OPTIMIZATION OF THE PLASTIC INJECTION MOLDING PROCESS AND COMPONENT QUALITY USING MOLDEX3D AND OPTISLANG

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KÄRCHER IS THE MARKET LEADER WORLDWIDE FOR CLEANING SOLUTIONS

We offer over 3000 products – almost all products include at least one molded part

2.578
Billion € sales volume in 2019

65%
Growth since 2010

85%
Foreign sales
HOW CAN WE OPTIMIZE THE INJECTION MOLDING PROCESS?
The goal is to find the balance between high quality and the lowest possible cost

RESPONSE METRICS

- Quality
  - Warpage
  - Surface Smoothness
  - etc.
- Costs
  - Machine operating cost and cycle time
  - etc.

INFLUENCING FACTORS

- Construction of the plastic component
- Mold design
- Manufacturing process conditions
EXAMPLE: OPTIMIZATION OF A BATTERY SLOT

Function and costs define the optimization goals

COMPONENT QUALITY REQUIREMENTS
1. Straight assembly surface
2. Straight battery slide
3. Screw dome position

ECONOMICAL REQUIREMENTS
Cycle time
OUR WORKFLOW INTEGRATES MOLDEX3D AND CAD SOFTWARE
This allows the consideration of the component design, the mold design and the molding process at once

- MOLDEX3D performs injection molding simulations
- „Kärcher Software“ enables the integration of MOLDEX3D
- More flexibility due to integrated CAD Software
- Result: The workflow can consider the entire development and manufacturing process
SETUP STEP 1: VARIATION OF THE COMPONENT DESIGN

There are 38 geometry related non-dependent parameters

VARIATION OF EXISTING RIBS
- Height
- Position and angle
- Thickness

VARIATION OF ADDITIONAL RIBS
- Position
- Thickness
SETUP STEP 2: VARIATION OF THE MOLD DESIGN

Only the injection location is varied

VARIATION OF THE MOLD DESIGN

- Injection position
- Also possible:
  - Cooling channel positions
  - Entire injection system
There are 14 manufacturing process related parameters.

- Filling time
- Packing time
- Cooling time
- Temperature of the coolant
- etc.
SETUP STEP 4: RESPONSE VALUES
The warpage is probed at 32 locations

Root mean square of five groups:
• RMS warpage 1
• RMS warpage 2
• RMS warpage 3
• RMS warpage SD1
• RMS warpage SD2
OPTIMIZATION STRATEGY
To control the strong impact of cycle time the optimization is divided into two steps

**FIRST OPTIMIZATION**
- Single objective optimization
- Cycle time related parameters are held constant
- Optimization of the warpage

**SECOND OPTIMIZATION**
- Multiple objective optimization
- Only cycle time related parameters are varied
- Trade-off between warpage and cycle time
FIRST SENSITIVITY ANALYSIS
Cycle time related parameters are held constant

The CoP’s of the first three groups are good (≈90%)
The CoP’s of the screw domes are acceptable (≈70%)

- 50 parameters in total
- 175 designs
- 137 successful designs (78%)
FIRST OPTIMIZATION

Cycle time related parameters are held constant

- Single objective optimization for the warpage objective function
- Evolutionary algorithm with standard settings

Objective of the best design: 0.64
Objective of the validated design: 0.78
Objective of the reference design: 2.20
SECONED SENSITIVITY ANALYSIS
Only cycle time related parameters are varied

The CoP’s of the first three groups are very good (>95%)
The CoP’s of the screw domes are acceptable (>60%)

- 3 parameters in total
- 65 designs
- 62 successful designs (95%)

COP MATRIX

<table>
<thead>
<tr>
<th></th>
<th>Packing time</th>
<th>Filling time</th>
<th>Cooling Time</th>
<th>Total</th>
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<tbody>
<tr>
<td>RMS warpage 1</td>
<td></td>
<td></td>
<td></td>
<td>95.2 %</td>
</tr>
<tr>
<td>RMS warpage 2</td>
<td></td>
<td></td>
<td></td>
<td>95.6 %</td>
</tr>
<tr>
<td>RMS warpage 3</td>
<td></td>
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<td>97.9 %</td>
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<tr>
<td>RMS_warpage SD 1</td>
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<td>2.1 %</td>
<td>61.8 %</td>
<td>63.1 %</td>
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<tr>
<td>RMS_warpage SD 2</td>
<td>33.1 %</td>
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<td>67.9 %</td>
<td>71.4 %</td>
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<td>Cycle time</td>
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<td></td>
<td>96.2 %</td>
<td>99.6 %</td>
</tr>
</tbody>
</table>
SECOND OPTIMIZATION
Only cycle time related parameters are varied

Objective of the validated design: 0.62
Objective of the reference design: 2.20
Cycle time of the validated design: 32s
Cycle time of the reference design: 29s

- Multiple objective optimization for the warpage objective function and the cycle time
- Evolutionary algorithm
The warpage was strongly reduced while maintaining cycle time at an economically viable level.

**Reference**
- Objective warpage: 2.20
- Cycle time: 29s
- Edge warpage: 1.6 mm

**Second optimization**
- Objective warpage: 0.62
- Cycle time: 32s
- Edge warpage: 0.6 mm

**SUMMARY: BATTERY SLOT**

- More than 3 times less warpage
- 10% more cycle time
SUMMARY: KEY BENEFITS OF OUR WORKFLOW

- Optimization of the entire injection molding development process
  - Enables better collaboration
  - Enables better trade-offs

- Get it right the first time
  - Overall less development effort
WHAT’S NEXT?

We aim to establish our workflow in the daily injection molding development

External meshing software:
- More geometric flexibility
- More control over mesh sizes

Balancing of the injection system:
- Balancing multi cavity molds
- Optimize the filling behaviour

Are you interested?
- Don't hesitate to contact us
- We are planning to offer our workflow as a consulting service
MAKE A DIFFERENCE
THANK YOU
CONTACT

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