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INJECTION MOLDING PROCESSES
PTC Creo Mold Analysis (CMA) is an injection molding simulation application that focuses on the filling process.
INJECTION MOLDING PROCESSES

The melt passes through different thickness areas.

1. Hesitation
2. Race track phenomenon
3. Air-trap
4. Flow mark
5. Unbalanced flow pattern
INTRODUCTION TO CREO MOLD ANALYSIS
Process Wide Mold Filling Simulation – Creo Mold Analysis
CMA WORK FLOW

- Startup CMA
- Assign material
- Gate setup
- Analysis setup
- Run analysis
- Review result advisor
- Check analysis results
- Create report
- Save and retrieve data
Run Creo

Open a *prt file
Launch Creo Mold Analysis

Click “Cold Analysis”

The “Mold Analysis” tab will come out
Choose Material (Ex: ABS, ASAHI, STYLAC VA29)
1. Select “Gate Setup”  
2. Select ”Add” and then click a melt entrance position
3. Enter the gate diameter

4. Users can add new gate, edit and delete existing gate
Select “Analysis setup” to set the process condition and mesh level

**Filling time (sec.)**
Filling time here is defined as the time required to fully fill the cavity with “incompressible” material. Based on cavity volume (part volume + cold runner volume) and filling time, a given volumetric flow rate is forwarded to Moldex3D Flow solver.

**Melt Temperature (℃)**
Melt temperature is the temperature of the plastic melt at the melt inlet of the model.

**Mold Temperature (℃)**
Mold temperature is applied to the temperature boundary condition between mold base and part. CMA assumes that the boundary temperature distribution is uniform.
Select “Analysis setup” to set the process condition and mesh level

If users calculate the max cooling time and sink mark, the packing analysis would be added into analysis process.
Select “Analysis setup” to set the process condition and mesh level.

Move slider can select from “Coarse” to “Fine” for different mesh levels.

- The lower level means the fewer elements, which speeds up the computation.
- The higher level means the more elements, which contributes to more accurate computation result.
When all settings are done. 
Click **Run Analysis** will launch analysis.
Click “Select Analysis” and choose the run

Melt front time is the default frame
Click “Results Advisor” to find the problem the model may have.

Air trap
Air traps found inside the cavity. This may cause voids or surface defect.

Degradation
The resultant melt temperature is more than the maximum working temperature of the material.

Hesitation
The flow speed is too low in some regions in the cavity causing flow hesitation. In extreme cases, flow hesitation may lead to hesitation mark on the model surface or even short shot.

Unbalanced gate contribution
The melt contribution for each gate is unbalanced.

Weld line
Sharp welding angles found at some places. Weld lines may become visible.

Short shot
Model is incompletely filled at the end of filling. Short shot may occur.
Click “Results Advisor” to find the problem the model may have.

Click the issues, the screen will show the corresponding result.
The screen can show the analysis result and x-y plot at the same time.
Choose the analysis result and click “View Control”

**Clipping Function**
To clip the present model to view result inside.

**Slicing**
Show single/multiple slicing plane.

**Parameters**
To define a clipping plane by entering the equation of the plane.
Choose the analysis result and click “View Control”

**Isosurface**
Show Isosurface on the model. The values of every point on the isosurface are the same.

**Parameters**
Define the value to display
Choose the analysis result and click “View Control”

Switch the Tab to “Legend” to the display limit of the legend
Click ”Generate Report” to generate power point report.
• Click “Save Project” to save CMA data as *.xedz file.
• To check the previously analyzed result, click “Retrieve Project” and load the *.xedz file that keeps the CMA data.
CASE STUDY - CELL PHONE HOUSING
CASE STUDY - CELL PHONE HOUSING

Product Information

• Dimension
  – Length: 127 mm
  – Width: 50 mm
  – Height: 5 mm
  – Average Thickness: 0.7 mm

• Materials
  – PP \ Advanced Composites \ ATX-880N-1

• Processing Conditions
  – Filling time: 0.54 Sec
  – Melt temperature: 210°C
  – Mold temperature: 50°C
Original Design – Two Gates located on the ends of the product

- Potential Problems
  - Air Trap
  - Degradation
  - Unbalanced flow
  - Welding line
Welding Line

- **Length/Thickness Ratio**
  - The maximum L/T ratio reaches to 153.54

The welding lines are aligned, forming a long weak line on the center.
POTENTIAL PROBLEMS

Sprue pressure

- Unbalanced flow
  - There is a 13% difference between the contributions of each gate

The maximum sprue pressure reaches to 76.78 MPa
REVISED DESIGN – THREE GATES

Gates
• **Length/Thickness Ratio**
  – The maximum L/T ratio has been reduced from 153.54 to 63.487
• Unbalanced flow
  – The gate contributions are even in the revised design
• Sprue pressure
  – The maximum sprue pressure decreased by 29 MP in revised design
**IMPROVEMENTS – WELD LINE**

- **Weld Line**
  - The number and length of weld lines decreased
  - The weld line aren’t aligned
MOLDEX3D PRODUCT PORTFOLIO
MOLDEX3D PRODUCT STRUCTURE

Structure and Market Position

- **Solution Add-on**
- **Advanced**
- **Professional**
- **eDesign**
- **eDesign Basic**

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**eDesignSYNC**

- **Creo**

**CMA**

- **Creo**

**eDesign Basic**
01 Flow
Everything starts from filling analysis

02 Pack
Shrinkage compensation, minimize warpage effect

03 Cool
Efficient mold temperature management

04 Warp
Minimize part deformation for design accuracy

MCM
Precise multi-component molding analysis

Fiber
Predict fiber length and orientation to obtain optimal designs and process conditions

High Performance Computing (HPC)
Enable parallel computing and cluster speed up the analysis process
APPENDIX - A
Indicators provide information and suggestions to optimize the analysis results:
- Automatic Gate Creation (Gate Location Indicator)
- Cooling Time Indicator
- L/t Indicator

Detail instruction will be shown in the following pages.
AUTOMATIC GATE CREATION

- Number of gates – The gate counts
- Gate Direction – mold open direction (+/- X,Y,Z)
- Gate diameter – The diameter of gates (All the gates are the same)
- Click “Calculate” will calculate proper gates location.
- After calculation click “Apply” can add gate automatically
L/T INDICATOR

- Flow Length / Thickness Ratio
- Legend Range Setting – slider can change Min. and Max. scale bar
• Legend Range Setting – slider can change Min. and Max. scale bar
• Material Information – info of material
  – Density (g/cm^3)
  – Melt Temperature (°C)
  – Mold Temperature (°C)
  – Eject Temperature (°C)
  – Heat Capacity (erg/g.K)
  – Thermal Conductivity (erg/sec.cm.K)
APPENDIX – B
RESULT INTERPRETATIONS
• Melt front is a position indicator as melt front boundary movement in different time duration in the filling process.

• From the melt front advancement one can:
  – Examine the filling pattern of the molding
  – Check potential incomplete filling (short shot) problem
  – Identify weld line locations
  – Identify air trap locations
  – Check gate contribution for runner balance
  – Check proper gate location to balance flow and eliminate weldline.
• Air Trap result shows the possible locations that air trap could have occurred.

• Weld Line result shows the weld lines that indicate potential spots of weaker structure. The darker the weld line, the weaker the structure.
- Sink Mark Indicator is the index to evaluate the packing effect.
- Positive value indicates that the packing is not enough, which it may lead to sink mark. Negative value indicates over-packing.
- An optimized packing result will have sink mark indicator close to zero.
Moldability result shows the ease of fill.
Pressure distribution of the cavity is shown in different colors at current instant. Based on the pressure drop and distribution, users can revise the part and mold design.

From the pressure distribution one can:
- Check the pressure transmission situation
- Check runner system pressure drop
- Check flow balance of the design
- Avoid overpacking and flashing of melt
- Examine the extent of packing/holding.
• Plastic melt temperature distribution at current instant.

• For 3D calculation, the temperature distribution expresses temperatures in all three dimensional for the entire cavity.
• Center temperature result shows the center melt temperature in the thickness direction at current time step.

• The center temperature is calculated by interpolating from the temperature values of the nodes that forms the element at the center of the path along the thickness direction.
• Bulk temperature is the velocity-weighted average melt temperature in the thickness direction at current time step.

• In general, bulk temperature distribution can reflect the trend of flow path and therefore the actual path of pressure transmission.
• This result shows the recorded peak value of shear stress of each element during the filling stage. Note that the maximum shear stress values shown in this result are not necessarily in the same time step.

• You can use this result to determine if the maximum shear stress in the finished part will exceed the maximum allowed shear stress.
• This result shows the recorded peak value of shear rate of each element during the filling stage. Note that the maximum shear rate values shown in this result are not necessarily in the same time step.

• Shear rate is the rate of shear deformation of the material during the polymer processing. Shear rate distribution is related to the variation of velocity gradient and molecular orientation. High shear rate tends to drastically deform molecular chains even to break and then weaken the strength of product. Viscous heating due to high shear rate also should be noticed.
Frozen Layer Ratio result shows the volume percentage of frozen plastic with respect to part thickness at current time step. This value will reach 100% as time passes by.

The picture and the equation below explain how frozen layer ratio is calculated.

Where \( t_A \) is the thickness of the upper frozen layer, \( t_B \) is the thickness of the lower frozen layer, and \( t \) is the thickness of the cavity.
• Max. Volume Shrinkage shows the maximum volumetric shrinkage across the part thickness at current time step.

• If this result shows locally high positive value, sink mark or void may appear on the finished part depends on the thickness of frozen layer.
• Velocity Vector result shows the velocity vector of plastic melt at current time step.
VOLUMETRIC SHRINKAGE

- Volumetric shrinkage shows the percentage of part volume change due to PVT change as the part is cooled from high temperature, high pressure conditions at current instant to room temperature, ambient pressure conditions.

- Positive value represents volume shrinkage while negative value represents volume expansion due to over-packing.

- Non-uniform volumetric shrinkage will lead to warpage and distortion of molded parts.
• Gate Contribution result shows the contribution to the volume of injected melt for each gate at current time step.

• Note that the result values are shown in percentage.

• Normally a balanced gate contribution is required for obtaining optimized results.
Material Orientation result shows the flow direction of plastic melt at current time step.
• This result shows the plot of sprue pressure versus filling time.

• You can use this result to look for any unusual sprue pressure rise during filling.

• Often the sprue pressure will not exceed the maximum allowed injection pressure that is set in the process condition. If the resulting sprue pressure curve stays at the maximum allowed injection pressure, hesitation or even short shot might occur.
• This result shows the plot of clamping force versus filling time.

• Note that this value is the calculated required clamping force; it is not the force that molding machine outputs.

• You can use this result to identify possible flash problem. From past experience, if the calculated clamping force is larger than 70% of machine maximum clamping force, there is a good chance that plastic melt will be squeezed outside the cavity and cause flash.
This result shows the plot of flow rate at the sprue versus filling time.

In most cases, the first stage of filling is controlled by the flow rate set by the machine operator. Therefore in this result, the flow rate usually stays at the value set in the process condition of Moldex3D. If the resulting flow rate appears otherwise, you need to check if the maximum allowed injection pressure is too low.