

COMPARING PLASTICS INJECTION MOLDING SIMULATION RESULTS TO REAL-WORLD MOLDED PARTS

White Paper



EXECUTIVE SUMMARY

The fundamental solver, meshing and material data technology (aka injection molding simulation technology) required to predict how melted plastic flows during the injection molding process has been in existence for approximately 40 years. However, although injection molding simulation has been well understood and widely accepted for decades, software technology providers have an ongoing obligation to ensure the accuracy of simulation results by comparing analysis predictions to real-world molding results. Therefore, the specific focus of this white paper is regarding the validation of Dassault Systèmes SOLIDWORKS Plastics injection molding simulation software tools.

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SOLIDWORKS PLASTICS
VALIDATION FINDINGS

INTRODUCTION

To validate the accuracy of SOLIDWORKS Plastics simulation results, Dassault Systèmes initiated a project with Taiwan, ROC (Republic of China)'s Chung Yuan Christian University (CYCU), one of the world's leading plastics engineering research centers, to compare SOLIDWORKS Plastics analysis predictions with empirical (real-world) molding results. While this report provides in-depth detail regarding the scope of the study, part and mold geometry, injection molding process parameters, material data and empirical evidence generated, the key findings are as follows:

- SOLIDWORKS Plastics filling pattern predictions exhibited outstanding correlation with empirical evidence.
- Improvements made to the SOLIDWORKS Plastics 2019 solvers resulted in better correlation with predicted pressure profiles.
- A new turbulence flow model introduced in SOLIDWORKS Plastics 2019 improved the accuracy of cooling circuit pressure drop & coolant temperature predictions.
- The combination of improved pressure profile & cooling analysis predictions resulted in improved warpage analysis results and correlation with empirical evidence.

As a result, injection molding design-to-manufacturing professionals can be confident that given the use of appropriate analysis geometry mesh models and accurate polymer material data, SOLIDWORKS Plastics solver technology is capable of producing simulation results that have outstanding correlation with real-world molding results.

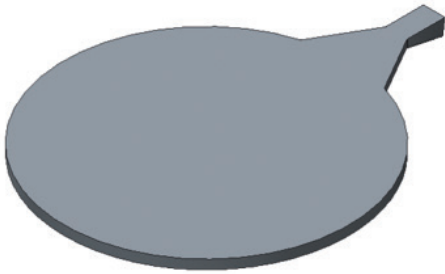
VALIDATING THE ACCURACY OF SOLIDWORKS PLASTICS MOLD-FILLING SIMULATIONS

To demonstrate the high degree of accuracy of mold-filling simulations conducted with SOLIDWORKS Plastics software, Dassault Systèmes commissioned the renowned Mechanical Engineering Department at Chung Yuan Christian University (CYCU) in Taiwan to conduct a series of physical experiments on three dissimilar part and mold designs and then compare the empirical evidence of these physical tests with SOLIDWORKS Plastics simulation results. Dassault Systèmes chose to partner with CYCU because the university has an outstanding plastics program, operates state-of-the-art injection-molding systems and equipment, and has contributed to the development of cutting edge injection-molding technology, such as research into artificial-intelligence-driven knowledge-based intelligent molding and an Industry 4.0 intelligent manufacturing service system.



Chung Yuan Christian University (CYCU) in Taiwan

CYCU Engineering Department Chair Professor Dr. Shia Chung Shelley Chen supervised the project, which involved shooting three different test part geometries using five different materials, instrumenting the molds with pressure and temperature sensors, and measuring numerous key variable processing parameters, including melt temperature, mold temperature, fill rate, cavity pressure, coolant flow rate, coolant temperature, and coolant pressure. The CYCU validation project team then compared its real-world experimental findings with SOLIDWORKS Plastics simulation results. The experiments involved 125 unique combinations based on differing geometries, materials and processing parameters for the following three models:



Disc Model



Assembly Model

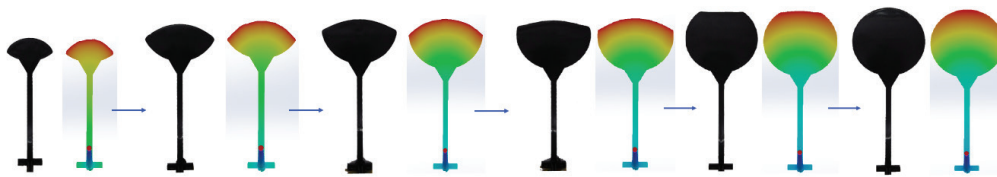


Bow Model

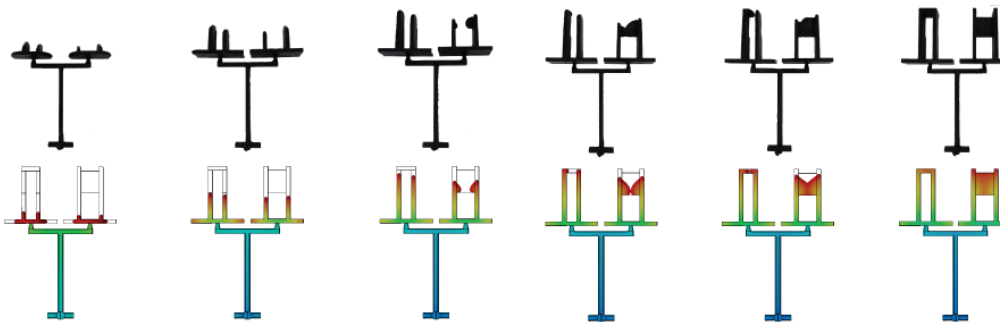
The disc, assembly and bow models were chosen for this project as representative of just how diverse plastic parts can be, and include a rounded part with curvature, a part that is a portion of an assembly and a part with a thin-walled feature that flexes easily. Using 125 unique combinations for these three parts, the project team measured the correlation between empirical evidence and SOLIDWORKS Plastics simulation results at each of the phases of the injection-molding process: filling, packing, cooling and warpage. It was critically important to assess the accuracy of simulation results at each of these stages because the accuracy of the results at each stage impacts the accuracy of the findings in subsequent stages.

FILLING PATTERN VALIDATION

The most fundamental result of an injection molding simulation is the filling pattern prediction because if the filling pattern isn't accurate, related results such as pressure drop through the mold cavity won't be accurate either. In this phase, the CYCU validation project team compared the predicted filling pattern using SOLIDWORKS Plastics simulations for all three models with the actual short-shot-series-filling-pattern results for the same models. In both reality and the simulation environment, molds for the parts are filled at various percentages, such as 20 percent filled, 30 percent filled, 40 percent filled, and so on. As can be seen, the filling pattern correlations between the virtual and the real are quite close, validating the accuracy of SOLIDWORKS Plastics mold-filling simulation technology for further predicting mold and part behavior in the packing, cooling and warpage analysis phases that follow.



Disc Model - Short Shot Series Fill Pattern Comparison



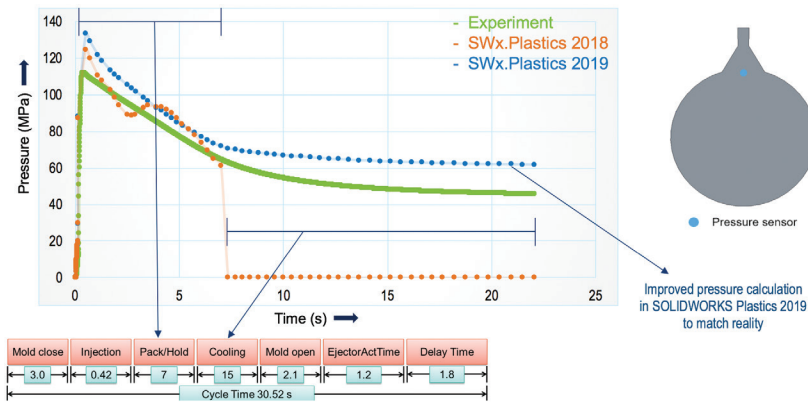
Assembly Model - Short Shot Series Fill Pattern Comparison



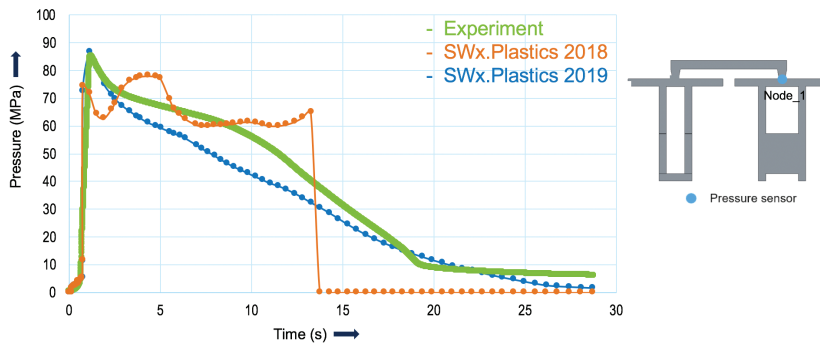
Bow Model - Short Shot Series Fill Pattern Comparison

CAVITY PRESSURE VALIDATION

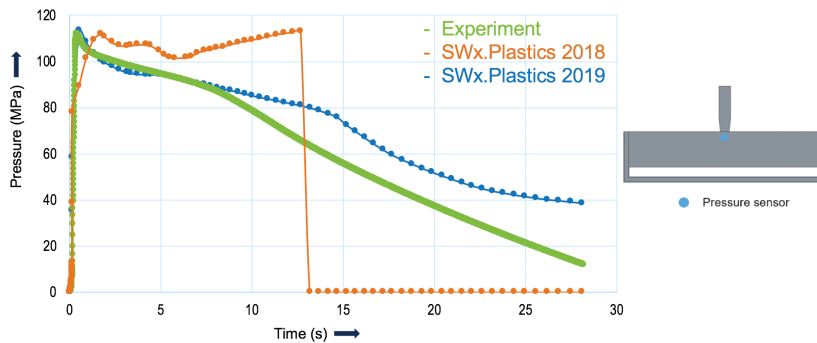
After the CYCU validation project team confirmed the filling pattern predictions, they compared the pressure at which the material is injected into the mold with the actual pressure and pressure profile predictions over time inside the mold. Physical pressures were measured by placing a pressure transducer inside the mold cavity. Again, the correlation of the curves showing the actual pressure profile and the pressure profile predicted by SOLIDWORKS Plastics validates the accuracy of the simulation results. However as a result of these findings, the SOLIDWORKS Plastics R&D team implemented changes to the solvers in SOLIDWORKS Plastics 2019 to more accurately predict pressure decay and achieve even better correlation with reality, making the 2019 version of SOLIDWORKS Plastics even more accurate than previous releases.



Disc Model - Pressure Profile



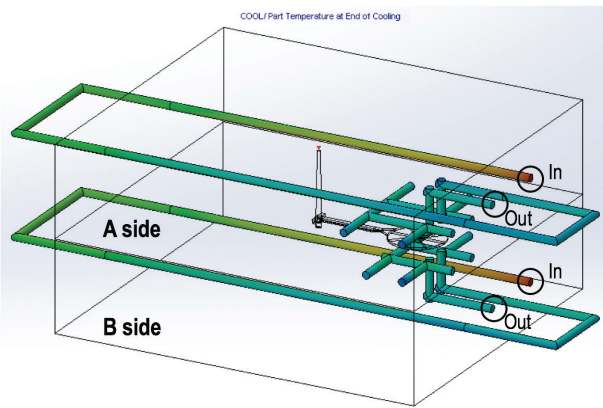
Assembly Model - Pressure Profile



Bow Model - Pressure Profile

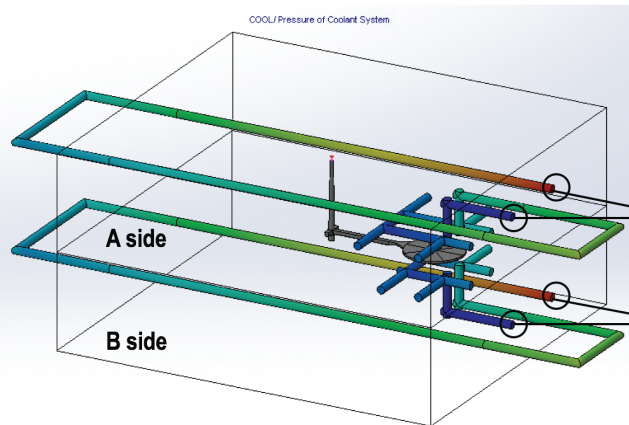
MOLD COOLING VALIDATION

Following the filling and packing phases of the injection molding process, the CYCU validation team ran experiments and simulations related to the cooling phase. During mold cooling, cooling channel inlet and outlet temperatures and the cooling channel pressure drop are important variables for verifying the most suitable cooling channel arrangement. Again, the team found good correlation between the simulated and experimental results. A new turbulence model in SOLIDWORKS Plastics 2019 has made the solution's cooling results even more accurate because it accounts for the fact that the coolant pumped through the mold cooling system typically reaches a turbulent state. In fact, this is highly desirable to ensure efficient heat extraction from the mold.



		A side	B side
INLET	Experiment (IN)		
	SWx.Plastics 2018	64.6 °C	64.6 °C
	SWx.Plastics 2019		
OUTLET	Experiment (OUT)	61.7 °C	61.7 °C
	SWx.Plastics 2018	64.7 °C	64.7 °C
	SWx.Plastics 2019	60.4 °C	60.2 °C

Disc Model - Cooling Circuit Temperature

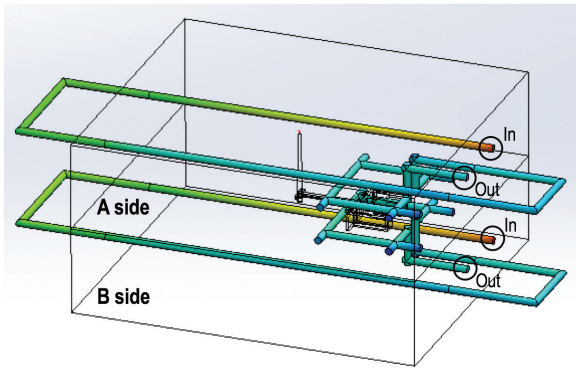


Experiment :

A side	B side
0.14 MPa	0.14 MPa

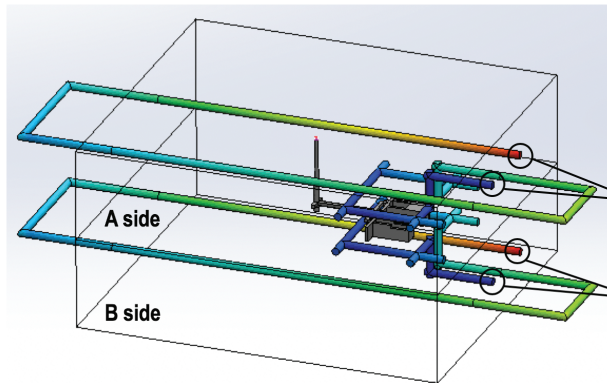
- Simulation (A side)
 - SWx.Plastics 2018 = 0.091 MPa
 - SWx.Plastics 2019 = 0.106 MPa
- Simulation (B side)
 - SWx.Plastics 2018 = 0.089 MPa
 - SWx.Plastics 2019 = 0.104 MPa

Disc Model - Pressure Drop



		A side	B side
INLET	Experiment (IN)		
	SWx.Plastics 2018	65.6 °C	65.6 °C
	SWx.Plastics 2019		
OUTLET	Experiment (OUT)	62.2 °C	62.2 °C
	SWx.Plastics 2018	65.6 °C	65.7 °C
	SWx.Plastics 2019	61.1 °C	61.3 °C

Assembly Model - Cooling Circuit Temperature



Experiment :

A side	B side
0.14 MPa	0.14 MPa

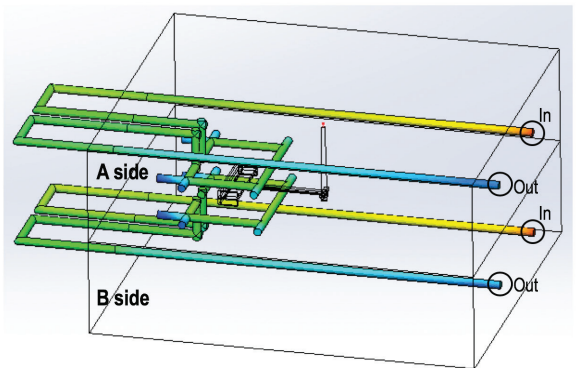
Simulation (A side)

- SWx.Plastics 2018 = 0.086 MPa
- SWx.Plastics 2019 = 0.101 MPa

Simulation (B side)

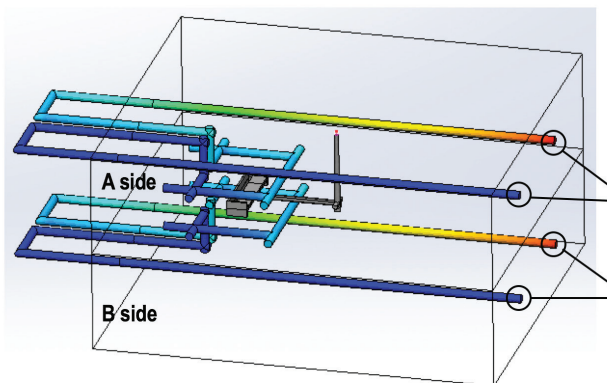
- SWx.Plastics 2018 = 0.086 MPa
- SWx.Plastics 2019 = 0.101 MPa

Assembly Model - Pressure Drop



		A side	B side
INLET	Experiment (IN)		
	SWx.Plastics 2018	66.4 °C	66.4 °C
	SWx.Plastics 2019		
OUTLET	Experiment (OUT)	63.0 °C	63.0 °C
	SWx.Plastics 2018	66.4 °C	66.5 °C
	SWx.Plastics 2019	62.0 °C	62.0 °C

Bow Model - Cooling Circuit Temperature



Experiment :

A side	B side
0.14 MPa	0.14 MPa

Simulation (A side)

- SWx.Plastics 2018 = 0.083 MPa
- SWx.Plastics 2019 = 0.095 MPa

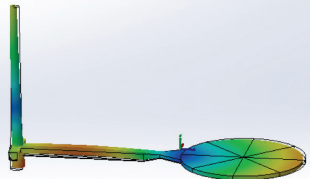
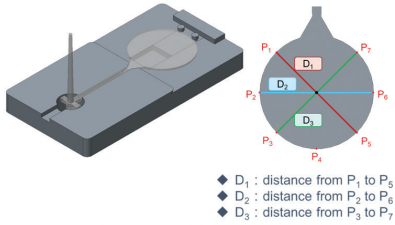
Simulation (B side)

- SWx.Plastics 2018 = 0.082 MPa
- SWx.Plastics 2019 = 0.094 MPa

Bow Model - Pressure Drop

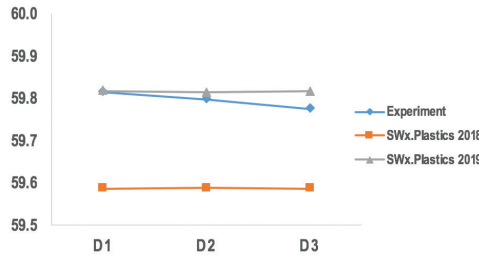
WARPAGE ANALYSIS VALIDATION

The last stage of the injection molding process—after filling, packing and cooling—is to inspect part warpage-related defects. Warpage is a manufacturing defect that can be caused by the effects of molded-in stresses, fiber orientation and differential cooling. The improvements made to the solvers in SOLIDWORKS Plastics 2019 contribute to more accurate warpage analysis results, which results in analysis predictions even closer to the actual experimental results. By measuring the dimensions of the molded parts, including the deformation of the parts due to warpage, the CYCU validation project team found very close correlation between the SOLIDWORKS Plastics analysis predictions and the real-world results.

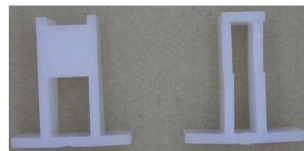
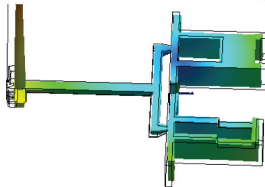
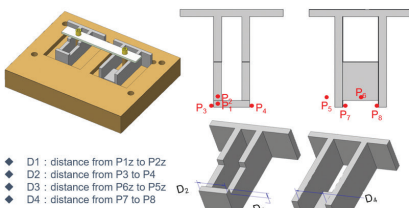


	D1	D2	D3
Experiment	59.815	59.798	59.775
SWx.Plastics 2018	59.587	59.588	59.587
SWx.Plastics 2019	59.818	59.814	59.817

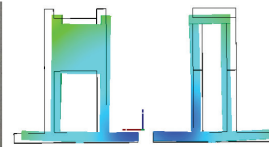
All dimensions in mm



Disc Model - Warpage Analysis



Experiment

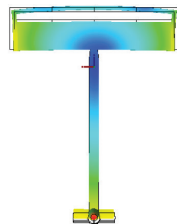
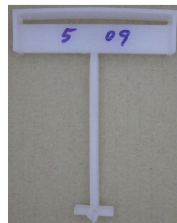
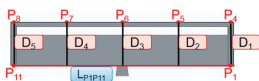
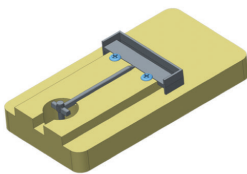


SOLIDWORKS Plastics 2019

	D1	D2	D3	D4
Experiment	2.946	13.851	2.984	12.556
SWx.Plastics 2018	2.971	13.856	2.979	13.620
SWx.Plastics 2019	2.972	13.861	2.980	13.619

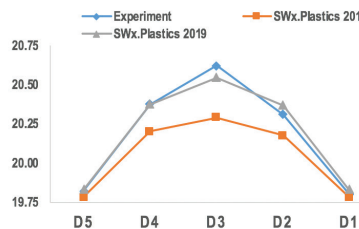
All dimensions in mm

Assembly Model - Warpage Analysis



	D5	D4	D3	D2	D1
Experiment	19.824	20.376	20.625	20.313	19.803
SWx.Plastics 2018	19.784	20.203	20.293	20.176	19.784
SWx.Plastics 2019	19.835	20.379	20.549	20.372	19.835

All dimensions in mm



Bow Model - Warpage Analysis

SOLIDWORKS PLASTICS VALIDATION FINDINGS

The overall findings of the CYCU/SOLIDWORKS Plastics Validation Project show excellent correlation between analysis predictions and empirical, real-world molding results for every phase of the injection molding process. Beginning with filling patterns and continuing with mold pressure profiles, cooling circuit pressure drops, coolant temperatures and warpage analyses, the project validated the fundamental accuracy of the solvers, as well as the increase in accuracy due to improvements made to SOLIDWORKS Plastics 2019. The key findings can be summarized as follows:

- **SOLIDWORKS Plastics filling pattern predictions exhibited outstanding correlation with empirical evidence.**
- **Improvements made to the SOLIDWORKS Plastics 2019 solvers resulted in better correlation with predicted pressure profiles.**
- **A new turbulence flow model introduced in SOLIDWORKS Plastics 2019 improved the accuracy of cooling circuit pressure drop & coolant temperature predictions.**
- **The combination of improved pressure profile & cooling analysis predictions resulted in improved warpage analysis results and correlation with empirical evidence.**

As a result, injection molding design-to-manufacturing professionals can be confident that given the use of appropriate analysis geometry mesh models and accurate polymer material data, SOLIDWORKS Plastics solver technology is capable of producing simulation results that have outstanding correlation with real-world molding results.

To learn more about how the accuracy of SOLIDWORKS Plastics software can help you optimize every phase of the injection molding design-to-manufacturing process and eliminate or minimize manufacturing defects to save energy, natural resources, time and money, visit www.solidworks.com or call 1 800 693 9000 or 1 781 810 5011.

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