Fall 2011 | No. 86

MOLDING VIEWS

Brought to you by the Injection Molding Division of the Society of Plastics Engineers

Chair's Message

Greetings,

It is my honor to serve as the SPE Injection Molding Division (IMD) Board of Directors Chair. Our board team is very pleased to provide you with technical resources and activities to support your continued growth and success in the plastics industry.

Over the next few months, we will be reaching out to your regional section officers, both professional and student sections. The IMD Board wants to listen and respond to the needs of your groups. We encourage you to join our IMD Group on Linked In.

Be sure to mark your calendars for NPE and ANTEC 2012 in Orlando! The show begins Sunday, April 1, 2012 and ANTEC begins Monday, April 2, 2012. We hope to see you there!

Best regards,
Susan Montgomery
Chair, IMD Board of Directors

In This Issue:

This Month's Features:

Industry Events Calendar

November 2011

November 8-10
**MC2 MTconnect:
CONNECTING MANUFACTURING CONFERENCE**
Cincinnati, OH
www.mtconnectconference.org

November 10
**INJECTION MOLDING DIAGNOSTICS
FOR QUALITY CONTROL**
ERIE, PA
www.beaumontinc.com

November 14-15
EUROTECH 2011
Barcelona, Spain
www.4spe.org/spe-eurotec-conference

January 2012

January 22,-25
MOLDING 2012
Miami, FL
http://executive-conference.com

January 24,-25
THERMOSET 2012 CONFERENCE
San Antonio, TX
http://www.spetopcon.com

February 2012

February 10
DETRIOIT SECTION MATERIAL AUCTION
Detrioit, MI
http://www.4spe.org/events/technical-groups/detroit-section-material-auction

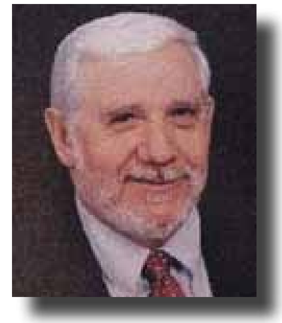
Click the show links for more information on these events!

February 26-29, 2012
SPI INTERNATIONAL POLYOLEFINS® AND FLEXPACKCON® 2012 CONFERENCE
Houston, TX
http://www.4spe.org/conferences/spe-international-polyolefins®-and-flexpackcon®-2012-conference

April 2012

Injection Molding Questions

Rules of Thumb Concerning Material



Bob Dealey, owner and president of Dealey's Mold Engineering, Inc. answers your questions about injection molding.

Bob has over 30 years of experience in plastics injection-molding design, tooling, and processing.

You can reach Bob by e-mailing molddoctor@ dealeyme.com

Q: What are the rules of thumb concerning what the first material that should be injected when designing a part for two shot molding? I want to design a number of keys where they will have two sets of marking, one on the top and the other on a side. I'm debating if it would be best to first mold the main part of the button with voids for the wording and then use the second shot to fill in the cavity, or is it better to over mold the body with the letters standing and last material covering just the body?

A: I am not sure there are rules of thumb concerning your question related to two shot (two color) molding. What I do know is that when you have two materials with different melt temperatures, you mold the highest melt temperature first.

Also, when two different plastic materials of different hardness are utilized, the preferred method is to mold the harder material first and over mold the softer materials. When the same material is used to make a two color molded part the factors to consider are: what is the lowest part cost; cost of the mold, considering both the initial cost; and maintaining the mold over its life.

For example, in the case of a push button where the same material will be used to mold both the body and only a different color for the over molded part like the following examples. The main body is molded first. Two advantages of doing that, the mold while requiring a slide for the side lettering, is more robust for molding a standing letter than a mold with an opening creating an opening for receiving the second color. The second is should the part have any sink marks from a thicker section, the second color will cover that defect. *See example 1, for the first shot molded component body.*

Example 1

When the second color is over molded, the blue color in our example, the button body will be encased in a solid cavity and the second material molded over the body. The lettering will retain the color of the first plastic and show in contrast with the second color. *See example 2 for the two colored component.*

Ask the Experts: Bob Dealy Continued

Example 2

While this method results in a high quality key that will retain it marking for life, other options could be considered for reducing costs. The keyboard I'm working on would require a dedicated first cavity for each button with 92 cavities. A second mold with the same number of cavities, in the same layout is necessary for an automated two shot molding operation. My calculator requires 33 different cavities and some are different shapes, plus the second mold. Therefore, tooling costs can be high.

Pad printing or hot stamping might be considered. The buttons can be molded in a conventional injection molding machine in just one mold. The buttons can then be printed as desired. In the 1970's the automotive industry was so concerned that the lettering could wear off printed dash buttons that paint filling was the only accepted method of marking. This was a tedious and expensive decoration method. Today, I note that my car has pad printed markings. In addition to being more cost effective, the appearance much better and I believe they will out last the life of my car.

The tooling costs are easier to control. If all the buttons are of the same shape, low volume requirements can be met with lower number of cavities. Large volume applications can have high cavitation to reduce the molded part cost. Additionally, buttons with different color combinations, both molded and printed, are more cost effective and convenient to manufacture.

As always, if any of our readers know of any rules of thumb or can offer additional advice, please write me at MoldDoctor@DealeyME.com

Have a question on Injection Molding?
E-mail Bob Dealey: molddoctor@dealeyme.com

BE UP-TO-DATE WITH THE LATEST INFORMATION. VISIT OUR WEBINARS.

Basic Two-Plate Mold Injection Mold Construction

Dec 15, 2011 11:00 a.m.
Dec 15, 2011 12:00 p.m.

This course describes the features and components of a basic two-plate injection mold. Participants will gain an understanding of the functions of each plate and associated hardware.

Visit www.4spe.org

Mold Maintenance Questions

Changing Your Maintenance Culture

Please submit any questions or comments to maintenance expert **Steve Johnson**, *Operations Manager for ToolingDocs LLC, and owner of MoldTrax.*

Steve has worked in this industry for more than 32 years. E-mail Steve at steve.johnson@toolingdocs.com or call (419) 281-0790.

Q: Our mold maintenance program seems to be controlled by whatever lands on our bench at any given time. We do a pretty good job of getting things fixed and running again, but the problems and costly mistakes keep coming and the stress level is getting to everyone. Developing into a proactive culture seems impossible. How do we start?

A: Any initiative that concerns changing long standing and comfortable reactive maintenance practices to an aggressive, data-driven "*let's fix it before it breaks*" mentality must start with determining *where you are now*. It's about developing a baseline of specific, trustworthy and measurable statistics, and using this information to become more efficient, make better maintenance decisions and improve bench practices. It's about being more disciplined and team oriented to share mold knowledge, repair molds more systematically and consistently, utilize standard terms. As mentioned in the last column, you must examine the 5 factors that control mold performance and maintenance efficiencies with an open, unbiased mind. Then develop a baseline of specific data with which to measure improvement.

But before this can happen there is some ground work to do in order to even get that far.

Step 1: Create a Business Process Review (BPR) team.

Typically, companies serious about getting better will formalize/legitimize this project since the scope will affect an entire department and, in this case, two departments — those being the tool room and the molding floor. The molding floor also plays a critical role and each department will have data responsibilities that they must be accountable for.

Molding needs to document basic information concerning the production run. This includes start and stop time and dates, who started it and why it was stopped plus other information that is critical to developing an accurate maintenance plan.

Ask the Experts: Steve Johnson Continued

Comprehensive documentation plays a significant role in establishing a proactive mold maintenance program.

The tool room will document repairs made, tooling used, and so on. It is important to have the run/repair information recorded in the exact sequence of events in order to aid in troubleshooting, which in turn helps discover root causes.

Appoint a "*Tool Room Efficiency Improvement*" project leader to drive the initiative forward. The best candidate is someone whose yearly bonus is affected by the success of the project. Keep in mind the tool room manager/supervisor may not be the best choice here since they are sometimes too close to the action.

Step 2: Determine BPR team members.

The old adage "*too many cooks can spoil the brew*" comes to mind, so keep the numbers limited. Too many team members involved can cause them to over-think the process and it will get bogged down in confusion. It's a good idea to include HR, Quality and IT to keep them up to speed and prevent hurt feelings from being left out.

Ask the Experts: Steve Johnson Continued

You need:

- Tool room Manager/Supervisor
- Designee from the repair shop (lead man, senior or most experienced)
- Molding or Process Manager/Supervisor
- Designee from the process technicians (lead man, senior or most experienced)
- Training or HR (not necessary but might want to sit in on action planning)
- Quality (will be consulted with to help determine product or part defect terminology)
- IT (will need to be included during the discovery phase and when software questions arise)

The first meeting should concern an overview of the scope of the project. The meeting should end with an assignment to bring samples of documentation tools currently used to manage mold repair to the next meeting for review of strengths and weaknesses and to specifically address:

Your data collection method to track ***Mold Performance*** problems:

- Unscheduled mold stop reasons
- Part/production defects (flash, shorts, dimensional, finish, etc.)
- Mold issues, (broken and worn tooling, electrical issues, leaks, etc.)

Your data collection method to track ***Maintenance Efficiency*** or shop information:

- Corrective actions (replace, clean, fabricate, polish, weld, etc.)
- Scheduled tasks (tooling change-overs, PM's, etc.)
- Technician stats (average mold repair time, tooling used, mold count, start-up efficiency, etc.)

Gather up the above documentation that's available; i.e., log books, spreadsheets, work orders etc. Determine if these tools provide the information you need to move forward. To properly set baseline data and target high cost and high frequency issues, as well as subsequent reports, you need to identify the top 10 culprits in each of the 6 bullet points listed above.

Following these steps will help get your company on track for developing a more proactive and efficient mold maintenance culture that is based on accountability and comprehensive documentation. As a result, you will see a significant reduction of those costly issues and mistakes and a boost in overall productivity.

Steve Johnson *ToolingDocs LLC, and owner of MoldTrax.*

Have a question on Mold Maintence?

E-mail Steve Johnson at steve.johnson@toolingdocs.com

?

Ask the Experts: Terry L. Schwenk

Hot Runner Questions

Reduce Gate Wear

Q: **How can I reduce gate wear with glass filled resins?**

A: This is a complex question, however after many years of analysis and trying several different methods, I can share with you what I have found to be the primary cause of excessive gate wear with filled resins and it's not what you may think. To understand how the gate steel and hot runner tips wear, we need to investigate the mechanics of the process. Plastic flows laminar. As the resin flows through the hot runner system, the material against the outer walls does not flow. The resin moves much like a carpet being rolled down on a floor or rolled up from the floor. The carpet doesn't slide on the floor. So this being the case, how does the gate wear occur? While investigating gear wear cause and knowing that resins flow laminar, it was clear that the wear could not come from the flow of the resin during the filling process. We need to look closer at the process and the mechanics of hot tip gates. Ideally the gate geometry creates a fracture point very close to the part surface, giving a clean break with minimal vestige (**Figure 1**).

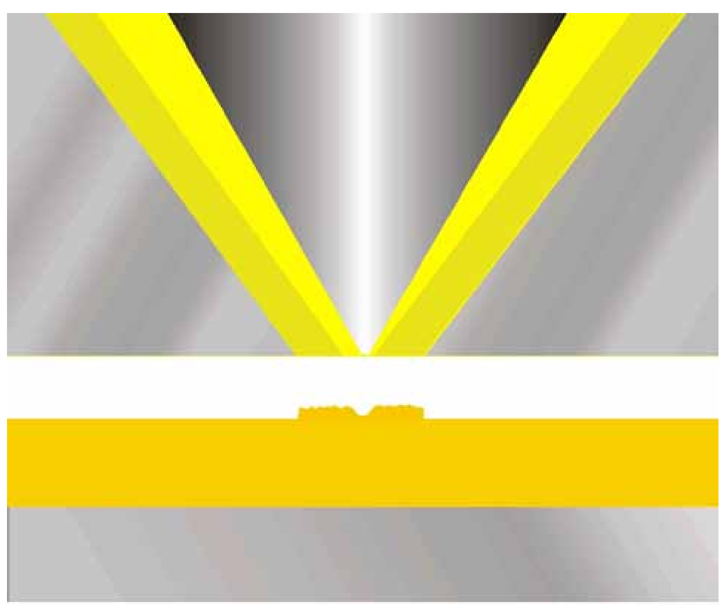


Figure 1

The purpose of this column is to provide valid information concerning hot runner technology.

We invite you to submit questions or comments to our hot runner expert.

Terry L. Schwenk has over 34 years of processing and hot runner experience.

Terry is currently employed with EWIKON Molding Technologies and can be reached by mailing: terry.schwenk@ewikonusa.com.

Ask the Experts: Terry L. Schwenk Continued

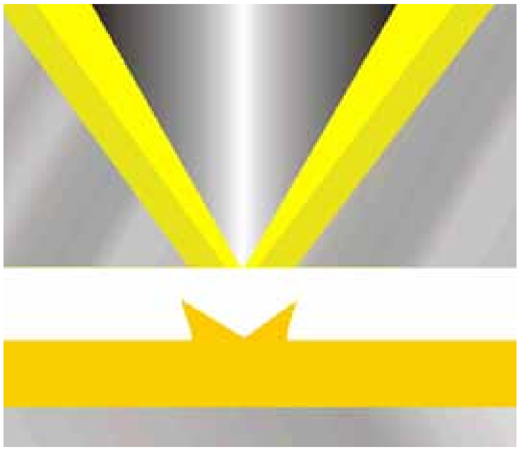


Figure 2

However, in cases where I saw excessive wear this was not the case. A lot of the time a big vestige was present with excessive wear. It was at that point I discovered, excess wear wasn't occurring during the filling process, but rather during the de-molding process and specifically when the material wasn't fracturing cleaning and the part was dragging a large vestige out of the gate when the mold opened (**Figure 2**). With glassed filled material this is the effect of a file working on the gate every time the mold opened. Another area of concern is if the heat profile of the hot runner system is inadequate to prevent too much solidification of material in the gate area and high injection pressure could force cold material through the gate causing excessive wear. High injection pressures and high runner tip temperatures are a good indicator of heat profile concerns.

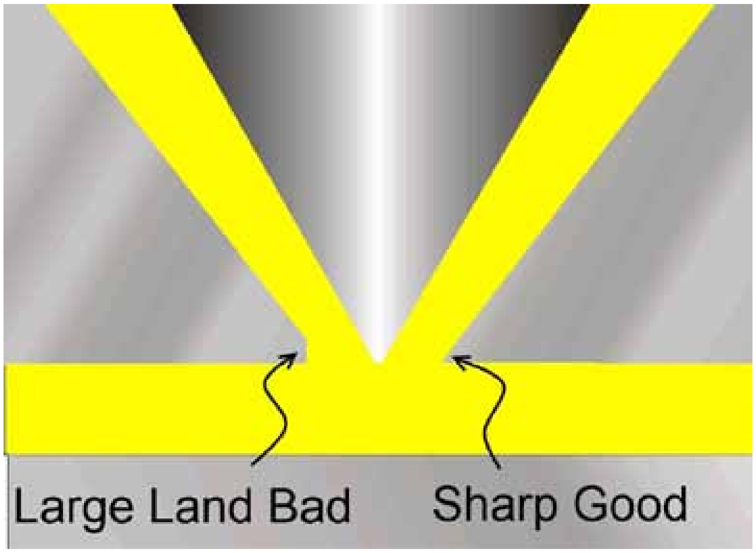


Figure 3

Figure 4

So understanding that gate wear occurs on de-molding and where the material is not fracturing in the ideal location, it became evident how important good gate geometry really is.

First of all, the correct gate size needs to be in the tool. It also ties into having the proper expectations for what vestige is acceptable. What you can expect in the form of gate vestige is the vestige will protrude above the molded surface by half the gate diameter. With fillers expect 20%-50% more vestige depending on the filler prop ties. If this type of vestige is not acceptable then you will have to consider using valve gates.

Secondly, the gate steel geometry and finish are critical to the performance of the gate fracture point. The sharper the gate angle is, the better chance the gate will break cleanly resulting in substantially less wear (**Figure 3**).

A EDM surface (**Figure 4**) is best for creating a sharp fracture point also serves for holding a skin of material in place on the inside of the gate thus protecting the gate during filling process should a plastic or glass filler particle strike the gate during the filling process. The following examples are the before and after effects of applying correct steel geometry along with an EDM finish. Prior to the steel and finish changes gates were wearing out in an as little as 500 shots. After applying the changes the gates lasted approximately 500,000 shots.

As you can see from the examples creating good gate geometry have lasting effects and performance of the gate steel.

Terry L. Schwenk *EWIKON Molding Technologies.*

Have a question on Hot Runners?

E-mail Terry L. Schwenk at terry.schwenk@ewikonusa.com.

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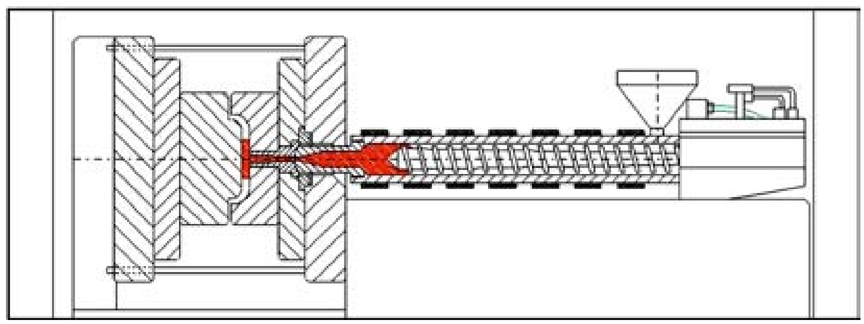
Compression Injection Molding

CIM attempts to combine the high productivity of conventional injection molding with the stress free molding obtained by compression molding. It is well suited for articles with a high flow path/ wall thickness ratio. It is possible to mold articles on a lower clamp tonnage than conventional injection molding.

Historically molding of plastics started with compression molding. The majority of thermosets are still compression molded, yet most thermoplastics are injection molded. They are melt processible, making it suitable for the injection molding process. The advantages of Injection moulding are well known, much faster cycle times, in seconds as compared to minutes in compression molding. However compression molding has two distinct advantages even with Thermoplastics.



Stress Free Moldings. The high pressures exerted on the melt and the fast cooling in injection molding locks in a lot of stresses in the molding. This is the driving force for warpage and dimensional instability in injection molded products. Such built in stresses may be unacceptable in certain products especially if they are thin and flat and have to be molded from high viscosity polymer systems.

A classic case is the vinyl LP record. PVC has a very high melt viscosity and compression molding allowed the discs to

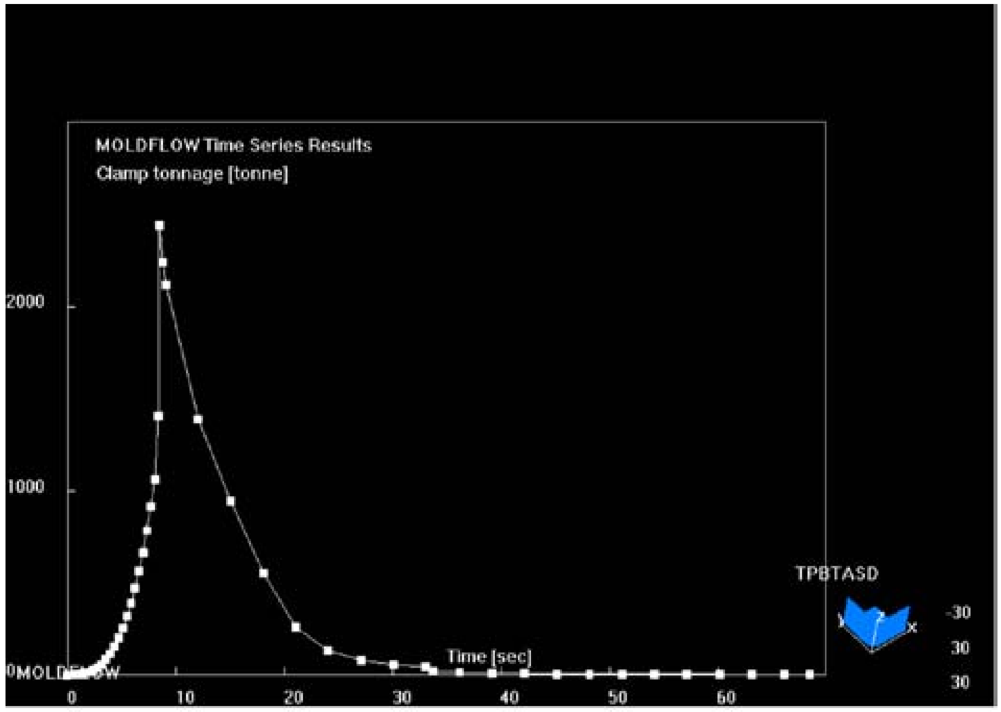
Feature: Compression Injection Molding Continued

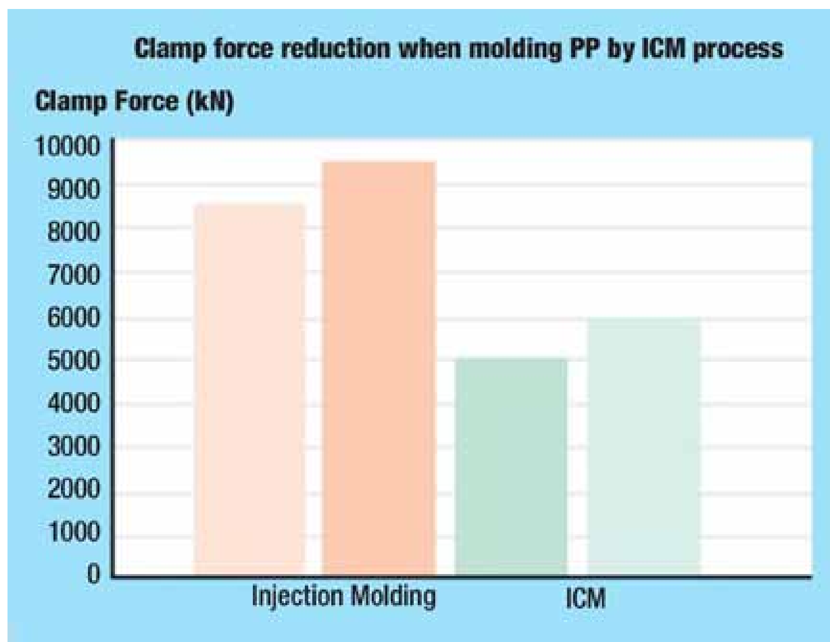
be moulded without warpage and excellent retention of the microgroove fidelity needed for flawless sound reproduction. The longer cycle times of compression molding had to be lived with since it was nearly impossible to mold a good quality LP on injection molding machines. Some 45 RPM singles were injection molded, but the weight used to be more than their compression molded brethren.

Compact disks injection molded from the less viscous Polycarbonate has displaced the vinyl LP, but some music aficionados still swear by the rich analogue sounds of vinyl and some are still produced by compression molding.

Again in the PVC field, laboratory test sheets for tensile tests and other physical properties are compression molded from roll milled stock. The test sheets have no residual stresses which would interfere with the physical properties being tested. Dumbell and other test pieces are punched from the stress free compression molded sheet.

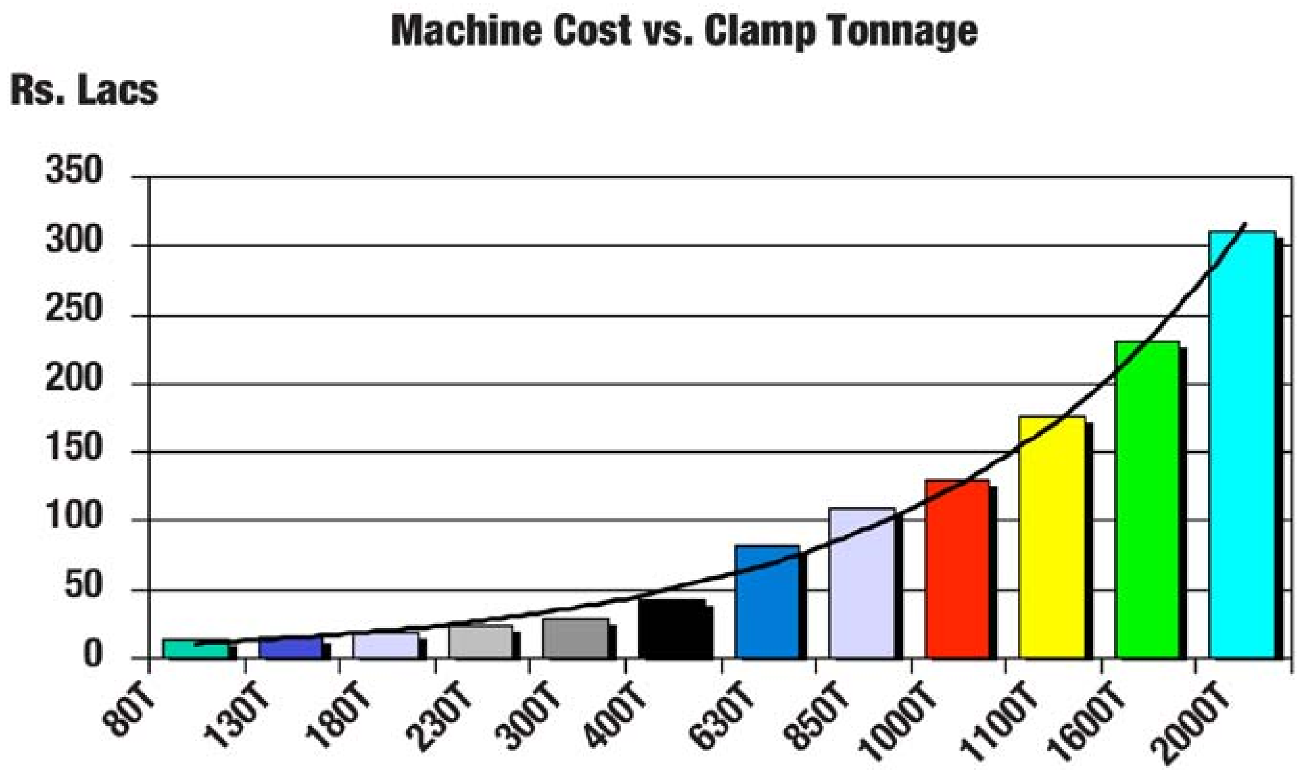
Lower Clamping Tonnages: The clamping tonnages required for a molded component being compression moulded is much lower than in Injection molding. In injection molding, the clamp tonnage needed is actually determined by the peak filling pressure required to fill the last extremities of the mold cavity. This is usually a sharp spike and is much higher than the average filling pressure. However, the clamp tonnage of the machine has to be high enough to resist this peak pressure or the mold will open.





Flow Behavior	EASY	POOR	EASY	POOR
Type of Process	Injection Molding		ICM	
Compression Rate (%)	—	—	99	99
Clamp Force (kN)	8,500	9,500	5,000	6,000

Feature: Compression Injection Molding Continued



This plot shows that a clamping tonnage of ~2,000T is required to prevent the mold from opening up during injection. The platen size of such a large machine may be much more than required by the mold dimensions.

In compression molding, there is no end of fill peak, and much smaller dimensioned presses can be used to gently squeeze the heated polymer to fill the mold completely. The molding force required to close the press platens would be much lower than in injection molding. This is well illustrated in the data provided by Sumitomo-Demag in their literature on Injection Compression Molding.

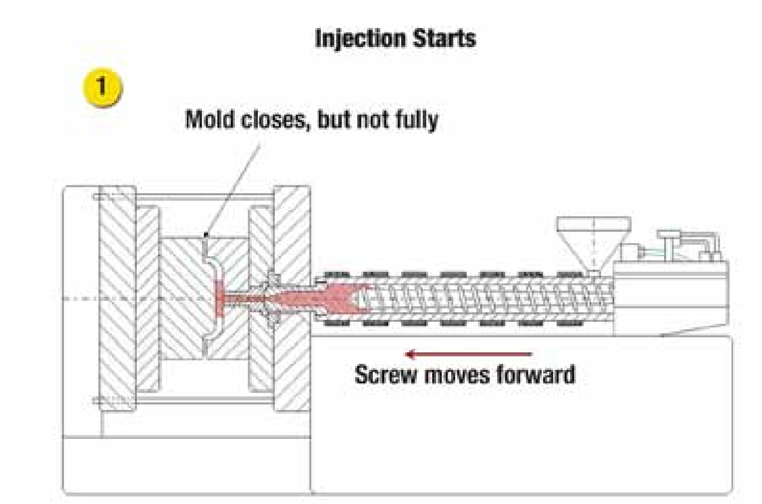
There could be significant savings in capital costs as the prices of injection molding machines increase exponentially with clamp tonnage:

Compression Injection Molding:

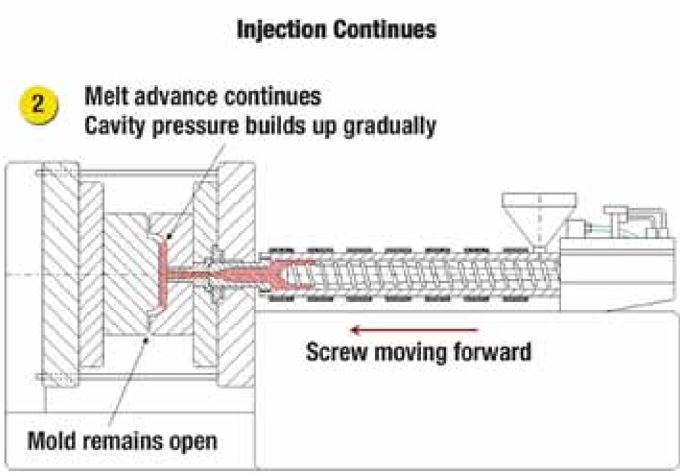
Compression injection molding (CIM) is a technique, which synergizes the advantages of injection molding and compression molding to offer a solution for difficult and costly to mould components using conventional techniques.

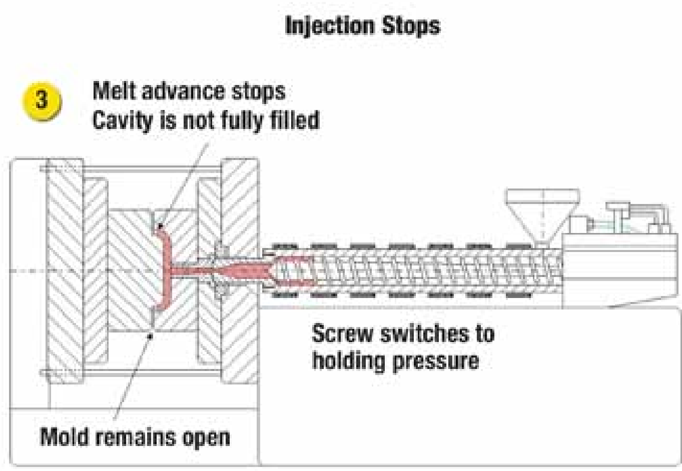
Let us have a closer look at the process stepwise:

The process sequence needs modifications in from the normal injection cycle. Nowadays, microprocessor controlled injection molding machines are quite common, thus setting up the



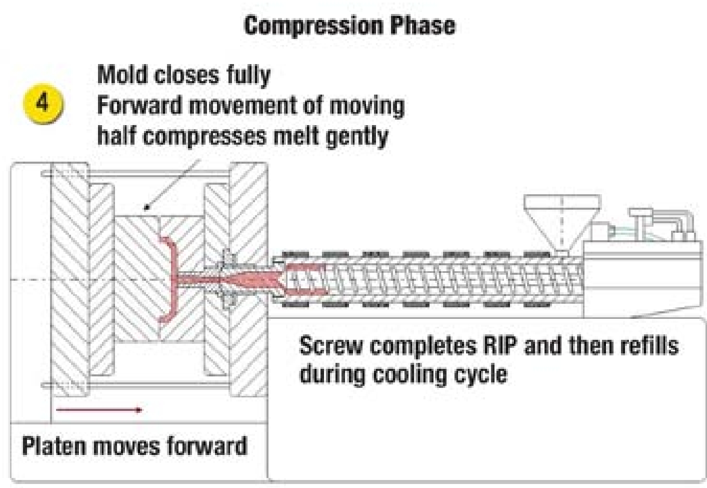
Feature: Compression Injection Molding Continued





compression injection molding sequence is a lot easier than with electromechanically controlled machines of yore. Linear transducers have also replaced limit switches which adds to setting accuracy.

However, precise control is needed to make CIM work, and the setting up with a new mold needs precise adjustments. Machines with memory storage would be very helpful to shorten setup times. Over flashing or under filling is always a danger if set conditions drift slightly. If part design permits, a variant of CIM can be used.

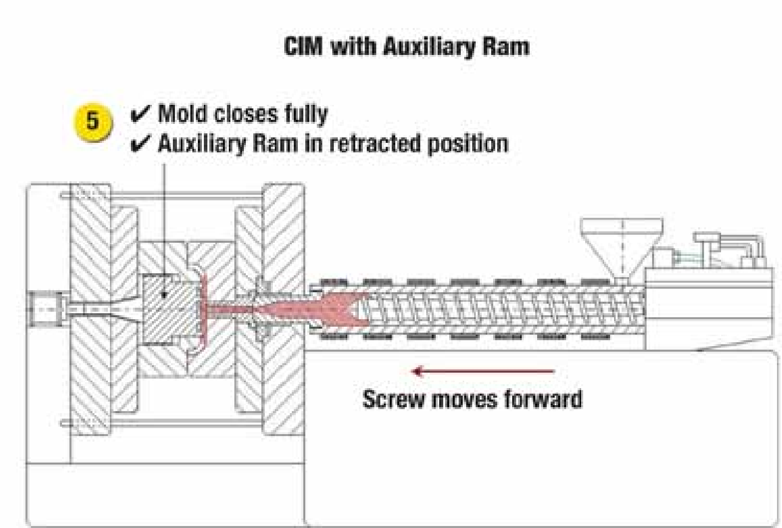


Feature: Compression Injection Molding Continued

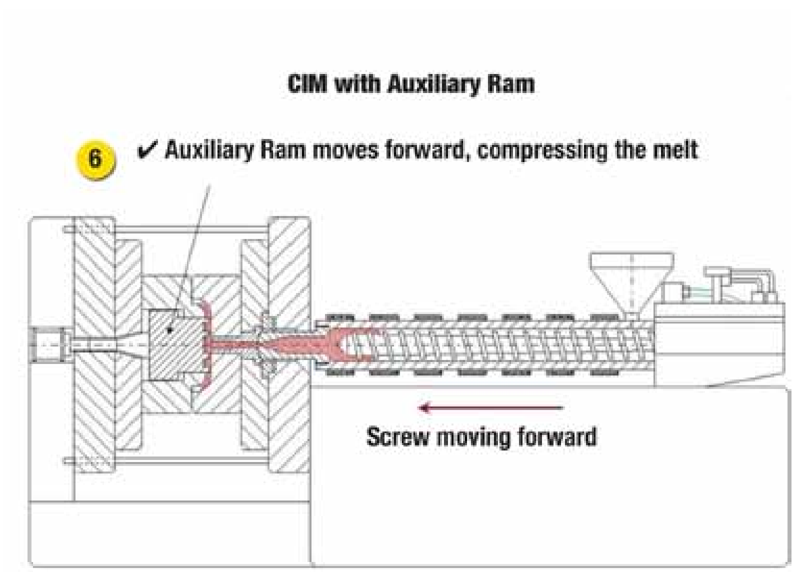
CIM with Auxiliary Ram

The main mold closes fully during injection. Precise clamping stroke adjustments during the cycle which may be difficult with toggle machines are not needed.

An auxiliary ram is required to be fitted concentric to the main clamping system. The action is similar to ejector pins but actually moves part of the mold. A hydraulic circuit is needed to build up sufficient pressure for the auxiliary ram.

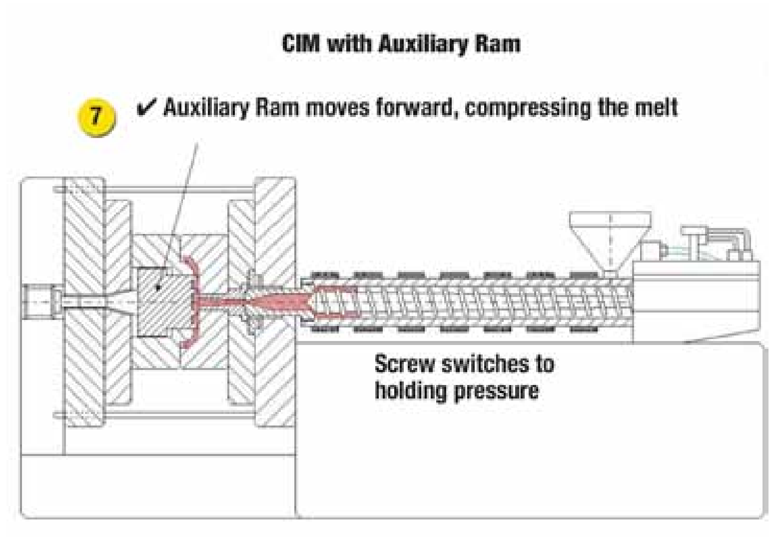


1. Injection Starts

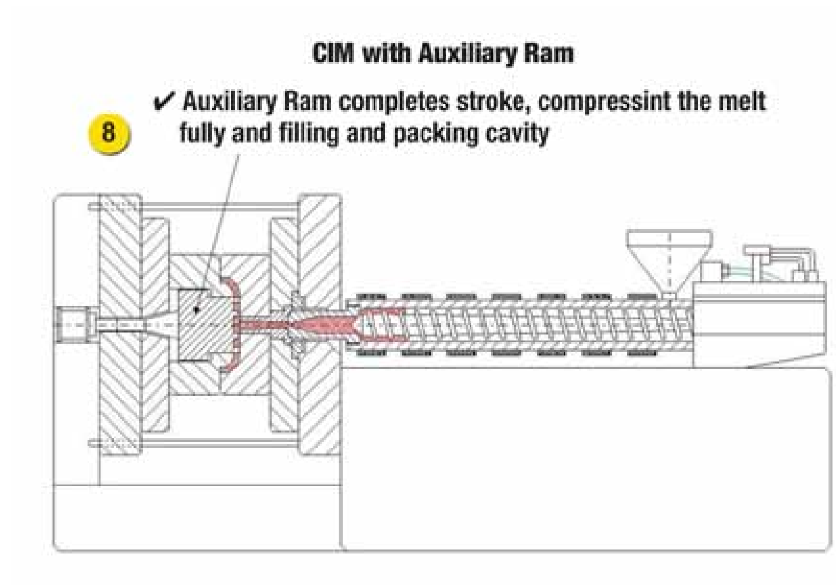


2. Injection Continues

Feature: Compression Injection Molding Continued



3. Injection Stops, Auxiliary Ram Movement Starts.



4. Auxiliary Ram Moves Fully Forward

Compression injection molding is a solution to tackle difficult to mold components. It is best suited for:

- Flow path/Thickness Ratios 100~150,
- High Melt Viscosity Engineering Plastics,
- Long Fibre Reinforced Polymers,
- Moldings with Finely Textured Surfaces,
- Foam Moldings Requiring Good Surface Finish.

Thin wall injection molding is cutting edge technology and is very expensive. Injection pressures needed are several orders higher than in normal injection molding. This calls for materials of construction which are

Feature: Compression Injection Molding Continued

much stronger than the steels used in conventional injection molding machines. CIM which is based on modifications on conventional injection equipment and may work out cheaper than a full fledged TWIM (Thin Walled Injection Molding) Machines.

The consumer fuelled trend of making laptops, handheld computers and mobile phones smaller and lighter has spawned a lot of thin wall moldings from high strength engineering plastics, and high flow path/thickness ratios were common. CIM could be adapted to produce such difficult to mold components.

One common problem in thin wall moldings like keypad covers is the numerous flow obstructions forced by the button cutouts. There are numerous weld lines which are potential failure points,

The Auxiliary Ram process could be effectively used so that the moving part of the mold mounted on the ram squeezes out the holes in the weld free melt already injected. This is better than mechanically punching out the holes after the shell has cooled down. Stress points and stress whitening are common in post molding blanking. The compression molding process could also eliminate off cuts of costly polymer generated in blanking. Added to this, the very low level of molding stresses guarantees a warpage free component. This is very important for moldings that have to be assembled with close tolerances.

IMD parts.

Thin-walled packaging articles.

About the Author

Mr. Siddhartha Roy *is a Chemical Engineer from IIT Kharagpur (1968). He has worked with plastics all throughout his career and actively involved in the development of PVC markets and applications, specializing in pipes and fittings. He has worked with Shriram Vinyls, PRC (now DCW) and Chemplast, manufacturers of PVC Resin & Compounds. He has managed a PVC pipes and fittings factory in Kuwait, as well as helped Jain Pipes (now Jain Irrigation) set-up their pipe production facilities. He headed R&D at VIP Industries, Nasik, and is well versed in the processing of Polyolefins, Styrenics, Polyamides and PC. He has been active in IPI activities and has delivered several Endowment lectures. He was recently awarded the Fellowship by the Governing Council of IPI for his contribution in the Plastic Industry. Mr. Siddhartha Roy is currently a consultant and can be contacted at royplastech@rediffmail.com or via phone at 989-036-6632.*

By Mark A. Spalding,
The Dow Chemical Company
Midland, MI
Joseph R. Powers
Midland, MI

Elimination of Defects From Injection Molded Polystyrene Parts via Screw Modifications

Many injection molded part defects are caused by improper screw designs. Elimination of the defect and optimization of the process can often be performed via simple modifications to the screw. A case study is presented where a splay defect was caused by a screw with a low compression ratio, with regions where resin can stagnate and degrade, and with a limited melting capacity. Modification of the screw eliminated the defects and decreased the cycle time by 8% and improved the plant capacity by 14%.

Injection molding is an extremely complex process with many sub-processes and moving components. These sub-processes must have the correct capability and be optimized for the tooling and the resin if the molding process cycle time is to be minimized with optimal part quality. Sub-processes that are not optimized will often force longer cycle times and create parts with defects. In extreme cases, the press will not be able to produce any acceptable parts.

Many papers have been written that describe methods to eliminate problems associated with the filling of the tool with molten resin. These methods include balancing the flows into multiple cavity tools[1], energy optimization [2], flows for gas assisted molding[3], elimination of halo defects near gates[4], thin wall part optimization[5], process control schemes using either part weigh[6] or pressure and temperature at the nozzle[7], and process tuning using designed experiments[8]. The molding machine must also have the correct capability such as two plasticators for overmolding processes[9].

Considerably less effort has been applied to understand the problems associated with the screw in the plasticator. Typically, the screw will be labeled as either a general purpose screw or a mixing screw. Screws that fall into these categories, however, can have extremely wide performances in molding machines. For example, screws with low compression ratios are often used to mold ignition resistant polystyrene (IRPS) resins. This type of screw characteristic, however, can cause parts to have a high level of surface defects[10]. High performance screws with higher compression ratios can eliminate the defects and reduce the cycle time by up to 20% for these applications. Improper screw design can also lead to stagnation regions in the screw that cause the resin to degrade. The degraded resin will eventually dislodge from the screw and contaminate the discharge resin, creating defects in the molded parts.

The goal of this paper is to present a case study where a low compression screw with a spiral mixing section was causing defects in parts and increasing the cycle time of the process. Simple modifications to the screw eliminated the defect and reduced the cycle time.

Feature: Eliminate Defects from IM Parts via Screw Modifications Cont.

Resin

The resin used in this commercial application was a general purpose polystyrene (PS) resin. The resin had a melt flow rate (MFR) of 5.5 dg/min (200°C and 5 kg).

Defects in the Parts

Visual defects occurred in a clear PS packaging part when new injection molding presses were installed in a commercial application and run at increasing rates. These defects accounted for about 5% of the parts molded, and the defects could be minimized by running the process at a slower speed. The defects were causing a significant loss in productivity through the loss of finished parts per shift and the additional cost of quality assurance to remove the defective parts. With the anticipation of these presses operating at higher rates and thus lower cycle times, this level of defects was not acceptable. The defects consisted of "silver" spots and streaks that were mostly near the gate area. This type of defect is commonly referred to as splay. The defects were examined using optical microscopy, and a microphotograph is shown by **Figure 1**. The defect was internal to the thin-walled part and was not directly on the surface. It consisted of a single point or tail closer to the gate area with a large fan of bubbles farther from the gate. The tail appeared to contain an "unmelted" polymer fragment and the material surrounding the bubble fan appeared to be different than the material in the rest of the package; i.e., possibly a more viscous component or a different light diffraction caused by air entrapment. A microphotograph of a single bubble is shown by **Figure 2**. It was unclear from the microscopic analysis whether these were air bubbles (air entrapment) or incompletely melted polymer, or both. Both scenarios indicated that the problem was related to the screw design. The defects would not occur when the process was operated at considerably slower rates. On occasion, very small flecks of dark-colored degraded resin were observed in the defects. The cycle time for the process was consistent at 6.1 s.

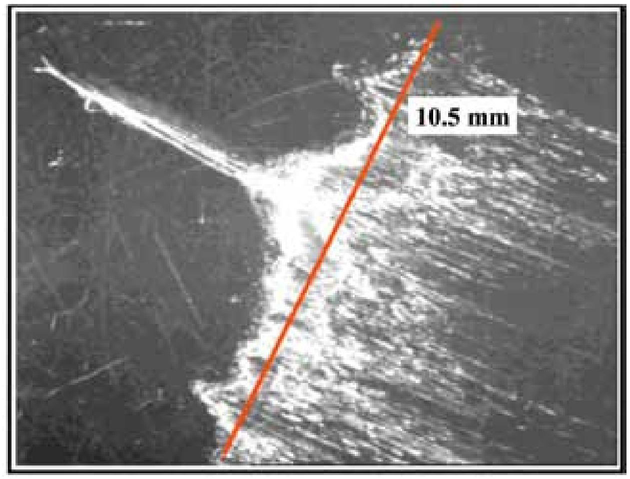


Figure 1: Microphotograph of the silver colored defect in a clear PS injection molded packaging part. The flow direction was from the upper left to the lower right.

Molding Equipment and Process

The new injection molding presses were 250 ton in size, and they were equipped with 63 mm diameter, 22 length-to-diameter (L/D) plasticators. The

Feature: Eliminate Defects from IM Parts via Screw Modifications Cont.

screws were all identical and were conventional, single-flighted designs, and had spiral dams positioned in the last 3.3 diameters of the transition sections. The screws were fabricated with three sections: 1) a 12 diameter long feed section with a constant depth of 8.26 mm, 2) an 8 diameter long transition section, and 3) a 2.5 diameter long metering section with a constant depth of 3.43 mm. A schematic of the spiral dam is shown by **Figure 3**. The lead length was 63 mm for all sections of the screw, and the mixing flight undercut for the spiral dam was 0.76 mm. The size of the flight radii in the metering section were relatively large compared to the depth of the channel[11] such that stagnation zones at the corners of the channels were not likely to occur. The specific drag flow rate for the metering section was calculated at 0.94 kg/(h rpm). The specific drag flow rate is the rate due to just screw rotation without an imposed pressure gradient.

These screws had a very low compression ratio of 2.4 and a compression rate of 0.0029. For this resin and application, a compression ratio near 3 and a compression rate of about 0.0035 is desired. The calculation of the compression ratio for a screw with a constant lead length is as follows:

$$C = \frac{H}{h} \qquad (1)$$

Where C is the compression ratio, H is the channel depth of the feed section; h is the depth of the metering channel. The compression rate for the transition section of the screw describes the rate that the channel depth changes as the resin is transported through the section. The compression rate is calculated as follows:

$$R = \frac{(H - h)\sin\theta_b}{ML} \qquad (2)$$

$$\tan\theta_b = \frac{L}{\pi D_b} \qquad (3)$$

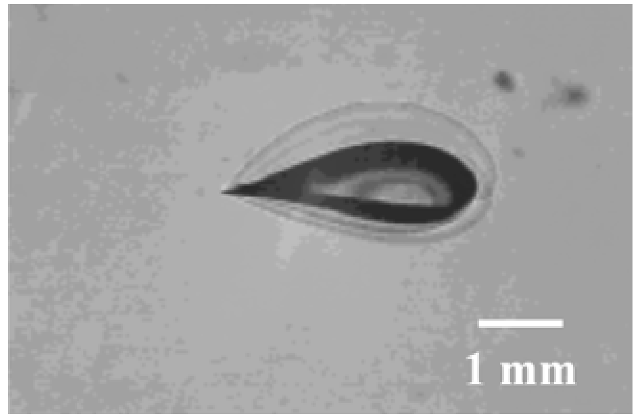


Figure 2: Microphotograph of a single bubble defect. The resin surrounding the bubble appeared to be more viscous than the bulk material prior to solidification. The flow direction was from left to right.

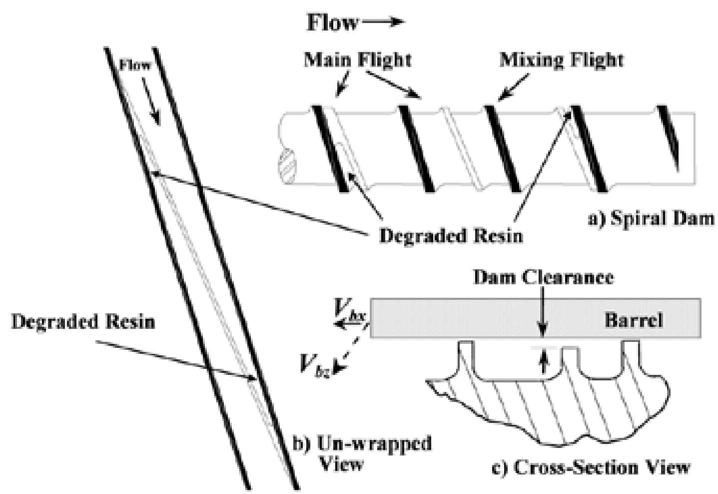


Figure 3: Schematic of a spiral dam[12]: a) side view, b) un-wrapped view, and c) a cross-sectional view perpendicular to the flight edge showing the clearance between the dam and the barrel wall. Degraded resin was observed at the pushing side of the channel just downstream of the entry to the spiral dam and at the trailing side of the channel just upstream of the exit to the spiral dam.

Feature: Eliminate Defects from IM Parts via Screw Modifications Cont.

Where R is the compression rate in the transition section, M is the number of turns in the transition section, θ_b is the helix angle at the barrel wall, L is the lead length, and D_b is the inside diameter of the barrel.

The press chosen for the study was able to produce a 0.244 kg part and runner system with a plasticating time (or screw recovery time) of 4.1 s, at a screw speed of 250 rpm and a tip pressure of 10 MPa. Thus, the screw was operating at a specific rate of 0.86 kg/(h rpm). The specific rate is defined as the rate divided by the screw speed. This specific rate was just slightly less than the specific drag rate calculated at 0.94 kg/(h rpm). The lower specific rate during operation was explained by the pressure gradient imposed in the metering channel of the screw during plastication as discussed next.

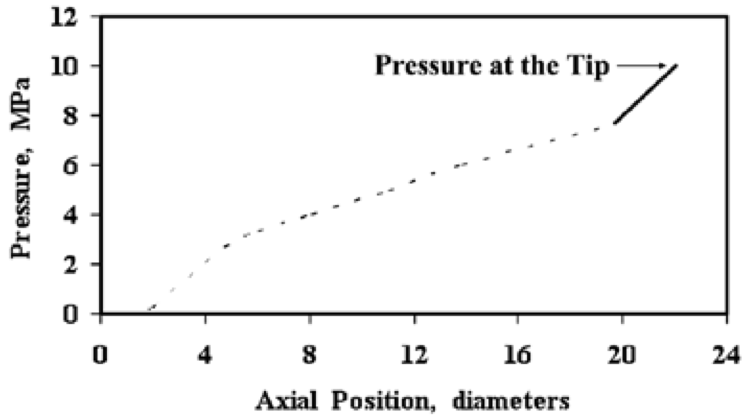


Figure 4: Simulated axial pressure profile at a rate of 215 kg/h and a screw speed of 250 rpm. The solid line in this figure was calculated using the methods described previously for metering sections[14], and the dashed line represents the expected pressure profile and it was not calculated.

For the plastication process, the metering section of the screw must control the specific rate. If the metering section was not controlling the specific rate, then sections of the screw upstream of the metering section would control the rate and some of the channels would be operating partially filled. For this application, partially filled channels would lead to the degradation of the resin[13]. As the first diagnostic measure, the axial pressure profile for this screw and process was calculated[14] to determine if the screw channels were operating full and thus under pressure. The calculated axial pressure in the channels using the method described previously[14] is shown by **Figure 4**. Based on the specific rate and the axial pressure profile, the screw was completely full of resin and operating under pressure; i.e., the metering section is operating properly and thus controlling the specific rate of the process.

Feature: Eliminate Defects from IM Parts via Screw Modifications Cont.

Since the metering section of the screw was operating properly, it was then hypothesized that the screw was operating at too high of a screw speed and thus beyond its ability to melt resin. To test this hypothesis, process changes were made in an attempt to increase the discharge temperature to enhance melting. These attempts were unsuccessful. Process changes that were made include increasing the barrel temperature set points, increasing back pressure, and increasing the injection velocity. The only process variables that worked to minimize splay were lengthening the cycle time by increasing the dwell time in the barrel and decreasing the screw speed. Increasing the dwell time in the barrel was done to increase the temperature of the resin and remove unmelts. As previously stated, decreasing the screw speed to considerably lower levels eliminated the defect, but increased the cycle time. Increasing the cycle time was unacceptable to the plant personnel.

The barrel temperatures were maintained at 250, 260, 270, and 270oC for the zones starting at the feed and ending at the tip, respectively. These temperatures were higher than would be typically used. When the barrel temperatures were decreased, the scrap rate due to the defects increased. This information suggests that the screw was limited by its melting rate. It is well known that as the screw speed is increased that eventually the machine will be limited by its melting capacity, discharging solid polymer fragments with the injectate (or extrudate)[15].

A screw was removed from one of the presses and examined. A large amount of dark-brown resin deposits were observed at the pushing side of the channel just downstream of the entry to the spiral dam. Similar deposits were observed at the trailing side of the channel just upstream of the exit to the spiral dam. The locations for these deposits are shown by **Figure 3 (page 21)**. These deposits were likely the source for the very small flecks of dark-colored degraded resin that were observed in the defects. On further examination, the channels with the degraded resin were too deep at these locations, causing regions that were essentially stagnant.

Modifications to the Screw

In order to eliminate the splay problem, the compression ratio of the screw was increased from the original ratio of 2.4 to 3.0. The higher compression ratio should allow entrained air between the pellets to escape out through the hopper and not be entrained with the injectate, and increase the melting capacity of the screw by increasing the pressure in the transition section [16]. This modification was made by increasing the feed channel depth from 8.26 to 10.3 mm by removing small amounts of metal from the feed channel. In order to maintain a constant compression rate on the transition section, deepening the feed section to 10.3 mm also decreased the feed section length by about 3.3 diameters and increased the length of the transition section by the same length. A summary of the channel dimensions for the original and modified screws are shown by **Figure 5**.

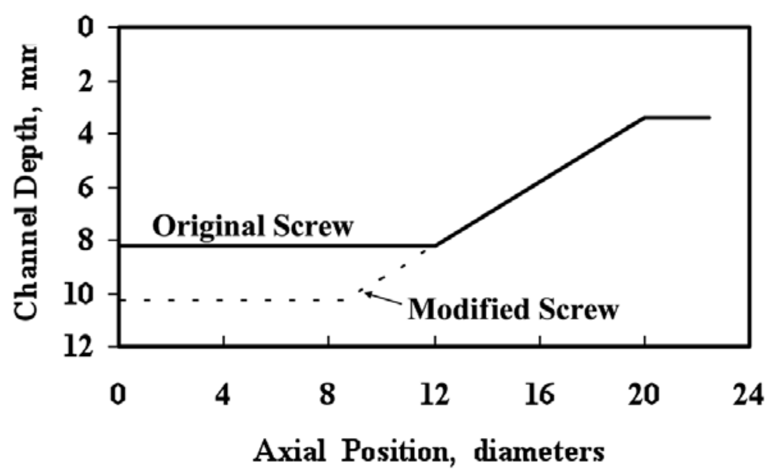


Figure 5: Channel depths for the original screw and the modified screw.

Feature: Eliminate Defects from IM Parts via Screw Modifications Cont.

The entrance and exit regions to the spiral dam were also modified to eliminate the stagnant sections of the channel. The modification is shown by **Figure 6**. This modification allowed a relatively small amount of resin to flow into the smaller channel at the entry such that stagnation of the resin cannot occur. A similar modification was made at the exit to allow a small amount of resin to flow out of the smaller channel into the main flow channel. To eliminate the unmelted particles or the particles that appeared to be more viscous because they were at a lower temperature, the clearance to the spiral dam was decreased from 0.76 to 0.25 mm. Since the meter channel depth was unchanged, the specific drag flow rate for the modified screw was unchanged at 0.94 kg/(h rpm).

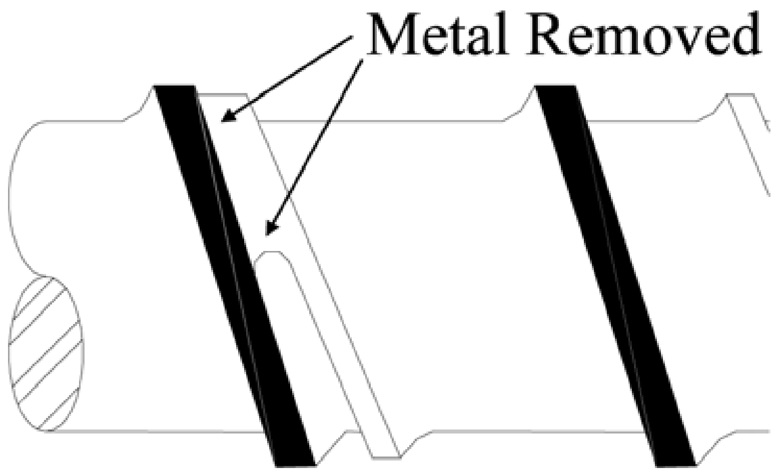


Figure 6.: Location at the entry of the spiral dam where a small amount of metal was removed. Metal was also removed (not shown) at the exit of the spiral dam.

The modified screw was placed back into the injection molding press and evaluated for performance. The barrel temperatures were maintained at 245, 255, 260, and 260oC for the feed zone through the last barrel zone, respectively. This temperature setting was lower than that used for the original screw. The screw was rotated at a speed of 235 rpm and the back pressure was set so that the pressure at the tip was 10 MPa. The 0.244 kg part and runner system were plasticated in 4.2 s for a specific rate of 0.89 kg/(h rpm). All parts produced were completely free of the splay defect. The modifications were able to eliminate the bubbles and the unmelted material.

The screw modifications allowed the cooling time to be decreased by 0.5 s as shown by **Table 1**. This decrease was due to the injectate having a lower temperature. For the original screw, the barrel temperatures had to be increased to 270°C in the metering zone to increase the melting capacity of the screw. With the modified screw, the higher compression ratio and the smaller clearance on the spiral dam increased the melting capacity and allowed lower barrel temperatures (260°C) and thus a lower injectate temperature. Since the cooling step was the rate limiting step of the process, a decrease in cooling time resulted in an improved cycle time, as shown by **Table 1**. The modified screw decreased the cycle time from 6.1 to 5.6 s for a cycle time improvement of 8%. The plasticating time increased for the modified screw, but since the plasticating operation was not the rate limiting step the slightly longer plasticating times did not affect the cycle time.

	Original Screw	Modified Screw
Plasticating Time/s	4.1	4.2
Cooling Times/s	3.3	2.8
Cycle Time/s	6.1	5.6

Table 1: Key cycle times for the molding machine using the original screw and the modified screw.

The modifications to the entry and the exit of the spiral dam section were successful in eliminating the stagnant portions of the section. That is, no dark-colored degraded resin flecks were observed in the molded parts.

Feature: Eliminate Defects from IM Parts via Screw Modifications Cont.

Discussion

The injection molding process is very complex and requires tuning for all sections of the process including the plasticating screw. The part defects presented here could not be eliminated without severely affecting the process economics; i.e., by decreasing the screw speed and thus increasing the cycle time. Simple modifications to the screw, however, allowed the elimination of the defects and an 8% decrease in the cycle time. Moreover, with the elimination of the defective parts, the number of parts produced per shift increased by 14%. The modifications were performed very quickly and at a very low cost.

A systematic approach allowed the troubleshooting process to focus on the melting capacity of the screw as the root cause of the defects. The melting capacity was increased by increasing the compression ratio of the screw. The higher compression ratio caused the pressure in the melting section to increase. Higher pressures are known to increase the melting rate of PS resins [16]. The higher compression ratio also increased the ability of the screw to force air that is entrained between the pellets back out through the hopper. Any solid polymer fragments that flowed downstream were then dispersed by the smaller clearance for the mixing flight in the spiral mixer. The stagnation regions that caused the resin to degrade were eliminated by allowing resin to flow through the passages at the entry and exit of the spiral dam.

Conclusions

Simple and low-cost modifications to the plasticating screw eliminated a difficult and costly defect in PS molded parts. The melting capacity of the screw was determined to be the root cause of the defects. The melting capacity was increased by increasing the compression ratio of the screw and by decreasing the clearance on the mixing flight of the spiral dam.

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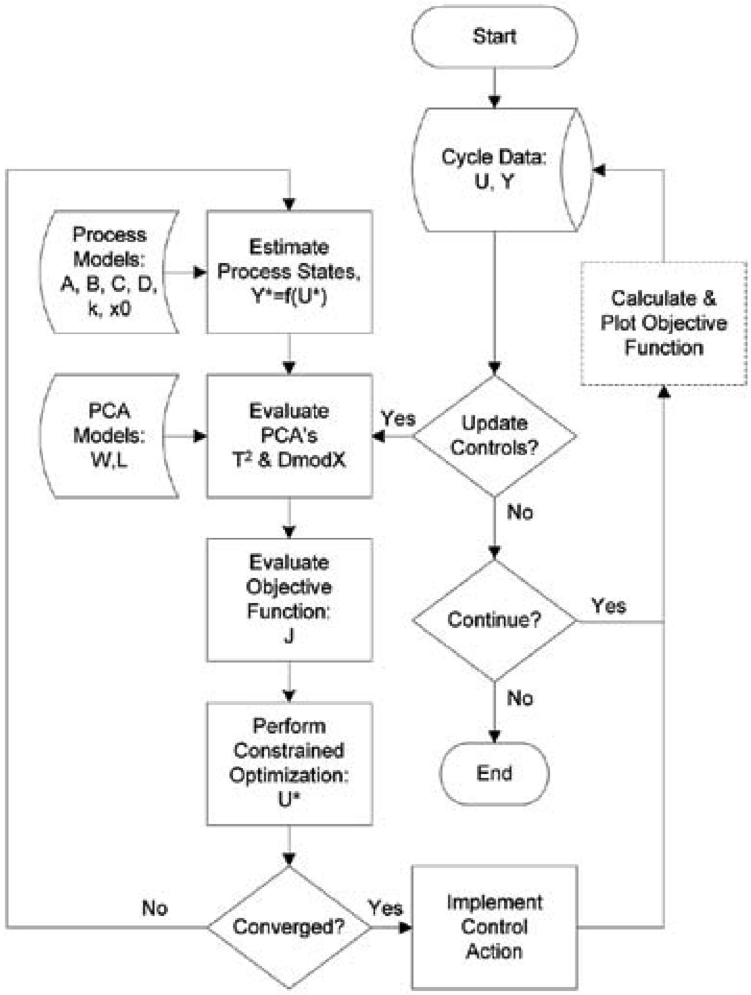
On-line Optimization of Injection Molding

An auxiliary controller was designed, implemented, and validated for on-line process and quality optimization. The architecture relies on a multivariate process model to perform optimization interleaved with the molding process. Two different experiments investigated the controller's ability to adjust the process subject to material and cycle time variances. In every case, the controller was able to reduce the value of the objective function while also improving the part dimensions relative to tight tolerance specifications. The use of a process model greatly speeds convergence and facilitates the consideration of various cost and quality terms in the objective function.

Injection molding is a commercial production process characterized by many process settings and quality requirements. Sustained competitive pressure motivates molders to reduce cost by reducing cycle time, energy and resin consumption, as well as labor utilization. Plastics engineers have been searching for optimization for decades[1]. However, the complexity of the process dynamics coupled with multiple competing objectives can prohibit the operation of the molding process at efficient, let alone "optimal" conditions[2].

Optimization relying on numerical methods has been explored as a means to increase the efficiency of plastics processing. The underlying models used in optimization can be of varying forms including neural networks as described by Yonehara[3]. The objectives of the optimization can also vary widely. For example, Seaman[4] utilized a multi-objective optimization method to tune a PID controller for plastication of injection molding. Similarly, Castro describes an optimization intended to reduce variation[5]. Kazmer et al.[6-10] also explored the use of various models, objectives, and architectures. This paper describes a new approach that incorporates two advances not previously described in the literature. First, a multivariate model based on principal component analysis is introduced to capture the relationships between process settings. Second, the dynamics of the process states are explicitly modeled as a function of the process settings. These features of the controller design are generally described in the next section. Afterwards, the training of the controller is presented with the characterization experiments. Then, the performance is demonstrated using on-line optimization for an altered material and cycle time minimization.

Figure 1: Controller Design



Controller Design

The controller was implemented using a Seneslink™ QMTM process controller (MKS Instruments, Andover, MA) connected by Ethernet to a PC running Matlab (Mathworks, Natick, MA) interfaced to SIMCA-QP (Umetrics, San Jose, CA). The controller design is shown in **Figure 1**. In operation, each cycle's process settings, U, and observed process states, Y, are input to the controller. If the settings are to be updated, then the controller performs the optimization loop shown at left in **Figure 1**.

The first step in the optimization loop is to evaluate the process behavior according to principal components analysis (PCA). As previously described[11,12] PCA is used since a well instrumented process can literally provide hundreds of data points for each manufacturing cycle. Much of the provided data is redundant since it is highly inter-related. As such, PCA reduces the redundancy by introducing new variables called principle components that consist of orthogonal linear combinations of the original variables. The resulting model will typically have fewer principle components than the original number of process states while explaining more of the observed process variation than a conventional linear regression. The PCA analysis provides two statistics of the process behavior: the DmodX and T^2. The DmodX is the residual standard deviation calculated from the residuals, i.e., after subtracting the accepted model behavior from the scaled and centered process data; a high DmodX score indicates that the current process observation is deviating from the expected behavior of the model. The T^2 value is a second summary statistic that represents the distance of the collected data from that of the standard operating conditions. In other words, the DmodX statistic can be considered a measure of the *uncertainty* while the T^2 statistic can be considered a measure of the *variation*. Referring back to **Figure 1**, the objective function, ***J***, for the current process settings and states, ***U*** and ***Y***, is then evaluated according to:

$$J = \alpha(\tilde{T})^2 + (1-\alpha)(\tilde{D})^2 + \beta(\tilde{E})^2 \qquad (1)$$

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Here, $\tilde{T}$ and $\tilde{D}$ are normalized values of the T^2 and DmodX values relative to the critical limits of the trained model at the 95% confidence level. $\tilde{E}$ is a normalized measure of the control energy, defined as:

$$\tilde{E} = \sum_{i=1}^{n} \left(\frac{2(U_i - U_i^0)}{U_i^{\max} - U_i^{\min}} \right)^2 \qquad (2)$$

such that each control setting, i, provides no contribution when equal to its nominal setting and a value of one when equal to its extreme values, U_i^{min} and U_i^{max}.

Generally, the purpose of the optimization is to minimize the objective function, *J*. The coefficients α and β are weights selected to indicate the relative importance of the variation, uncertainty, and control energy terms included in the objective function. As α approaches 1, the T^2 contribution will play a more significant role in the optimization relative to DmodX, and vice-versa as α approaches 0. As the coefficient β increases, the value of the objective function will be heavily influenced by the control energy so that the optimization will seek to improve the process by making proportionally smaller changes to the process settings. To demonstrate the effect of the weighting coefficients on the objective function, **Figure 2** shows several results obtained via optimization with different weightings. When α is 0, the T^2 statistic has no significance in the objective function and so the optimization focuses on reducing the DmodX value. As α increases, small increases in the DmodX can provide substantial reductions in the resulting T^2 values. At even higher values of α, the T^2 statistic can be further reduced only slightly, and with significant increases in the DmodX values. **Figure 2** also shows the effect of increases the β coefficient: higher values limit the range of process changes such that only higher values of T^2 and DmodX are provided. The "best" selection of α and β are dependent on the plastics application requirements and molder preferences; the diamond symbol provides the selected default operating objective function weights with α equal to 0.7 and β equal to 0.01.

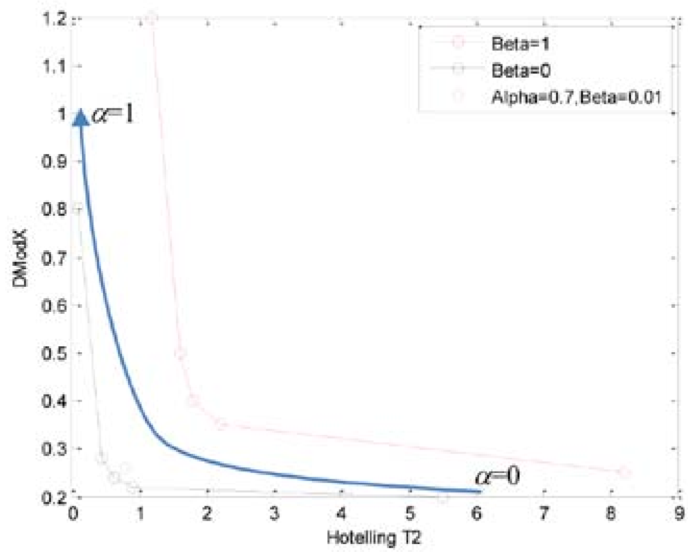

Figure 2: Effect of Tuning Parameters

Returning to the controller operation depicted in **Figure 1**, a constrained optimization is performed after the objective function of equation (1) is evaluated. The optimization was performed with the Matlab Optimization Toolbox function **fmincon**:

$$\min_U J \text{ such that } U^{\min} \le U \le U^{\max} \qquad (3)$$

In this step, the optimization algorithm examines past observations of the process settings, *U*, and corresponding values of the objective function, *J*. The optimization then proposes a candidate set of process conditions, *U**, that are expected to lead to improved performance. This set of process conditions is used to predict the expected process states, *Y**, using dynamic process models without actually implementing the process conditions on the molding machine. To provide the best possible results, dynamic process models were developed for each process state included in the optimization. Two different types of process models were considered including a linear first order model having a transfer function of the form:

$$G(s) = \frac{K}{1 + T_p s} \quad (4)$$

as well as a state space model of the form:

$$\begin{aligned} x(t + \Delta t) &= Ax(t) + Bu(t) + Ke(t) \\ y(t) &= Cx(t) + Du(t) + e(t) \end{aligned} \quad (5)$$

where *K, Tp, A, B, C, D*, and *K* are coefficients mapping the current process state to future process states. The coefficients were determined by matching the model predictions to the observed process behavior from the characterization experiments using the Matlab System Identification Toolbox function pem (Mathworks, Natick, MA).

Given the current and expected process states, the PCA outputs updated values for the T^2 and DmodX values. The optimization loop then proceeds to evaluate the objective function, *J*, and return new process conditions *U** until a stable solution is obtained. The recommended process settings are then implemented on the molding process.

Characterization Experiments

As indicated in Figure 1 and previously described, dynamic process and PCA models are needed to perform the optimization. Both types of models were derived from a single characterization experiment implemented on a Milacron Roboshot 55 ton all electric molding machine. The application was a two cavity family mold which yields a medical tubing connector when the moldings are assembled. **Figure 3** depicts the sprue/runner and moldings produced of polypropylene (Huntsman, Salt Lake City, UT). The width and diameter of the moldings were on the order of 10 mm, with a 3 mm wall thickness.

Figure 3: Medical tubing connector

The characterization experiments sought to provide models suitable for optimizing many different process settings. The twelve factors included in the design of experiments (DOE) are listed in Table 1 along with their lower (-), upper (+), and nominal (0) values. The twelfth factor, labeled Melt Viscosity, corresponded to a low melt flow rate (MFR), high MFR, and 50/50 blend.

A thirteen run D-optimal design of experiments[13] was implemented to capture the main effects of the twelve factors. To improve the robustness of the model and verify the process repeatability, center point runs were added at the start and end of the D-optimal block.

Table 1: DOE Factors and Settings

Description	#	-	+	0
Shot Size (mm)	1	15	17	16
VP Switchover (mm)	2	9	11	10
Injection speed (mm/a)	3	40	80	60
Screw Speed (RPM)	4	125	175	150
Back Pressure (MPa)	5	8	12	10
Zone 1 Temp (C)	6	220	240	230
Zone 2 Temp (C)	7	210	230	220
Coolant Temp (C)	8	26	38	32
Cooling Time (s)	9	6	10	8
Pack Time (s)	10	6	10	8
Pack Pressure (MPa)	11	50	60	55
Melt Viscosity [0,1]	12	M1	M2	M1/2

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The experiment's runs were implemented consecutively allowing approximately 30 minutes of continuous operation to allow the process to equilibrate. The training data consisted of 942 molding cycles across 8 hours of molding. Process data was collected at 10 ms intervals and programmatically analyzed to provide 47 process states for each molding cycle, including:

- Times for filling, packing, cooling, plastication, mold open, and total cycle;
- Screw displacements during filling, packing, cooling, and plastication as well as cushion;
- Screw velocities during filling, start of packing, average
- Pressures such as peak filling, average and integral of filling, average and integral of packing, average and integral of plastication;
- Energies, such as during injection, packing, and plastication;
- Melt viscosity inference from start of filling and entire plastication; and,
- Temperatures, including minimum, average, and maximum measured at the nozzle, metering zone, compression zone, feed zone, and cooling lines.

For each of these process states, a dynamic process model was developed. The black traces in **Figure 4**, for example, show the observed screw displacement during cooling (labeled VID-8) across all the molding cycles (the data is fairly noisy given limitations in the displacement transducer). Interestingly, this process state is not directly determined by any one process setting of the molding machine, but rather is influenced by many process settings such as shot size, VP switchover, injection speeds, pack pressure, pack time, and temperatures. Even so, the superimposed blue traces show the predictions of the different dynamic process models. It is observed from the two plots at left in **Figure 4** that both the first order and state space models of equations (4) and (5) provide excellent fidelity when all the process settings, *X*, of **Table 1** are included. Removal of some of the process settings from the dynamic process models can result in poor predictive capability as shown in the two plots at right in **Figure 4**. Similar behaviors were observed for different process states.

Table 2: 13 Run D-Optimal Design with Center Points

	Factor Number											
Run	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	+	-	-	-	+	-	-	-	-	-	+	-
3	+	+	-	+	+	+	+	-	-	+	-	-
4	-	-	+	-	-	+	-	-	-	+	-	-
5	+	+	+	+	-	-	-	-	+	-	-	-
6	-	-	-	+	-	-	+	+	+	+	+	-
7	-	+	+	-	+	-	+	+	-	-	-	-
8	+	+	+	-	+	+	-	+	+	+	+	-
9	+	-	+	-	+	-	+	-	+	+	-	+
10	-	+	-	-	-	+	+	-	+	-	+	+
11	-	+	+	+	+	-	-	-	-	+	+	+
12	+	-	+	+	-	+	+	+	-	-	+	+
13	+	+	-	-	-	-	-	+	-	+	-	+
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15	0	0	0	0	0	0	0	0	0	0	0	0

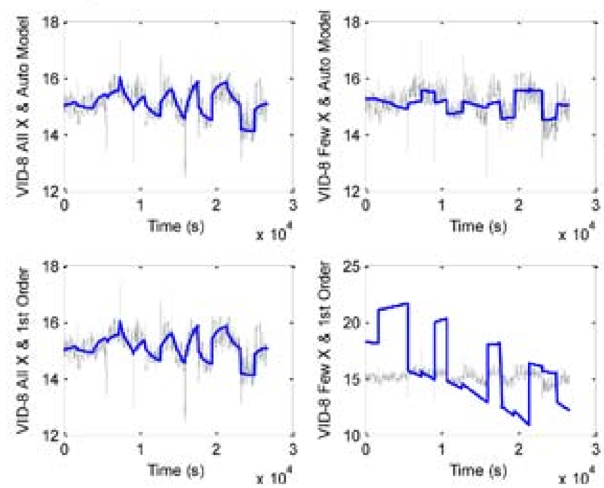

Figure 4: Screw Displacement Dynamics during Cooling

The same data was used to develop PCA models to capture the relationships between the process states. The resulting model had ten principal components and accounted for 81% of the observed process behavior. This level of model correlation is relatively low, but should be expected given that the PCA model includes all of the transient process data such as shown in **Figure 4** and not just the steady state data. The loadings plot of **Figure 5** shows the relationships in the first two principal components between the process settings, *X*, and the observed process states, *Y*, numbered 1 to 47.

IMD Best Paper Continued

Results

The capability of the described optimization was investigated on-line using the molding machine and application as previously described. Two experiments were conducted that should be of broad interest to production molders. In the first case, the process was changed to use a different material and set of process conditions. In the second case, the packing and cooling times were consecutively reduced to improve molding productivity. The controller's response in each of these cases is next presented.

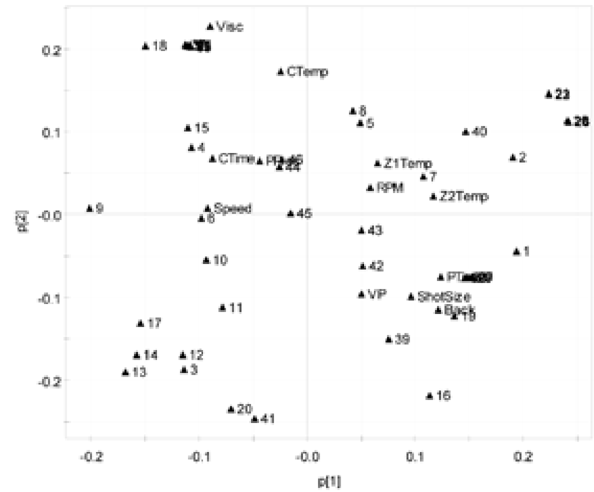

Figure 5: PCA Loadings Plot

Material Optimization

As previously described, the characterization experiments considered different grades of PP with low and high melt flow rates. More specifically, the standard process used a 50/50 blend of the two grades as indicated in the right column of Table 1. In this first experiment, the 50/50 blend of the two materials was replaced in entirety with the low melt flow rate (high viscosity) material. The process was then set up by an operator with other settings within the ranges used during the characterization experiments chosen to produce "good" product. The initial conditions are provided in column 1 of **Table 3**, and may be compared directly with the baseline conditions of the characterization experiment shown at right in **Table 1**.

These initial process settings were directly input to the molding machine controller. The molding process was then operated for forty cycles after which the last ten cycles of data were transferred to the described process controller. The controller then used the dynamic process and PCA models to provide new process settings, which are recorded in column 2 of Table 3. These settings were then implemented in the machine controller after which the process was again operated and so iterated to provide the process conditions listed in columns 3 and 4. The resulting values of the objective function are plotted for the last ten cycles of each iteration of the optimization in **Figure 6**, as separated by the vertical dashed lines. It is observed that the initial material, with its high viscosity, provided moderate T^2 values but very high DmodX values for cycles 1 to 10. This result occurs since the relationships between the process states (for example, injection energy:filling time) will change significantly with the melt viscosity. After observing the first iteration, the controller has selected a different blend of the two materials as well as other process conditions. The data plotted for cycles 11 to 20 in **Figure 6** correspond to the process conditions listed in column 2 of Table 3. It is observed that both the T^2 and DmodX values have been significantly reduced. As shown by the later cycles in Figure 6, additional optimization iterations provide increasingly small changes to the process settings without further reduction in the objective function.

Table 3: Material Optimization Iterations

Optimization Iteration	1	2	3	4
Shot Size (mm)	17	16.1	16.2	16.2
VP Switchover (mm)	9	10.0	10.0	10.0
Injection speed (mm/a)	80	59.9	60.3	60.7
Screw Speed (RPM)	175	154.4	153.9	153.1
Back Pressure (MPa)	8	10.3	10.4	10.5
Zone 1 Temp (C)	240	228.2	227.6	227.5
Zone 2 Temp (C)	230	217.6	217.4	217.3
Coolant Temp (C)	38	32.6	32.0	32.1
Cooling Time (s)	6	8.0	8.0	8.0
Pack Time (s)	6	7.9	7.9	7.9
Pack Pressure (MPa)	60	55.1	55.0	55.1
Melt Viscosity [0,1]	1	0.47	0.43	0.42

The described controller design did not explicitly consider part dimensions or yield predictions in its objective function of equation (1). While such a criterion could be explicitly included in the controller, the part metrology would incur significant delay and expense, so was omitted in this application. Still, dimensional control is of significant interest to many molders. **Figure 7** plots the evolution of part widths for the different optimization iterations listed in Table 3. The horizontal dashed lines indicate standard specification limits of the mean dimension of 10.22 mm ± 0.2%, which would be considered a tight tolerance[14]. The part widths indicate no significant trend but a significant amount of variation relative to the specification limits; approximately 90% of the parts are in compliance. Interestingly, the standard deviation of the widths has been reduced 33% from 0.16 mm for cycles 1 to 10 to 0.12 mm for cycles 30 to 40.

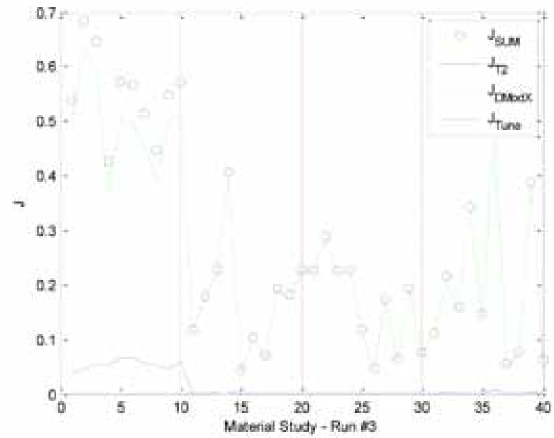

Figure 6: Evolution of Objective Function

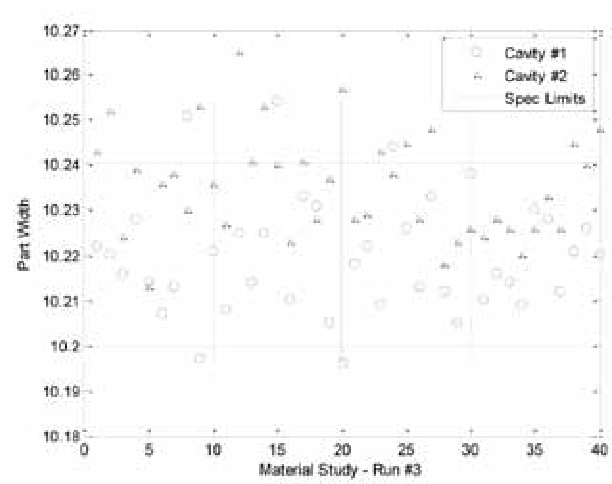

Figure 7: Evolution of Part Widths

Cycle Time Optimization

As a second experiment, the controller's ability to reduce cycle time was investigated. There are two different optimization approaches to solving the cycle time. The first approach is to add a penalty term to the objective function that corresponds to the cycle time, such as:

$$J = \alpha(\tilde{T})^2 + (1-\alpha)(\tilde{D})^2 + \beta(\tilde{E})^2 + \tau(\tilde{t})^2 \qquad (6)$$

where τ is a weighting coefficient on the cycle time, $\tilde{t}$. However, this approach's use of an added weighting coefficient introduces interactions with the other weighting coefficients, α and β For this reason, a second approach was used in which the cycle times were sequentially reduced from 22 to 16 s by modifying the constraints in the objective problem formulation to directly reduce the packing and cooling times. Specifically, this approach sets the upper and lower constraints in equation (3), U_i^{min} and U_i^{max}, for these process settings to equal the required times and removes their contribution from the control energy, $\tilde{E}$, in equation (2). The controller is then restricted from changing these values, but is free to change other process settings to compensate for any possible negative effects of the reduced cycle times.

Table 4 provides the process settings for the baseline case with a 22 s cycle time, as well as the results of three different optimal processes with decreasing cycle times of 20, 18, and 16 s. In each of the three optimization cases, the processes were initialized with the same settings as in the baseline case with the exception of the packing and cooling times, which were reduced in proportion to the cycle time target. After allowing the process to stabilize, the process data was fed back into the controller and analyzed according to Figure 1. Using the same characterization model described with Tables 1 and 2, the controller converged in two to three iterations, after which another iteration was conducted to verify convergence.

The resulting part dimensions are shown in **Figure 8** for the four different molding trials with different cycle

IMD Best Paper Continued

times; the horizontal dashed lines again correspond to a tight tolerance specification of 10.22 mm ± 0.2% while the vertical dashed lines indicate an implemented change in the process settings after each iteration of the optimization. It is interesting to note that all four of the processes initially start outside the specification limits. After three to four optimization iterations, the average part dimensions for the 16 and 18 s cycle times are within the specifications while the dimensions for the 20 and 22 s cycle times are outside specification but improved from their initial settings.

Table 4: Cycle Time Minimization

Run	Baseline	1	2	3
Cycle Time (s)	22	20	18	16
Shot Size (mm)	16.0	16.1	16.2	16.2
VP Switchover (mm)	19.0	10.1	10.1	10.1
Injection speed (mm/a)	60.0	60.5	61.2	60.7
Screw Speed (RPM)	150.0	150.6	149.1	153.1
Back Pressure (MPa)	10.0	10.3	10.3	10.4
Zone 1 Temp (C)	230.0	229.1	229.7	228.1
Zone 2 Temp (C)	220.0	219.1	220.5	217.8
Coolant Temp (C)	32.0	31.7	31.8	31.8
Cooling Time (s)	8	7	6	5
Pack Time (s)	8	7	6	5
Pack Pressure (MPa)	55.0	54.9	55.0	55.0
Melt Viscosity [0,1]	0.5	0.41	0.4	0.41

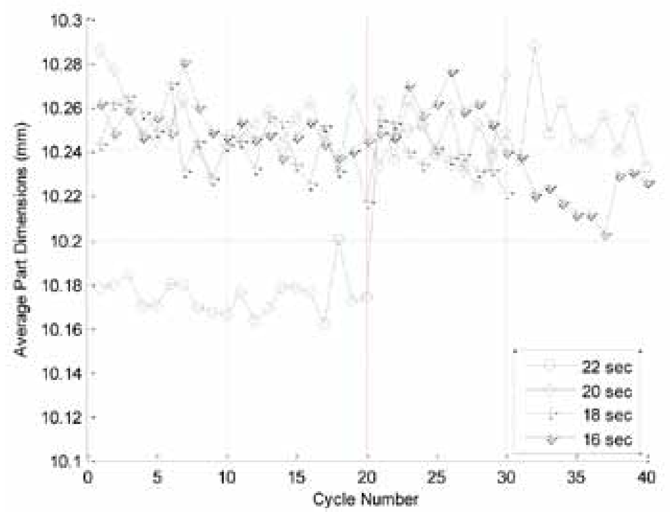

Figure 8: Evolution of Part Dimensions

Discussion

Upon reflection of these results, the reader may wonder why the objective function, *J*, does not trend asymptotically to zero in Figure 6 and why the part dimensions in Figures 7 and 8 do not converge directly to the center of the specification limits. The reason is that the optimization relies on a multivariate model of the process that was derived from a set of characterization experiments. As previously mentioned with respect to the loadings plot of Figure 5, this model captured roughly 81% of the observed process behavior. Since the model does not perfectly describe the process, the optimization that is based on the model provides results that are not precisely optimal.

Still, it is the authors' contention that the presented architecture is sound and valuable. Indeed, the presented results are fairly remarkable in that the process model relied solely on a principal components analysis of the process settings and did not explicitly model their influence on part dimensions. Still, this issue of optimality raises two questions:

1. Are the results useful?
2. Can similar results be achieved more easily in some other way?

In response to the first question, the results need not be truly optimal in order to be useful. Indeed, the definition of "optimality" in practice remains a hotly debated topic in both the engineering and economics research communities. As such, the plastics engineer can be well served by the described methodology which relies on an application specific approach to characterizing their process and then continuously minimizing variation and uncertainty in the face of external changes in the process.

In response to the second question, there are two alternative approaches that might provide similar results. One alternative is the conventional, ad hoc, trial and error approach to adjusting the process settings based upon human observation and expert knowledge. The success of this approach varies widely with the level of application requirements and expert knowledge. In many cases, a greater number of iterations may be required to converge to a less optimal result than those presented here. In other cases, however, the trial and error approach may be acceptable relative to the instrumentation and characterization costs of the presented approach.

There is also a second alternative that eliminates the need for an application specific process model and the required characterization experiments. Referring again to Figure 1, the described approach uses the process model in the optimization loop at left to reduce the number of molding cycles required for convergence. Conversely, an alternative approach referred to as "direct search" could directly optimize the process without a process model by implementing new process settings every molding cycle. However, this approach requires many (literally hundreds or thousands) of cycles to converge without any guarantee of finding a global optimum or feedback on the result's fidelity.

Conclusions

An auxiliary controller was designed, implemented, and validated for on-line process and quality optimization. Two different experiments investigated the controller's ability to optimize the process according to different constraints. In the first experiment, a 50/50 blend of low/high MFR PP was replaced with the low MFR grade. During processing, the process controller immediately detected high process variation as well as differences in the process behavior compared to the reference process model. Subsequent iterations of the optimization were successful in reducing the value of the objective function, which also corresponded to improvement in the dimensional consistency of the molded part dimensions. The second experiment investigated the ability of the controller to adjust the process for reduced cycle times. In every case, the controller was able to reduce the value of the objective function and also improve the part dimensions.

The use of a process model greatly speeds convergence to near optimal processes as well as stability and feedback statistics. Furthermore, the architecture, process models, and objective function are readily extensible. For example, the part dimension results of Figures 7 and 8 could be further improved by measuring the dimensions of the parts produced in the characterization experiments, explicitly modeling the relationships between the dimensions and the process settings, then directly optimizing the dimensions during production by including the dimensions in the objective function or constraints. As such, it is possible by optimization to directly trade-off cost and quality attributes on an application-specific basis.

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On The Road
2011 SPE Automotive TPO Global Conference

The SPE Automotive TPO Global Conference was held in Troy, Michigan from October 3 to October 5, 2011. Organized by the Detroit Section and co-sponsored by the Automotive Division, the event promotes technical interchange among stakeholders in the automotive industry – OEMs, tier molders, compounders, and material suppliers.

This year the program included sessions on *Material Developments, Advanced Polyolefins, Automotive TPO/TPE, Surface Enhancements, Applications Development and the new session Polyolefin Foams & Advances in Process Development.* Light weighting and sustainability were two major themes of the presentations. More than 450 attendees benefited from the networking opportunities throughout the three days.

Exhibitors from a broad spectrum of the TPO supply chain were on-hand to present and discuss their products and technologies. Washington Penn Plastic, a custom compounder of mineral filled polyolefins, showcased a 2011 Buick Lacrosse bumper made from their engineered TPO.

2011 Buick Lacrosse bumper molded with Washington Penn Plastic TPO

Feature 2001 SPE Automotive TPO Global Conference Continued

Imerys featured their Jetfine ® talc grade, which is of ultrafine grind, for increased stiffness, high impact resistance and low CLTE. Mitsui Plastics provided information on a variety of products – elastomers, MOS Hige fillers, metallic film laminates, etc. Among their offerings, Evonik discussed their product Tegomer ® AS 100 for scratch resistance. A complete list of exhibitors can be found at http://www.speautomotive.com/tpo.htm.

On Tuesday, October 4, the Executive Management Panel addressed the trends that have started reshaping the global automotive market through 2016. Moderating the discussions were Bob Eller (Robert Eller Assoc., LLC) and Ron Price (Global Polymer Solutions). The panel consisted of executives from Ford Motor Co., General Motors Co., Sabic Innovative Plastics, Advanced Composites and Magna International.

Some highlights of the keynote addresses are:

Global Automotive Light Weight Market – Where Do We Go From Here?,
by Jeff Shuster, Executive Director, J.D. Power & Associates

- Mature markets are expected to reach former levels until 2016, and the light weight vehicles are expected to cross 100 million units by 2015.
- Markets continue to shift by 2015, with China overshadowing the global growth.
- Despite the current economic outlook, the drivers for long term growth are new household growth, replacement demand, credit availability and increasing leasing trend. Sustaining the growth trend is the fleet market.
- The OEM landscape is aggressive, with model activity reigniting the hypercompetitive market. The current trend is small vehicles, although the US is still lagging the rest of the world in small car growth. Hybrid and electric vehicles will grow to 1.24 million units by 2016, with 31% coming from Toyota.

Polyolefins Are A Sustainable Solution,
by Tom Henry, Global Automotive Business Manager, Exxon Mobil

- Automotive production continues to expand globally.
- Increased demand of vehicles in developing economies contributes significantly to the increased demand of energy.
- Improved efficiency gains are required to meet growth in energy demand.
- For the automotive industry, light weighting with high performance polyolefins can save energy and reduce emissions.

The Opportunities & Challenges Of A Globalizing Automotive Industry
by Leon Jacobs, PP Global Director, Sabic Innovative Plastics

- Globalization of the automotive industry affects plastics raw material supply, particularly PP-based materials.
- OEMs increasingly demand materials that meet global quality standards and specifications.
- The pool of global suppliers is limited; thus we must align with value-chain participants with the ability to meet short-term demand and deliver long-term supply reliability.

Feature 2001 SPE Automotive TPO Global Conference Continued

CAFÉ Requirements: Lightweighting For Improved Energy Efficiency
by Dagmar Van Heur, VP Automotive, Styron LLC

The European Union CO_2 emissions legislation drives the aggressive trend of weight reduction (in Europe). A similar trend is developing in the US to meet the current CAFÉ requirements.

Even with the push for light weighting, steel and aluminum use in car design are back because vehicle engineers are more familiar with the concept of designing with steel.

The need to reduce weight pushes plastics into more structural applications, thus creating opportunities for resin suppliers and molders.

To further grow plastics use in vehicles, more emphasis on composites and plastics engineering is necessary in the education/training of vehicle engineers. Thus, critical to the growth of plastics is a more active participation of polymer and plastics manufacturers in high schools and technical universities.

About the Author

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IMD Board of Directors Meeting

October 31, 2011 – Teleconference

Chair:	**Lee Filbert**
Chair-Elect:	**Jan Stevens**
Councilor:	**Jack Dispenza**
Technical Director:	**Peter Grelle**
Treasurer:	**Jim Wenskus**
Secretary:	**Walter Smith/Hoa Pham**

Welcome

This meeting was organized by Chair-Elect Susan Montgomery in the absence of Jan Stevens, the current IMD Chair.

Susan called the meeting to order at 11:00 am ET, and welcomed all attendees to the *Join Me* teleconference.

Lee Filbert introduced Jeremy Dworshak from Steinwall Molding as an invited guest. The Board welcomed Jeremy.

Roll Call

Present were:

Susan Montgomery (Chair-Elect), Jim Wenskus; Peter Grelle; Hoa Pham; Jack Dispenza; Brad Johnson; Lee Filbert; Erik Foltz; Larry Schmitt, Kishor Mehta; Tom Turng; Michael Uhrain; and Jeremy Dworshak (Guest).

Absent were:

Pat Gorton; Nick Fountas; Adam Kramschuster; Jack Dispenza; Raymond McKee; Jan Stevens.

This constituted quorum.

Approval of May 1, 2011 Meeting Minutes

The meeting minutes of May 1, 2011 were presented.

Motion: Peter Grelle moved that the May 1, 2011 meeting minutes be approved, as written and distributed. Kishor seconded and the motion carried.

Financial Report – Jim Wenskus, Treasurer

For the 2011-2012 fiscal year, financial figures of the quarter from July 1, 2011 through September 30, 2011 were reviewed. The SPE quarterly rebate and the newsletter sponsorships have been received. The newsletter sponsorships are now set up to be received through PayPal at a fee of 3.5%. For this quarter, the major expense item was the cost of the newsletter production.

Councilor Report – Brad Johnson, Councilor

The SPE is financially healthier with a net operating surplus. The major contributor was the pay-off of the 2007 loan. The net revenue after expenses showed positive for publishing, conferencing and Foundation (Restricted Funds), and negative for membership and corporate support.

The 2012 budget was developed with expectations of a flat growth rate in membership, slight decrease in revenues from webinars, TopCons, and bookstore, and ANTEC co-locating with NPE. The net revenue after expenses was expected to show a continued negative in memberships and a slight decrease for the Foundation restricted revenues.

IMD Board of Directors Meeting Continued

In extending its ANTEC brand globally, the SPE will hold an ANTEC event in Mumbai, India in late 2012. The Council meeting will be on November 12 in Barcelona, Spain.

Communications Committee Report – Adam Kramschuster (absent)

Adam's report will be sent to the Board after the meeting.

Pinnacle Award – Susan Montgomery

Susan thanked the Board for their input on the activities that would be used to meet the criteria of the Award.

Technical Director Report – Peter Grelle

Peter presented the status of the technical programs. With ANTEC 2012 being held earlier than usual, the timelines for all related activities have been pushed up. Thus, the IMD paper review will be on November 3 in Madison, WI.

For TopCon, Brad Johnson will lead the injection molding conference at Penn State, Erie. The Medical Minitec, which was to be organized with the Medical Division and the Upper Midwest Section, is still open pending feedback from these groups.

Action Item: *Peter will contact Len Czuba at the Medical Division for status update.*

ANTEC 2012 Report – Erik Foltz, TPC

Erik gave an update on the IMD preparation for ANTEC 2012. The conference will be held on April 2 – 5, 2012 and will co-locate with NPE in Orlando, FL. The total number of received papers was 62. Erik confirmed one keynote speaker and was working on getting two other speakers.

SPE Update – Tricia McKnight, SPE Leadership Liaison (absent)

No additional update.

Education Committee – Susan Montgomery for Pat Gorton, Chair (absent)

Work is on-going to identify the advantages and disadvantages of having an IMD Plastics Certification program. Pat will present a proposal at the next Board meeting.

Action Item: *Pat will present the proposal for the certification program at the next meeting.*

Nomination Committee – Hoa Pham, Chair

In preparation for the 2012 Ballot, Hoa asked the Officers to indicate their interest in continuing with their roles on the Board. A short bio will be needed from Directors whose term ends at ANTEC 2012 and who are eligible for inclusion in the ballot.

Action Item: *(1) Officers e-mail to Hoa indicating interest.*
(2) Hoa will e-mail the list of Directors and their corresponding terms.

IMD Board of Directors Meeting Continued

Membership Committee – Nick Fountas, Chair (absent)

No membership update.

Fellows & HSM Committee – Larry Schmidt, Chair

Larry reported that Jack Dispenza has submitted his HSM application. John Bozelli will complete his Fellows application.

Larry asked the Board to recommend Fellows and HSM candidates for 2013 and beyond. The list of current Fellows is included in the IMD History report, which will be sent with the minutes to the Board.

Old Business

Congratulations to Erik on the arrival of his baby!

Review of action items from the May 1 meeting:

Newsletter contract status: Hoa and Adam completed the contract with Heidi for the term from May through the publication of the November 2011 issue. A new contract will be necessary to continue.

- Assistant Treasurer: Jim sent to Hoa the bank information recently. Hoa will follow-up to complete the process.
- TPC presentation: Peter Grelle sent the presentation to SPE HQ as Best Practice share
- New nominee for Board: Filbert had invited Jeremy Dworshak, who attended this meeting.
- Chapter reach-out activities: No update
- Revision to the Bylaws wording on the responsibilities of Education Committee Chair: No update.

New Business

With Jan being absent, the Board discussed having an Acting Chair until ANTEC 2012 when the new Chair would be in place.

Motion: Jim Wenskus made a motion to approve Susan as the Acting Chair in Jan's absence. Lee Filbert seconded, and the motion carried.

The next meeting will be February 3, 2012. Kishor informed that David Kusuma at Tupperware would continue hosting the IMD Board winter meeting. Susan will coordinate with David on the meeting arrangements.

Adjournment

Motion: Peter Grelle made a motion to adjourn the meeting. Tom Turng seconded and the motion carried.

The meeting was adjourned at 12:10 PM ET.

IMD Leadership

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The IMD Welcomes 245 New Members From Around the World

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Miklos Antal
Avinash Arankalle
R. Haresh Babu
D. Badve
Hossein Baghdadi
Jeff Baines
Bryan Baker
Nancy Barrie
Greg Bartlett
Scott Baxter
Jeff Bennett
Vincent Berger
Harsh Bhagat
Matthew Botros
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John Busa
John Cadotte
Enrique Camacho
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Kleta Childs
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Clinton Cowen
Maureen Cress
C. Stephen Cunningham
Steve Cunningham
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Gary Dalton
Jaime Navarrete Damian
Gourab Das
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Vinod Deshmukh
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Leo Devellian
Kuldeep Sukhdev
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R. Giles Dillingham
Anant Doiphode
Joseph Dolan
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Kishor khatu
Dong-Hak Kim
Paresh Kitchloo
Robert Knaster
William Knipper
Pankaj Kohli
Shailesh Kolhe
Sudhir Moreshawar Koli
Ken Kostecki
Andrew Kountz
Greg Krueger
Michael Kuhlman
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Kanchan Kumar
Evan Laganis
Vikas Lalwani
Ben Lanza
Bruce LeBlanc
Han Chang Lee
Barbara Leesha
Ian Leong
Chengtao Li
Di Ling
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Manjula M
David Macellari
Yash Madan
Rohit Mahajan
Bruce Maier
Ferenc Majzik
Abraham Mathew
Carol McCrum
Michael McGee
Bhagyashree Meghe
Chandresh Mehta
Karan Mehta
Shruti Parthesh Mehta
Vishal Mehta
Nicholas Melfi
Vaibhav Mhapralkar
Hemant Minocha
Reza Mirsaeian
T. Bruce Montgomery
Alexander Mora
Roger Morris
Rich Mowad
Lisa Mueller

IMD New Members Continued

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Sandesh Naik
Gi-Joon Nam
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Jake William Nelson
Johnny Netzloff
John Nowell
Greg Paaske
P Pachathan
Anindya Pal
Lokesh Mohan Pancholi
Ramesh Parasuraman
P.P. Patil
Aditee Patwardhan
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Dragica Petrovic
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Leo Popp
Andre Potthoff
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Winie Pronjul
Martin Puetz
Maulik Radia
Rajen Rathod
Satyajit Rawat
Eugene Regala
Peter Rizk
Dean Roberts
Luis Robles
Janet Roncelli
Kevin Rottinghaus
Siddhartha Roy
William Royals
Gagan Saini
Nayan Sarnot
Avinash Sarode
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N.S. Sawale
Martin Schaefers
Andreas Schobel
Chris Schreck
Greg Schriner
Dan James Schuneman
Adam Scott
Rajesh Sharma
B. P. Shiv
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Ronald Smierciak
Douglas Smock
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V. Srikrishnan
Rob States
Jeffrey Steltz
Philip Alan Stott
Joseph Abraham Thayyil
Charles Thiele
David Thomas
Suhas Thorat
Suresh Todkar
Show Chong Toh
Jeff Ullrich
Varun Upadhyay
Sandeep Vanjara
Dominic Vimod
Jack Walker
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Steven Waterman
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Jian Zhou
Christopher David Zook

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Allied Solutions (I) Pvt. Ltd.
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Bermar Associates Inc.
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GVS Envicon Technologies
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Hasbro Games
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Henkel Corp.
Henkel Surface Technologies
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IEEC PBJ Industrial Electronics Ltd
Institute of Plastics Processing (IKV Aachen)
IMS
Indian Oil Corp. Ltd.
INEOS ABS (India) Ltd.
Instituto Tecnologico de Celaya
Intercontinental Polymer Pvt. Ltd.
Intricon
Iran Techno Systems Co. Ltd.
ITW Engineered Fasteners
ITW India Ltd.
ITW-Dahti Seating
J.B. Polymers Inc.
John Cimbrella Mart
K.K. Nag Ltd.
Ketch
Kohler Co.
Kyoto Institute of Technology
Lighthouse Industries
Lalitha Chem Ind. Pvt. Ltd.
LS Cable Ltd.
Lubrizol Corp.
Lubrizol Advanced Materials
Mahindra & Mahindra Ltd.
Manar Inc.
Maquette Cardiac Assist Div.
Maruka USA Inc.
Medical Action Industries
Meridian Medical Technologies
MGS Manufacturing Group
Michigan Tech U.
Micro Mold Company Inc.
Micron Products Inc.
Milacron
Milliken Chemical
Minda Valeo Security Systems Pvt.Ltd
Modified Plastics
Moldmax Technology Corp.
MRP Corp.
MSI Technology
Multibase India Ltd.
Niagara Bottling
Niagara Water
Nike
Nirma U.
NJT dba Mayco International
Nova Chemicals Corp.
Nypro Inc.
Nypro Kanaak
Orthomerica Products Inc.
Osaka Resin Industry Co. Ltd.
Overseas Polymers Pvt. Ltd.
Paradise Plastics Enterprises Ltd.
Penn State U. Erie - The Behrend College
Performance Plastics Ltd.
Plaspros Inc
Plastech Solutions S.A.
Plastic Metal USA
Plastics Solutions
Poly Marketing Pty. Ltd.
Poly Plastech
Polymers International Australia Pty. Ltd.
Premier Plastics
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IMD New Members Continued

Ring Container Technologies
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Samtec
Sanner Plastics
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SGS Consumer Testing Services
Silgan Plastics Corp.
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SMC
Soonchunhyang U.
Steinwall Inc.
Stress Engineering Services
Sussex IM
Synventive Molding Solutions
TATA Autocomp Systems Ltd.
TATA Consultancy Services
TATA Motors Ltd.
Tech Tooling LLC
Testor Corp.
ThermoFisher Scientific
Thornhurst Manufacturing Inc
Trademark Plastics Inc.
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Vivekanand Society
VMTECH
Walmart Inc.
WM Plastics Inc.

Crafts Technology Pioneers Tungsten Carbide Core Pins: Cuts Cycle Time by 20 to 40% for Plastic Injection Molding

Crafts Technology has introduced a new core pin made from a special grade of tungsten carbide that directly addresses the problems of thermal conductivity and deflection in the plastic injection molding process. The tungsten carbide core pin has a very high thermal conductivity with extreme rigidity. In such applications as medical parts and consumer components, the use of tungsten carbide core pins has resulted in cycle-time savings of as much as 20 to 40% without sacrificing the quality of the molded part.

In high-volume production of plastic injection molded components, cycle time is critical to profitability, and one of the limiting factors is the removal of heat from the mold. Some plastic injection molded parts have deep internal features that require the use of long core pins. During solidification and cooling, the plastic contracts on the core pin; thus, the rate of cooling is controlled by the heat transfer through the core pin. Whether or not the core pin has a bubbler, heat transfer is dependent upon the thermal conductivity of the core pin material.

Before the development of tungsten carbide core pins, hardened copper alloys typically were selected as the material of choice for long core pins. However, the copper alloys are not very rigid, and for high-aspect ratio configurations, they will deflect during the injection phase. The deflection results in unacceptable dimensional stability. In situations where deflection occurs, hardened tool steel is used. But because steel does not have high thermal conductivity, cycle times suffer.

"We have been testing the use of tungsten carbide core pins for our clients for several years with outstanding results," explains Dave LeMaistre, Vice President, Crafts Technology. "Although tungsten carbide is a more expensive material than the copper alloys or the tool steel typically used in core pins, its ability to be used to produce high-quality

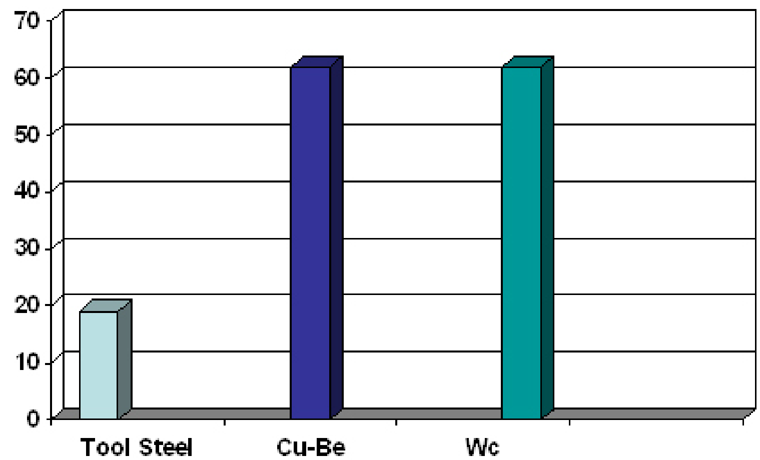

Figure 1 compares the thermal conductivity of tungsten carbide to beryllium-copper and tool steel, showing that tungsten carbide will transfer heat as fast as Cu-Be, and much faster than tool steel.

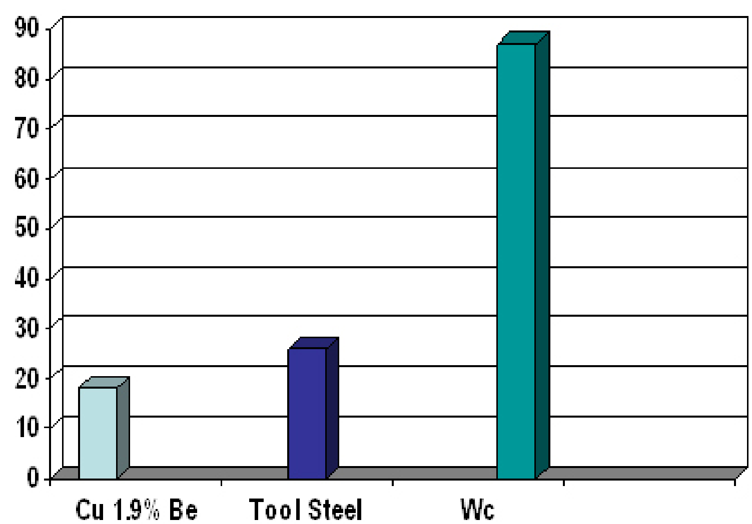

Figure 2 shows the theoretical deflection data for the three materials. Tungsten carbide has a very high modulus of elasticity, easily outclassing other materials in the reduction of deflection. The high rigidity also means that the tungsten carbide material possesses very high resistance to wear, outperforming tool steel by up to 100 times, and Cu-Be by much more.

Products Continued

molded parts and to cut cycle time significantly makes tungsten carbide core pins worth the investment for many applications."

Based in the Chicago suburb of Elk Grove Village, Crafts Technology designs and manufactures specialized products using hard materials, such as tungsten carbide, advanced ceramics and polycrystalline diamond, to produce wear parts, components and custom tooling. Crafts Technology is known for its application engineering, which helps customers identify the optimum material to achieve the best product performance and the least cost method of manufacturing.

About Crafts Technology

Crafts Technology is an engineering-manufacturing service company that specializes in the manufacturing of ultra-hard wear parts, components and custom tooling made from specific grades of tungsten carbide, advanced ceramics or polycrystalline diamond. **For more information visit www.craftstech.net .**

Neutrex Expands Production Facilities by 50% for Purgex

Neutrex, Inc., Houston, TX, announces a 50% increase in the size of its production facilities for the company's line of Purgex Commercial Purging Compounds (CPC). Stating that the company has added new jobs during the past year and has outgrown its present space, the expanded facilities will be fully on-stream by the end of 2011. The expansion will include additional manufacturing and warehousing capability to supply Purgex to plastics processors in the domestic market and to Purgex distributors in Europe, Asia, Africa, and South America. The expansion will also allow the company more flexibility in the development of new products planned for introduction in 2011, Neutrex states.

In announcing the expansion, Arthur P. Haag, President of Neutrex and inventor of Purgex said, "Our rapid development worldwide, and continued growth in North America are driving the need to expand our facilities. Over the last two decades, our efforts have been dedicated to meeting the purging needs of the thermoplastic resin industry. As we grow, a high level of R&D activity will continue."

Introduced in 1992, Purgex is a CPC used to clean injection molding and extrusion equipment during color and material changeovers, and as part of routine or preventive maintenance. According to the company, Purgex cuts downtime, decreases scrap rates, and reduces the amount of otherwise usable resin wasted when purging. The overall effect is to lower purging costs and improve productivity for thermoplastic resin processors.

The company is well-situated to serve all markets, as Houston commands approximately 40% of chemical-production capacity in the United States and is the 10th largest international port.

"Our competitiveness is based on engineered quality; however, being close to such a good source of raw material for our products and having ready access to a major shipping hub strengthen our position the market," Haag said.

For more information, contact: Neutrex, Inc. 11119 Jones Road West, Houston, TX 77065. Toll-Free: 800-803-6242. Phone: 281-807-9449. Fax: 281-807-9748. Email: sales@purgexonline.com. www.PurgexOnline.com.

Feature

New DoveTail Collapsible Core Improves Undercut Molding Efficiency

Patent-pending solution overcomes challenges of o-ring grooves, slots, snap-fits and other features

The DoveTail Collapsible Core, now available from DME Company, a leading manufacturer of mold technologies, is an essential tool for molders seeking to master undercuts.

Eliminating the need for complex unscrewing mechanisms, the patent-pending DoveTail Collapsible Core provides solutions for hard-to-mold internal undercut features such as o-ring grooves, slots and snap fit details. Its compact design and simplified mold approach help reduce cycle times, maximize the number of mold cavities and increase part design and application flexibility.

"The DoveTail Collapsible Core brings molders a powerful new weapon in tackling difficult undercut molding applications," said Dave Lange, Director of Sales. "We're always looking to bring our customers innovative technologies in support of their success, and the DoveTail is one more example of how we're with them every step of the way."

Available in four standard sizes, as well as custom sizes, the DoveTail offers advantages including:

- Positive, mechanically actuated collapse of 5% to 7%
- Customizable collapse angles
- Quick-lock system for installation and removal while the mold is in the press
- Elimination of costly rack-and-gear systems
- Center cooling channel
- Gradual release from undercut
- Large, robust segments
- Reliable shut-off with front half of mold
- Shorter stroke on mold staging, deeper undercuts and taller parts
- High-quality construction of A2 steel and other durable materials

For more information on DME's DoveTail Collapsible core and other DME Undercut Solutions, visit www.dme.net/dme/landing/undercut.html.

Find DME on Facebook at: http://www.facebook.com/pages/DME-Company/21435469379

DME

Every step of the way

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Demographics

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❑ Other
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❑ Quality Control
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❑ Student
❑ Tech Support

Materials *(choose all that apply)*
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❑ Film
❑ General Interest
❑ Nylon
❑ PET
❑ Foam/Thermoplastics
❑ Polyolefins
❑ Polystyrene
❑ TPEs
❑ Thermoset
❑ Vinyls
❑ No Interest

Process *(choose all that apply)*
❑ Blow Molding
❑ Compression
❑ Compounding
❑ Engineering Properties
❑ Extrusion
❑ Fabrication
❑ Foam
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Message from the Publisher

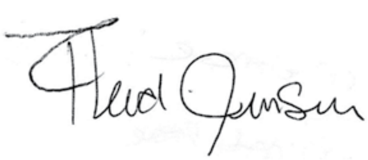
Dear Readers,

I hope you enjoyed this Fall edition of the SPE IMD Publication. There are many new articles this month that I hope you find useful. As always our Ask the Expert columns are informative so please remember to send any questions our experts.

The new year will be coming quickly as the holidays are fast approaching and I'm sure everyone is busy finishing budgets and projects before the year ends. The next issue will be closing in February so feel free to submit any papers for the next issue. I am always looking for new tips and informative information that you have to share with the rest of our fellow readers!

If you have any company news or products you would like to share with fellow members please send them in. I would enjoy receiving new updates for our products and news section.

Thank you for taking the time to read this edition. I hope everyone has wonderful holidays and a successful rest of the year.



Heidi Jensen
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Spring Issue: ***February 1, 2011***

AD SIZE	(W X H in inches)
1/10 page:	3 x 2 1/2
1/4 page std:	3-3/8 X 4-7/8
1/4 page horiz.:	4-3/4 X 3-1/4
1/3 page square:	4-3/4 X 4-3/4
1/3 page vertical:	2-1/4X 10
1/2 page horiz.:	7 X 4-7/8
1/2 page isl.:	4-3/4 X 7
Full page:	7 X 10

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