Closing the Loop in Practice: Exchanging Process Set-up Data between Design Analysis and Manufacturing Solutions Tools

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Moldflow's overall design-through-manufacturing optimization strategy relies on closing the loop between manufacturing-driven design and analysis-driven manufacturing. One of the company's research and development projects has focused on interfacing mechanisms between injection molding process analysis tools and tools for automating machine setup.

Recent work has shown that the interface is an effective way to communicate between these tools. The results can benefit both design and process analysts and manufacturers by achieving process conditions that are consistent and based on scientific principles. Analysis results yield more accurate predictions of molding outcomes when input process conditions match shop floor process parameters, and more accurate predictions of process conditions in turn yield machine setup parameters that are more accurate, thus cutting the time required to set up a successful process when manufacturing begins.

Evolution of Design Analysis and Manufacturing Solutions

Since the early 1980s, computer-aided-engineering tools have been commercially available for injection molding process simulation. These software tools focus on plastic part and mold designs as well as processing conditions to analyze the plastic material flow and solidification behavior during the molding process. While countless examples have been published over the years to illustrate the benefits of Moldflow Plastics Insight® (MPI®) and Moldflow Plastics Advisers® (MPA®) design analysis tools, a continuing source of concern in using these tools remains: if the input processing conditions used for analyses do not match the actual processing conditions used in manufacturing, the results of the simulated process will differ from the actual molding outcomes.

In the 1990s, Moldflow developers began looking for a way to apply process knowledge and feedback at the machine itself, to minimize molding defects and achieve consistent quality of molded parts in production. This newer type of tool monitors important process parameters, such as pressure and ram position, which are used to automatically set up, optimize and control the molding process during manufacturing. The Moldflow Plastics Xpert® (MPX®) system was released commercially in 1998. While the method applies scientific principles to achieve and maintain a robust process window that produces consistent quality parts, if the initial conditions set are far from the optimal conditions, it may take a long while to arrive at the optimal conditions through iterations of the method.

Reaching Across Time

Both the design analysis tools and manufacturing control tools described above cover the details of the injection molding process, but these two types of tools work in different time scales. Generally, minutes to hours are required to complete a molding simulation (depending on the design complexity), while the typical cycle time required to mold one part is seconds, and process control tools must send feedback in this short timeframe.

Developing an interface for exchanging data between the two types of tools is the easiest way to realize the benefits of both and close the loop across the time gap.

The obvious application of such an interface should be to detect possible molding problems during the mold trial, because the actual processing conditions may not be known during the earlier part and mold design stages. Before molding trials begin, the emphasis is on using design analysis tools to investigate alternatives and troubleshoot potential problems related to runner systems, gate locations and types, dimensional stability, cooling efficiency, cycle time and operation cost reduction, and so on, in order to begin the molding trial with a design that is close to optimized based on theoretically reasonable process parameters.

Identifying Data Requirements

Input of correct processing conditions into a process simulation is one of the key elements required to achieve accurate analysis results. Table 1 lists important processing conditions required for analysis.

The process parameters recorded by injection molding machine control tools represent the actual interaction among particular part and mold designs, plastic material and process conditions. The recorded data can be classified as either machine information or time series data. Table 2 lists the data produced from machine control tools.

The machine data and major process data, such as injection pressure and ram position time series, can be used directly or indirectly to establish the process conditions required for analysis, as described in Table 1.

Table 1: Process conditions used for flow analysis.

Feature	Description
Velocity control	Various options such as fill time, flow rate or ram speed control
Pressure control	Various options to set up a profile; extends into packing phase of molding process
Velocity/Pressure switch-over control	Typically set as a percent of cavity volume filled; other options may be used
Melt temperature	Temperature of the molten plastic when it enters the mold cavity
Cooling time	Time required for plastic to cool and solidify before the part is ejected; typically the greatest contributor to total cycle time

Table 2: Process data from control tools.

Data	Feature	Type/availability
Machine Data	Maximum injection stroke	Single value
	Maximum injection rate	Single value
	Machine screw diameter	Single value
	Intensification factor	Single value
	Maximum injection pressure	Single value
Process Data	Ram position	Time series
	Ram velocity	Time series
	Injection pressure	Time series
	Velocity/Pressure switch-over	Indirect
	Mold surface temperature	Time series (if available)
	Melt temperature	Time series (if available)
	Open time	Indirect
	Cycle time	Indirect

Developing the Two-Way Interface

From Machine Control Tool to Analysis Tool

The time series data from the machine control tool comprise hundreds of values and often include some "noise." Also, some parameters need to be derived indirectly from the recorded process data, such as the switch-over point and the end of filling point. The interface from the control tool to the analysis tool includes these capabilities:

- Filters out noise and non-physical values
- Builds a characteristic curve with fewer data points
- Derives important parameters from curves
- Allows human intervention to modify the resulting process conditions, if desired

From Analysis Tool to Machine Control Tool

The second component of the interface is to pass results from analysis tools to the machine control tool. This feature is to help set up the machine with optimized process conditions determined through design analysis.

Example

Figure 1 shows the pressure time series data recorded for an example case. In order to follow the pressure curve closely in the filling and packing stages, one option is to set the switch-over point in the flow analysis earlier than it was set in the machine. For demonstration purposes, a switch-over value of 0.67 second is used in this example, and the pressure trace curve is then converted from this time on — the resulting fitted curve is shown in Figure 2.

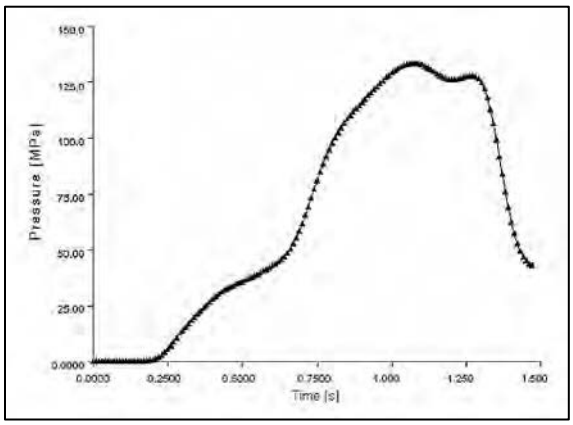

Figure 1. Injection pressure time series data recorded by the machine control tool.

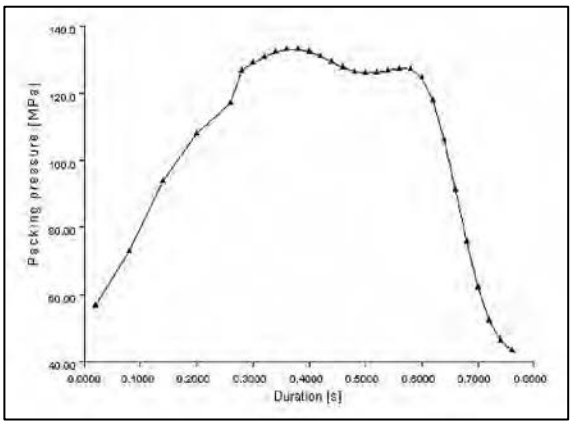

Figure 2. Pressure profile fitted from time series data when switch-over is set to 0.67 sec.

Figure 3 shows the resulting injection pressure profile from the flow analysis for this case. There is good agreement between the fitted data and the traced data, and between the pressure profile setting and the resulting predicted injection pressure.

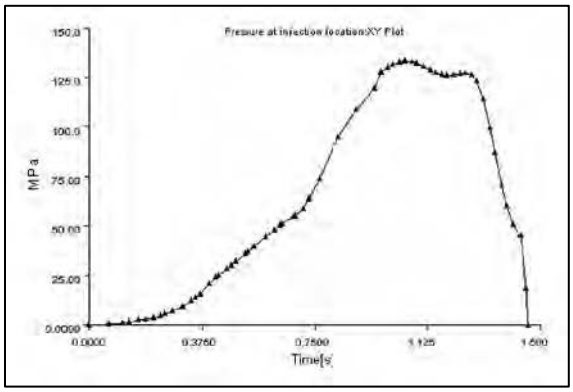

Figure 3. Injection pressure profile predicted by the analysis tool.

With data passing from both analysis tools to control tools and control tools to analysis tools, the interface provides a two-way communication mechanism which is a powerful tool for users to diagnose technical problems in the real world of plastic injection molding.

Based on research reported in "Interfacing Process Setting Data between Analysis and Machine Control," by Xiaoshi Jin, Paul Brincat, Baojiu Lin and Zhongshuang Yuan, submitted for presentation at the Society of Plastics Engineers Annual Technical Conference, Boston (2005).

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