Using Design of Experiment Analysis with Autodesk® Moldflow® Insight

Speakers: Martin Schultz – Summit Polymers Incorporated
Jay Shoemaker – Autodesk

MA7440-P   Learn how to set up, run, and interpret the results for a Design of Experiment (DOE) analysis. The DOE tool in Moldflow Insight is now very powerful and can help you solve many problems. Setting up a DOE analysis to target specific requirements is the key to getting the most from the analysis. This class will also provide some tips and detailed information to get the most from the DOE analysis.

Learning Objectives

At the end of this class, you will be able to:

- Determine the analysis objectives
- Pick the experiment type required
- Select analysis variables and quality criteria
- Execute the analysis
- Interpret the analysis results

About the Speakers

Martin Schultz

Martin is the in-house CAE analyst at Summit Polymers Incorporated, an automotive supplier, and has been responsible for performing all internal computer-aided engineering work including mold filling (Autodesk® Moldflow®), air flow (Autodesk® Simulation CFD), and structural analysis for 18 years. Prior to this, he worked as a CAD instructor for Intergraph Corporation in the Mechanical Design Products group.

Jay Shoemaker

Jay is a Principle User Experience Designer at Autodesk. After working for a family owned machine shop and graduating with a B.S. in Manufacturing from Western Michigan University, Jay has spent 27 years as a project engineer, customer support engineer, trainer, training material developer and product designer for Moldflow and now Autodesk. Jay started his career as a Project Engineer where he worked with customers optimizing mold designs using Moldflow to make tools that fill better and cool the part efficiently. During most of Jay's career, he has been in some way involved with training, starting as a trainer and since 2000 the primary developer of training material for injection molding simulation products. Using his knowledge of tooling design, Jay has taught Moldflow and written training material for Moldflow with the understanding of the importance of good tooling design in mind. Jay is the editor of the book ***Moldflow***

Design Guide. He is a member of the SIM Squad, a group of Autodesk simulation experts committed to uncovering and discussing the trends, issues and developments in the world of simulation. Today, Jay's role in Autodesk not only continues his tradition of working with training materials, he works with Autodesk product designers and developers to ensure Autodesk products fit the needs of the injection molding and tooling industries.

In addition, Jay has published numerous papers relating to injection molding simulation and tooling. Many of his publications are with researchers at Western Michigan University where he is an Adjunct Assistant Professor. Since 1985, Jay has assisted with plastics tooling classes, and injection molding related research. Jay works on the campus of Western Michigan University so he can continually interact with young engineers.

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Introduction to Design of Experiments (DOE)

What is a Design of Experiments?

A Design of Experiments (DOE) is a structured, organized statistical method for determining the relationship between factors (As) affecting a process and the output of that process (B). It is from the field of applied statistics and the principles were pioneered by Ronald Fisher in the 1920's. Others who refined and expanded the field include C.R Rao and Genichi Taguchi.
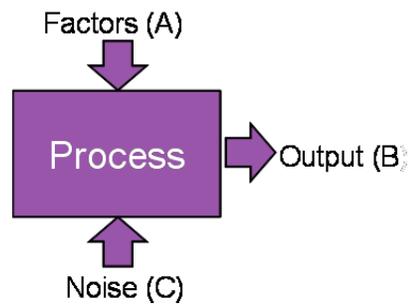

You can use a DOE to understand things such as the sensitivity of results to variables such as processing parameters or thickness changes, interactions between variables and the influence of a variable on a desired result. A DOE is not the same as optimization.

Moldflow DOE takes user defined input variables such as Mold Temperature, Melt Temperature or Flow rate, runs a series of simulations based on statistical models and creates results based on a statistical analysis of the simulation results.

With AMI 2012, there is extensive versatility with DoE. Previously DoE was limited to Fill and Flow for midplane and fusion. Now it can be used with all available analysis sequences, all model types, and common input variables, both single values and profiles.

Quality Criteria for a DOE includes all results relevant to the analysis being run and the ability to define critical dimensions and areas of the part for investigation.

DOE results include variable influence rankings, 2D and 3D Quality response surfaces and contour plots.
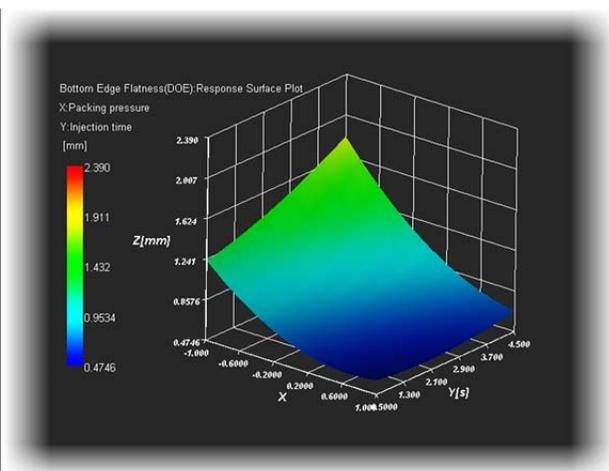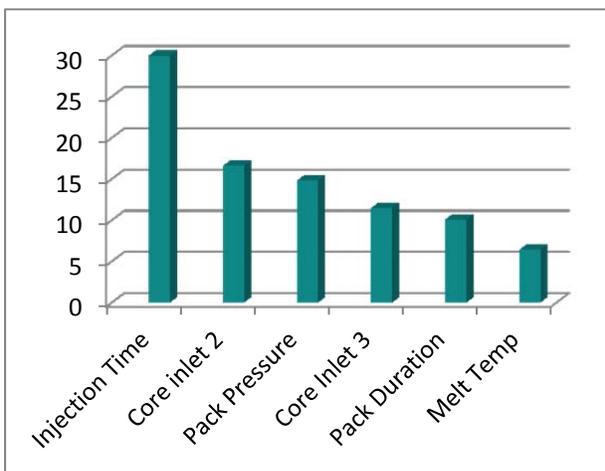
Why use a Design of Experiments?

DOEs produce orders of magnitude more information than one factor at a time (OFAT) tests at the same or lower test costs. For example, if I have an experiment with 7 variables at 2 levels, a one factor at a time analysis of all combinations will require 128 analysis runs. A DOE analysis can be done in 32 analysis runs.

DOE estimates of the effect of each variable on results are higher in precision (less variability)

The *interaction* between variables can be estimated systematically. - "hit and miss" experiments usually do not estimate interaction.

DOE allows us to predict behavior within the design space and allows limited extrapolation behavior outside the design space

DOE Sequence

The sequence for a performing a DOE includes the following steps: Determine your objectives. Design your experiment, Run the Analysis, Interpret the results.
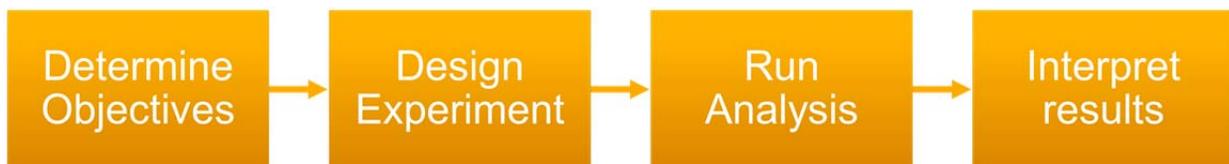
There are some limitations to a DOE.

A DOE doesn't directly compare results against a control or standard (Go/No-Go). It evaluates all effects and interactions and determines if there are statistically significant differences among them.

You must have a defined objective, or set of objectives to use DOE effectively. Without objectives the DOE analysis may not be set up correctly and will be difficult to interpret the results.

Determine DOE Analysis Objectives

You must have a defined objective, or set of objectives to use DOE effectively. Setting up a DOE analysis to target specific requirements is the key to getting the most from the analysis. Examples include: Comparing alternatives, Identifying significant variables affecting a result, Achieving an optimal process output, Minimizing, maximizing, or targeting an output or Balancing tradeoffs.

Identifying Variables and Quality Criteria

The next step is to identify and record possible contributing variables or variables that can be changed. Finally, you want to identify what results you are going to use to evaluate the success of the experiment. These will be your quality criteria. Multiple criteria can be defined and the relative importance (weighting) of the criteria can be defined.

Design the experiment

Designing the experiment starts with opening up the DOE Builder from either the Optimization tab on the home menu or from the Study tasks list. When designing your experiment many of the choices will be based on the existing analysis sequence.

Pick the experiment type required

From the experiment tab, pick the experiment type

One Variable

Variable Influences

Influence of each variable

Variable responses

Quality response surfaces and Optimum variable values

Combined Influence then response

Filter 'N' most influential variables before determination of the quality responses.

Select analysis variables and quality criteria

Variables Tab

The variables tab defines the process settings that will be changed during the analysis. The list of available variables is defined by the analysis sequences being used. For every variable the middle value comes from the inputs on the process settings wizard. The default min and max are +/- 20%. Up to 8 variables can be selected. Profiles and thickness can also be used as variables.

Quality Criteria

The quality criteria tab allows you to pick what results are used to determine how quality for the part is determined. The results available are based on the analysis sequences picked. For each result there is a description of the result used and the goal associated with the result. Goals could be minimize, maximize, minimize variation, etc. Any number of quality criteria can be used.

Execute the analysis

Autodesk Moldflow Insight uses the distribution queue and runs as many analyses at a time as Licenses allow (3 instances per licenses) and Processors available.

Moldflow Insight WS uses cloud computing and the studies are processed in parallel.

Interpret the analysis results

After the execution of all analysis runs are complete you can start to interpret the results.

Log File

The log file lists Variable influences on quality criteria for a influence analysis and quality range and estimate of optimum (using the response equation) for a variable response analysis.

2D Response Graphs

For each quality criterion specified, there are response results. If there is only one variable in the analysis the only type of response result available is a 2D XY graph. One variable is plotted with quality criterion while the other variables have sliders. The DOE control panel opens with Plot Properties.
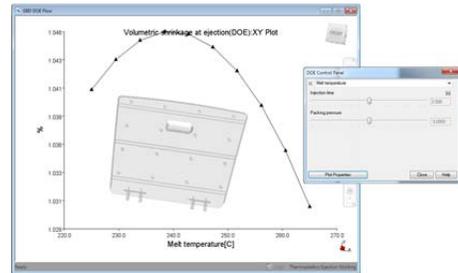
3D Response Graphs

Two variables plotted with quality criterion. Other variables have sliders. DOE control panel opens with Plot Properties
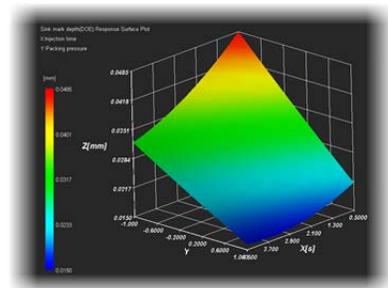
Contour plots

Observe the impact of variables on results. Variables have sliders. DOE control panel opens with Plot Properties

DOE Implementation in AMI

Variable influence analysis

For a variable influence analysis in AMI, a 2 level L_8 Taguchi design is used. The L8 matrix allows up to 7 variables to be evaluated and each variable range is mapped to [-1,+1]. Orthogonal arrays are used to maximize the number of variables for a minimum of runs.

The downside of the Taguchi method is that interactions between variables are mixed within

Experiment	P1	P2	P3	P4	P5	P6	P7
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

the influence results. Also, a variable with very low direct influence on a quality criteria but large interactions with other variable(s) may sometimes receive a large influence result.

Variable response analysis

For Variable response analysis in AMI, a face centered cubic design is used. Fitting of a quadratic equation through the data requires three values per variable: {-1}, {0}, {+1} (Min, Median, Max)
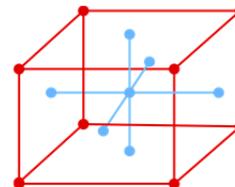
CSV results file

The CSV (comma separated values) file is a file located in the project folder which contains all the raw results for the analysis run such as the experimental data for influence and/or response analysis, quality response equations, range and optimum results, and individual file locations for each design run when the runs are saved. The file is written by default but can be turned off using: 'DoE Builder' / 'Options' , uncheck: "Save results in CSV files"

Handling a Short Shot

If a short shot is encountered in the design space, the DoE solver will automatically try to reduce the variable range to find a successful solution. The maximum number of times the solver will try to re-launch the analysis due to short shots is set on the DOE builder Form under options. "DoE Builder" / "Options", Fill: "Max number of relaunch"

Conclusion

- Using Moldflow DOE can help you:

    - Gather more information at the same or lower costs.

    - Understand the sensitivity of results to inputs

    - Identify the influence of a variable on a desired result

    - Systematically estimate the interaction between factors

    - Identify optimum variable (factor) values

    - Get an overall understanding of processing variable sensitivity

    - Predict behavior within the design space

    - Extrapolate behavior outside the design space

Where to go for more information

AMI DOE
http://wikihelp.autodesk.com/User:Jay.Shoemaker/Autodesk_Moldflow_Insight_(AMI)/DOE

Design of Experiments
http://www.moresteam.com/toolbox/index.cfm

http://asq.org/knowledge-center/index.html

http://www.isixsigma.com/index.php?option=com_k2&view=itemlist&layout=category&task=category&id=70&Itemid=202