Plastic Injection Molding Using ANSYS

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• Introduction
• Issue
• Assumption
• Approach
• Simulation Results
• Conclusions and Future Work
Aurora Optical Inc. Introduction
“A Quality Picture Worth a Thousand Words”

AO produces a wide range of camera modules, including FPC or socket based, Ultrathin, Macro, and Auto-Focus - custom module design is our business!

Camera Module Applications:
- Personal Security Systems
- Embedded PC Cameras
- Mobile Phones
- VoIP Phone Systems
- Wireless Devices
- Consumer Electronics
- Medical Applications
- Automotive Optical Systems
PADT Intro -
“We Bring Dimension to Your Ideas”

• PADT is an Engineering Services Company
  – Mechanical Engineering
  • Design
  • Simulation
  • Manufacturing
A plastic part has larger shrinkage rate than steel parts during manufacturing. This is a major issue for our precision plastic parts.

An example of a plastic part with shrinkage over 7~10 µm during cooling
Factors

Plastic Part Shrinkage varies depending on:

- Geometries
- Material Properties
- Process Parameters
Plastic injection molding process simulation provides:

• Shrinkage prediction for tooling compensations to produce parts with best precision

• Information for optimization, which can produce parts with minimum shrinkage and shortest cycle time
The simulation models a completed plastic injection molding cycle:

Temperature/pressure vs. Time during a cycle

- Green line: Packing Pressure (Given)
- Red dashed line: Gate Temperature (Given)
- Blue line: Part Pressure
- Red line: Part Temperature
Approach

Plastic Injection Molding Simulation

- Resin Material Properties
- Plastic Injection Molding Process Parameters

3D Model

- Solid Material Properties
- Boundary Conditions

Workbench

CFX-Mesh

CFX

T(x,y,z,t)
CFX Convection Load

P(x,y,z,t)
Volume Fraction (t)

Thermal Transient Analysis

T(x,y,z,t)

Static Analysis

Delta x, y, z

Shrinkage Profile

Multiphysics
Assumptions

• Polymers:
  1. Amorphous
  2. Non-fiber reinforced

• Known Input:
  1. Process parameters
  2. Gate temperature vs. time measurement data
  3. Material properties
Five stages at PVT diagram:

- Injection phase: A-B
- Packing/Holding phase: B-C
- Gate Freeze-off and in-mold cooling phase: C-D
- Ejection parts: D
- Outside mold cooling phase: D-E
Injection Phase

CFX Simulation Results:

- Injection flow
- Temperature
- Pressure
Packing/Holding Phase

CFX Simulation Results:

• Volume Fraction

• Temperature

• Pressure
Gate Freeze Phase

CFX Simulation Results:

- Temperature
- Pressure
Transient Results of the In-mold (Cured) Cycle

- Transient Temperature at the part center
- Transient Pressure at the part center
Cooling after Ejection

Thermal transient analysis shrinkage results
Shrinkage Data in Multiphysics

The shrinkage data are exported to Excel for shrinkage contour plots.
ANSYS results vs. Measurement Results

Shrinkage Predicted by ANSYS

Measured Shrinkage*

* The data were provided by Process Engineer Rick Culler
An Example of a Finished part using ANSYS Shrinkage Compensation

Dimension Deviation $\text{actual-nonimal} < 1\mu m$ !

Measurement data after tooling compensation predicted by ANSYS*

* The data were provided by Process Engineer Rick Culler
Process Optimization

- ANSYS Design Explorer
  Six-Sigma tools
- Design of Experiments performed to optimize mold temperature, deformation, stress
Design for Six-Sigma

Input Parameters
- Inlet temperature
- Mold wall convective film coefficient
Output Parameters
- Temperature
- Directional deformation
- Von Mises Stress
## Design Points – 3X3 DOE

### Design Point 1
- **Input Parameters**: The input parameter values listed below were chosen programmatically to construct an accurate response surface set. All parameter ratings were determined with respect to the current goals.
- **Hard Response Parameters**: The response parameter values listed below were generated by an analysis solution.

<table>
<thead>
<tr>
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<tr>
<td>Temperature Magnitude</td>
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### Design Point 2
- **Input Parameters**: The input parameter values listed below were chosen programmatically to construct an accurate response surface set. All parameter ratings were determined with respect to the current goals.
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### Design Point 3
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- **Hard Response Parameters**: The response parameter values listed below were generated by an analysis solution.

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### Design Point 4
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### Design Point 5
- **Input Parameters**: The input parameter values listed below were chosen programmatically to construct an accurate response surface set. All parameter ratings were determined with respect to the current goals.
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### Design Point 6
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### Design Point 7
- **Input Parameters**: The input parameter values listed below were chosen programmatically to construct an accurate response surface set. All parameter ratings were determined with respect to the current goals.
- **Hard Response Parameters**: The response parameter values listed below were generated by an analysis solution.

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### Design Point 8
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### Design Point 9
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<td>Contraction Film Coefficient</td>
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**Parameters varied – block factorial design, in order to characterize the design space**
Response Charts – Design Space

Response Parameters
- Maximum deformation
- Maximum Von Mises stress
### Min/Max Search Results*

#### Output Parameter Minimums

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<tr>
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<th>Temperature Maximum</th>
<th>Directional Deformation Maximum</th>
<th>Equivalent Stress Maximum</th>
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<td>Magnitude</td>
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<td>Coefficient</td>
<td>1.0958e-005</td>
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<td>9.0185e-006</td>
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#### Output Parameter Maximums

<table>
<thead>
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<th>Temperature Maximum</th>
<th>Directional Deformation Maximum</th>
<th>Equivalent Stress Maximum</th>
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<tr>
<td>Maximum</td>
<td>207.35</td>
<td>3.3603e-005</td>
<td>61.635</td>
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<tr>
<td>Magnitude</td>
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DFSS Study – Summary

- Parameters varied were mold inlet temperature, mold to Lexan convective film coefficient for cooling.
- Design of Experiments performed to examine effect of these parameters on cooled solid part deformation, maximum stress.
- Results show for inlet temperature = 240F (design point)
  \[ h_f = 5.895 \text{ Btu/hr-ft}^2\text{-F} \]
  maximum residual stress = 61.6 psi
Conclusions and Future Work

• ANSYS results provide accurate shrinkage compensation for tooling.

• Future work includes non-amorphous, fiber-reinforced polymer injection molding simulation, gate/runner optimization etc.
Acknowledgements

• A special thank to Arnie Sen, Raymond Hsiao, George Kelly, and Dave Fredley for their consistent support of the project. Also thanks Rick Culler for providing shrinkage measurement data.
Questions and Answers

Thank you!