TR500021

Optimization of Injection Molding Process Settings using Iliad and Moldflow

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Learning Objectives

- Introduction to design exploration, multi-disciplinary optimization software Iliad
- Demonstrate the application of numerical optimization to injection molding simulation
- Use of meta-modelling to identify optimal injection molding settings

Description

The optimization of injection molding process parameters and part designs is usually a manual process, utilizing ad hoc methods and dependent on user expertise. OmniQuest's Iliad Design Exploration and Automation Studio now features a dedicated interface with Moldflow Insight software, bringing enhanced optimization and design automation capabilities to injection molding simulation. This interface creates the opportunity for design space exploration through studies such as 1) optimization, 2) response surface modeling to establish mathematical relationships between process parameters, 3) design of experiments, and 4) reliability analysis. By using Iliad's integration capability and direct interfaces to Ansys Workbench, Python, and other CAE software, you can also control the complete design cycle using a single platform, including running macros and additional stress analysis. We will showcase how Iliad delivers real cost benefits to Moldflow Insight users through multiple case studies.

Speaker(s)

Dr. Shubhamkar Kulkarni leads the development of Iiad at OmniQuest. He earned his PhD in Mechanical Engineering from Clemson Universirty. His area of expertise is numerical optimization, computer aided engineering, design and manufacturing.

Introduction to OmniQuest® Iliad™

Who are we?

We at OmniQuest, also known as Vanderplaats Research & Development, are pioneers in the field of applied optimization. Over the past four decades, we have created and deployed breakthrough technologies that has enabled the application of numerical optimization in different industries bringing real dollar value to our customers. Please visit our website for more information: http://omniquest.world/

What is Iliad?

Iliad is our design exploration, integration and process automation tool (see Figure 1). It is a tool for design and process engineers to bring all the disconnected analysis steps in their solution development process into a single workflow. This workflow can then be controlled for design space exploration, used for automates task execution and for optimizing solutions. Iliad is intended to deliver improvements beyond human intuition. Additional information can be found at https://omniquest.world/iliad/

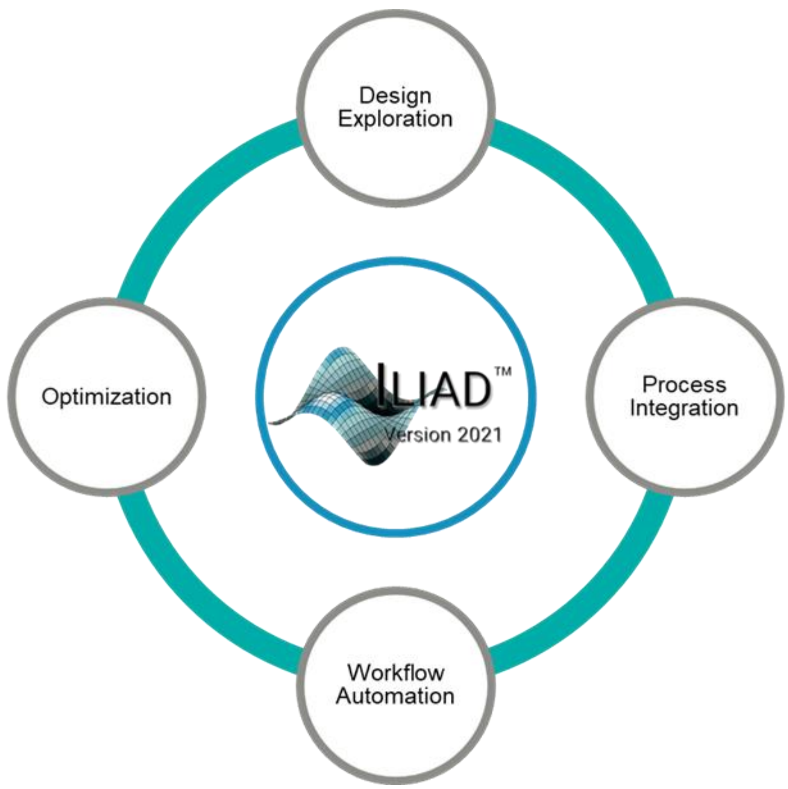


Figure 1. Iliad capabilities

As part of our collabartion with Autodesk, we have developed an interface to Moldflow Insight in Iliad which greatly simplifies the task of integrating injection molding simulation analysis into the solution workflow. This document describes the capabilities,setup and operation of this interface.

Demonstrate the application of numerical optimization to injection molding simulation

Optimization in the field of injection molding is a manual, ad-hoc process, primararily based on heuristic techniques develop by engineers and technical experts. The highs costs associated with tooling and modification to the equipment severely restricts the use of experimental investigation techniques for solution space exploration. With the advent of powerful simulation software such as Autodesk Moldflow, experts have been increasingly looking into non-empirical ways of determing the optimal settings for injection molding process. Currently, Moldflow offers design exploration tools including DOE, parametric studies, and gate location and packing profile optimization. While some of these tools are automated, other require the engineer to process the information and make the improvements manually. Also, the typical computational times with each simulation run are in the range of a few hours, which limits the application of numerical optimization techniques. Iliad, with its diverse fleet of optimization engines, automates the process of design improvement, identifies solutions which may be beyond human intuition and, reduces the effort and input on part of the engineer. A summary of the design space exploration and optimization tools in Moldlfow Insight and the additional capabilities enabled by Iliad ae summarized in Table 1.

Table 1. Summary of optimization capabilities added by Iliad

Moldflow Capability	Feature	Applicable to	What Iliad Adds
Optimization	Design of Experiments	• Mold/melt temperature, Injection/packing time, Thickness Multiplier, Injection/packing profile multiplier • Flow front temperature, shear stress, injection pressure, clamp force, volumetric shrinkage, sink mark depth, part weight, cycle time	• In addition, to the interactive response surfaces created by Moldflow, Iliad can automatically run the analysis using optimal settings • Additional DOE designs with more control over the model order. • Equations displayed to the user • Dynamically evolving response surface model available
	Parametric Studies	• Geometry modification • Process settings modification	• Reduces the number of evaluations X Currently geometry modification is not supported

Process Optimization	Ram speed and packing pressure profile	• Ram speed profile • Packing pressure profile	X Currently not supported
Gate Location	Gate Region Locator Algorithm	• Gate location using geometry and molding feasibility	• Automatically modifies gate location based on analysis run results, reducing the need for manual intervention • Gates placed using optimization algorithms which read user given responses
	Advanced Gate Locator Algorithm	• Gate locations with none present. Uses flow resistance	

How does the interface work?

The interface to Moldflow Insight uses the *studymod, runstudy,* and *studyrlt* utilities for modifying the settings, running the analyses and exporting the results respectively(Figure 2). More information on these utilities can be foud here: https://knowledge.autodesk.com/support/moldflow-insight/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/MoldflowInsight-Linux/files/GUID-554A0327-5AFB-4084-A654-009E0106D714-htm.html

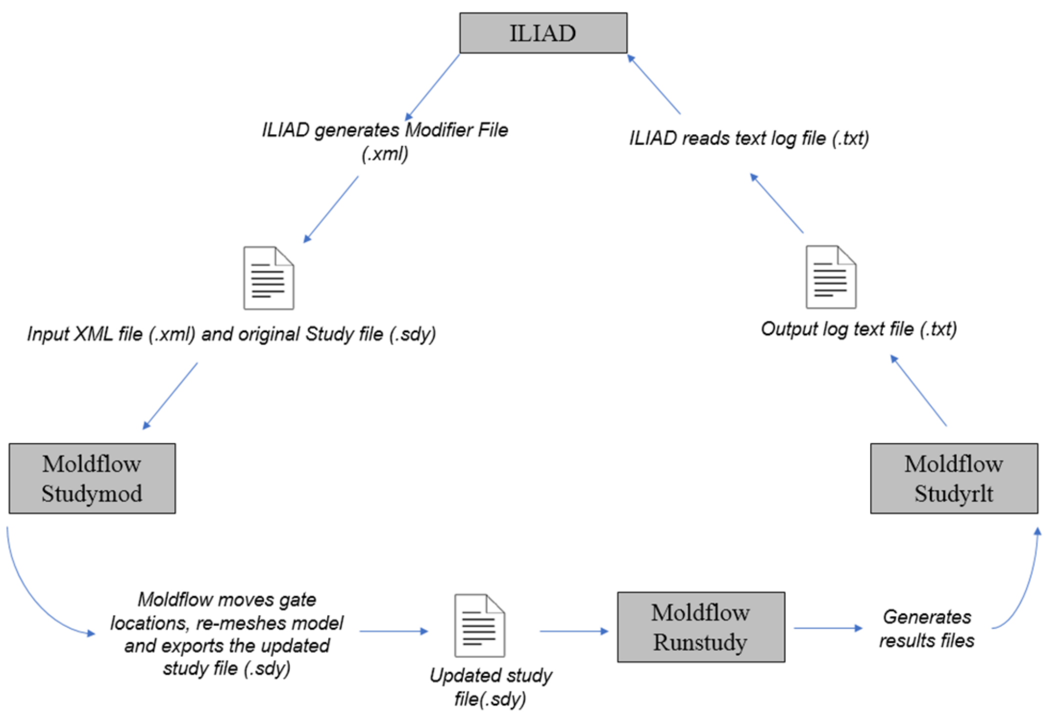


Figure 2. Moldflow utilities used by Iliad

Use of meta-modelling to identify optimal injection molding settings

Numerical optimization engines operate using direct evaluations to estimate the impact of changing the input settings on the responses. This usually entails the evauation of underlying differential equations provided by a simulation software such as Moldflow or an user-generated script. These analyses may take a large amount of time and computational resources for each evaluation. In such cases, an approximate optimization problem can be solved instead for practical reasosns. This can be called meta-model or response surface driven optimization. Iliad can construct the meta-model by automatically executing multiple instances of the analysis and followed by a regression analysis. This regression model is then supplied to the optimization engine for improving the design solution. This is demonstrated here through a use-case.
Consider the built-in mouse cover example available in Moldlfow Insight. For simplicity, only a single cavity is considered. We are running a Cool+fill+pack+warp analysis.

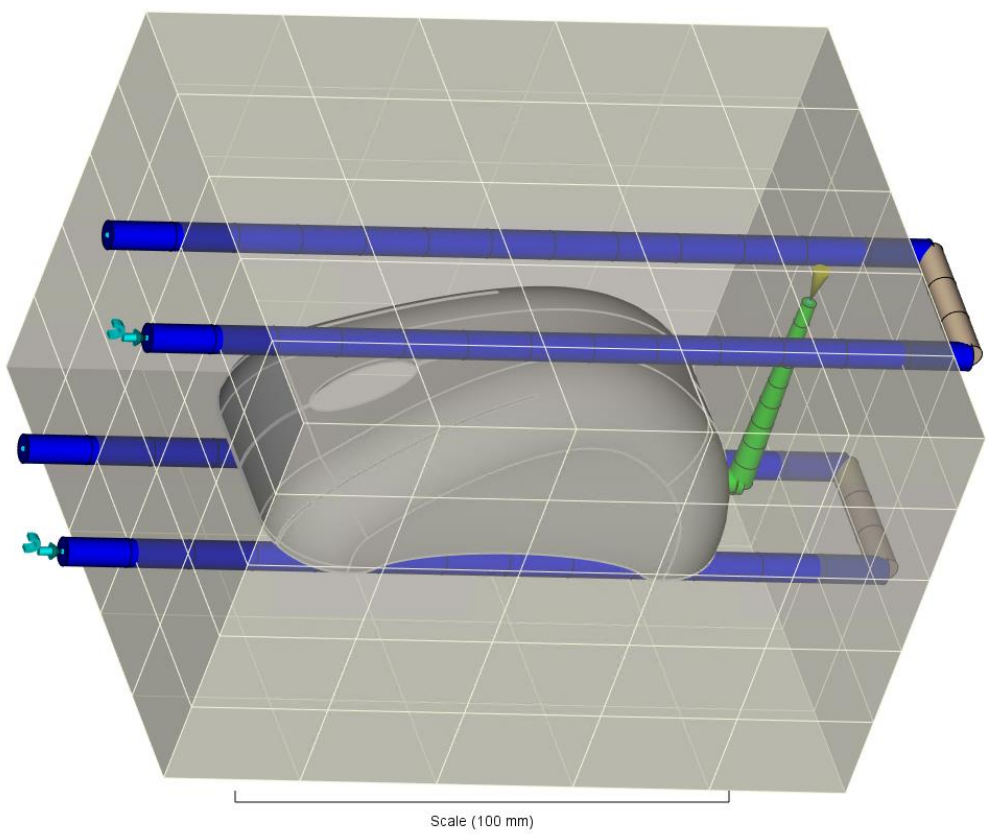


Figure 3. Model setup

The objective in this case is to minimize the differential warpage by adjusting the coolant inlet temperature and flow rate. This is a case of unconstrained optimization and can be formulated as below:

Table 2. Problem Formulation

Objective		Minimize differential Warpage	
		Lower Bound	Upper Bound
Design Variables	Coolant inlet temperature	293.15 K	333.13 K
	Cooling inlet flow rate	5E-5 m^3/s	5E-4 m^3/s

Let's look at how to setup this study in Iliad.

Building the Design Workflow in Iliad

The workflow is constructed as follows:

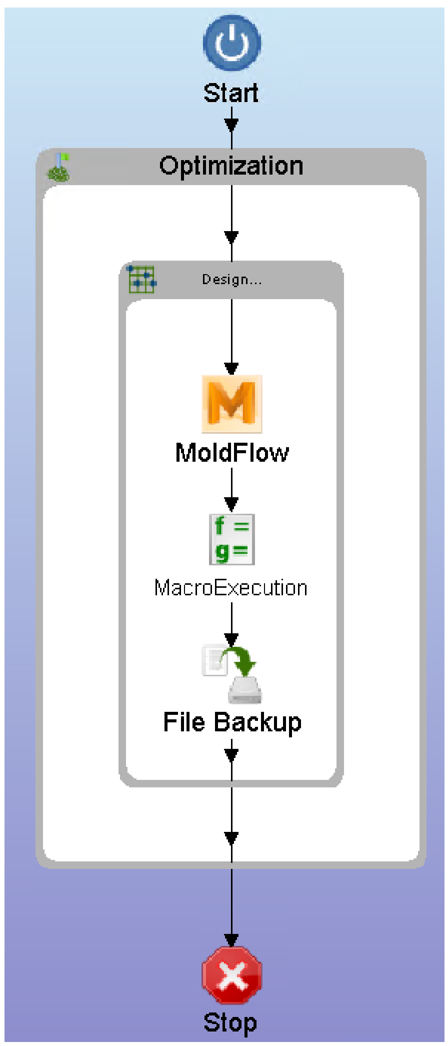


Figure 4. Workflow in Iliad

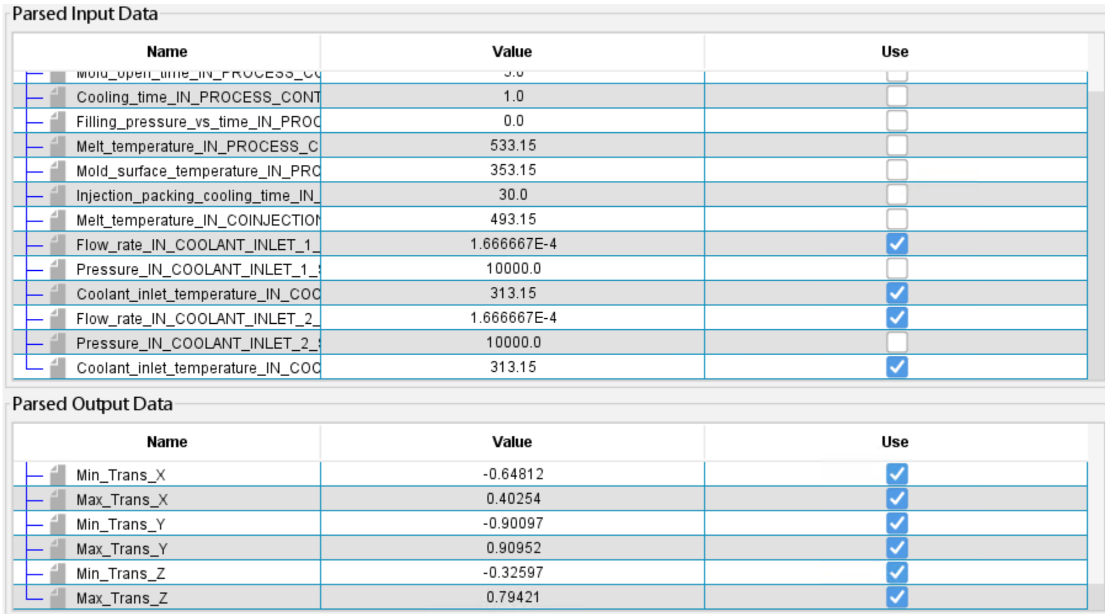
Building the Response Surface Model using the DOE component

The DOE component is used to generate a design of experiment, evaluate each design (input value combination) through the Moldflow Component and conduct a regression analysis. The engineer can select the option to either create a new design of experiments, or to import past data using the user-defined option. There are more than 9 different DOE design options including Taguchi, Factorial and Latin Hypercube. The engineer can also control the order of the regression model, between a linear and second order polynomials and, a Kriging interpolation function. In this case the Latin hypercube model is chosen with 10 design evaluations. The Forward Stepwise Regression model is used for eliminating non-contributing terms.

Configuring the Moldflow component

The Moldflow component simplifies the process of coupling Iliad around Moldflow. The following information is required:

1. Run mode – locally in a sequential order, remotely in a sequential order, parallely on local and remote nodes
2. Directory – place where the analysis reads and writes to
3. Executable Location – This information needs to be netered only once and then Iliad remembers it.
4. The interface works in two modes: 'Process Settings and Gate Locations' and 'Process Settings and Other Boundary Conditions'. Since we are dealing with coolant information, the second option is selecte here.
5. The location of the study file, design file and log file
   a. The design file (.UDM) can be exported from Moldflow Insight using File->Export design. The design file is an ASCII formatted file which contains the process setting information. This information is coded using the Tset and Tcodes. More information on this can be found at https://knowledge.autodesk.com/support/moldflow-insight/learn-explore/caas/CloudHelp/cloudhelp/2018/ENU/MoldflowInsight-Linux/files/GUID-249B946E-904F-437B-A61A-6E0ECC23C2CD-htm.html
   b. The text analysis log needs to be exported by running the studyrlt utility. This log is used for parsing the ouputs into Iliad.
6. Once the files are defined, the default set of TCODES are imported into Iliad and disaplayed in the Parsed Input and Output data tables. By default only selected Tcodes are imported. The user can import additional settings by editing the configurational file (Included_Tcodes.dat). The user can then select the desired settings and responses by checking appropriate selection boxes in the parsed input and output data tables (Figure 5).



Parsed Input Data

Name	Value	Use
Mold_open_time_IN_PROCESS_C	5.0	☐
Cooling_time_IN_PROCESS_CONT	1.0	☐
Filling_pressure_vs_time_IN_PROC	0.0	☐
Melt_temperature_IN_PROCESS_C	533.15	☐
Mold_surface_temperature_IN_PRC	353.15	☐
Injection_packing_cooling_time_IN_	30.0	☐
Melt_temperature_IN_COINJECTIOI	493.15	☐
Flow_rate_IN_COOLANT_INLET_1_	1.666667E-4	☑
Pressure_IN_COOLANT_INLET_1_	10000.0	☐
Coolant_inlet_temperature_IN_COC	313.15	☑
Flow_rate_IN_COOLANT_INLET_2_	1.666667E-4	☑
Pressure_IN_COOLANT_INLET_2_	10000.0	☐
Coolant_inlet_temperature_IN_COC	313.15	☑

Parsed Output Data

Name	Value	Use
Min_Trans_X	-0.64812	☑
Max_Trans_X	0.40254	☑
Min_Trans_Y	-0.90097	☑
Max_Trans_Y	0.90952	☑
Min_Trans_Z	-0.32597	☑
Max_Trans_Z	0.79421	☑

Figure 5. Parsed input and output data tables

7. Since, we are concerned with the magnitude of the warpage, synthetic variables are created to quantify the maximum warpage in each direction. This is done using the in-built Python component inside Iliad (Figure 6).

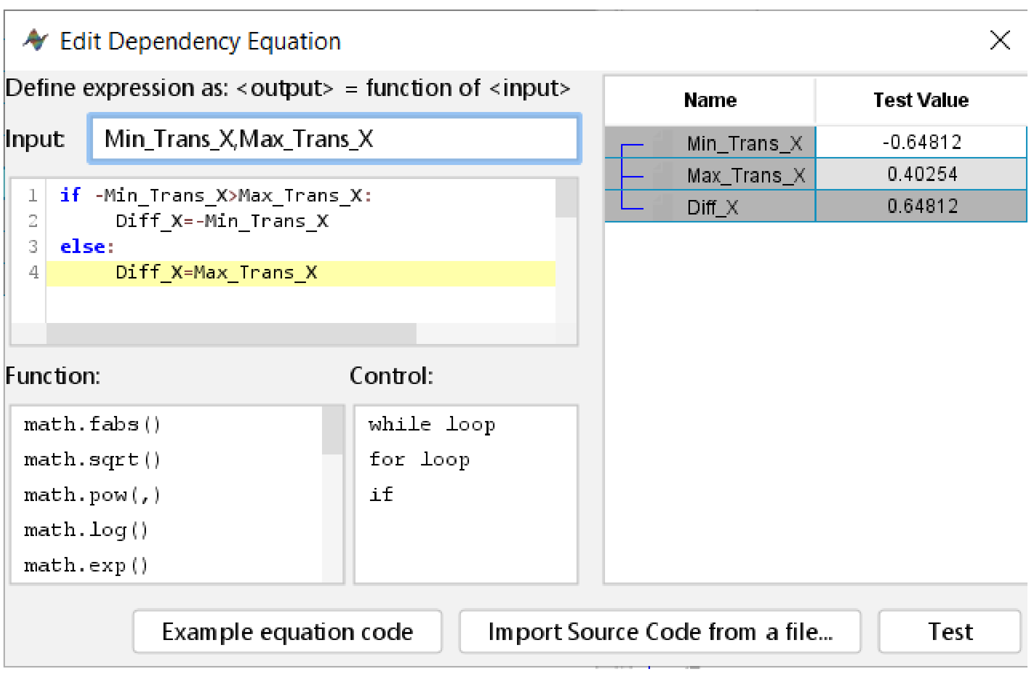


Figure 6. Creating synthetic variables

Gradient based Optimization Using the Response Surface Model

Next, Gradient based optimization is used. Since this an unconstrained problem, the defualt option i.e Modified Modualr Feasible Direction is used. Bounds are placed on the variables per the formulation (Table 2). The objective is then selected using the appropriate check-box. The setup is now complete (Figure 7).

Name	Input/Output	Data Type	Value Type	Adv. Attribute	Variable	Objective	Constraint
Flow_rate_IN_COOLANT	Input	Scalar	Real	None	✓		
Coolant_inlet_temperatu	Input	Scalar	Real	None	✓		
Diff_X	Output	Scalar	Real	None			
Diff_Y	Output	Scalar	Real	None			
Diff_Z	Output	Scalar	Real	None			
Total_Diff	Output	Scalar	Real	Synthetic		✓	

Figure 7. Optimization Setup

Automatic Execution of Macros

A pre-recorded Macro to export resulting plots is also integrated into the study. The Macro is executed using the in-built python component. The plots are suffixed with the design point number for identification.

Creating backup of files

Using an Iliad component, the files are backed up. Individual files are added to the back up component. This is done to have a repository of each analysis results log, update study files and Modifier files.

Setting up monitoring tools

An optimization history monitor is created to keep track of the progress of the optimization in real-time.

Using the post processing tool

Interacting with the response surface model

The response surface can be viewed by using the post-processig tab. The equations are defined here. The user can interact with the surface, by adjusting the value of the input variables and looking at the outputs. This is design exploration and is similar to the tools in Moldflow (Figure 8).

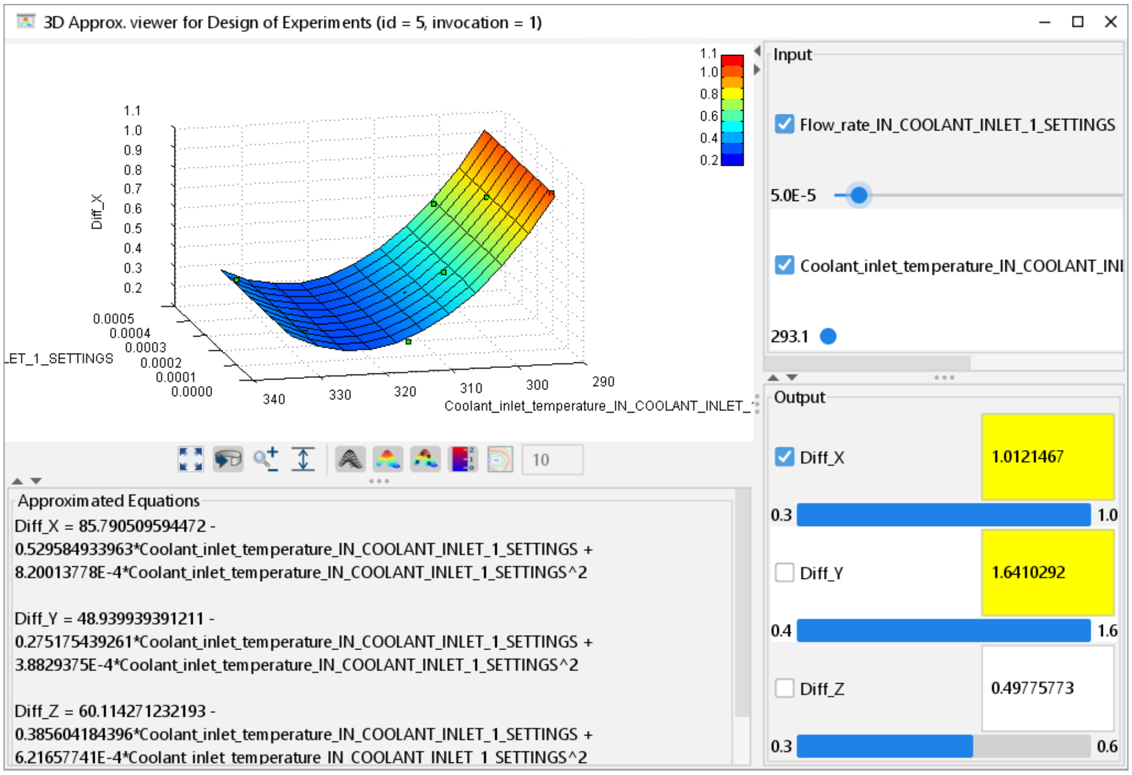


Figure 8. Interactive response surface visualizer

Analyzing the optimization

The comparison between the initial point and predicted optimal is shown in Table 3.

Table 3. Comparison between inital and optimum point

	Initial	Optimal
Coolant inlet temperature	313.15 K	325.242 K
Cooling inlet flow rate	1.667E-4 m^3/s	2.667E-4 m^3/s
Minimize differential Warpage	2.352	1.266

Thus a reduction of approximately 50% is seen in the warpage showing significant improvement over the starting point.

Using an auto-evolving response surface driven optimization

Additional examples including a dynamically evolving response surface and the addition of other analyses and scripts such as Ansys are also included in the demo.

Conclusion

Iliad enhances the design exploration capabilites available inside Moldlfow by bringing numerical optimization and meta modelling capabilities. The dedicated interface to Moldflow greatly simplifies the task of coupling Iliad to Moldflow and gives greater flexibility and control to the engineer. Additional analyses and user desfined scripts such as macros can also be integrated easily into injection molding solution development using Iiliad. Response surface driven optimization offers the advantage of reduced number of analysis executions compared to direct evaluation.

For additional questions, please contact iliad.support@omniquest.world.