Injection Molding Division
Molding Views

Fall 2023 | No. 121 www.injectionmoldingdivision.org Keep the connection! Join us on:

Chair's Message Jeremy Dworshak

Dear Members of the Injection Molding Division,

I hope this message finds you well. I am thrilled to share with you the outcomes of our recent strategic planning session, which took place in September at the 3M Campus in St. Paul, Minnesota! This gathering was a great success! Not only was it wonderful to meet up as friends, it also served as a way to reinvigorate our leadership team to set a clear course for the upcoming year.

Our journey towards these strategies began with you, the Injection Molding SPE members. Your survey responses provided essential insights and guidance that shaped the direction of our discussions. I want to extend my sincere gratitude to each of you for your participation and contribution.

Through rigorous discussions and careful deliberation, we have distilled our collective vision into these core strategies for the year ahead:

1. **ANTEC:** SPE's annual technical conference is a premier event for our industry. We will continue to make it a high priority within our board.
2. **Technical Workshops:** Your survey responses highlighted the vital role technical education plays in our industry. How we best balance this need, along with building on the workshop successes of SPE headquarters, will be part of our board's focus.
3. **Sustainability Collaboration:** Sustainability is at the forefront of our industry's future. Our board's goal, around this topic, will be discussed throughout the year.
4. ***Communication:*** Effective communication is key to our division's success. How we best provide communication will be at the forefront of our minds throughout the year.

Our vision for the year is to make tangible progress in each of these focus areas, all while ensuring that we make the most efficient use of our volunteer time as leaders in the Society of Plastics Engineers. We are committed to ensuring that our efforts yield real benefits for our diverse membership.

We look forward to your continued support, collaboration, and dedication in the journey ahead. Together, we will shape the future of the Injection Molding Division within SPE to make a meaningful impact on our industry.

My best regards,

Jeremy Dworshak Chair,
Injection Molding Division Society of Plastics Engineers (SPE)

IN THIS ISSUE:

NOVEMBER 2023

SPE WEBINAR: FRACTOGRAPHY OF GLASS REINFORCED PLASTICS

THURSDAY, NOVEMBER 16, 2023 12:00 PM (EST) - 1:00 PM (EST))

VIRTUAL EVENT

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8234

DECEMBER 2023

IMPLEMENTAM WORKSHOP—PHOENIX

THURSDAY, DECEMBER 7, 2023 8:00 AM (EST) - 5:00 PM (EST)

FRASHER'S SMOKEHOUSE,
222 EAST INDIAN SCHOOL ROAD
PHOENIX, AZ

Join us in Phoenix for a day of learning, collaboration, and networking. Expand your knowledge about the foundational 3D printing technologies and learn about the business cases behind additive manufacturing. We have expert speakers from major 3D printing machine OEMs, software providers, and service bureaus. It'll be a dynamic day involving plenty of networking opportunities as well as group activities designed to get you away from PowerPoint and experience a more interactive learning experience.

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8483

SPE WEBINAR: AN OVERVIEW OF POLYCARBONATE RESIN

THURSDAY, DECEMBER 7, 2023 11:00 AM (EST) - 12:00 PM (EST)

VIRTUAL EVENT

Polycarbonate resins are used across a wide range of applications in many different sectors. They offer many advantages to the product designer in physical properties and aesthetics. Polycarbonate is also compounded with a variety of thermoplastics to, and these blends results in an even more diverse property set. It is essential to thoroughly understand the mechanical, thermal, and chemical properties of polycarbonate and polycarbonate-based resins to effectively utilize their potential.

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8253

JANUARY 2024

IMPLEMENTAM WORKSHOP—AUSTIN

WEDNESDAY, JANUARY 17, 2024 8:00 AM (EST) - 5:00 PM (EST)

PINTHOUSE BREWING
2201 E BEN WHITE BLVD
AUSTIN, TX 78741

Join us in Phoenix for a day of learning, collaboration, and networking. Expand your knowledge about the foundational 3D printing technologies and learn about the business cases behind additive manufacturing. We have expert speakers from major 3D printing machine OEMs, software providers, and service bureaus. It'll be a dynamic day involving plenty of networking opportunities as well as group activities designed to get you away from PowerPoint and experience a more interactive learning experience.

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8484

THE FUTURE OF ROTOMOLDING: MAKING OUR INDUSTRY INNOVATIVE AND SUSTAINABLE!

TUESDAY, JANUARY 30, 2024 - THURSDAY, FEBRUARY 1, 2024

VIRTUAL EVENT

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8388

FEBRUARY 2024

SPE CONFERENCE: REDUCING PLASTIC WASTE THROUGH ARTIFICIAL INTELLIGENCE AND DIGITALIZATION

MONDAY, FEBRUARY 5, 2024 - WEDNESDAY, FEBRUARY 7, 2024

VIRTUAL EVENT

In this event, we will explore how artificial intelligence (AI) and digitalization are revolutionizing the plastic industry, offering robust solutions that can effectively mitigate plastic waste and optimize its usage through increased recycling. By harnessing the power of intelligent algorithms in conjunction with advanced technologies like the Internet of Things (IoT) and geolocation, waste collection in urban areas can be significantly improved and optimized.

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8318

SPE INTERNATIONAL POLYOLEFINS CONFERENCE

SUNDAY, FEBRUARY 18, 2024 12:00 AM (CST) - WEDNESDAY, FEBRUARY 21, 2024 12:00 AM (CST)

GALVESTON ISLAND CONVENTION CENTER AT THE SAN LUIS RESORT, SPA & CONFERENCE CENTER

5600 SEAWALL BLVD., GALVESTON, TEXAS 77551

For more information: https://spe-stx.org/international-polyolefins-conference-3/

Venting in a Two-Stage Process Boosts the Efficiency of Recycling Processes

High Quality Recycled Plastics Obtained Directly from Flakes

ENGEL

ENGEL has developed a new way to process plastic scrap as flakes on an in-jection molding machine straight after grinding. This innovation eliminates the pelletization step and significantly boosts the economics of plastics recycling. The key to consistently high product quality is to vent the plastic melt.

In order to be able to process flakes by injection molding, ENGEL has developed a two-stage process that divides plasticizing and injection into two separate, coordinated process steps that shorten the recycling process. In the first stage, the feedstock, e.g. single-resin plastic flakes obtained from post-consumer or post-industrial collection, is melted on a conventional plasticizing screw. The melt is then transferred to another screw for injection into the cavity in the second stage. A melt filter and a venting unit can be integrated into the transition section for transferring the melt from the plasticizing to the injection screw. As a result, high-quality products can even be obtained from contaminated plastic scrap.

Usually, sorting, cleaning and grinding of post-consumer and post-industrial plastic scrap is followed by compounding, pelletizing and feeding it into the injection molding process as re-claim. The plastic is therefore melted twice. Pelletizing recycled regrind is an energy-intensive process that also normally entails a certain amount of logistics. ENGEL's two-stage approach eliminates this step entirely, thereby improving the carbon footprint and lowering the costs of recycling. The company calculates that the energy requirement is reduced by around 30 % as a result. This innovation is a further contribution made by ENGEL to greater sustainability and the development of a circular economy for plastics.

New Venting Unit Enhances Product Quality

A particular focus of the development work on the two-stage process was the venting unit. Venting is necessary because certain contaminants can pass the melt filter. These may be residual moisture or low-molecular compounds produced by material degradation or printing ink residues. Unless they are removed before the melt is injected, pores and defects may form on the inside and outer surface of the parts and thus reduce their mechanical load-bearing capacity.

The venting unit developed by ENGEL forms the transition section between the plasticizing screw and the injection screw and consists of a transfer head through which the melt is pressed. This increases the surface area of the melted material and shears off the melt strand. The corollary is that the injection screw is only partially filled and volatile components can readily escape from the melt. To an extent depending on the application and the ex-pected contaminants, negative pressure generated by a vacuum pump may also be employed.

Simulating Low-Molecular Contaminants

To test the performance of the new venting unit and demonstrate the potential of the new two-stage process, ENGEL conducted extensive trials on three different materials (**Figure 1**):

Figure 1: The tests were carried out on three different materials: pellets of virgin PP (left), PP agglomerate obtained from post-consumer film (center) and regrind obtained from HDPE beverage closures (right).

- Deliberately contaminated virgin PP: the material was processed into sheets that were then shredded for the trials. The flakes were processed in a single-stage pro-cess without venting in one case, and in a two-stage process with venting in another.
- PP agglomerate from post-consumer film: this material was also processed both with and without venting. The study examined the influence of partial screw filling and the influence of the vacuum.
- Regrind from HDPE beverage closures: the material was processed in one case in a two-stage process with venting and, in another, it was cleaned up in the conventional way on a separate twin-screw extruder, with venting and melt filtering, and processed in a single-stage process without further venting.

The two post-consumer fractions were selected from feedstock frequently employed by injec-tion molders. Pellets from HDPE closures are already being used nowadays in the produc-tion of pallets. ENGEL sees great potential in this area for replacing the conventional multi-stage process with the more efficient two-stage process. Film agglomerate has proved to be a very good feedstock for the two-stage process. Since shredded film scrap is not free-flowing, it is agglomerated before processing. No melting of the material is necessary for this: it is simply heated and compressed.

PP virgin material was used because, in this case, low-molecular contaminants can be simu-lated very readily with water. Natural fibers served as the carrier material for the water. It was shown that, with venting, residual moisture of up to 1.1 % can be removed from the melt stream.

Test setup at the pilot plant in St. Valentin: for the two-stage process, ENGEL has combined a plasticizing screw with an injection screw.

All three test series were conducted at the ENGEL pilot plant in St. Valentin, Austria (Above). In addition to venting, a commercial melt filter was used in all test series. The samples were evaluated at the CHASE Competence Center in Linz, Austria.

High-Quality Product from Regrind or Agglomerate

Without venting, the sample parts produced from all three materials have very large pores. Venting the melt gives a substantial boost to part quality. Venting performance was found to increase with increase in the surface area of the melt. The size of the surface area can be controlled by the degree to which the injection screw is filled. When screw filling is reduced by 50 %, pore formation does not even occur at atmospheric pressure. If it is reduced by 25 %, negative pressure is required to prevent the formation of pores (**Figure 2**). An absolute pressure of 0.1 bar was used. Venting leads to a higher elastic modulus, as confirmed by molding tests on test panels 2 mm thick. In other words, the parts become stiffer as a result of venting (**Figure 3**).

The tests showed that the speed of the injection screw has hardly any effect on vent-ing per-formance. Accordingly, even when the feedstock is heavily contaminated, the two-stage process can be used at high speeds and thus with short dosing times.

Parts of consistently high qual-ity were obtained for all three materials in the two-stage pro-cess. Compared to conventional multi-stage recycling, there are no disadvantages in terms of at-tainable material properties. It can be assumed that better vent-ing of the feedstock is achieved than when preparation and pel-letization take place indepen-dently of the injection molding process.

The trials have confirmed that the new two-stage process is robust enough to handle both regrind and agglomerate from single-resin post-consumer collections. The shape of the flake feedstock has no impact on product quality. The only requirement is that the material be free-flowing.

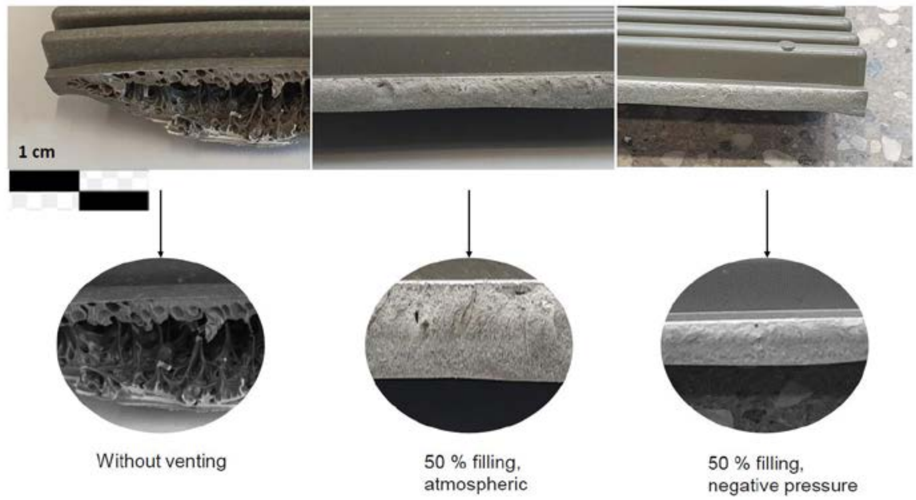


Figure 2: Vacuum supports venting and further improves part quality. The picture shows the results of tests on PP agglomerate.

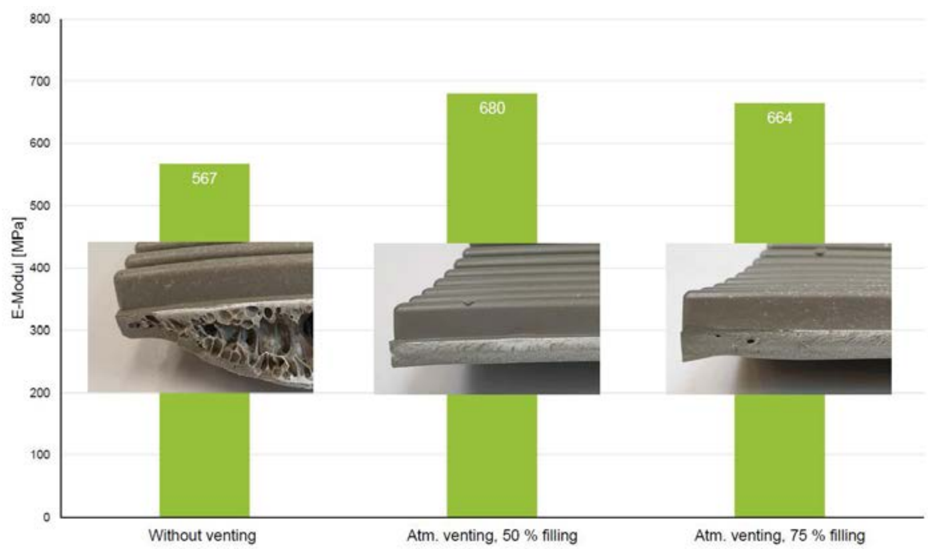


Figure 3: Part quality depends on venting and the degree to which the injection screw is filled. Without venting, the sample part has very large pores. The picture shows the elastic modulus values for the test series conducted on PP film agglomerate.

The Authors

ENGEL
be the first

DI Dr. Thomas Köpplmayr and DI Dr. Klaus Fellner are polymer engineers in the Department for Developing Plasticizing Systems and Recycling at ENGEL Austria GmbH in the St. Valen-tin site; thomas.koepplmayr@engel.at; klaus.fellner@engel.at DI Ines Traxler is a research engineer at the Competence Center CHASE GmbH in Linz, Austria; ines.traxler@chasecenter.at

A Novel Approach to Control Switchover Between Injection and Holding Phase for a Hydraulic Injection Molding Machine

Rasmus A. Hertz, Jesper K. Christensen, Ole Therkelsen and Søren Kristiansen, LEGO System A/S, Denmark
Christian-Emil Helver, Frederik A. Hansson and Lasse Schmidt, Aalborg University, Denmark

The repeatability of injection moulding machines has been a focus point since the 1970's. An important part of the molding process, when utilizing secondary over point, is the switchover between the velocity and pressure-controlled phase. Minimizing the transients in the response increases the moulding quality. A novel switchover method is presented in this paper, based on a hydraulic injection moulding machine. Controlling the flow into each of the injection cylinder chambers combined with a cascaded control structure makes it possible to execute a fully controlled switchover with a single parameter related to the permissible time duration of the pressure settling period. The controllers are implemented on an industrial state of the art injection molding machine, and the results show good agreement with theory. The response time and transients are minimized. It is further experimentally verified that it is possible to tune the desired switchover duration. The method further more simplifies the task for the molding machine operator, when setting up a new mold, as it is possible to control the dynamics of the switchover with a single parameter.

Introduction

Injection molding is an important manufacturing process in the fabrication of plastic parts. The repeatability of injection molding machines has been an area of interest for several decades, to ensure the quality in the molded product. A typical production facility requires that each machine runs with multiple molds and materials. The diversity of molds and materials, require robust controllers that works well for different setpoints of temperature, speed, and pressure. The tuning of machine controllers is a complicated task and should not be carried out each time a new mold or material is changed to ensure a consistent production flow. The molding machine operator should only have to worry about setting the correct velocities, pressures, and temperatures.

The injection molding process is divided into several phases. The predominant molding process in the industry is called secondary overpoint [1]. It consists of a velocity-controlled fill phase and pressure controlled holding phase. The switchover between velocity control and pressure control of the injection cylinder is an important part of the cycle [2]. It is important that the switchover occurs almost instantly to avoid overfilling the mold. Ideally the pressure from velocity control and the set holding pressure matches at switchover. However, this is not practically realizable as these ideal references are not known [3]. Instead, it is desired to minimize the transient response of e.g., the pressure because an undershoot before the holding pressure reference is achieved is undesired [4]. A pressure undershoot results in reduction of the melt flow into the mold. This is unwanted because the reduced flow will reduce the shear rate, hence increase the frozen layer making it harder or impossible to pack the elements. This will furthermore challenge the stability of the process.

Previous research of switchover has mainly focused on the trigger for switchover, whether it should be position, pressure or time dependent, for further information see e.g. [3]-[5]. Less research effort has been used to ensure it is a bump-less transfer between the velocity-controlled phase and the pressure-controlled phase. The bumpless transfer problem is defined as the transfer or switch between one closed loop controller acting on a plant and a second controller waiting to take over according to Zheng and Alleyne [6]. There are two main methods that are utilized in research; first approach is based on online adjustment of the states of the second controller at the switching time, whereas the second approach uses an input output matching where the second controller track the first controller while it is active. This ensures that an identical control signal is sent to the plant at switch over and will in general remove unwanted jumps in the states and reference [7].

In this work a novel bump-less switchover method is presented for hydraulic injection molding machines based on the first approach of matching states at switchover, ensuring a continues control reference at the instant of switchover.

Related Work

Havlicsek and Alleyne [8] created independent learning controllers and utilized an open loop controller between the two sections. The learning control was not able to remove transients when the pressure controller started. The open loop section reduces the possibilities of a smooth switchover as the learning controller worked better as a standalone controller. Graebe and Ahlén [9] describe a general method to switch between two controllers, utilizing a latent tracking controller. Zheng and Alleyne [6], [7] utilize the findings from [9] to create two iterative learning controllers. One for velocity and one for position, with a smooth switchover based on a latent pressure controller that tracks the velocity controller. A series of switches and a reset loop ensures continuity of the control input signal when the switchover occurs. Huang and Lee [10] designed two independent trained neural networks, for velocity and pressure control to minimize the transient after switchover, however the reference worked as a step to the controller. Lin and Lian [11] similarly designed two independent fuzzy logic rule-based controllers to minimize the transient after switchover. Froehlich et al. [12] designed a model predictive controller with two independent cost functions, one for velocity and one for pressure control. The model predictive controller improved the transient response at switchover, compared to a state-of-the-art machine.

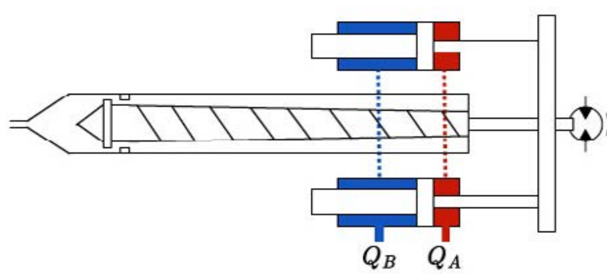


Figure 1: Sketch of injection unit and driving hydraulic cylinders.

Hardware and Material

The experiments are conducted on a hydraulic industrial state-of-the-art injection molding machine (SOA). The machine has a 40T clamping unit and a 30 mm screw. The machine is rebuilt with an adapter making it possible to switch between the SOA machine and a new dual pump drive (DPD). A sketch of the hydraulic injection unit and the driving cylinder, from the injection molding machine is shown in **Figure 1**.

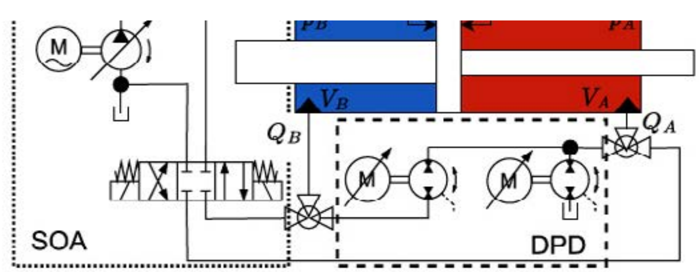


Figure 2: Hydraulic sketch of SOA and DPD.

The pressure drop between the two cylinders are assumed negligible, meaning the hydraulic schematic can be simplified to one cylinder. A schematic of the SOA machine and the DPD can be seen in **Figure 2**. Switching between the two machines is done by a set of ball valves with a minimal pressure drop. This makes it possible to easily compare the performance of the two machines. The DPD is essentially an electro-hydraulic variable speed drive [13], [14] being similar to [15], [16]. The control does not rely on sophisticated algorithms like [17]-[21] but is physically motivated following the design principles in [22], [23]. The mold is a 16-cavity cold runner mold producing a bricklike element. The mold is run in as a standard mold, and the main machine settings can be seen in **Table 1.**

Parameter	Value	Unit
Injection Velocity	100	mm/s
Dosage	59, 63, 71	mm
Hydraulic Holding Pressure	50	bar
Switchover point	11	mm

Table 1: Molding process settings for mould used in experiment.

The resin used in the experiment is an ABS with a Melt Volume Rate at 220 ºC of approximately 34 cm3/10 min, a solid density of approximately 1040 kg/m3 and a thermal conductivity of 0.17 W/(m K). The moisture in the resin is measured to 0.0306 %.

Controller Structure

Assuming the flows Q_A andQ_B can be controlled, it is possible to set up a cascaded control structure. With an inner load pressure loop and an outer velocity loop. An illustration of the cascaded control loop can be seen in **Figure 3**. It is desired to control the load pressure, as it is proportional to the force when defined as Equation 1.

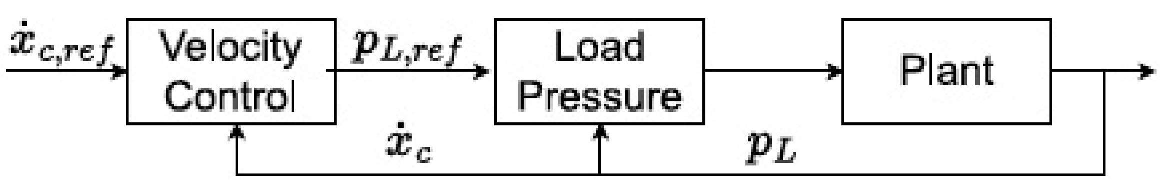


Figure 3: Cascaded control loop of velocity and load pressure.

$$p_L = p_A - \alpha \cdot p_B \tag{1}$$

Where P_R is the load pressure, P_A and P_B are the chamber pressures and a is the area ratio between piston sides B and A. As the focus of this work is the switchover between the velocity-controlled injection phase and the pressure controlled holding phase, it is omitted to describe the design of the velocity and the pressure controller.

It is desired that the switchover is as fast as possible, and without any over or undershoot. This can be achieved if the pressure trajectory follows the response of a low pass filter which in the discrete form can be written as Equation 2.

$$m(k) = \frac{e(k)\omega_n T_s + e(k-1)\omega_n T_s - m(k-1)(\omega_n T_s - 2)}{2 + \omega_n T_s} \quad (2)$$

Here $m(k)$ is the output value of the filter, $m(k-1)$ is the previous output value, w_n is the filter frequency, m T_s is the sampling time of the control loop, $e(k)$ is the current input and $e(k-1)$ the input to the filter in the previous time step.

Utilizing the filter when switching between the velocity and pressure controller will ensure a smooth and continues reference and states if the pressure controller is effective. The implementation of the filter can be seen in **Figure 4.** The low pass filter is inserted between the holding pressure reference and the switch controlled by the switchover criterion x_s.

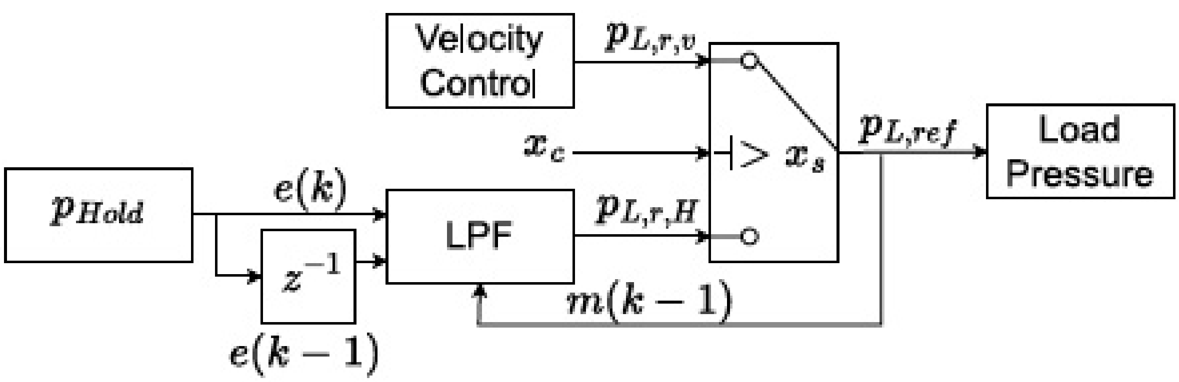


Figure 4: Implementation of filter for switchover between velocity and pressure-controlled phase.

P_{Hold} is the desired holding pressure after switchover, $P_{L,r,v}$ is the pressure reference from the velocity controller and $P_{L,r,H}$ is the low pass filtered desired holding pressure. This implementation ensures continuous reference generation to the pressure controller. The continuous reference to the pressure controller is ensured due to the usage of the old PL,ref through the value $m(k-1)$. This ensures that the filtered P_{Hold} will always start in the same point, as the velocity reference finishes in. It is furthermore possible to adjust the switchover time by controlling the filter frequency w_n. The filter frequency is approximately related to the settling time by Equation 3.

$$t_{set} \approx 4\tau, \quad \tau = \frac{1}{\omega_n} \quad (3$$

Where t_{set} is the settling time of the filter and τ is the time constant of the filter. If a desired switchover time is required, it is possible to calculate the needed filter frequency.

The switchover criterion can be chosen arbitrarily. In this work it is chosen to switchover based on screw position, as it minimizes the adjustment related to e.g., change of injection speed.

The limitations of this implementation compared to the general terms of switchover is that it is only possible to switch from velocity control to pressure control and not vice versa. It would be possible to introduce a low pass filter to the velocity-controlled side as well, to make it possible to switch in both directions. However, the low pass filter has the unwanted effect of a phase lag meaning the reference will be delayed. The delay also needs to be considered if a profiled holding pressure is desired. Due to the possibility of relating settling time to filter frequency through the time constant of the system it could be possible for the operator to change the filter depending on the mold. The filter frequency can then be adjusted based on whether an undershoot is present. If an undershoot is present the pressure control bandwidth is too low compared to the filter frequency and the filter frequency needs to be lowered. If no undershoot is seen the filter frequency can be increased to reach the holding pressure faster.

Experimental Results

The switchover performance of the SOA machine and the DPD is tested by switching over at different points in relation to how full the mold is. The baseline for the test is the standard run in of the mold with a dosing of 63 mm and switchover at 11 mm. The switchover point is chosen at this point as the mold is 99% full ensuring one percent to perform the switchover before the mold is packed with the holding pressure. The other two cases tested are with a late and early switchover. The late switchover will result in a pressure peak just before switchover as the mold is full whereas early switchover will result in melt entering the cavities after velocity control is switched to pressure control. The exact filling level of the mold is difficult to know, as it can depend on e.g. material vendor, viscosity and density. The overfill and underfill is ensured by changing the dosage to 59 mm and 71 mm. To be able to compare the two processes in the time domain, a matching of the two cycles have been made at the switchover time instant. This is done as the switchover occur at a given position that can be achieved at different times depending on e.g., the velocity controller. The filter frequency w_n = 30 rad/s for these experiments.

Figure 5 and **Figure 6** shows the pressure and velocity from the baseline test run with the SOA and DPD. The results at switchover are comparable with a similar settling time and none of them have over or undershoot. With the algorithm shown it is possible to adjust the settling time by changing the filter frequency. From **Figure 6** it can further be seen that the screw has a strictly positive velocity meaning the flow in the mold will not change sign. The performance is as expected as the mold and the SOA are optimized for these settings. The filter frequency of the new configuration could be increased as there is no sign of undershoot when approaching the desired holding pressure ref-

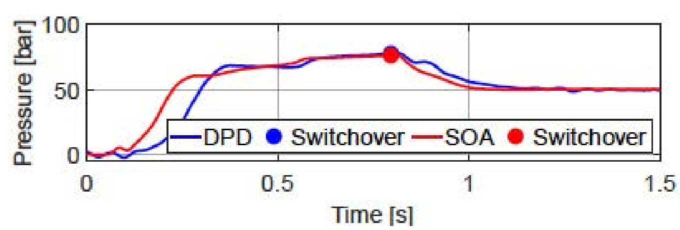


Figure 5: Hydraulic load pressure as a function of time for the baseline test.

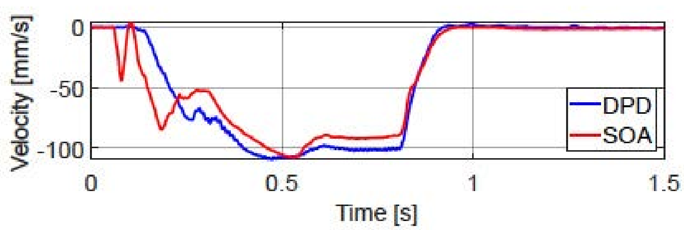


Figure 6: Screw velocity as a function of time for the baseline test.

erence. This is not done in this work to make it more comparable when considering the late and early switchover.

Switching over early means the mold cavities are not 99% full when switching to pressure control. This means melt is still entering the cavity at a reasonable rate, and the stiffness in the system is comparably low. This does not put the hardest requirements on the controllers. The results are shown in **Figure 7** and **Figure 8**. Again, both controllers have a comparable switchover duration, and the screw has a similar velocity profile. The low stiffness in the system damps pressure peaks, meaning the system is less sensitive to the method chosen to perform the switchover. Also, in this case it would be possible to increase the filter frequency to obtain a lower settling time.

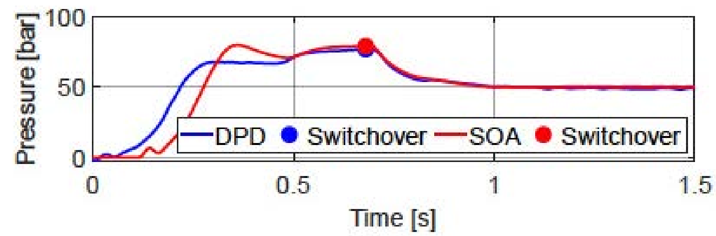


Figure 7: Hydraulic load pressure as a function of time for the case of early switchover.

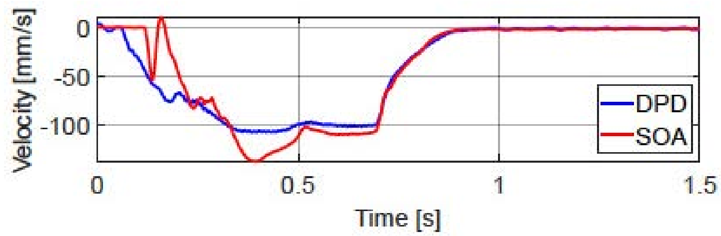


Figure 8: Screw velocity as a function of time for the case of early switchover.

In the case of late switchover, the cavities in the mould are essentially more than 99% full approaching 100% full. This will increase the stiffness in the system and therefore also the possible pressure peaks. **Figure 9** and **Figure 10** shows the pressure and screw velocity for this case. Note first the pressure increase after switchover. It is larger on the DPD due to a velocity closer to the desired velocity. The pressure peak is due to the inertia in the mechanical system and the high stiffness in the plastic system, as the mold is almost full the pressure spikes. After the spike there is a clear difference between the SOA machine and the DPD. The SOA machine creates an unwanted undershoot in pressure of approximately 3 bar before returning to the desired holding pressure. The proposed concept however does not create that unwanted effect, as the pressure decline follows a first order filter as expected from the control design. The settling time of both controller concepts are the same of approximately 0.25 s. Again, it is possible to tune the filter frequency for the pressure to settle faster. The reason for the difference in pressure peak results before the decay to the set holding pressure is the difference in actual screw velocity. The SOA machine does not obtain the full 100 mm/s, but only obtains about 90 mm/s. It is further seen from **Figure 10** that the screw has a negative velocity shortly for both controller concepts. This is due to the pressure inside the mold being larger than the pressure in the barrel. This effect is unwanted and

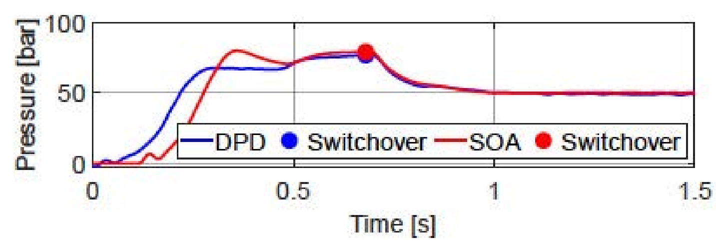


Figure 9: Hydraulic load pressure as a function of time for the case of late switchover.

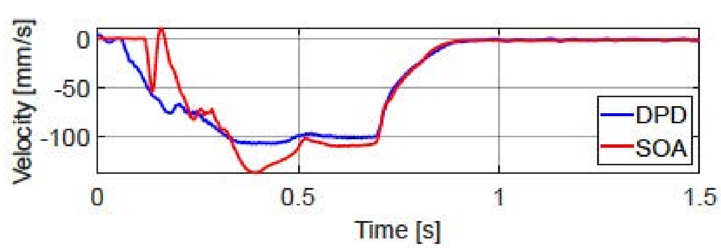


Figure 10: Screw velocity as a function of time for the case of early switchover.

will result in a negative flow out of the mold dependent on material mass temperature.

The time for switchover given in Equation 3 is also investigated experimentally. As discussed above, it is possible to change the filter frequency if a different response is desired. The test is performed with constant molding parameters as shown in **Table 1**. Dosage is chosen to 63 mm. Two different filter frequencies are chosen, w_n = [10,30] rad/s. Experimental results are shown in **Figure 11**. It is clear to see from the switchover that the settling time is faster with a larger filter frequency w_n. According to Equation 3 the settling time for w_n =30 rad/s, should be approximately 0.13 seconds which can also be seen on the graph.

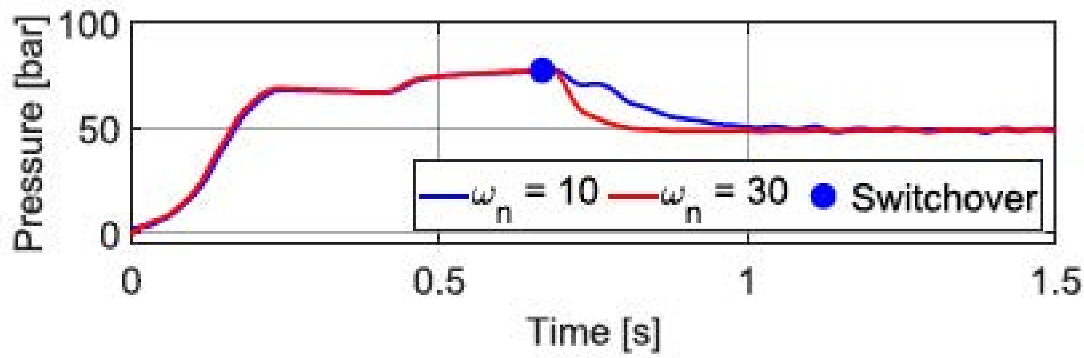


Figure 11: Hydraulic load pressure on the DPD as a function of time for different filter frequencies on the low pass filter

Discussion

The proposed control concept for the switchover between velocity and pressure control on an industrial state of the art injection molding machine, has been proven effective. As the machine can run in two configurations it is possible to switch between the standard original SOA machine and the proposed DPD. It has been decided to tune the filter frequency once, so it matches the SOA machine for the baseline test, to ease the comparison. The main idea behind this is that the moulding operator, as is, does not have the possibility to decide the length of the switchover period. The controllers have shown smooth transition of pressure from the velocity-controlled fill phase to the pressure controlled holding phase. This will make the system more robust towards e.g. material variations, as the switchover is smooth. The process variation will be minimized as the pressure transients are minimized. It is furthermore proven that it is possible to predict the time it takes to conduct the switchover, which if desired makes it possible to use as a parameter the injection molding operator can use. It is possible to set up simple guidelines to tune the filter to get the quickest switchover, without any undesired oscillations or pressure drops.

Conclusion

A novel switchover controller structure is proposed and implemented successfully on a standalone controller. The structure includes the use of a first order filter ensuring a smooth and continues reference for the pressure state when switching from the velocity-controlled injection phase to the pressure-controlled holding phase. The proposed switchover method shows good results for optimum switchover at 99% full cavities and for early and late switchover. It is furthermore shown that a single parameter related to the settling time can be tuned easily, making it possible for the moulding machine operator to tune this when setting up a new mold.

References

1. R. A. Hertz, J. K. Christensen, S. Kristiansen, O. Therkelsen, L. Schmidt, Production & Manufacturing Research, 10, 938–963 (2022). https://doi.org/10.1080/21693277.2022.2148136

2. D. Zheng, and A. Alleyne, Journal of Manufacturing Science and Engineering, 125, 154–163 (2003): https://doi.org/10.1115/1.1540126

3. D. O. Kazmer, S. Velusamy, S. Westerdale, S. Johnston, R. X. Gao, Polymer Engineering & Science. 50, 2031–2043 (2010): https://doi.org/10.1002/pen.21731

4. J. W. Bozzelli, J. Cardinal, Proceedings from the 1996 Annual Technical Conference of the Society of Plastics Engineers, 584–587 (1996).

5. M.-S. Huang, Journal of Materials Processing Technology, 183, 419–424 (2007): https://doi.org/10.1016/j.jmatprotec.2006.10.037

6. D. Zheng, A. Alleyne, Journal of Manufacturing Science and Engineering, 125, 154–163 (2003): https://doi.org/10.1115/1.1540126

7. D. Zheng, A. Alleyne, Proceedings of the 2000 American Control Conference, 4, 2558–2562 (2000): https://doi.org/10.1109/ACC.2000.878669

8. H. Havlicsek, A. Alleyne, IEEE/ASME Transactions on Mechatronics, 4, 312–323 (1999): https://doi.org/10.1109/3516.789689

9. S. F. Graebe, A. L. B. Ahlen, IEEE Transactions on Control Systems Technology, 4, 92–99 (1996): https://doi.org/10.1109/87.481772

10. S.-J. Huang, T.-H. Lee, The International Journal of Advanced Manufacturing Technology, 21, 956–964 (2003): https://doi.org/10.1007/s00170-002-1417-9

11. J. Lin, R.-J. Lian, Journal of Process Control, 20, 585–595 (2010): https://doi.org/10.1016/j.jprocont.2010.02.010

12. C. Froehlich, W. Kemmetmüller, A. Kugi, IEEE Transactions on Control Systems Technology, 28, 1665–1680 (2020): https://doi.org/10.1109/TCST.2019.2918993

13. S. Ketelsen, S. Michel, T.O. Andersen, M.K. Ebbesen, J. Weber, L. Schmidt, MDPI Energies, 14(9), (2021): https://doi.org/10.3390/en14092375

14. D. Padovani, S. Ketelsen, L. Schmidt, Proceedings of the BATH/ASME 2020 Symposium on Fluid Power and Motion Control, 83754 (2020): https://doi.org/10.1115/FPMC2020-2717

15. S. Ketelsen, T.O. Andersen, M.K. Ebbesen, L. Schmidt, MIC Journal, 41(3), 185-205 (2020): https://doi.org/10.4173/mic.2020.3.4

16. S. Ketelsen, D. Padovani, M.K. Ebbesen, T.O. Andersen, L. Schmidt, Proceedings of the BATH/ASME 2020 Symposium on Fluid Power and Motion Control, 83745 (2020): https://doi.org/10.1115/FPMC2020-2773

17. L. Schmidt, T.O. Andersen, H.C. Pedersen, M.M. Bech, Applied Mechanics and Materials, 233, 131-134 (2012): https://doi.org/10.4028/www.scientific.net/AMM.233.131

18. L. Schmidt, T.O. Andersen, e&i Elektrotechnik und Informationstechnik, 133, 238-247 (2016): https://doi.org/10.1007/s00502-016-0425-7

19. L. Schmidt, T.O. Andersen, H.C. Pedersen, Proceedings of the ASME 2014 12th Biennial Conference on Engineering Systems Design and Analysis, 40851 (2014): https://doi.org/10.1115/ESDA2014-20470

20. L. Schmidt, T.O. Andersen, P. Johansen, H.C. Pedersen, Proceedings of the ASME/BATH 2017 Symposium on Fluid Power and Motion Control, 58332 (2017): https://doi.org/10.1115/FPMC2017-4265

21. L. Schmidt, T.O. Andersen, H.C. Pedersen, Proceedings of the ASME/BATH 2013 Symposium on Fluid Power and Motion Control, 56086, (2014): https://doi.org/10.1115/FPMC2013-4441

22. L. Schmidt, S. Ketelsen, N. Grønkær, K.V. Hansen, Proceedings of the BATH/ASME 2020 Symposium on Fluid Power and Motion Control, 83754 (2020): https://doi.org/10.1115/FPMC2020-2722

23. L. Schmidt, K.V. Hansen, MDPI Energies, 15(3) (2022): https://doi.org/10.3390/en15031228

IMD Board of Directors Meeting
September 9th, 2023 – Virtual

Meeting minutes taken and submitted by Davide Masato (2023-2024 SPE IMD Secretary).

The following notes include relevant screenshots taken from the individual reports. Action items are highlighted in yellow. For more detailed information please see the attached files.

12 members of the IMD Board of Directors gathered together on Sept 28th, at a space graciously hosted by 3M. The purpose of this meeting was to take a deep dive into how the IMD serves and meets the needs of SPE members.

The meeting was kicked-off by a keynote address from 3M's VP of Corporate Research Process Lab, Stan Rendon, who delved into the intricate landscape of the injection molding industry. Afterwards, we had a tour of 3M's Innovation Center which inspired us to think beyond traditional boundaries.

The rest of the day, we all participated in a brainstorming session, skillfully facilitated by SPE CEO Pat Farrey. As a team, we embarked on a collaborative journey to refocus and renew our commitment to IMD's mission.

Overall, it was a great day where we came together as a team and walked away with a unified vision for IMD's future.

List of attendees:

- Brad Johnson
- Chad Ulven
- Davide Masato
- David Kusuma
- Erik Foltz
- Joseph Lawrence
- Saeed Farahani
- Srikanth Pilla
- Tom Turng
- Tom Giovannetti
- Monika Kleczek
- Pat Farrey
- Jeremy Dworshak
- Stan Rendon

Welcome & Opening Remarks (David Okonski / Jeremy Dworshak)

Roll Call: 20 active board members on roster: quorum achieved

Guests: Monika (Nova Chemicals, Calgary + 1 yr appointment); John Blundy, Janam Shah (1 yr appointment).

David Okonski is happily passing the gavel to Jeremy and wish him success. David apologized for being out of touch and not having other meetings during the year. He left GM and retired. Has started recently a new job for Michigan State University on the scale up of research facilities..

Approval of previous Meeting Minutes (Davide Masato)

Motion: Approval of previous meeting (1/25/2023, virtual) motion from Chad, Ray second. All in favor but Edwin Tam, which abstained because he has not received an email (AI: Jeremy will update Edwin email address). eptprowork@gmail.com Motion passes.

Financial Report (Ray McKee, Treasurer)

The fiscal year (July 1st - June 30th) was closed with a balance of $53,305.11. Compared to the previous year we closed $3k higher. The conference IMTECH was about $1k loss (gain because of previous expense for $4k deposit). No significant activity since the previous meeting. Tax return for 2022/2023 was filed. Reporting for SPE HQ due by mid November. Financially stable. Ray: we should continue the discussion about a scholarship in honor of Pete Grelle with the SPE Detroit section.

Next year: quarterly rebate received ($1,930) + SPE NIMW ($4,422 – 50/50 split with SPE HQ).

NWOIM Sponsors 3 Silver	$1,500
NWOIM Reg -59	$7,803
TOTAL $	$9,303
Less LinkedIn Ad	$ 134
Less 3.5% CC FEE	$ 325
HQ/Injection Molding 50/50 Split ($8,844)	$4,422

Motion: Budget approval Ray makes a motion, Tom Turng seconded.

Technical Director's Report (Chad Ulven, Technical Director)

It was a busy year! Thanks for all that contributed to planning and realization of successful events!.

ANTEC 2023:

- Jeremy D.: IKV students were at ANTEC and then visited Wisconsin. The synergy with the date seems to be positive. He appreciated the content and the networking opportunities. Great blend of knowledge and networking. Tom Turng stated the coordination with ANTEC should favor international attendees.

Polymer Colloquium:

There was great interactions and high quality of presentations. Next year to be held the Friday after ANTEC.

Innovation and Emerging Plastics Technologies Conference:

Brad: To be held 3rd week of June in 2025.

NWIM:

Sue W. from HQ stated it was great working with the IMD board. Strong program. Pat Farrey noted it is a good way to showcase the division. Feedback to improve? Chad Ulven stated that Erik Foltz mentioned it is a difficult time of the year.

ANTEC 2024:

Pat Farrey says the number of available spots will increase by 50%. Meeting with TPCs coming up (Tom Giovanetti was not on the email list but PF fixed it during the call). Flow of the event will be similar to last year. Good social and networking events are being planned.

Auto Epcon:

David Okonski noted that attendance was down (180, typically get 225-250). Sponsorship and revenue went down. This year profit was about $11k. Next year will be on 5/14.

NPE 2024:

Pat Farrey on NPE stated the plastics industry is big enough to support other events on the same year.

Next IMTECH:

Susan is planning a tech conference for October 2024. Focus on 3d printing technology. Looking for sponsorship. The last event was about 60 people but they are open to double. Students participation is encouraged. Any interest from the IMD to help? Pat F mentioned 3d natives could help with speakers, promotion, or sponsors. Chad U would like to stay engaged. Susan will send him emails.

Membership Committee Update (Erik Foltz)

Erik Foltz reported (Jeremy presented) we have 945 members of the IMD where 678 are professional members, 143 Young Professional, 35 Student, 82 Emeritus and 7 Distinguished. About 50% drop since 2019. Monika asked if we can we have older membership data? Pat F says that data can be extracted and that SPE loses about 25% of its membership per year. We need activities to get new members to avoid compounding the loss over time. SPE is focused on engagement and new membership. There will be more discussion at the in person strategic planning event. Edwin T points out the fact that professional have gone up and down. Jeremy D will need to look at the data closer. Interesting strong representation from MIT World Peace University.

Membership Duration (Years)	
50+	33
40-49	46
30-39	116
20-29	130
10,19	210
5,10	169
2,5	215
0-1	105

Councilor Report (Edwin Tam)

Summary of three meetings. Some topics (ANTEC, 3D Natives) were already discussed by Pat Farrey:

- 05/23 Meeting
  - o SPE calendar has the updated list of events.
  - o Plastics engineering magazine will no longer be printed.
- 6/15 Meeting
  - o Change in the SPE by laws:
    SPE Leadship Round Table Update - May, 23, 2023
    Councilors Meeting (remote) - June 15, 2023
    Rount Table: Hot Topics to Serve Chapter Member - June 27, 2023

Bylaw Change

- Remove remaining Named Director Positions
  - Director of Finance and Director of Chapters
  - Positions will be elected from the seated Directors by the Board at the January meeting along with the Secretary
    - Eliminates the Director of Finance name; just use Treasurer
  - Council continues to elect seven Director positions
    - Election Year 1: Three Director Positions (2023-2025)
    - Election Year 2: ~~Director of Finance, One~~ Two Director Positions
    - Election Year 3: ~~Director of Chapters, One~~ Two Director Positions
- Eliminates unintended consequence of having exceptional candidates not choose to run due to the named position
- Simplifies the election process

Financial Recap – The Covid Years

	2020	2021	2022
Ordinary Income	$ 2,797,807	$ 3,336,589	$ 3,083,507
Investment Income	$ 222,189	$ 556,293	$ 461,146
Total Income	$ 3,019,996	$ 3,892,882	$ 3,544,653
Expenses	$ 2,729,576	$ 3,045,866	$ 3,738,376
Net Profit (Loss)	$ 290,420	$ 847,016	$ (193,723)
Total Profit (Loss)	$ 943,713		

2023 Financial Projection (Jay Waddell)

Ordinary Income	$ 3,613,925
Investment Income	$ 583,270
Total Income	$ 4,197,195
Expenses	$ 4,036,100

Nominations Committee Update (Hoa Pham)

Hoa Pham reported:

The results of the elections are presented. See below. Edwin Tam is re-elected as councilor for 2023-2026. Hoa Pham will collect the names of the respondent and share it with Erik. Volunteers for 2025-2026 Secretary positions: no volunteers for now. We will discuss at the in person event. Jeremy D asked if we can add the BOD officers on the website?

CHAIR PROGRESSION

Reviewed and approved 6/7/2022

Term	Secretary	TPC	Chair-Elect	Chair
2022 - 2023	Tom Giovannetti	Raymond McKee	Jeremy Dworshak	David Okonski
2023 - 2024	Davide Masato	Tom Giovannetti	David Kusuma	Jeremy Dworshak
2024 - 2025	Saeed Farahani	Davide Masato	Tom Giovannetti	David Kusuma
2025 - 2026		Saeed Farahani	Davide Masato	Tom Giovannetti

We need volunteer for Secretary 2026 who will progress to TPC 2027 etc.
Suggestion: 1st Pool – Alex Beaumont, Larry Geist, Vikram Barghava
2nd Pool – Angela Rodenburgh, Sriraj Patel

Fellows & Honored Service Member Update (Tom Turng)

Tom Turng reported Brad Johnson was elected as a Honored Service Member. Tom asked for nominations.

SPE Fellow Candidate: Srikanth Pilla.

SPE Honored Service Member: David Okonski is being nominated also by the Detroit Section. IMD will support the case. Edwin Tam suggests having Detroit and IMD both being sponsors for the nomination.

Motion to approve Tom Turng moves to nominate Srikanth for Fellow and David Okonski for HSM. Edwin second. Motion passes.

Awards & Scholarships Committee Update (Ray McKee)

IMD scholarship application process was completed. 6 on the committee. 34 applicants. Awardee: Patrick M about $2,300. Outstanding Injection Molding Young Professional? Lynzie Nebel.

Communications (Newsletter) Committee Update (Angela Rodenburgh)

Angela stated that since the format has changed the numbers are steady but not huge. AI: need more notice about events to allow better promotion and marketing.

Sponsorship Committee Update (Sriraj Patel)

An updated sponsorship form, this was derived from some conversations with Punch Industries and the Mold Technologies division. It incorporates both website sponsorship and event sponsorship to help tie them together. Also attached is the MTD sponsorship form.

• *Chasing Sponsorships*

• In separate meetings and email communications with Dave O, Heidi, Ray and Angela we determined that the leads should be given to Heidi and she should be responsible to chase them down and secure them. Being a volunteer organization, it makes it difficult to put that on a single volunteer to tackle and the commission to Heidi (10%) is a low cost solution to help secure sponsorships that we otherwise may not have had a chance to get. Is there any opposition to this?

If so, why, and what other solutions do you have in mind?

• *Partnerships*

• There is a lot of overlap from IMD, MTD, Medical Plastics, etc. how do we partner the groups together to support Injection Molding as a whole and trickle funds into the appropriate groups?

New Business/Next Meeting Venue and Dates

Joseph Lawrence asked about the updated bylaws. JD confirms they are now approved.

Strategic Planning Session

• Jeremy:

o Dinner.

o Speaker from VP of R&D.

o 3M innovation center tour.

o Planning session hosted by Pat Farrey.

o What do we do best?

• Pat Farrey:

o The last couple of years brought a lot of disruption. Taking a step back and looking at the future is important.

o The meeting will not focus on the mission statement. We will take a 30.000 ft view of the industry and we will discuss why we do what we do. SPE has evolved, industry expectations are different. We have to change course to serve the stakeholders.

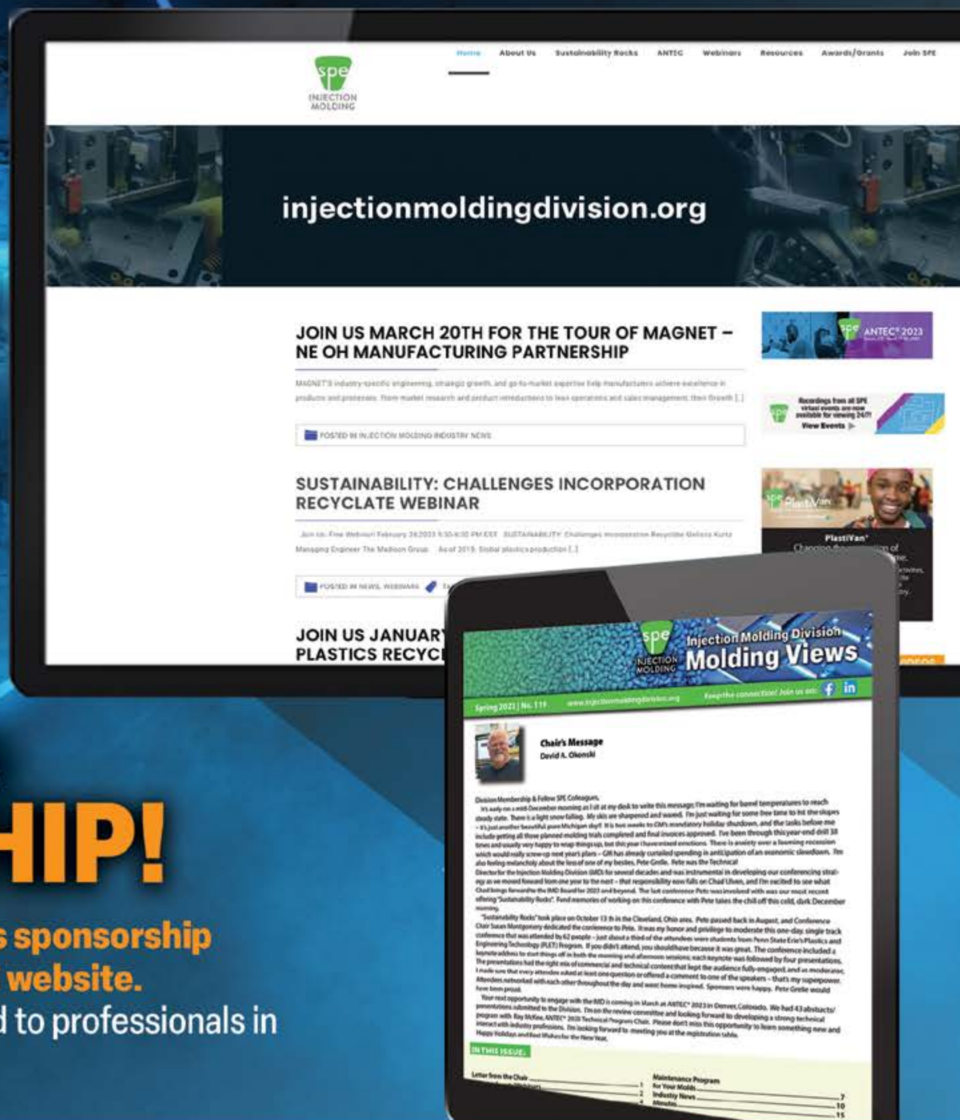
o Pat will be facilitating the conversation. Come prepared to share the industry needs, wants, and more. Please complete the survey. It will be the starting point for the conversation. The same survey was sent out to about 900 members. We received 40 responses back. With things 5% rate is good.

Adjournment

spe INJECTION MOLDING

REACH YOUR TARGET AUDIENCE AND GROW YOUR BUSINESS WITH A SPONSORSHIP!

The Injection Molding Division offers sponsorship advertising with the newsletter and website.
Reach the IMD membership with your ad to professionals in the injection molding industry.



The SPE Injection Molding Division Newsletter readership is composed of individuals involved in all aspects of the injection molding industry. These issues are made possible through the support of sponsors shown in this Newsletter and injection molding website.

OPTION 1: $2,500/yr
- Full page ad placed in 3 newsletters
- Side Button on website for the year
- First right of refusal for tabletop at ANTEC
- Company logo recognizion on signage at SPE IMD events
- Plastchick interview
- Technical article in newsletter & website
- Company press releases for website, social media and newsletter

OPTION 2: $1,500/yr
- Half page ad placed in 3 newsletters
- Side Button on website for the year
- Company logo recognizion on signage at SPE IMD events
- Technical article in newsletter & website
- Company press releases for website, social media and newsletter

OPTION 3: $1,000/yr
- Full page ad placed in 3 newsletters
- Side Button on website for the year
- Company press releases for website, social media and newsletter

OPTION 4: $750/yr
- Half page ad placed in 3 newsletters
- Side Button on website for 6 months
- Company press releases for website, social media and newsletter

OPTION 5: $450/yr
- Half page ad placed in 1 newsletter
- Side Button on website for 3 months

To schedule your ad contact: publisherIMDNewsletter@gmail.com

Division Officers:

Chair:	Jeremy Dworshak (3M)
Chair-Elect:	David Kusuma
Treasurer:	Raymond McKee (Currier Plastics)
Secretary:	Davide Masato
Technical Director:	Chad Ulven
Education Committee Chair:	Srikanth Pilla (Clemson University)
Past Chair:	David Okonski
Councilor:	Edwin Tam
ANTEC TPC:	Tom Giovannetti
Membership	Erik Foltz
Nominations:	Hoa Pham
Communications:	Angela Rodenburgh
Scholarship:	Lynzie Nebel
Education:	Srikanth Pilla
Sponsorships:	Sriraj Patel
TopCon Chair - Penn State Plastics Conference:	Brad Johnson
HSM & Fellows:	Lih-Sheng (Tom) Turng
Board Member:	Saeed Farahani
Board Member:	Joseph Lawrence
Board Member:	Vikram Barghava
Board Member:	Alex Beaumont
Board Member:	Kishor Mehta
Board Member:	Larry Geist
Board Member:	Davide Masato

Thank you to Everyone that Completed the Recent Survey!

The survey conducted among SPE IMD members within the injection molding industry highlights a spectrum of challenges and concerns shared across the industry.

Technological advancements and the need to integrate new technologies like automation, artificial intelligence (AI), and machine learning stand out as key issues. The industry is focused on enhancing operational efficiency, particularly through improved simulation in the development phase and balancing these new technologies with traditional practices. Workforce challenges also emerge prominently, with an emphasis on attracting young professionals, transferring knowledge from retiring experts, and addressing skill gaps, particularly in critical thinking and problem-solving.

Economic and competitive pressures due to cost management, economic fluctuations, and global competition are also central concerns. The high cost of equipment and raw materials, combined with the need to remain competitive against low-cost producers, is creating significant strain. This is intertwined with the challenges of managing costs and lead times, particularly in tooling and production.

Sustainability and environmental challenges are paramount, with industry players navigating regulatory compliance, integrating sustainable practices, and managing the negative perception of plastics. The industry is also contending with material management, supply chain disruptions, and ensuring consistent material supply, especially for recycled materials.

Innovation within the industry is a key focus, with the aim to foster continued evolution and adjust to new dynamics. This includes leveraging data for optimization and advancements in mold design. Education, collaboration, and public awareness are noted as avenues for countering misinformation and enhancing public understanding of injection molding processes.

The survey results also underscore the significance of diversity and inclusion in retaining a diverse workforce, along with the importance of industry-education institution partnerships. Carbon footprint reduction is highlighted as part of environmental sustainability efforts.

Operational efficiency, workforce development, talent acquisition, and the need for industry innovation are repeated themes. Management and bureaucracy, work-life balance, and various operational challenges such as managing remote employees and expanding customer bases are also mentioned as areas of concern.

In response to these insights, the SPE IMD board has distilled our collective vision into core strategies for the year ahead, ensuring that the organization's actions align with the industry's needs and aspirations which Jeremy Dworshak shared in his Chair Message.

We welcome and value continuous feedback from our members to shape our collective future. Please direct any further insights to Angela Rodenburgh, our Communications Coordinator, at angela@ladderupinc.com.