products. Interestingly, a higher percentage of counterrotating intermeshing TSE are used by pharmaceutical users, perhaps because there is not a pre-conceived, probably sub-conscious, bias in favor of co-rotation.

Pelletization is a downstream process where the melt stream is pumped through the die, cooled and formed into a pellet. Water soluble polymers are used as a binder for pharmaceutical products, which necessitates that strands are extruded and cooled on a stainless steel or FDA plastic belt conveyer. The feed-rolls of the pelletizer pull the strands and push them into the cutting assembly. Die designs become more critical as strand velocities must be precisely matched across the die face, which can be particularly challenging when attempting to produce micro-pellets for capsule filling.
Die face pelletization is also used for pharmaceutical products, where the pellets are cut at the die face. Instead of water, the pellets are conveyed/cooled by are conveyed to chilled air chimneys and vibratory towers to facilitate pellet formation. Smaller pellets can be used for direct capsule filling, whereas larger pellets are typically milled and pressed into tablet.
Twin Screw Extruder Developments to Produce Consistent/Repeatable Concentrates (continued)

electronic records are deemed trustworthy. Practically speaking, Part 11 requires drug makers to implement controls, audits and system validation for software and systems involved in processing electronic data. Protocols must be followed with regard to limiting system access to authorized individuals, operational checks, device checks, controls over systems documentation, and a plethora of other guidelines. Strict adherence with regard to copies of records and record retention is part of the guideline.

Equipment validation documentation related to equipment installations into a pharmaceutical class environment is much more intensive as compared to a typical plastics format machine. Detailed/project specific document packages for the Factory Acceptance Test (FAT), Installation Qualification (IQ) and Operational Qualification (OQ) are required for pharmaceutical class installations, which typically add months of time and effort to the installation and commissioning of the equipment.

There are also cGMP guidelines for cleaning pharmaceutical class TSE systems. For instance, the equipment must be cleaned at appropriate intervals and written procedures are required that must be specific and detailed. Cleaned equipment must be protected from contamination prior to use and inspected for cleanliness just before using. Records and equipment logs of all cleaning and inspection must be kept, and the time between end of processing and cleaning steps must be recorded.

The basic design of a twin screw extruder for plastics or pharmaceutical usage is the same. The mixing mechanisms and staging of unit operations are also virtually identical. TSE process technologies proven in industrial settings can often be quickly implemented for a pharmaceutical process- the TSE process is a known quantity.

The challenge often lies elsewhere. Due to the regulatory requirements inherent with manufacturing a dosage form, the TSE manufacturing cell necessitates a more regimented and documented approach as compared to standard practices in the plastics industry. It is not the author’s suggestion that FDA guidelines and regulations for pharmaceutical products be strictly applied to the manufacture of plastics concentrates, but that it may be useful to audit the practices of pharmaceutical manufacturing companies and selectively implement those that are practical and useful to help make a more consistent, repeatable masterbatch product.

References

- I. Ghebre-Sellassie, C. Martin - Pharmaceutical Extrusion Technology
- Website:http://www.fda.gov/regulatoryinformation/guidances/ucm125067.htm
- Website:http://www.fda.gov/food/guidancecomplianceregulatoryinformation/currentgoodmanufacturingpracticescgmps/default.htm
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 Extrusion Division
Screw elements for twin screw extruders are segmented and assembled on shafts. Sometimes getting these elements off the shafts can be problematic.

![Screw set showing “baked on” degraded polymer](image)

The typical method to removing screw elements is as follows:

- Remove the screws immediately after cleaning the outer surfaces after screw removal from the barrels
- If cool, put one or both screws back in the heated extruder barrel for 20 minutes or so to reheat the elements
- Separate the 2 screws and work on one at a time
- Support screws evenly, using at least 4 or 5 support points for longer screws, otherwise the elements may not slide along the shaft splines
- **Use “hot” gloves!!!**
- Unscrew the tip and remove the last element, if it doesn’t slide off use a propane torch to heat the element (typically about 30 seconds for a lab-scale TSE and 4-5 minutes for a 100 mm class TSE)
- Apply heat as evenly as possible and remove each element by pulling it straight toward the shaft end….if it doesn’t budge apply force with a brass drift punch and hammer
- Angle the brass punch against the screw flight and give it a few “hits” ….keep heating and hammering until the element moves
- As each element is removed, start brush-cleaning and/or scraping the exposed shaft, to make it easier to remove the rest of the elements.

When screw elements are “stuck”, a pneumatic impact gun (air-hammer) is an inexpensive and helpful screw element removal tool. The impact gun must be modified to accept a brass tip to help avoid damage to the screw element/shaft. This gadget is noisy, but generally works to break loose “stuck” elements.
Air hammer with brass punch to facilitate screw removal

Preventative measures are encouraged for screw maintenance. If the screw set is left together for extended periods, it will be difficult to remove the elements. Experienced compounding firms will periodically remove the elements, clean the elements/shafts and apply anti-seize to the shafts on a periodic basis to prevent “stuck” screw elements.

Anti-seize on splined shafts
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Please contact Dan Smith at dansmith@maag.com
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