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Molding Views
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Chair's Message Jeremy Dwordshak

Dear Members of the Injection Molding Division,

I am honored and excited to address you as the newly elected Chair of the Injection Molding Division (IMD) within the Society of Plastics Engineers (SPE). I want to express my gratitude for entrusting me with this important role, and I am committed to serving our division and advancing our collective goals.

First and foremost, I want to acknowledge the exceptional group of plastics professionals that make up our division. Our members are the backbone of the IMD, and it is your expertise, dedication, and passion that drive our division's success. I am proud to be a part of such a talented and diverse community.

However, as we move forward, we face a significant challenge - a decline in our membership. It is crucial for us to address this issue head-on and find effective ways to engage and attract new members. To do so, we must focus on understanding and meeting the needs of the people we serve within the IMD.

In light of this challenge, I am thrilled to announce that we will be hosting a strategic planning session in September. This session will provide us with a unique opportunity to come together, brainstorm ideas, and chart a course for the future of our division. I am delighted to inform you that the 3M Campus in St. Paul, MN, has graciously agreed to be our host for this important event.

During our strategic planning session, we will delve into critical topics such as member engagement, value proposition, communication strategies, and member collaboration. Our goal is to develop actionable plans and initiatives that will invigorate our division and strengthen our connection with the plastics community.

I encourage each and every one of you to actively participate in the strategic planning session. Your input and ideas are invaluable as we work together to shape the future of the IMD. Together, we can overcome the challenges we face and create a vibrant, thriving community of plastics professionals.

In the coming weeks, you will receive further details about the session, including the agenda and logistical information. I look forward to your enthusiastic involvement and the fruitful discussions that lie ahead.

As Chair, my door is always open to your thoughts, suggestions, and concerns. I am here to listen and advocate for our members. Let us embark on this journey together, united in our commitment to advancing the Injection Molding Division and promoting excellence within the plastics industry.

Thank you for your ongoing support and dedication. I am honored to serve as your Chair, and I eagerly anticipate our future successes.

Sincerely,

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

IN THIS ISSUE:

SEPTEMBER 2023

ARTIFICIAL INTELLIGENCE FOR POLYMER DEVELOPMENT AND PROCESSING - DAY 1

MONDAY, SEPTEMBER 11, 2023 11:00 AM (EDT) - 12:00 PM (EDT)

VIRTUAL EVENT

This workshop will introduce participants to applications of AI for materials and product development and manufacturing processes, covering basic concepts and how AI and domain knowledge can be leveraged to accelerate processes, reduce costs, and innovate products. Participants will be engaged in an end-to-end AI modeling workflow on product development case studies. Participants will learn: How to apply AI in product development, How to select the right projects for AI, Basic materials informatics concepts

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8212

ARTIFICIAL INTELLIGENCE FOR POLYMER DEVELOPMENT AND PROCESSING - DAY 2

TUESDAY, SEPTEMBER 12, 2023 11:00 AM (EDT) - 12:00 PM (EDT)

VIRTUAL EVENT

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8212

ARTIFICIAL INTELLIGENCE FOR POLYMER DEVELOPMENT AND PROCESSING - DAY 3

WEDNESDAY, SEPTEMBER 13, 2023 11:00 AM (EDT) - 12:00 PM (EDT)

VIRTUAL EVENT

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8212

ARTIFICIAL INTELLIGENCE FOR POLYMER DEVELOPMENT AND PROCESSING - DAY 4

THURSDAY, SEPTEMBER 14, 2023 11:00 AM (EDT) - 12:00 PM (EDT)

VIRTUAL EVENT

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8212

SPE WEBINAR: CREEP FAILURE OF PLASTICS

THURSDAY, SEPTEMBER 21, 2023 11:00 AM (EDT) - 12:00 PM (EDT)

VIRTUAL EVENT

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8232

SEPTEMBER 2023

SPE WORKSHOP: PLASTIC PACKAGING POWER-UP: LEVEL UP YOUR SUSTAINABILITY GAME - PART I

FRIDAY, SEPTEMBER 29, 2023 11:00 AM (EDT) - 12:30 PM (EDT)

VIRTUAL EVENT

Get ready to level up your sustainable packaging game at this interactive workshop by stepping into the arcade of sustainable practices with a focus on the plastics industry. This session will take you on a journey through various topics, equipping you with valuable insights and practical strategies. Discover power-packed techniques for reducing packaging without compromising quality, unlock sustainable material options that align with your values, and earn high scores by enhancing packaging efficiency. Navigate the challenging levels of designing packaging for optimal recyclability and stay ahead of the game with up-to-date knowledge on ever-changing regulations. Don't miss this opportunity to turbo charge your packaging approach and become an environmental champion. Game on!

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8252

OCTOBER 2023

SPE WORKSHOP: PLASTIC PACKAGING POWER-UP: LEVEL UP YOUR SUSTAINABILITY GAME - PART II

MONDAY, OCTOBER 2, 2023 11:00 AM (EDT) - 12:30 PM (EDT)

VIRTUAL EVEN

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8252

SPE WORKSHOP: PLASTIC PACKAGING POWER-UP: LEVEL UP YOUR SUSTAINABILITY GAME - PART III

FRIDAY, OCTOBER 6, 2023 11:00 AM (EDT) - 12:30 PM (EDT)

VIRTUAL EVEN

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8252

SPE WORKSHOP: PLASTIC PACKAGING POWER-UP: LEVEL UP YOUR SUSTAINABILITY GAME - PART IV

MONDAY, OCTOBER 9, 2023 11:00 AM (EDT) - 12:30 PM (EDT)

VIRTUAL EVEN

For more information: https://www.4spe.org/i4a/pages/index.cfm?pageID=8252

SPE CONFERENCE: REDUCING PLASTIC WASTE THROUGH ARTIFICIAL INTELLIGENCE AND DIGITALIZATION

MONDAY, OCTOBER 16, 2023 8:00 AM (EDT) - TUESDAY, OCTOBER 17, 2023 5:00 PM (EDT)

SHERATON INNER HARBOR HOTEL, BALTIMORE, MD

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

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If accepted, Speakers will then submit their final paper or presentation by November 24, 2023.

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- Accepted Speakers Notified: October 27, 2023
- Paper/Presentation Submission Deadline: November 24, 2023

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Simulation of Polymer Imprinting and Embossing Using Smoothed Dissipative Particle Dynamics

James St Julien and Donggang Yao, School of Materials Science & Engineering, Georgia Institute of Technology, Atlanta, GA

A simulation of an imprinting process using Smoothed Dissipative Particle Dynamics is shown. Cavity filling modes and their dependence on die parameters is demonstrated for single and multi-cavity die, showing results consistent with FEM simulations and experimental data. Particle-based simulation methods can allow for modeling of more complex fluid behaviors.

Introduction

Embossing or imprinting is a contact shaping process by which patterns may be made on the surface of a material by pressing a mold onto its surface. This process can form complex images with details as small as 10 nanometers, called nanoimprinting. At the nanoscale, imprinting is used in the lithographic process to make electronics, and at the macroscale, imprinting is used in metal manufacturing and minting coins. Numerous simulations have been developed to model the imprinting process using finite element methods (FEM); these models are effective at capturing general behaviors of materials but lack the capability of describing discrete or complex fluid behaviors. Thus, there has been a growing interest in particle-based methods of process modeling. Smoothed Dissipative Particle Dynamics (SDPD) [1] utilizes macroscopic properties of fluids to simulate fluid flow, and has been used to model polymer fluids, suspensions, and nanoscale hydrodynamics [2-4]. In this paper, we demonstrate the ability of SDPD to simulate fluid flow in the imprinting process and show how cavity filling is affected by the geometry of the system.

Model Formulation

Governing Equations

Smoothed Dissipative Particle Dynamics utilizes a discretization of the Navier-Stokes equations which algorithmically preserves the first and second law of thermodynamics; this means that fluids may be modeled with particles that will both follow the rheological behaviors of the fluid and incorporate properly scaled thermal fluctuations via Brownian motion (Eq. (1)).

$$
\begin{aligned}
\dot{r}_i &= \boldsymbol{v}_i, \\
m\boldsymbol{v}_i &= -\sum_j \left(\frac{P_i}{d_i^2} + \frac{P_j}{d_j^2}\right) W'_{ij}\boldsymbol{e}_{ij} \\
&\qquad + \frac{5\eta}{3}\sum_{jAA} \frac{W'_{ij}}{d_i d_j r_{ij}} (\boldsymbol{v}_{ij} \\
&\qquad + (\boldsymbol{e}_{ij}\cdot\boldsymbol{v}_{ij})\boldsymbol{e}_{ij}) + \sum_j \tilde{\boldsymbol{F}}_{ij}, \\
T_i\dot{S}_i &= -\frac{5\eta}{6}\sum_j \frac{W'_{ij}}{d_i d_j r_{ij}} \left(\boldsymbol{v}_{ij}^2 + (\boldsymbol{e}_{ij}\cdot\boldsymbol{v}_{ij})^2\right) \\
&\qquad + 2\kappa \sum_j \frac{W'_{ij}}{d_i d_j r_{ij}} T_{ij} + \sum_j \tilde{Q}_{ij} \\
&\qquad - \frac{1}{2}\sum_j \tilde{F}_{ij}\cdot\boldsymbol{v}_{ij},
\end{aligned}
\tag{1}
$$

Simulation of Polymere Imprinting and Embossing Using Smoothed Dissipative Particle Dynamics Continued

The implementation of SDPD in LAMMPS via the pair style sdpd/taitwater/isothermal operates under a few additional assumptions; constant and uniform temperature & shear viscosity, a negligible volume viscosity versus shear viscosity, and a negligible Boltzmann constant compared to the heat capacity of a single fluid particle [5,6]. Furthermore, the pressure between particles is calculated using Tait's equation of state (Eq. (2)):

$$p = p_0 + \frac{c_0^2 \rho_0}{\gamma}\left[\left(\frac{\rho}{\rho_0}\right)^{\gamma} - 1\right] \qquad (2)$$

Also, a Lucy kernel function is used to calculate the number density of particles (Eq. (3)):

$$w(r) = \frac{105}{16\pi h^3}\left(1 + 3\frac{r}{h}\right)\left(1 - \frac{r}{h}\right)^3 \qquad (3)$$

Geometry and Boundary Conditions

A 2D simulation box is constructed, with the x walls given fixed period boundary conditions, the lower y wall given a fixed non-periodic boundary condition, and the upper y wall given a shrink-wrapped non-periodic boundary. A wall of fixed particles is placed at the bottom of the simulation box, and a movable set of particles is placed at the top; these two represent the belt and imprint die, respectively [8]. The imprint die is moved with a constant force downwards, generating pressure on the fluid and deforming it. The size of the simulation box may vary between 20µmx80µm and 50µmx180µm.

Simulation Results

To demonstrate the effectiveness of SDPD in modeling the imprinting process, it is imperative to show that it exhibits the general behavior shown in FEM simulations and in experimental results [7]. It is known that peak formation within a cavity is dependent on several parameters; the film thickness, the cavity height, the tool width, and the cavity width.

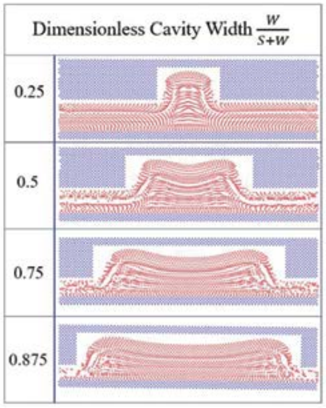

Figure 1:
Demonstration of peak mode dependency on the dimensionless cavity width: as the cavity width increases, the peak mode transitions from single peak to dual peak.

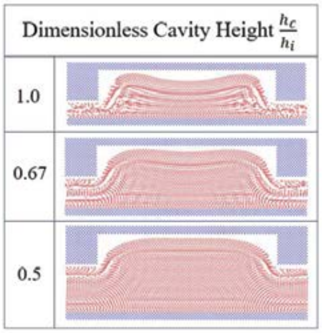

Figure 2:
Demonstration of peak mode dependency on the dimensionless cavity height: as the cavity height decreases, the peak mode transitions from dual peak to single peak.

Figure 1 shows the transition between single and dual peak formation in relation to the dimensionless cavity width: for a given indenter thickness, as the cavity width increases, the peak mode transitions from single to dual. The distance of the dual peaks from the edge of the imprint die is approximately equal to the polymer thickness. **Figure 2** shows the transition between single and dual peak formations in relation to the ratio of cavity height to film thickness: for a given imprint die, as the thickness of the polymer increases, the peak mode transitions from dual to single. This indicates the simulation well approximates the flow of a Newtonian polymer in the imprinting process.

The stress within the polymer fluid may also be determined, as shown in **figure 3**. The stress at the middle of the fluid increases as the indenter width decreases, which follows trends found previously [7]. The stress information gives some insight into the flow and displacement of the fluid: the upper layer of the fluid within the cavity does not seem to experience much stress until it reaches the cavity floor, which indicates that the relative motion of this upper layer is small relative to the fluid below it.

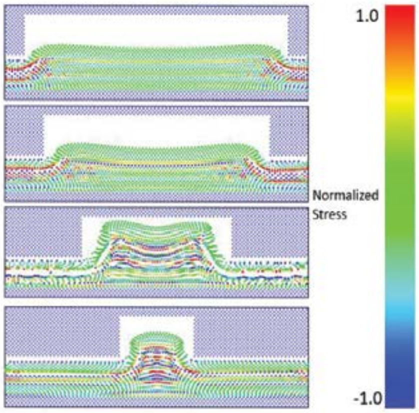

Figure 3: Demonstration of stress in fluid at various values of dimensionless cavity width; notice the low stress value of the fluid at the top of the peak in each instance, indicating lower relative particle movements.

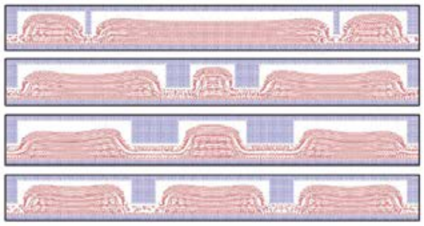

Figure 4: Demonstration of multicavity flow and filling dependency on local cavity size.

Multicavity Flow

The flow behavior of polymers in a multicavity die is of particular interest to manufacturers, as most geometries will involve more than one cavity. For shear flow, the preferential filling of cavities is dependent upon the ratio of the local cavity half width of the smallest cavity and the film thickness; when $W < 0.5h_i$, the smaller cavities fill first, and when $W < 0.5h_i$, the larger cavities fill first, as shown in **figure 4**. The central cavity will have either a single or dual peak mode, determined in a similar manner to single cavity flow.

Discussion

There is a limitation to the current utility of this method: the assumption of a simple Newtonian fluid made by the sdpd/taitwater/isothermal pair style in LAMMPS can predict many of the general flow trends in the imprinting process but may be limited in its capacity to make precise predictions of non-Newtonian flow behavior. The effective viscosity of the fluid can be modified, however, if one uses chains of particles connected by a molecular bonding potential, effectively creating polymer molecules. This method of altering the viscosity can also enable an understanding of discrete effects on flow behavior.

Conclusions

We have shown from our initial results the capability of SDPD in simulating polymer flow in the imprinting process. The peak formation behavior and its dependency on die geometry was explored, and the stress and its implications for the fluid flow was analyzed. The changes in peak mode and filling behavior of multicavity imprint die was also shown.

References

1. P. Espanol and M. Revenga, "Smoothed dissipative particle dynamics". Physical Review E 67, 026705, (2003).
2. S. Litvinov, Q. Xie, X. Hu, N. Adams, and M. Ellero, "Simulation of Individual Polymer Chains and Polymer Solutions with Smoothed Dissipative Particle Dynamics". Fluids 1, 7, (2016).
3. X. Bian, S. Litvinov, R. Qian, M. Ellero, and N.

A. Adams, "Multiscale modeling of particle in suspension with smoothed dissipative particle dynamics". Physics of Fluids 24, 012002, (2012).

4. H. Lei, C. J. Mundy, G. K. Schenter, and N. K. Voulgarakis, "Modeling nanoscale hydrodynamics by smoothed dissipative particle dynamics", The Journal of Chemical Physics 142, 194504 (2015).
5. M. Jalalvand, M. A. Charsooghi, and S. Mohammadinejad, "Smoothed Dissipative Particle Dynamics package for LAMMPS". Computer Physics Communications 255, 107261, (2020).
6. M. Ellero and P. Español, "Everything you always wanted to know about SDPD* (*but were afraid to ask)". Applied Mathematics and Mechancics-English Edition 39, (2018), pp. 103–124.
7. H. D. Rowland, "Thermomechanical Manufacturing of Polymer Microstructures and Nanostructures", (2007).
8. C. Yang, M. Li, J. Wang, H. Ye, and J. Qiu, "Residual Layer Assisted Demolding in Roll-to-roll UV Imprint Lithography". Microelectronic Engineering 217, 111110, (2019).
9. S. Plimpton, "Fast Parallel Algorithms for Short-Range Molecular Dynamics". Journal of Computational Physics, vol. 117, no. 1, Elsevier Inc, (1995), pp. 1–19.

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Study on Machine Identification and its Effect on the RSM Optimization in Injection Molding

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3. CoreTech System (Moldex3D) Co., Ltd., Hsinchu 302, Taiwan

Different optimization methods or strategies have been proposed and utilized to enhance the quality of injected products for many years. However, what is the machine characteristics to influence the efficiency of the optimization method? It is not fully understood yet. In this study, the injection machine characteristics has been identified using numerical simulation (Moldex3D) based on a round plate system. The response surface method (RSM) was further utilized for both simulation prediction and experimental conduction to discuss the efficiency of the optimization for operation parameters in injection molding. Results showed that before the machine identification and calibration, the quality of injected part can be improved by 75% theoretically. At the same time, the real experimental system demonstrated worse result. However, the difference between simulation and experiment has the same amount no matter the system has been optimized or not through RSM method. Moreover, after the machine identified and calibrated, the difference between simulation prediction and experimental observation has been improved by 71.4%. Also, the accuracy of the RSM optimization in the real experiment has been enhanced by 50% (from -0.06 mm to 0.03 mm). Obviously, it showed that the machine identification for the real capability is very important.

Introduction

Different optimization methods or strategies have been proposed and utilized to enhance the quality of injected products for many years. In general, some optimization methods could integrate various operation parameters to deal with the complex system successfully. For example, Lee and Kim [1] considered to modified part wall thickness within dimensional tolerances to minimize the warpage. Yen et al [2] utilized the diameter and length of the runner system to optimize the warpage performance. Ozcelik and Erzurumlu [3-4] tried to integrate finite element analysis, statistical design of experiment (DOE) method, response surface methodology, ANN, and genetic algorithm to reduce warpage. Zhai and Xie [5] applied sequential linear programming (SLP) and CAE to optimize the gate performance to achieve a balanced flow and then to reduce the warpage of injected parts. Tseng et al [6] have studied the shrinkage behavior along the full domain of a mobile phone cover. They applied 3D volume shrinkage compensation method (3DVSCM) to reduce the warpage. Moreover, to optimize the complex factors, many researchers have applied design of experiment (DOE) method, RSM method, or other methods. Tsai and Tang [7] utilized response surface method to establish the process window of injection molding process for a given form accuracy of spherical lenses. They claimed that their proposed method for constructing a process window is reasonably accurate with 7-10% error. Xu and Yang [8] integrated Taguchi's parameter design method, neural network and grey correlation analysis (GCA) to solve the multi-objective optimization problem. Kitayama et al. [9] applied a sequential approximate optimization (SAO) based on the CAE simulation to determine the optimal process parameter. The data was further used to identify a pareto-frontier. The idea could be utilized for multi-objective optimization, such as short cycle time, warpage reduction, weld lines reduction and clamping force minimization and so on. Furthermore, Huang et al [10] have been discussed the influence of the machine calibration effect on the quality optimization using design of experiments (DOE) in injection molding. However, when the optimization method is switched to response surface methodology (RSM), what is the machine characteristics to influence the efficiency of RSM optimization? It is not fully understood yet.

Hence, in this study, the injection machine characteristics has been identified using numerical simulation (Moldex3D) based on a round plate system. Then a series virtual tests based on RSM using the round plate system have been performed via computer-aided engineering (afterward, it is called CAE-RSM) to optimize the processes. Moreover, the virtual optimized factors will be specified into an injection molding process for a real experimental testing and see how accurate it is. Finally, the machine identification effect on the accuracy of quality will be discussed.

Investigation Method and Procedures

In this study, Moldex3D R16® was adopted for injection molding processes simulation and CAE-RSM. **Figure 1(a)** presents the sprue and runner of the model. The main structure is a round plate with diameter of 60 mm, and 2 mm thickness. The moldbase and cooling channel layout is displayed in **Figure 2**. The size of moldbase is 350 mm x 300 mm x 320.5 mm. There are two cooling channels inside the core side and cavity side respectively. The material utilized is ABS (PA757 supplied by Che-Mei Co., Tainan City, Taiwan).

Furthermore, to evaluate the quality factor of the injected parts, the shrinkage behavior over the injection round disc was examined as shown in **Figure 3**. Specifically, the circumference of the injected round plate has been divided into eight equal portions using four diameters I (DI) to IV (DIV). Then the average diameter is obtained, as defined by Equation (1). In addition, the deviation has been considered from the target value (60 mm). It is defined as the difference between the injected diameter and the design diameter as in Equation (2), where Ddesign is 60 mm. In the rest of this paper, the "deviation" factor will be applied as the standard to evaluate the quality.

$$D_{ave} = (D_{I} + D_{II} + D_{III} + D_{IV})/4 \qquad (1)$$

$$\text{Deviation (mm)} = D_{ave} - D_{design} \qquad (2)$$

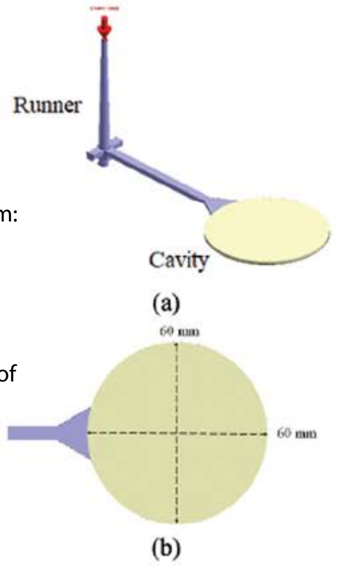


Figure 1: The system: (a) geometrical structure, (b) round plate with diameter of 60 mm.

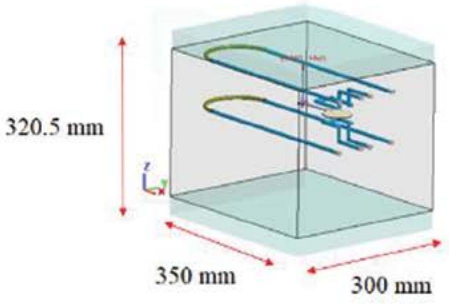


Figure 2: The moldbase and cooling channel layout.

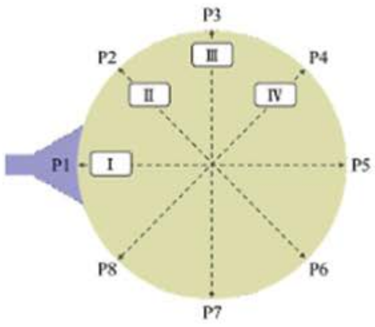


Figure 3: The diameter of injected part is measured one-by-one from four different directions.

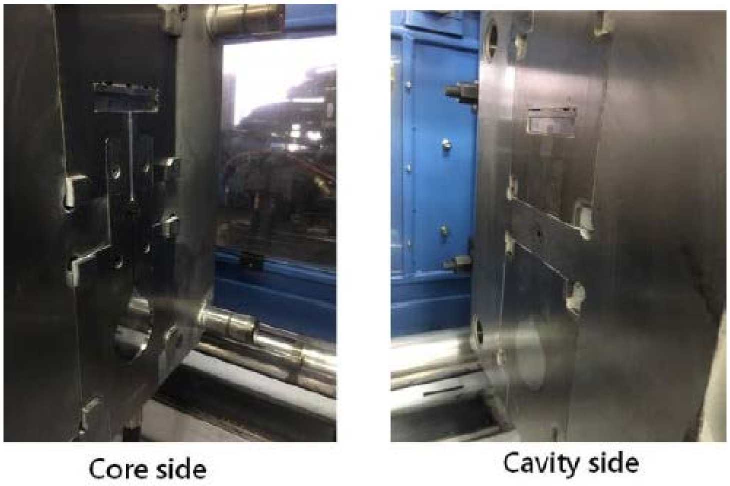


Figure 4:
The mold structure for the experimental study.

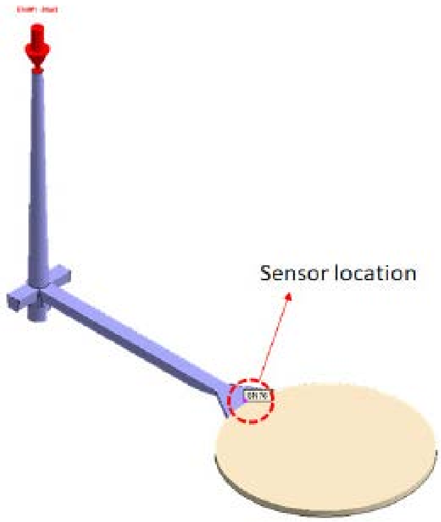
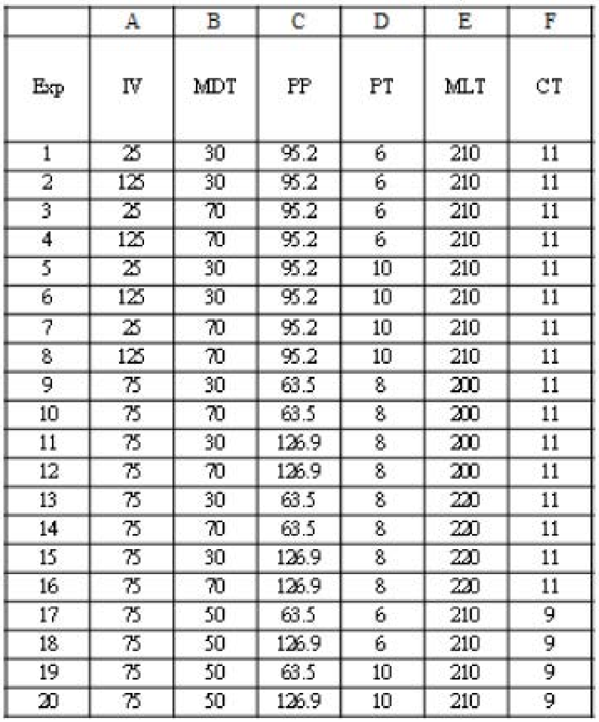


Figure 5.
The sensor node location or setting up the pressure transducer.

Moreover, to verify the accuracy of the numerical prediction, the real injection molding system was setup based on FCS injection machine (supplied by Fu Chun Shin Machinery Co. Ltd, Tainan City, Taiwan.) as exhibited in **Figure 4**. In order to identify the machine performance, one pressure transducer has been installed into the system at the sensor node locations as shown in **Figure 5** for both simulation and experiment. Then a series basic test has been performed to make the comparison between simulation and experimental results with the same operation condition settings. The operation conditions for basic settings are as follows: injection velocity setting is 50% (75 mm/s); packing time is 8 s; cooling time is 11 s; melt temperature is 210°C; mold temperature is 50°C; packing pressure setting is from 50% to 100% of the end of filling pressure.

Furthermore, a series virtual injection molding trials based on Response Surface Methodology (RSM) have been performed as defined in **Table 1**. Specifically, there are six factors which have been considered including injection velocity (IV), mold temperature (MDT), packing pressure (PP), packing time (PT), melt temperature (MLT), and cooling time (CT). Regarding the second-order model for RSM in this study, the Box-Behnken Design (BBD) algorithm is adopted. Based on BBD, each factor has three level set (-1, 0, +1). A 54-set of the orthogonal array has been constructed as listed in **Table 1**. Since the table is too long, only 20/54 sets have been listed here\. Later, before doing the machine identification, the detailed operation conditions for each set can be described in **Table 2**. For



	A	B	C	D	E	F
Exp	IV	MDT	PP	PT	MLT	CT
1	25	30	95.2	6	210	11
2	125	30	95.2	6	210	11
3	25	70	95.2	6	210	11
4	125	70	95.2	6	210	11
5	25	30	95.2	10	210	11
6	125	30	95.2	10	210	11
7	25	70	95.2	10	210	11
8	125	70	95.2	10	210	11
9	75	30	63.5	8	200	11
10	75	70	63.5	8	200	11
11	75	30	126.9	8	200	11
12	75	70	126.9	8	200	11
13	75	30	63.5	8	220	11
14	75	70	63.5	8	220	11
15	75	30	126.9	8	220	11
16	75	70	126.9	8	220	11
17	75	50	63.5	6	210	9
18	75	50	126.9	6	210	9
19	75	50	63.5	10	210	9
20	75	50	126.9	10	210	9

Table 1:
The orthogonal array for RSM performance (only 20/54 sets has been shown) where IV is injection velocity; MDT is mold temperature; PP is packing pressure; PT is packing time; MLT is melt temperature; CT is cooling time.

CAE-RSM (before machine identified)				
Control factor		-1	0	1
A	Injection velocity (mm/s)	25 (20%)	75 (60%)	125 (100%)
B	Mold temperature (˚C)	30	50	70
C	Packing Pressure (MPa)	63.5 (50%)	95.2 (75%)	126.9 (100%)
D	Packing time (s)	6	8	10
E	Melt temperature (˚C)	200	210	220
F	Cooling time (s)	9	11	13

Table 2.:
The optimized factors and their levels before machine identified. *The grey area shows the original design operation condition.

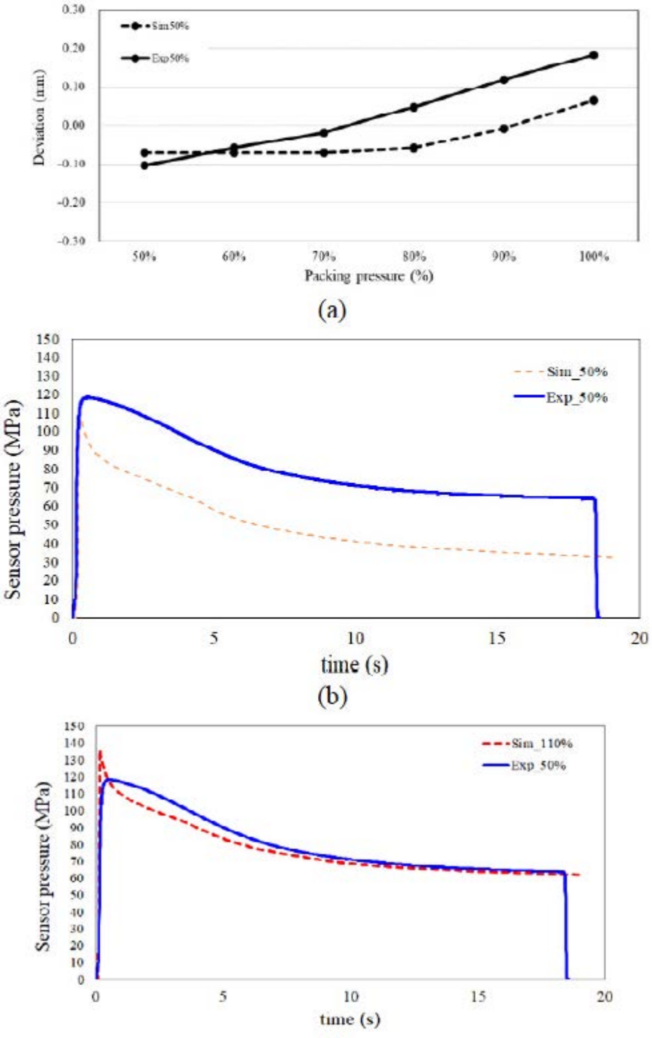


Figure 6: (a) The comparison of the shrinkage behavior between simulation and experiment for basic test, (b) the original injection pressure history curves at 50% injection speed setting for both simulation and experiment, (d) the matched pair for both simulation and experiment with simulation 110% injection speed setting is matched with experimental 50% injection speed setting.

example, regarding the injection velocity etting, three levels are 25 mm/s (20% injection setting), 75 mm/s (60% injection setting), and 125 mm/s (100% injection setting), respectively. Here the maximum injection velocity of machine is 125 mm/s. Then the original operation condition can be selected as the grey area (the column of Control factor with "0") in **Table 2**. Specifically, the injection speed is 75 mm/s. The mold temperature is 50°C. The packing pressure is 95.2 MPa. The packing time is 8 s. The melt temperature is 210°C. The cooling time is 11 s. The dimensional precision of the diameter of the injection round disc will be used as the criteria to evaluate of quality for this study.

Results and Discussion

Figure 6(a) presents the comparison of the shrinkage behavior between numerical simulation and experimental observation via the basic test. When the packing pressure setting is 72% for experimental test, the deviation is around zero. That is at 72% packing pressure setting the shrinkage of the injected part can be fully compensated. However, to touch zero deviation it needs to change the packing pressure to 90% for simulation system. Clearly, even the operation condition settings are exact the same, the injection performance capability of the experiment is higher than that of simulation counterpart. But how the machine capability can be identified? To evaluate the internal capability, the injection pressure history carve can be utilized [10]. **Figure 6(b)** shows the injection pressure history curves for simulation and experimental cases with the same operation conditions. Obviously, the pressure of the experimental case is higher than that of simulation one over the entire filling and packing period. It is the reason why the deviation of the shrinkage behavior of the experimental system is more positive (that is expansive) than that of simulation one. In addition, to evaluate the real capability of the experimental system, it can be increased the driving theoretically. When the injection velocity is increased to 110% setting virtually, the injection pressure history of the simulation is matched with that of experimental 50% injection velocity setting. The simulation of 110% injection velocity

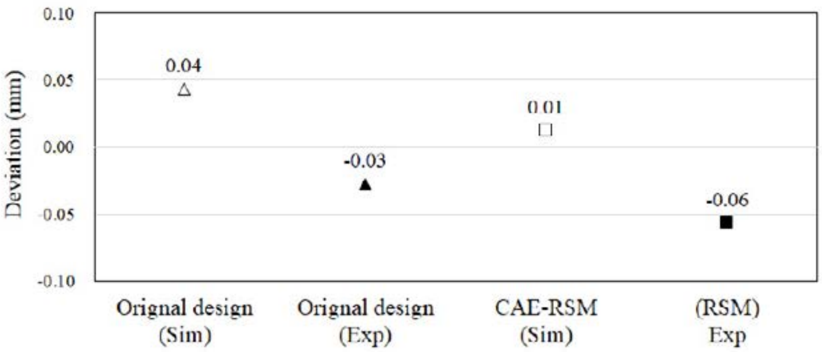


Figure 7: The comparison for deviation between simulation and experiment for various operations without machine identification.

CAE-RSM (after machine identified)				
	Control factor	-1	0	1
A	Injection velocity (mm/s)	67 (90%)	79.5 (110%)	92 (130%)
B	Mold temperature (˚C)	30	50	70
C	Packing pressure (MPa)	64.7 (50%)	97.05 (75%)	129.4 (100%)
D	Packing time (s)	6	8	10
E	Melt temperature (˚C)	200	210	220
F	Cooling time (s)	9	11	13

Table 3: The optimized factors and their levels after machine identified.

setting and experiment of 50% injection velocity setting are regarded as the matched pair. Using the same logic, other simulation and experimental matched pairs can be obtained. Based on the matched relationship, the real capability of the injection machine can be identified and calibrated using simulation counterparts.

Moreover, the injection operation parameters can be optimized through RSM technique. Before doing the machine identification and calibration, the RSM optimization can be performed based on the recipe described from **Table 1** and **Table 2**. The results are presented in **Figure 7**. In that Figure, the deviation from the simulation is about 0.04 mm, and that from experiment is around -0.03 mm for the original design. The difference between simulation and experiment is 0.07 mm. After performed RSM optimization through evaluated 54-set of injection molding trials virtually, the analysis of variance for second order model can be obtained. The predicted R square is around 77.32%. After clean the non-significant second order items, the updated analysis of variance for second order model can be obtained again. The revised predicted R square is around 91.33%. The relation of the optimized operation parameters is achieved. The optimization result is exhibited as "CAE-RSM (Sim)" with deviation of 0.01 mm. Furthermore, the optimized parameters can be further applied to the real injection molding and result is exhibited as "RSM (Exp)" with deviation of -0.06 mm. Clearly, after applied RSM optimization, the difference between simulation and experimental results are still 0.07 mm. Meanwhile, comparing the Original design (Sim) and CAE-RSM (Sim), the deviation is from 0.04 mm to 0.01 mm. The deviation has been reduced by 75%theoretically. On the other hand, from the difference between Original design (Exp) and RSM (Exp), the deviation is from -0.03 mm to -0.06 mm (reduced 0.03 mm) experimentally. Although the result is getting worse in the real system, the variation trend of the deviation is exact same as in simulation system.

Moreover, after the injection machine has been identified and calibrated, the parameter range has been turned up as listed in **Table 3**. Using **Table 3** and the 54-parameter set from the orthogonal array in **Table 1**, the RSM optimization could be executed. The result is updated into ***Figure 8***. After machine identified and calibrated, the deviation of injected part is presented as "CAE-RSM (Sim-calibrated) with 0.0 mm by simulation prediction. Furthermore, the RSM optimized parameter set has been introduced into the real injection molding, the result is displayed as "RSM (Exp_calibrated)" with deviation of 0.03 mm in **Figure 8**. Comparing to the RSM optimized system before identified, the difference between simulation prediction and experimental observation has been improved by 71.4% (from 0.07 mm to 0.02 mm). In addition, the accuracy of the RSM optimization in the real experiment has been enhanced by 50% (from -0.06 mm to 0.03 mm). Obviously, it demonstrated that the machine identification for the real capability is very important.

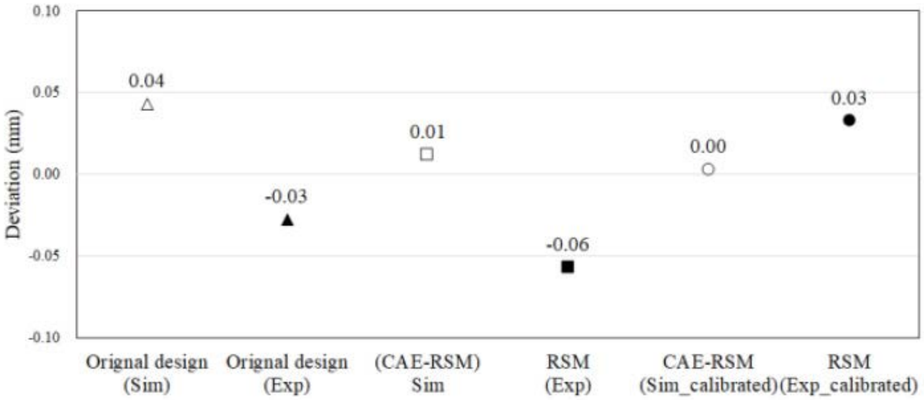


Figure 8: The comparison for deviation between simulation and experiment for various operations with machine identification.

Conclusions

In this study, the injection machine characteristics has been identified using numerical simulation based on a round plate system. The response surface method (RSM) has been further utilized for both simulation prediction and experimental conduction to discuss the efficiency of the optimization for operation parameters in injection molding. Results showed that before the machine identification and calibration, the quality of injected part can be improved by 75% theoretically, but the real experimental one demonstrated worse result. However, he difference between simulation and experiment is the same no matter the system has been through RSM optimized or not. Moreover, after the machine has been identified and calibrated, the difference between simulation prediction and experimental observation has been improved by 71.4%. Also, the accuracy of the RSM optimization in the real experiment has been enhanced by 50% (from -0.06 mm to 0.03 mm). Obviously, it demonstrated that the machine identification for the real capability is very important.

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References

1. B. H. Lee, and B. H. Kim, *Polymer-Plastics Technology and Engineering*, 34(5), 793-811 (1995).
2. Yen C, Lin JC, Li WJ, Huang MF, *Journal of Materials Processing Technology*, 174, 22-28 (2006).
3. B. Ozcelik and T. Erzurumlu, *International Communications in Heat and Mass Transfer*, 32, 1085–1094 (2005)
4. B. Ozcelik and T. Erzurumlu, Journal of Materials Processing Technology, 171, 437–445 (2006)
5. Zhai M, Xie Y, I*nternational Journal of Advanced Manufacturing Technology*, 49, 97-103 (2010).
6. C.-H. Tseng, C.-T. Huang, Y.-C. Liu, W.-L. Yang, and R.-Y. Chang, *SPE Technical Paper*s, No. 2096337, 1-6. (2015)
7. K. M. Tsai, B. H. Tang, *International Journal of Advanced Manufacturing Technology*, Volume, 75, 947–958 (2014).
8. G. Xu and Z. Yang, *International Journal of Advanced Manufacturing Technology*, 78, 525–536 (2015).
9. S. Kitayama, H. Miyakawa, M. Takano, and S. Aiba, *International Journal of Advanced Manufacturing Technology*, 88, 1735–1744 (2017
10. C.-T. Huang, Y.-H. Hsu, and B.-S. Chen, Polymer Testing, 75, pp 327-336 (2019).

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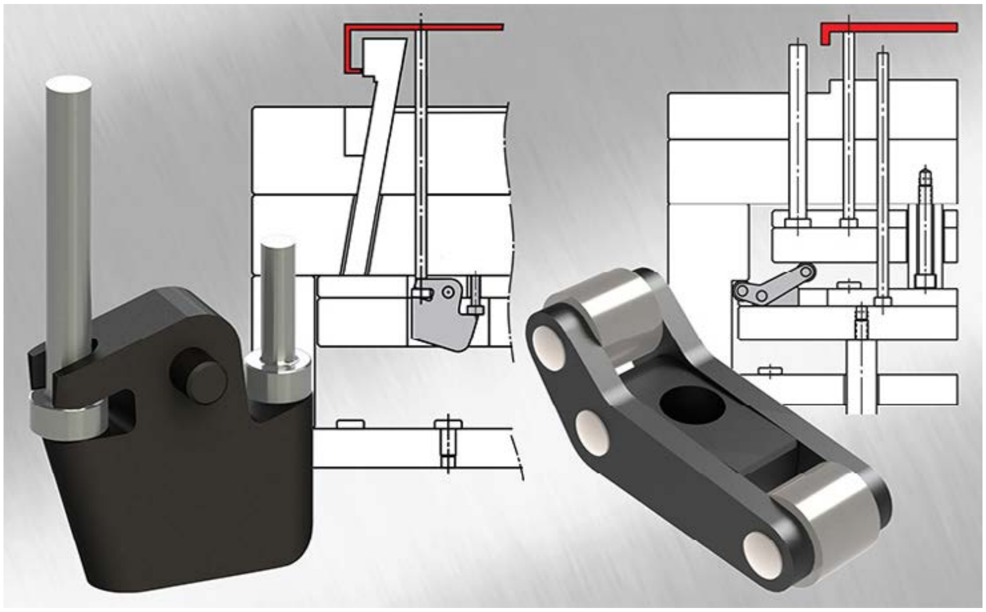

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