Autodesk® Moldflow® Insight 2012

AMI Design of Experiments Analysis

Autodesk®

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Design of Experiment analysis

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Design of Experiment (DOE) is a statistical tool which enables you to see the effect of some intervention, for example changing an experimental processing variable, on the quality of the part. It can also tell you which processing conditions have the greatest impact on a given quality indicator. To do this, the DOE Builder runs a series of experiments while varying selected processing conditions, and then calculates the results based on user-defined quality indicators.

The benefit of DOE is that a significantly greater volume of high-quality information can be obtained from the resulting pattern of test data, than from more conventional trial-and-error experimenting. In general, a DOE analysis can be run at anytime during the design phase. However, it is probably best utilized after the material and gate location have been selected, and you have performed an initial analysis.

DOE analysis is supported by Midplane, Dual Domain and 3D mesh types, and is available for all molding process.

To run a DOE analysis, select **Design of Experiment (DOE)** from the **Optimization Method** dialog to launch the **DOE Builder**:

DOE Experiment types on page 9 > *Input Variables* on page 19 > *Quality Criteria* on page 28 > continue the analysis.

Once the analysis is complete, *study the results*. If you find that your optimized part can be made with a combination of the variables you selected, rerun the analysis using those optimum conditions to verify. It is important that you verify your conditions.

NOTE: If you decide that you need to change the value of some of the input variables, make a significant change, for example change the thickness by 20%-50% and rerun the DOE analysis. The effect of a small change, such as 1%-10% will be difficult to determine among the effect of all the other variables.

NOTE: *Parallel soution (multi-threaded) technology* is implemented by default for 3D analyses that include Fill + Pack. This option should be switched off for DOE analysis to improve the speed of the analysis.

Design of Experiment analysis

Design of Experiment analyses can be run on any molding processes, all analysis sequences and any material.

Prerequisites to setting up a Design of Experiment analysis

The following table summarizes the setup tasks required to prepare a Design of Experiment analysis of a non fiber-filled, or fiber-filled thermoplastic material.

Setup task	Analysis technology
Molding processes	
Meshing the model	
Checking the mesh before analysis	
Analysis sequence	
Selecting a material	
Injection locations	
Process settings	
Design of Experiment analysis on page 1	

Launching a Design of Experiment analysis

A Design of Experiment (DOE) is an analysis that allows you to optimize the design and processing of your part. You can select the variables (processing conditions), the weighting of each variable, and the quality criteria in order to determine the best possible combination of processing conditions for the part.

1 Create a new project, or open an existing one.

2 Click **Import** from the Quick Access toolbar, and import a CAD model.

Alternatively, click then **(Open > Import)** to import a model.

3 Click **(Mesh tab > Mesh panel > Generate Mesh)** and create a mesh on your model.

4 Click **(Home tab > Molding Process Setup panel)**, and select a molding process.

5 Click **(Home tab > Molding Process Setup panel > Analysis Sequence)**, and select an analysis sequence.

6 Click **(Home tab > Molding Process Setup panel > Select Material)**, and select a material for analysis.

7 Click **(Home tab > Molding Process Setup panel > Injection Location)**, and set an injection location on your model

8 Click **(Home tab > Molding Process Setup panel > Process Settings)**, and enter the processing conditions for analysis. On the DOE Settings

page, select the experiment type, specify the DOE variables, and the Quality Criteria, and click **Finish**.

9 Click **(Home tab > Molding Process Setup panel > Optimization)**, and select the experiment type, specify the DOE variables, and the Quality Criteria, and click **Finish**.

10 Click **Home tab > Analysis panel > Start Analysis** to launch the analysis.

Deactivating DOE

Right-click on **Optimization** in the Study Tasks pane, and select **None** from the list of options.

Collapsing the DOE tree in the Study Tasks pane

All the Variables and Quality Criteria that you select are listed in the **Study Tasks** pane, under Optimization. This list can be collapsed so you can see the Results more easily.

Click on the check mark associated with **Optimization** in the Study Tasks pane.
The tree will collapse. If you click on it again, the tree will expand again.

Increasing the speed of your analysis

You can take advantage of your multiple processors to increase the speed of your analysis.

1 Click **(Home tab > Job Manager)** to open the **Job Manager** dialog.

2 In the **Job servers** panel, right-click **Priority Jobs** and select **Properties** from the drop-down menu.

3 In the **Job Server Properties** dialog, enter the number of available CPUs you would like to use for the analysis in both the **Batch queue max. running jobs** box and also the **Distribution queue max. running jobs** box.

4 Click **OK** to close the **Job Server Properties** dialog and monitor the jobs.

5 Click **Close** to close the **Job Manager** dialog.

Design of Experiment analysis

The **Options** tab of the **DOE Builder** enables you to manage the DOE process to ensure optimum performance.

Options tab

Option	Description
Save results in CSV files	If you select this option, the results will be saved in a format that enables you to perform your own post-processing. This option is selected by default.
Keep analysis results in temporary file folder	During the DOE analysis, the results are saved to the temporary file folder. When the analysis has finished, the results are discarded to save memory. If you would like access to the results, select this option. This option is not selected by default.
Max. number of relaunch	During an analysis, if there is a problem such as a short shot, the DOE will modify the parameters and relaunch the analysis. If you are operating at the limits of your design, you may want to increase the number of relaunch attempts. The greater the number, the longer the analysis may potentially run. The max. number of relaunch attempts is 3, by default.

Features of a DOE analysis

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DOE analyses can be run with any analysis sequence, including fill, pack, cool, warp and shrink. They are suported by Midplane, Dual Domain and 3D mesh types and are available for all molding processes.

When setting up a DOE analysis, you can:

- change any numerical process setting,
- change all numerical boundary conditions, such as the coolant flow rate,
- make geometric changes to the model, such as thickness,
- choose from multiple experimental designs,
- set up quality measures based on results from any analysis sequence,

Having run a DOE analysis, you can:

- readily interpret the results,
- identify which process settings produced any given result,
- export the results so they can be imported into other statistical analysis packages.

Advantages of a DOE analysis 3

A DOE analysis can help manufacturing engineers understand how sensitive the tool and part design will be to variation in process variables. They may want to suggest changes in the part or tool design to make the molding more stable.

Multiple point solutions	The biggest advantage of a DOE analysis is that it provides a solution, and information about the space around that solution. This can lead to the engineer improving the design of the part, or changing an input parameter to improve the quality of the part.
Time to solution	A DOE analysis requires less manual input from engineers. Setting up a DOE analysis with current software is time consuming. Die trials can typically be shortened, as you will typically know which inputs affect part quality, and which do not.
Improved quality	DOE analyses can lead to solutions an engineer may not have thought of, and may help identify search directions that could improve part quality.
Scientific approach to provide better part quality	DOE analyses are robust, and have been used for a long time in engineering. Engineers typically have training in DOE, and understand the limitations. DOE analyses are an approved engineering tool. Therefore, there should be little resistance to the implementation of such tools.
Helps expand knowledge	By being able to relate physical inputs to physical outputs, in a real-time intuitive way, you are undergoing a self-learning process.

Limitations of a DOE analysis

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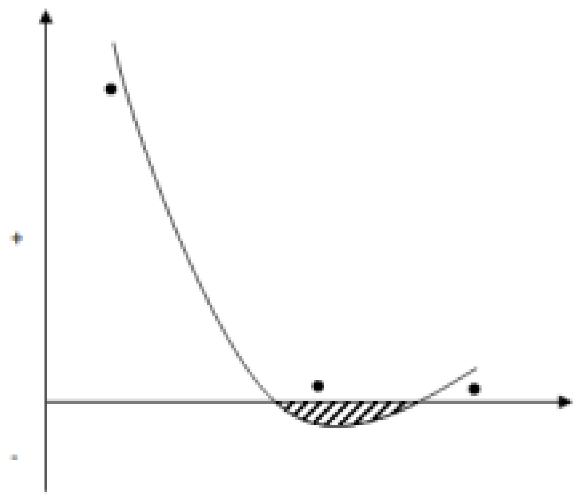
It is important that you scrutinize the results of your DOE analysis to determine whether they make sense. If they do not, reduce the range of the input variables and rerun the analysis.

Under some conditions, both the analysis of influences and the analysis of responses methodologies can result in unlikely results, due to limitations in the implementation of the statistical methods. These results can present themselves in the following ways:

Negative values

In order to minimize the number of runs required to produce DOE results for analysis of response experiments, a second order equation is applied to the data. In most cases, this produces logical results. In cases where there is a large differential between the data points, however, for example in the case of a short shot, the second order fitted curve will drop below the x-axis, resulting in negative values.



Solution - if you see negative values, reduce the range of the input data to encompass your area of interest more explicitly and to eliminate the outlying data points, then rerun the analysis. This is done in the **Variables** tab of the **DOE Builder**.

Unlikely or incorrect influence data when running the Taguchi methodology

When running an analysis of influences experiment, the number of experiments required using the basic methodology increases on the order 2^x,

where x = number of input variables.

Although the calculated percentage influence of an input variable on a quality criterion is due entirely to that variable using this approach, the analysis time can become prohibitively long. To reduce the analysis time, the Taguchi method is used here to analyze the influence of input variables on quality criteria.

The Taguchi method employs orthogonal combinations to extend the number of variables that can be included, for the same number of runs. Thus, with this approach, selecting 3 variables results in the need for only 4 runs, instead of $2^3 = 8$

Similarly, selecting 7 variables requires only 8 runs instead of $2^7 = 128$.

The disadvantage of this approach is that the calculated influence of the input variable is no longer dependent exclusively on that variable, but now has some contribution from orthogonal associations with the other variables. In most cases this effect is insignificant. However, in the case where the contribution of a given variable is negligible, but it has signigicant cross-influence from other variables, the calculated result will reflect the cross-influence.

5 DOE Experiment types

Design of Experiment offers four (4) experiment types, the selection of which depends on your personal objective.

One variable

One variable calculates the effect of a single variable of your choosing on part quality criteria that you select. This is the fastest of the DOE experiments and is a good option if you are interested in the effect of only one variable. The results of this experiment are written in the **Analysis Log**. XY plots of the data can be accessed in the **Results** section of the **Study Tasks** pane.

Variable Influences (Taguchi)

Variable Influences calculates the relative influence of each of the variables that you are interested in on the part quality criteria you select. The variables are ranked according to their relative impact, with those variables having the most significance given a higher percentage than those that have less. Since the results are strictly percent rankings, they are written to the Analysis Log; no plots are drawn.

Variable Influences is the recommended experiment to run if you are unsure which variables to monitor. The DOE solver launches an optimized set of analyses to determine this ranking, and from the results you can decide if you need to monitor all the selected variables, or a subset of them. You can select as many input variables as you like for this experiment.

Variable Responses (Face Centered Cubic)

If you know which variables to monitor, select Variable Responses to determine their effect on each quality criterion that you are interested in. In this experiment, a larger set of experiments is run than for Variable Influences, to test, extensively, various combinations of the input variables. As a result, this experiment takes more time than the previous two experiments. You can select as many input variables as you like for this experiment.

The results of this experiment are written in the **Analysis Log**, and 2D/3D response surface plots of the data can be accessed in the **Results** section of the **Study Tasks** pane. The results can then be examined graphically to determine the optimum conditions.

Variable Influences

Variable Influences then Responses uses the Taguchi method to determine which variables have the most influence on specific quality criteria, and

then Responses	then runs extensive factorial experiments on the most significant input variables to determine how they impact part quality. This option should be selected if you are interested in the effect on part quality of the various input variables, but are unsure which input variables have the most significant effect. The minimum number of input variables for this experiment is three (3). If you leave the default as three, but select more than three, all the selected variables will be ranked using the Taguchi method, then the three variables with the greatest influence will be used for the Responses experiments. The rankings of the various input variables are written to the Analysis Log first, followed by the responses data. 2D/3D response surface plots of the data can be accessed in the **Results** section of the **Study Tasks** pane. The results can then be examined graphically to determine the optimum conditions.

DOE Experiment types

There are four (4) DOE experiment types to choose from, depending upon the goal of your analysis. One variable is the most limited and takes the least amount of time. Variable Influences then Responses provides the most information and takes the longest time.

Selecting a DOE experiment type

1. Click **(Home tab > Molding Process Setup panel > Optimization)** to open the **DOE Builder** dialog.
2. Select the DOE experiment type of interest to you.
3. Click **Next** to go to the next tab.
4. Click **Finish** when you have populated all the tabs.

Experiment Type

Use this dialog to select the type of Design of Experiment analysis to be run.

DOE Builder - Experiment tab

The **Experiment** tab of the **DOE Builder** dialog is used to specify which Design of Experiment (DOE) analysis to run.

Experimental Design	[illegible]
One Variable	[illegible]

Experimental Design	[illegible]
	[illegible]

Experimental Design	Description
	[illegible]
Variable Influences (Taguchi)	[illegible]

Experimental Design	[illegible]
	[illegible]

Experimental Design	[illegible]
	[illegible]
Variable Responses (Face Centered Cubic)	[illegible]

Experimental Design

Experimental Design	[illegible]
Variable Influences then Responses	[illegible]

Experimental Design	[illegible]
	on the [illegible] [illegible] and analysis [illegible] [illegible] The set of criteria is [illegible] from the [illegible] [illegible] tab. This analysis is [illegible] if you are unsure which [illegible] [illegible] have the [illegible] [illegible] on part quality and you want to perform an [illegible] test to see how the [illegible] quality criteria

Experimental Design	[illegible]
	[illegible]

Input Variables

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A Design of Experiment (DOE) analysis enables you to see the effect of some intervention on the quality of the part. The input variables are the interventions. For example, you can change the melt temperature, or coolant inlet temperature, and see the effect on part quality.

The input variables listed in the **DOE Builder** are imported from the base study, and change depending upon the process settings you have chosen. When selected in the **DOE Builder**, these parameters appear in the **Optimization** tree in the **Study tasks** pane. The **Variables** tree may have as many as three sections, depending on the variables in the study:

- Processing conditions, for example Cool Settings, Fill+Pack Settings etc.,
- Boundary condition variables, for example coolant inlet data.
- Geometry variables, for example thickness.

The values you have set in the process settings are imported into the **DOE Builder**, where they are listed as the Middle Value. The **DOE Builder** assigns a range around the Middle Value, which you can change to make it wider or narrower. Profile data is also imported into the **DOE Builder** from the **Process Settings**. This data can only be changed in the process settings. However, Xmax, Xmin, Ymax and Ymin can all be edited in the **DOE Builder**.

Input Variables

The input variables that appear in the **Variables** tab are controlled by the original process settings and the ranges that they may have, to determine the quality of a molding.

Selecting input variables

1. Click **(Home tab > Molding Process Setup panel > Optimization)** to open the **DOE Builder** dialog.
2. Click on the Variables tab and select the variables of interest to you.
   The variables listed will depend on the analysis sequence you have chosen and the processing conditions you have set.
3. Click **Next** to go to the next tab.
4. Click **Finish** when you have populated all the tabs.

Importing process variations from MPX

You can simulate actual injection molding process variations by importing data about the process from Moldflow Plastics Expert (MPX).

The machine data must be exported from MPX in UDM file (ASCII model file *.udm) format. The imported data sets up a new **Design of Experiment** (DOE) analysis in the current study.

NOTE: Importing process variations is only available for the Thermoplastic Injection Molding Process.

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1. Open the project and study into which you want to place the imported data.
2. Click **Home tab > Molding Process Setup panel > Import MPX Process Variations**.

   The **Import Process Variation** dialog opens.
3. Locate the **UDM File (*.udm)** that contains the data you want to import.
4. Click **Open**.

   The **Import Process Variations Data from MPX** dialog opens to display the imported data. The option to **Create as DOE** is turned on by default.
5. Click **OK**.
   The **Import Process Variations Data from MPX** dialog appears. The parameter variations measured on the machine are represented by the **Delta** values in the dialog.
6. Click **OK**.
   The Analysis Sequence of the current study is updated to include the imported **Delta** values in the DOE analysis.

Input Variables

Design of Experiment (DOE) enables you to see the effect of some intervention on the quality of the part. The input variables are the interventions. For example, you can change the melt temperature, or coolant inlet temperature, and see the effect on part quality.

The left hand panel of the **DOE Builder Variables** tab lists the input variables that you can select to study. The right hand side provides you with an opportunity to change the experimental range for each variable. Select each input variable that you are interested in, accept the default values or change them if you prefer, then click **Next**.

NOTE: The list of input variables will change depending upon the analysis sequence selected.

Processing Conditions

The processing conditions include those variables associated with the actual production of the part.

The variables listed will depend on the molding process and analysis sequence selected, and include variables such as filling control, cooling time, curing temperature, injection time, pack/holding control, etc.

Processing Conditions and molding processes

The processing conditions listed will depend on the molding process and analaysis sequence selected. The following table lists processing conditions you can expect to find in the DOE builder, given certain selections of analysis sequence and molding process.

	Cool	Fill	Fill+Pack	Cool+Fill+Pack	Overmolding	Injection compression	Reactive molding (composite)	Reactive molding (composite)	Reactive compression molding	Microcellular injection molding	[illegible]	Underfill encapsulation	Note
Mold surface temperature	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓
Melt temperature	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		
Mold open time	✓			✓		✓							
Injection+Packing+Cooling Time	✓			✓									
Filling Control		✓	✓	✓	✓	✓		✓	✓				
Velocity/pressure switch-over		✓	✓	✓	✓	✓		✓	✓				
Pack/Holding control		✓	✓	✓	✓	✓		✓	✓				
Cooling time			✓		✓	✓							
Compression settings profile						✓			✓				
Press open distance						✓			✓				

	Cool	Fill	Fill+ Pack	Cool- Fill+ Pack	Overmolding	Injection compression	Reactive molding ([illegible])	Reactive molding ([illegible])	Reactive compression molding	Microcellular injection molding	[illegible]	Underfill encapsulation	[illegible]
Press waiting time						✓			✓				
Press compression time						✓			✓				
Press compression force cap						✓			✓				
Press compression speed vs distance						✓			✓				
Nominal injection time							✓				✓		✓
Melt initial conversion							✓	✓	✓		✓		✓
Curing time							✓	✓	✓		✓	✓	✓
Volume filled at start of foaming										✓			
Initial bubble radius										✓			
Number of cells per volume										✓			
Initial gas concentration										✓			
% Ram speed vs % stroke profile											✓		
Initial encapsulant temperature												✓	
Initial encapsulant conversion												✓	
Substrate temperature												✓	

	Cool	Fill	Fill+ Pack	Cool- Fill+ Pack	Overmolding	Injection compression	Reactive molding (composite)	Reactive molding (composite)	Reactive compression molding	Microcellular injection molding	[illegible]	Underfill encapsulation	Nozzle
Curing temperature												✔	

Conditions associated with input variables

Some processing conditions, for example filling control, have several options associated with them. The list that appears in **Variables** tab of the **DOE builder** will change depending on which option in the **Process Settings** has been selected. These details are explained in the table below.

The values shown in the DOE builder are brought in from the Process Settings. To change values in the DOE builder, go to Process Settings and make the changes there.

Processing Condition variables	Comment
% Ram speed vs % Stroke profile	Min and Max values editable in the DOE Builder. X and Ymin=0, X and Ymax=100 depending on the values set in the Process Settings
Compression Settings profile	Min and Max values editable in the DOE Builder. X and Ymin=0, X and Ymax=100 depending on the values set in the Process Settings
Cooling time	
Curing temperature	
Curing time	
Filling control	
Automatic	
Fill time	
Flow rate	
Absolute ram speed profiles	
Relative ram speed profiles	Min and Max values editable in the DOE Builder. X and Ymin=0, X and Ymax=100 depending on the values set in the Process Settings
Reference	Could be flow rate or injection time, indicated by parameter name
Stroke volume, machine screw diameter	Only available if stroke volume is set to specified, NOT automatic
Stroke volume, starting ram position	Only available if stroke volume is set to specified, NOT automatic
Initial bubble radius	

Processing Condition variables	Comment
Initial encapsulant conversion	
Initial encapsulant temperature	
Initial gas concentration	
Injection+Packing+Cooling time	
Melt initial conversion	
Melt temperature	
Mold open time	
Mold surface temperature	
Nominal injection time	
Number of cells per volume	
Pack/holding control	
% Filling pressure vs. time	Profile, Min=0 for X and Y; Max=300 for X and 200 for Y
Packing pressure vs. time	Profile, Min=0 for X and Y; Max=300 for X and 500 for Y
Hydraulic pressure vs. time	Profile, Min=0 for X and Y; Max=300 for X and 50 for Y
% Maximum machine pressure vs. time	Profile, Min=0 for X and Y; Max=300 for X and 100 for Y
Press compression force cap	
Press compression speed vs. distance	
Press compression time	
Press open distance	
Press waiting time	
Substrate temperature	
Velocity/pressure switch-over by	
by % volume	
by injection pressure	

Processing Condition variables	Comment
by pressure at a control point	Node defined in base study, only field for pressure
pressure	
Velocity/pressure switch-over	
Automatic	Only available if NOT set to automatic in base study
by % volume filled	
by ram position	
by injection pressure	
by hydraulic pressure	
by clamp force	
by pressure control point	Node defined in base study, only field for pressure
by injection time	
Volume filled at start of foaming	

Boundary condition variables

Boundary conditions include those variables that define how the heat transfer conditions between the mold and the material are modelled. They include the coolant inlet and all the variables associated with the coolant, and the hot gate pressure controller.

Geometry variables

Geometry refers to those variables associated with the physical design of the part, such as thickness.

Geometry variables	Comment
Dimension scale factor	Each layer with beams or triangular elements is listed. All elements on a layer will have a delta change in thickness.

Dimension scale factor

If you want to see the effect of changing the thickness of various elements on warpage, for example, this can be achieved using the dimension scale factor.

The dimension scale factor provides you with a tool to see the effect of varying the thickness of various aspects of the part. This tool is only available for beam elements or triangular elements.

To use the dimension scale factor, all the elements of interest should be isolated on a single layer. Thus, for example, you could select all the beam elements of a particular cooling channel. All the beam and triangle layers in the layer pane will be listed in the **Select Layers** dialog of the **DOE Builder** for you to choose from. If you want to select only specific elements from an exisiting layer, then you will need to create a new layer and isolate those elements on the new layer. The new layer will then appear automatically in the **Select Layers** dialog.

NOTE: Dimension scale factor is not available for tetrahedral elements in 3D models.

Dimension scale factor

To use the dimension scale factor, the elements of interest must all be together on a unique layer.

If the elements you are interested in are not on a unique layer, then you should create a *new layer* and assign them to it.

Defining a new dimension scale factor

NOTE: Dimension scale factor is only available in the **Variables** tab of the **DOE Builder** for midplane and dual domain models.

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1. Click **(Home tab > Molding Process Setup > Optimization)** to open the **DOE Builder**.
2. Select the **Variables** tab and scroll to the bottom of the left-hand panel to see **Geometry Information**.
3. Click the check box associated with **Dimension scale factor**, to select it.
4. In the right-hand panel, double click the **Dimension scale factor** box to open the **Select Layers** dialog.
5. Select the layer that you are interested in analyzing, from the list, then click **OK**.
   Your selection will appear in the Dimension Scale factor box.
6. Edit the **Range by percentage**, if required.

NOTE: You can define additional dimension scale factors using the other layers listed in the **Select Layers** dialog.

NOTE: You can assign specific elements to *new layers* for further investigation.

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7 Click **New dimension variable**
A new Dimension scale factor entry is created with a check mark already entered.

8 Repeat steps 4-6 above, to define the Dimension scale factor according to your needs.

9 Click **Next** to move to the next tab, or **Finish** to close the **DOE Builder** and start the analysis.

Quality Criteria

7

Design of Experiment (DOE) enables you to see the effect of some intervention on part quality. Quality criteria are those indicators that define part quality, such as sink mark depth, part mass or cooling time.

The Quality Criteria listed in the **DOE Builder** are imported from the base study based on the analysis sequence chosen. When selected in the **DOE Builder**, these parameters appear in the **Optimization (DOE)** tree in the **Study tasks** pane. Only quality indicators created by the analysis sequence of the base study are shown in the tree. Quality indicators are related to the following results categories:

- Filling and Packing
- Cooling
- Shrinkage and warpage

The left hand panel lists the results or Quality Criteria that you would like to study. The right hand side describes what information the DOE analysis results will provide. Look at the **Analysis Log** at the end of the experiment to see the results, or the results section of the **Study Tasks** pane to see the plots.

When you click on a quality criterion in the left-hand panel, the right-hand panel updates with information specific to that criterion, including the goal of the analysis and type of calculation being performed. You can alter the weighting of the criterion; the higher the weighting the more important you consider that criterion to be with regards to part quality.

Weighting Weighting refers to the importance you place on the specific quality criterion. Assign it a higher number if it is more important to you for part quality than other criteria.

Goal Goal refers to the objective of the DOE analysis. For example, 'Minimize' for sink marks indicates that the goal of the analysis is to minimize the depth of the sink marks.

Calculate Calculate refers to the source of the values that will be used in the DOE analysis. For example,

- 'Maximum' for sink marks indicates that the deepest sink mark identified in the results will be optimized during the DOE analysis.
- 'From Logs' for cycle time indicates that the cycle time listed in the Analysis log file will be optimized during the DOE analysis.

- 'Standard deviation' for cooling time indicates that the standard deviation, or variation from average, of the cooling time identified in the results will be calculated during each DOE run or study. The x-axis plots the change in value, the y-axis plots the number of elements with each value and the z-axis plots the standard deviation for each study. The number of studies is listed in the Analysis log.

NOTE: The selection of Quality Criteria listed in the left hand panel will change depending upon the molding process, analysis sequence and process settings chosen.

Quality Criteria

The quality criteria that appear in the Quality Criteria tab are controlled by the molding process, analysis sequence and process settings that you select.

Selecting quality indicators

1. Click **(Home tab > Molding Process Setup panel > Optimization)** to open the **DOE Builder** dialog.
2. Select the **Quality Criteria** tab to see the list of possible criteria.

Quality Criteria

Design of Experiment (DOE) enables you to see the effect of some intervention on the quality of the part. Quality criteria are those indicators that define part quality, such as sink mark depth, part mass or cooling time.

DOE Builder - Quality Criteria tab

This tab is used to select which analysis results you would like to study within the constraints you have selected in the **Variables** tab of the DOE Builder.

Table 1: Fill+Pack

These criteria are available for all mesh types, except where otherwise noted.

Quality Criteria	Analysis Objective; to find conditions that
Fill+Pack	
Bulk temperature at end of fill	minimize the bulk temperature variation (Midplane and Dual Domain mesh types only).
Clamp force	minimize the clamp force required to keep the mold closed during filling.

Quality Criteria	Analysis Objective; to find conditions that
Injection pressure	minimize the pressure required by the ram to cause the material to flow, to 75% or less of the machine pressure limit when runners are included.
Shear stress	minimize shear stress, or friction, between layers of plasitc flowing in the cavity, which can cause the plastic to degrade and fail due to stress cracks (Midplane and Dual Domain mesh types only).
Sink mark depth	minimize the depth of sink mark likely to be caused by features on the opposite face of the surface.
Temperature at flow front	minimize the flow front temperature variation, which should not drop more than 2-5°C during the filling stage.
Cooling time	minimize the cooling time, and thereby minimize the time to reach ejection.
Volumetric shrinkage at ejection	minimize the variation in volumetric shrinkage across the part, and thereby reduce warpage.
Time at end of packing	minimize the time taken to reach the end of packing, to optimize the cycle time (Midplane and Dual Domain mesh types, only).
Part weight/ mass	minimize the part weight (excluding runners), and thereby reduce cycle time and production costs.
Cool and Cool (FEM)	minimize the
	The following criteria are only available for Co-injection molding processes and Midplane meshes.
Volume of polymer A	minimize the volume of polymer A, and thereby ensure that there is sufficient space left for core material.
Volume of polymer B	maximize the volume of polymer B, and thereby ensure that the part is completely filled.
Weight of polymer A	minimize the weight of polymer A, and thereby ensure that there is sufficient space left for core material.
Weight of polymer B	maximize the weight of polymer B, and thereby ensure that the part is completely filled.

Table 2: Cool and Cool (FEM)

These criteria are available for thermoplastic molding processes with all mesh types, except where otherwise noted.

Quality Criteria	Analysis Objective; to find conditions that
Average cavity surface temperature	minimize the average cavity surface temperature, to minimize the cycle time and optimize part quality (Cool (FEM) only).
Average mold surface temperature	minimize the temperature of the mold at the plastic/metal interface where plastic touches the mold, to optimize the cooling time.
Circuit pressure	minimize the circuit pressure, and thereby optimize the cooling system.
Circuit Reynolds number	minimize the variation in Reynolds number, and thereby optimize the coolant flow rate.
Part heat flux (top/bottom)	minimize the variation in heat flux across the mold/part interface, to minimize cycle time and warpage.
Percentage frozen layer	minimize the percentage of frozen layer (Cool (FEM) only), to minimize the potential for warpage.
Percentage molten layer	minimize the percentage of molten layer (Cool (FEM) only), to minimize the potential for warpage.
Circuit coolant temperature	minimize the variation in the coolant temperature from coolant in to coolant out, which should not exceed 2-3°C.
Circuit metal temperature	minimize the variation in the temperature of the metal cooling circuit over the cycle, which should not exceed 5°C above the inlet temperature.
Mold surface temperature (top/bottom)	minimize the variation in temperature of the mold at the plastic/metal interface, to minimize cooling and warpage problems.
Temperature difference, part	minimize the variation in temperature between the part top and bottom, which should not exceed 5°C (Midplane only).
Cooling time	minimize the variation in cooling time across the part, to optimize the cycle time.
Maximum part temperature	minimize the part temperature, to minimize cycle time and part warpage.
Cycle time	minimize the cycle time, and thereby maximize throughput and minimize costs.

Table 3: Warp

These criteria are available for all mesh types.

Quality Criteria	Analysis Objective; to find conditions that
Deflection, all effects	minimize variations in deflection, to minimize warpage.

Table 4: Stress

These criteria are available for thermoplastic molding processes with all mesh types, except where otherwise noted.

Quality Criteria	Analysis Objective; to find conditions that
Small deflection, stress	minimize variations in deflection, to minimize warpage.
Large deflection, stress	minimize variations in deflection to minimize warpage.
Maximum shear stress	minimize variations in shear stress between layers of plastic flowing in the cavity, which can cause the plastic to degrade and fail due to stress cracks.
Mises-Hencky stress	minimize variations in the Mises-Hencky stress, which can cause the plastic to degrade and fail due to stress cracks.

Table 5: Shrink

These criteria are available for thermoplastic molding processes with Midplane and Dual Domain mesh types.

Quality Criteria	Analysis Objective; to find conditions that
Linear shrinkage	minimize variations in linear shrinkage.
Error in linear shrinkage	minimize variations in linear shrinkage.

Table 6: Overmolding

These criteria are available for overmolding molding processes.

Quality Criteria	Comments
2nd shot, Bulk temp at end of fill	Midplane and Dual Domain only
2nd shot, Clamp force	
2nd shot, Injection pressure	

Quality Criteria	Comments
2nd shot, Shear stress	Midplane and Dual Domain only
2nd shot, Temp at flow front	
2nd shot, Cooling time	
2nd shot, Vol shrinkage at ejection	
2nd shot, Time at end of packing	Midplane and Dual Domain only
2nd shot, Cycle time	3D only
2nd shot, Part mass/weight	

Table 7: Microchip Encapsulation

These criteria are only available for Microchip Encapsulation molding processes.

Quality Criteria	Comments
Paddle displacement	3D only
Von Mises stress	3D only
Wire sweep	Midplane and Dual Domain only
First principal stress, wire	Midplane and Dual Domain only
Wire shear stress	Midplane and Dual Domain only
Mises-Hencky stress, wire	Midplane and Dual Domain only
Wire sweep index	Midplane and Dual Domain only
In-plane wire sweep	Midplane and Dual Domain only
Paddle shift	Midplane and Dual Domain only
First principal stress, paddle	Midplane and Dual Domain only

Quality Criteria	Comments
Paddle shear stress	Midplane and Dual Domain only
Mises-Hencky stress, paddle	Midplane and Dual Domain only

Customized quality criteria

If you are running a warp analysis, you can create your own customized warp quality criteria.

Customized quality criteria

Before you attempt to select a customized criterion, you should set up the relevant parameters.

Creating a customized warp quality criterion

If you are running an analysis sequence that includes warp, you have the option to create your own custom warp quality criterion.

NOTE: You cannot create a customized warp criterion until you have created a node list or critical dimension to analyze. It is not necessary to specify an anchor plane, because what is used in the study is applied by default.

1 Click **(Home tab > Molding Process Setup panel > Optimization)** to open the **DOE Builder** dialog.

2 Select the **Quality Criteria** tab and scroll down the list to the **Warp** selection.

3 Click **New Warp Criterion** to open the **Deflection Criterion Type** dialog.

4 Select the type of criterion you would like to use to monitor warpage, then click **OK**.

5 If you have selected **Critical Dimension**,

  a on the right-hand side of the **Quality Criteria** tab in the **DOE Builder**, double-click the **Critical Dimension** box to open the **Select a critical dimension** dialog.

  b Select the critical dimension you are interested in from the list you have created, then click **OK**.

6 If you have selected **Node List**,

  a on the right-hand side of the **Quality Criteria** tab in the **DOE Builder**, double-click the **Node List** box to open the **Select a node list** dialog.

  NOTE: If you have created an anchor plane to use, double-click the **Anchor plane** box to select it.

b Select the node list you are interested in from the list you have created, then click **OK**.

7 Click **Next** to move to the next tab of the **DOE Builder**, or **Finish** to close it.

Creating a critical dimension

A *critical dimension* is a specific part dimension, which must meet the defined tolerances. In Autodesk Moldflow Insight, a critical dimension is defined by two points, and can be used in a DOE analysis to study warpage.

1 Click **(Boundary Conditions tab > Dimensions panel > Critical Dimensions)** and select **Design of Experiment** from the drop-down menu.
2 In the **DOE Critical Dimensions** dialog, type the ID of a node that defines one end of the critical dimension. Alternatively, click on the node on your model and the ID will be placed in the Node 1 box automatically.
3 Repeat the process for the second node.
4 Type a name in the **Name** box that is unique to this study.
5 Click **Close** to close the dialog.
6 Click **Finish Boundary Conditions** to close the **Boundary Conditions** tab.

Creating a node list

A node list is a selection of nodes that define a specific area of the part. Create a node list to define a section of the part of particular interest to you, with regards to its warpage.

1 Deselect any results that you may be looking at, and make sure that your nodes layer is selected in the **Layers** pane.
2 Click **(View tab > Navigate panel > Select)** to activate the **Select Tool**, and select all the nodes that define your area of interest.
3 Click **(Mesh tab > Selection panel > Save Selection)** , type a name for your node list and click **OK**.

   Notice that all the nodes are listed in the Selection panel.

   The node list has been created and is now available for selection in the DOE Builder.

Creating an anchor plane

Before you can create an anchor plane, you must have run a warp analysis. You will need a result from which to define an anchor plane.

An *anchor plane* is a reference plane against which to measure warpage.

1 Goto your warpage results in the **Study Tasks** pane and select a warpage result.
2 Click **(Results tab > Warpage panel > Visualize)** to open the **Warpage Visualization Tools** dialog.
3 Select **Anchors** from the list of visible options.
4 If you do not know the identity of the nodes to create an anchor plane, click on your model and select three nodes to define your anchor plane. A visual representation of the three nodes will appear on your model as you select them.
5 If you do know the identity of the nodes you would like to use to define the anchor plane, type them in to the **Anchor nodes** box, and click **Apply** after each one.
A visual representation of the three nodes will appear on your model as you select them.
6 Type a name in the **Anchor name** box to ensure that you can recall the purpose of this anchor plane.
7 Click **Close** when you have defined all three nodes.