Autodesk® Moldflow® Insight 2012

AMI Reactive Molding Processes

Autodesk®

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Reactive Molding processes, also called thermoset molding processes, use thermoset materials.

Thermosets, unlike thermoplastics, are characterized by the following:

- A chemical reaction during the molding process
- Cross-linked polymer structure
- Simultaneous polymerization and shaping during the molding process.

Processes

The Reactive Molding processes include the following:

- Reaction Injection Molding (RIM)
- Structural Reaction Injection Molding (SRIM)
- Resin Transfer Molding (RTM)
- Multiple-barrel reactive molding (RIM-MBI)
- Thermoset injection molding
- Rubber injection molding
- Microchip Encapsulation
- Underfill Encapsulation

Advantages

The Reactive Molding analysis offers the following advantages:

- Thermosets' cross-linked polymer structure generally imparts improved mechanical properties and greater heat and environmental resistance.
- Thermosets' typically low viscosity permits large and complex parts to be molded with relatively lower pressure and clamp force than required for thermoplastics molding.
- Thermosets can be used in composite processes. For example, RTM and SRIM processes, which use a preform made of long fibers, offer a way to make high-strength, low-volume, large parts. Fillers and reinforcing materials can enhance shrinkage control, chemical and shock resistance, electrical and thermal insulation, and/or reduce cost.

Reactive Molding analysis types and analysis technologies

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The following table shows the available analysis technologies for a Reactive Molding analysis type.

Table 1: Reactive Molding process and analysis types

Analysis Type	Analysis Technology
Fill+Pack	
Warp[1]	
Runner Balance	
Venting (Process Settings option)	

Reactive Molding analysis types and analysis technologies

There are a number of steps required to set up a reactive molding analysis.

Setting up a Reactive Molding analysis

The following table summarizes the setup tasks required to prepare a Reactive Molding analysis. Reactive Molding analyses include the following: Reaction Injection Molding (RIM) analysis, Structural Reaction Injection Molding (SRIM) analysis, Resin Transfer Molding (RTM), or Multiple-barrel Reactive Molding (RIM-MBI) analyses.

Setup task	Analysis technology
Meshing the model	
Checking the mesh before analysis	
Molding processes	

[1] To complete a Warp analysis for Midplane or Dual Domain analysis technology, you must select an analysis sequence that includes the Compressible solver.

Setup task	Analysis technology
Analysis sequence[2]	
Selecting a material[3] [4]	
Injection locations	
Multiple-barrel Reactive Molding analysis types and analysis technologies[5]	
RTM/SRIM analysis types and analysis technologies[6]	
Process settings	

Optional setup tasks

Setup task	Analysis technology
Occurrence numbers	
Runner balance constraints[7]	
Clamp force	
Gravity direction	
Valve gates	
Setting venting analysis locations	

Reactive Molding analysis types and analysis technologies

Use this dialog to specify settings for a Reactive Molding analysis.

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[2] To complete a Warp analysis for Midplane or Dual Domain analysis technology, you must select an analysis sequence that includes the Compressible solver.

[3] A reactive (thermoset) material is required for these analyses.

[4] To complete a Warp analysis for Midplane or Dual Domain analysis technology, you must select a material that includes pvT properties data.

[5] Multiple injection barrel locations are required for a RIM-MBI analysis only.

[6] A preform surface is required for a RTM/SRIM analysis only.

[7] Only for Runner Balance analyses.

Process Settings Wizard dialog—RIM Settings

This page of the **Process Settings Wizard**, which can be accessed by clicking  (**Home tab > Molding Process Setup panel > Process Settings**), is used to specify the Reactive Molding related process settings for the selected analysis sequence.

NOTE: Some of the items listed below may not be available on the current dialog. This is dependent on the mesh type, molding process and analysis sequence selected.

Mold surface temperature	The temperature of the mold at the plastic-metal interface, where the plastic touches the mold.
Melt temperature	The temperature of the molten plastic, or melt, as it starts to flow into the cavity.
Nominal injection time	Enter the injection time that you would use with the injection unit for the process.
Melt initial conversion	Enter a value between -1 and 1 to specify the initial conversion (curing) level at the injection location.
Curing time	The time taken for a thermoset material to become sufficiently cross-linked from heating to form a solid and freeze.
Machine pressure limit	The maximum allowable hydraulic pressure that can be used on the injection molding machine.
Intensification ratio	The ratio of the material pressure in front of the screw, compared to the oil pressure in the piston of the injection molding machine.
Preconditioning analysis	Specifies whether a preconditioning analysis should be performed.
Filling control	Specifies the method by which the filling phase of the analysis is controlled.
Velocity/pressure switch-over	The criteria by which the molding machine will switch from velocity control to pressure control.
Pack/holding control	Specifies the method by which the pressure phase of the molding process is controlled.

Process Settings Wizard dialog—RIM-MIB Settings

This page of the **Process Settings Wizard**, which can be accessed by clicking  (**Home tab > Molding Process Setup panel > Process Settings**), is used to specify the multiple-injection barrel Reactive Molding related process settings for the selected analysis sequence.

NOTE: Some of the items listed below may not be available on the current dialog. This is dependent on the mesh type, molding process and analysis sequence selected.

Mold surface temperature	The temperature of the mold at the plastic-metal interface, where the plastic touches the mold.
Melt temperature	The temperature of the molten plastic, or melt, as it starts to flow into the cavity.
Nominal injection time	Enter the injection time that you would use with the injection unit for the process.
Melt initial conversion	Enter a value between -1 and 1 to specify the initial conversion (curing) level at the injection location.
Machine pressure limit	The maximum allowable hydraulic pressure that can be used on the injection molding machine.
Intensification ratio	The ratio of the material pressure in front of the screw, compared to the oil pressure in the piston of the injection molding machine.
Preconditioning analysis	Specifies whether a preconditioning analysis should be performed.

Reactive Molding Advanced Options dialog

This dialog is used to specify the Reactive Molding analysis related advanced options for the selected analysis sequence.

To access this dialog, ensure that you have selected one of the Reactive Molding processes and an analysis sequence that includes, at a minimum, Fill. For **Reactive Injection-Compression Molding**, this is the only option.

For **Reactive Molding** this includes **Flow (Incompressible)**. Click  (**Home tab > Molding Process Setup panel > Process Settings**), and click **Advanced options** to open the **Reactive Molding Advanced Options** dialog. You may need to navigate to the next page of the Wizard to find the **Advanced options** button.

NOTE: Some of the links below may not be available on this dialog. This is dependent on the mesh type, molding process, and analysis sequence.

Molding material	Select and edit the material to analyze.
Process controller	Allows you to select and edit a process controller to control the injection molding process during the analysis. You can control the filling phase, velocity/pressure switch-over point, pack/holding phase, mold temperature and mold-open time.
Compression press controller	Allows you to select and/or edit a predefined compression press controller to be used for the Injection-compression analysis.
Injection molding machine	Select and edit an injection molding machine to simulate your molding machine during the analysis. You can configure the injection unit, hydraulic unit, and clamping unit.
Mold material	Allows you to select and edit the mold material to be used during the analysis. You can specify the density, specific heat, and thermal conductivity of the mold material.
Solver parameters	Allows you to select and edit the solver parameters to be used during the analysis.

Reactive Molding analysis 3

Reactive Molding provides useful information to detect various molding problems and to optimize part, mold, and process design in an efficient and cost-effective way.

Reactive Molding can be applied to various processes that use reactive (thermoset) materials, including Reaction Injection Molding (RIM), Structural Reaction Injection Molding (SRIM), Resin Transfer Molding for fiber reinforced plastic (RTM), thermoset injection molding, rubber compound injection molding, Microchip Encapsulation and Underfill Encapsulation.

Reactive Molding analyses help to predict how the mold will fill with or without the presence of fiber reinforced pre-forms, avoid short shots due to pre-gelation of the resin, highlight potential air trap or weld line problems, balance runner systems, select the proper molding machine size, and evaluate different reactive resins. The Reactive Molding analyses are integrated with the Autodesk material database, which offers more than 50 grades of lab-tested reactive molding materials.

Specifically, Autodesk Moldflow Insight's Reactive Molding analyses can:

- Predict the melt front pattern to aid in part design and gate placement to optimize cavity filling for most reactive processes.
- Calculate the conversion (extent of cure) versus time at any location within the mold during filling and post-filling.
- Determine injection pressure and clamp force requirements for proper molding machine selection.
- Display injection pressure at any point within the cavity at any time during the filling stage.
- Graphically display the temperature change as a result of the reaction kinetics inside the mold at any point in time.
- Detect short shots due to pre-gelation conditions.
- Accurately identify weld (knit) lines based on part design and gate placement.
- Accurately identify air traps for proper mold venting.
- For RTM and SRIM analyses: allow users to define multiple anisotropic fiber mats with different orientations in the cavity.
- For Reactive Molding and Microchip Encapsulation analyses, predict part warpage.[8]

[8] To complete a Warp analysis for Midplane or Dual Domain analysis technology, you must select an analysis sequence that includes the Compressible solver.

Reactive Molding analysis process

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Thermosets are usually purchased as liquid monomer-polymer mixtures or as a partially polymerized molding compound. Starting from this uncured condition, they can be formed to the final shape in the cavity by polymerization. The polymerization is activated either by heat or by chemical mixing, with or without pressure.

In the Reactive Molding process, the temperature in the feed mechanism (the barrel) is only slightly increased, however, the cavity is usually hot enough to initiate chemical cross-linking. As the warm pre-polymer is forced into the cavity, heat is added from the cavity wall, from viscous (shear) heating of the flow, and from the heat released by the reacting components. The temperature of the part often exceeds the temperature of the mold. When the reaction is sufficiently advanced for the part to be rigid (even at a high temperature), the cycle is complete and the part is ejected.

Molding problems

The chemical reactions that occur during filling and curing add complexity to mold and process design for Reactive Molding processes. For example, slow filling may cause premature gelling, resulting in a short shot. Fast filling may induce turbulent flow, creating internal porosity. Improper control of the mold-wall temperature and/or inadequate part thickness will result in either moldability problems or scorching of the materials.

Reactive Molding analyses can help you avoid such problems, without costly and time-consuming trial and error debugging.

Reactive Molding analysis process

These dialogs are used to edit process settings for reactive molding processes.

To access these dialogs, click **Tools tab > Databases panel > New**, and select **Process Conditions** from the **Category** drop-down list. Scroll down the list of options in the **Property type** window and select **Reactive molding process settings**.

Reactive molding process settings defaults dialog—Profile/Switch-Over Control tab

The **Profile/Switch-Over Control** tab of the **Reactive molding process settings defaults** dialog is used to specify default values for injection unit-related inputs to analyses of reactive molding processes.

NOTE: The values used for the current analysis sequence may be changed by entering the desired values on the Process Settings Wizard for the selected molding process.

Filling control	Specifies the method by which the filling phase of the analysis is controlled.
Velocity/pressure switch-over	Specifies the criteria by which the molding machine will switch from velocity control to pressure control.
Pack/holding control	Specifies the method by which the pressure phase of the molding process is controlled.

Reactive molding process settings defaults dialog—Filling Phase tab

The **Filling Phase** tab of the **Reactive molding process settings defaults** dialog is used to specify default values for the filling phase-related inputs to analyses of reactive molding processes.

NOTE: The values used for the current analysis sequence may be changed by entering the desired values on the Process Settings Wizard for the selected molding process.

Nominal injection time	Specifies a nominal injection time for the process.
Mold surface temperature	Specifies the temperature of the mold where the plastic touches the mold, or the plastic-metal interface.
Melt temperature	Specifies the temperature of the molten plastic, or melt, as it starts to flow into the cavity.

Reactive Molding process settings defaults dialog—Curing Phase tab

The **Curing Phase** tab of the **Reactive molding process settings defaults** dialog is used to specify default values for the curing phase-related inputs to analyses of reactive molding processes.

NOTE: The values used for the current analysis sequence may be changed by entering the desired values on the Process Settings Wizard for the selected molding process.

Melt initial conversion	Specifies the initial conversion (curing) level at the injection location.

Curing time	The time taken for a thermoset material to become sufficiently cross-linked from heating to form a solid and freeze.
%Air Mass	The percentage air mass value is used to simulate the effect of air in the molding compound on the polymer flow.

Reactive Molding analysis technical information

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This topic lists some useful technical details related to a Reactive Molding analysis.

- Mold filling is modeled by a generalized Hele-Shaw flow model for areas without reinforcement and by Darcy's Law for areas with fiber mat reinforcement.
- The numerical solution is based on a hybrid finite-element/finite-difference method for solving pressure, flow, and temperature, and a control-volume method to track moving melt fronts.
- Material viscosity is calculated as a function of temperature, conversion (extent of cure) and shear rate.
- The effect of induction time is included in flow calculations for rubbers and polyester resins.
- Special numerical methods are used to track the curing history of material at the melt front (fountain region).
- Curing kinetics are included in the calculations of both flow dynamics and temperature.

Material characteristics required by Reactive Molding analyses

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It is important to consider material characteristics when selecting a thermoset material grade.

Material data used in Reactive Molding analyses include the following:

- Melt temperature and recommended range.
- Mold temperature and recommended range.
- Ejection conversion—the lowest conversion value (degree of cure) at which a part can be ejected from the mold without causing defects.
- Reactive viscosity—calculated as a function of temperature, shear rate, and conversion (extent of cure).
- Gelation conversion—the level of conversion at which the resin stops flowing. It is also coupled with the reactive polymer viscosity models to determine the instant when viscosity becomes infinite.
- Melt density.
- Solid density.
- Specific heat.
- Thermal conductivity.
- N-th order kinetics with induction time—the reaction in the resin is described by the curing kinetics model during the conversion period and by the induction model during the induction period. Many fast-curing resins, such as epoxy or polyurethane, do not exhibit an induction period. This model is a general form and has been applied to various reactive resins.

The definition of conversion (degree of cure) is extended to include the induction period, if one exists. Under this model, conversion is described by a numerical value between 0 and 1, as indicated below:

Conversion value	Means
0	At the beginning of the reaction or induction period
0 < conversion < 1	During the induction or reaction (conversion) period
1	At the end of reaction (conversion)

If filler material is used, the following data must be specified:

- Density.
- Specific heat.
- Thermal conductivity.
- Mechanical data.

- Coefficient of thermal expansion (CTE) data.
- Tensile strength data.
- Aspect ratio.