Minimization of Clamping Force at Automotive Bumper
Kim, WooJin

Image courtesy of AutoHorizons Foundation and Delineate
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1. Background
2. Conventional methods
3. Proposal
   3-1. Optimization of injection speed
   3-2. Multi-step control of valve-gates
4. Conclusion
1. Background

- Design trend cause high injection pressure

<table>
<thead>
<tr>
<th>Background</th>
<th>Objective</th>
</tr>
</thead>
</table>
| • Getting bigger bumper size
  • Getting down bumper thickness | Decrease clamping force by using CAE analysis |
| • Demand more clamping force
  • Exceed present machine capacity |
2. Conventional methods

- Factors affecting clamping force

- Apply high fluidity material → decrease flow resistance
- Apply many valve gates → decrease flow length per gate
- Increase thickness partially → decrease flow resistance
- Optimize gate position and open timing → balance peak pressure

Materials

Thickess

Improve
Clamping force

CAE analysis

Mold structure
3-1. Optimization of injection speed

1) Generally recommended injection speed change

- How much amount of slow down?
- Start timing to slow down?

2) In case of using valve gate: Flow front speed changed several times
   - To decrease clamping force, it is necessary to focus on decelerating finally

- Most injection machine have only 4~5 steps of injection speed control
  → Hard to compensate all speed change

- Maximum clamping force take place at the end of filling
  → Final decelerating is the most important factor
3-1. Optimization of injection speed

3) Experiment: Best condition to decrease clamping force

- Three kinds of width and reduction ratio → 9 cases of injection speed condition

<table>
<thead>
<tr>
<th>CASE</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V3/V1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V1</td>
<td>32.5</td>
<td>35.2</td>
<td>34.3</td>
<td>33.4</td>
<td>36.4</td>
<td>36.1</td>
<td>33.8</td>
<td>38.2</td>
<td>36.3</td>
<td>34.4</td>
</tr>
<tr>
<td>V2</td>
<td>29.4</td>
<td>28.6</td>
<td>27.4</td>
<td>29.1</td>
<td>28.1</td>
<td>27.0</td>
<td>29.3</td>
<td>27.8</td>
<td>26.4</td>
<td></td>
</tr>
<tr>
<td>V3</td>
<td>17.6</td>
<td>17.2</td>
<td>16.7</td>
<td>14.6</td>
<td>14.0</td>
<td>13.5</td>
<td>11.5</td>
<td>10.9</td>
<td>10.3</td>
<td></td>
</tr>
</tbody>
</table>

[10 cases of injection speed condition which has same filling time]

To simplify conditions, fix variables (V2-V3)=2(V2-V1), L1=2L2 (Exponential decrease is more efficient than linear one)

V1 should be increased for compensating decrease of V2, V3 (To equalize each case of filling time)
3-1. Optimization of injection speed

3) Experiment: Finding the best condition to decrease clamping force

- The highest peak clamping force value (p3) is getting down to other peak values

  ![Graph showing clamping force over time for two conditions.](image)
  - [CASE0: \(v_0 = 32.5 \text{ mm/s}\)]
  - [CASE4: \(v_1 = 36.4, v_2 = 29.1, v_3 = 14.6 \text{ mm/s}\)]
  - 2265 ton
  - 1737 ton (23% ↓)

- Case4 is the most balanced condition

  ![Graph showing injection pressure over time.](image)
  - The less L/S, the higher new peak value
  - Slight change of peak2 mainly caused by \(v_1\) value change
  - The reduction of peak3 is too much and useless
  (It might be similar problem to v/p change quickly)
3-2. Multi-step control of valve-gates

1) Effect of thickness difference in the simple bumper model using valve gate

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Case1: <strong>ALL 2.8T</strong></th>
<th>Case2: <strong>CTR 3.0T, SIDE 2.6T</strong></th>
<th>Case3: <strong>CTR 2.6T, SIDE 3.0T</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection pressure</td>
<td>[Graph showing pressure distribution and peak]</td>
<td>[Graph showing 9% up]</td>
<td>[Graph showing 9% down]</td>
</tr>
<tr>
<td>Clamp force</td>
<td>3483 ton</td>
<td>4009 ton</td>
<td>2783 ton</td>
</tr>
<tr>
<td>Pressure at v/p switchover</td>
<td>[Projected area and THIN SIDE Demand High Pressure]</td>
<td>[THICK CTR Easy to Transfer Main Pressure]</td>
<td>[THIN CTR Hard to Transfer Main Pressure]</td>
</tr>
</tbody>
</table>
3-2. Multi-step control of valve-gates

2) Consideration of Result

- **Conclusion from the test**
  - Center thickness should be as thin as possible
  - Side thickness should be as thick as possible

- **Problems**
  - Short shot, low rigidity, low surface quality
  - Increase weight, increase cycle time → Increase cost

- There are lots of restrictions to apply thickness control
- Core idea: High pressure of center area affects high clamping force when the side area is filled

Q: Is it necessary to apply high pressure on center area?
3-2. Multi-step control of valve-gates

3) Cutting out center gate can reduce clamping force dramatically

Clamp force

Pressure for each point near the gate

Pressure at v/p switchover (8.9s)

clamping force reduced caused by blocking of pressure at center area (42% ↓)
3-2. Multi-step control of valve-gates

4) Open the center gate again to achieve complete packing

<table>
<thead>
<tr>
<th>Valve gate condition</th>
<th>CTR gate</th>
<th>ON</th>
<th>OFF</th>
<th>Re-ON !</th>
<th>OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIDEgate</td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>OFF</td>
</tr>
</tbody>
</table>

Pressure for each point near the gate

Clamp force

Pressure after v/p switchover (10.1s)

Center area in danger to make a shrinkage problem

Valve re-open to pack center area

Double control center gate
→ avoid high pressure
→ achieve packing sufficiently
4. Conclusion

1. There are many ways to decrease clamping force
2. Need to compromise about side effects
3. Choose or combine several methods to find the best solution by using CAE analysis
Moldflow Consulting Project for HKMC Suppliers
Contents

• WHY Moldflow Analysis?
• Scope and Procedure of MF consulting
• Moldflow Consulting Project Process
• Moldflow consulting ITEMS
• Direct Operation vs. Consulting Service
• Autodesk Moldflow Consulting resources
The proposal is that by using Moldflow consulting service, targeting at plastic parts vendors (Tier I company), HKMC improves vendor’s quality, optimizes mold develop process and thus reduces engineering change and maximizes productivity.

### Mission

<table>
<thead>
<tr>
<th>Goal</th>
<th>Maximizing plastic parts’ quality on concurrent engineering</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Quality improvement and reducing engineering change</td>
</tr>
<tr>
<td></td>
<td>Time saving by standardizing mold develop process</td>
</tr>
<tr>
<td></td>
<td>Reducing Cycle time</td>
</tr>
<tr>
<td></td>
<td>Prior consultation by Collaborating between HKMC, Tiers, Mold specialist</td>
</tr>
</tbody>
</table>

### Activity

<table>
<thead>
<tr>
<th>HKMC</th>
<th>Tier I</th>
<th>Autodesk Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts Selection w/ drawing</td>
<td>Providing part/mold drawing</td>
<td>MF Consulting scheduling</td>
</tr>
<tr>
<td>Vendor Requirement Collection</td>
<td>Optimization of Gate, Runner</td>
<td>MF Simulation and Analysis</td>
</tr>
<tr>
<td>Parts Develop Scheduling</td>
<td>Scheduling on Mold develop</td>
<td>Analyzing Injection Trial</td>
</tr>
<tr>
<td>Execution planning</td>
<td>Input material property and injection condition</td>
<td>Providing mold optimization</td>
</tr>
</tbody>
</table>
WHY Moldflow Analysis? (1/3)

• Long lead time and High cost from engineering change, due to vendor’s bad quality

The problems on current mold design and Injection process

There is No engineering validation on product engineering stage, by doing it on the tooling and trial stage. It causes too much time and cost. And It is barrier in optimizing engineering specification.
• Problems happen complexly and comes from many variant on each stage. Moldflow Simulation makes it possible to find all the problems of product design, mold design and tooling & Trial in advance and concurrently and to give solutions in digital environments.
• Possible to minimize the trouble shooting and reduce time.

Autodesk Moldflow is the best solver to standardize the digital process in solving the problems.
Minimize Cost
- Minimize the quantity of hot runner manifold drops required to make acceptable parts
- Minimize the cycle time
- Minimize clamping tonnage required, which minimize press size and burden rates

Maximize Quality
- Minimize effects of knit lines
- Minimize effects of gate sizes and locations
- Minimize pressure and temperature variations that cause undesirable warping of parts
- Minimize sink marks

WHY Moldflow Analysis? (3/3)
## Moldflow Consulting Project Process

<table>
<thead>
<tr>
<th>Task</th>
<th>Response</th>
</tr>
</thead>
</table>
| Material Evaluation           | 1. HKMC provides material information  
                             2. Moldflow material Lab                                                                                                           |
| Modelling                     | 1. HKMC provides drawing and 3D CAD Data                                                                                               |
| Specification of Machine      | 1. HKMC and Tier I provide specification of machine  
                             - Clamping Force of Machine, Rate of Injection Molding, Presser of Injection Molding, Condition of Injection Machine   |
| Specification of Product      | 1. HKMC and Tier I provide specification of products  
                             - Fixed Dimension and Gate optimization  
                             - Function of Product                                                                                                              |
| Processing Condition          | 1. Optimization of Injection Molding Condition                                                                                         |
| Fill/Pack Processing Analysis | 1. In MOLDFLOW                                                                                                                           |
| Structural Analysis (If required) | 1. In MOLDFLOW & Structural Program                                                     |
| Report                        | 1. Reporting MOLDFLOW simulations results                                                                                              |
## Direct Operation vs. Consulting Service

<table>
<thead>
<tr>
<th>Investment</th>
<th>Merit</th>
<th>Demerit</th>
</tr>
</thead>
</table>
| Direct Investment and operation by Tier I | • Tier I purchasing MF and manipulated by himself  
• Improve Knowledge improvement  
• Apply to optimization analysis by designer’s idea | • Purchasing Moldflow (cost)  
• Maintenance cost  
• Dedicated person on MF operation  
• Skill up for the dedicated person |
| Consulting by Certified consultants | • High level consultants (MF certified)  
• Equivalent resulting  
• Moldflow Silver Certification  
• No need to purchasing MF and low cost for maintenance  
• Knowledge accumulation by co-working w/ high level consultant | • Closer discussion, due to product and material information  
• Different injection condition between Moldflow input data and real machine data  
  -> Need to co-working with operator  
• Security issue on outsourcing |
Autodesk Moldflow Consulting resources

Background of Moldflow
Moldflow Corporation is the leading global provider of automation and optimization software solutions to all segments of the plastics injection molding industry. Moldflow is the established market leader with sound financial performance and a strong management team. Autodesk Moldflow produce products that add value to every phase of the plastics injection molding design-to-manufacturing process and can directly service and support our customers around the world.

Autodesk Korea based company specializing in injection molding process simulation. Autodesk Korea specializes in providing design optimization services to the automotive industry using analytical and statistical methods.

• Injection Molding Analysis --- Conventional Injection Molding
  --- Gas Injection Molding
  --- Thermoset Injection Molding

• Structural Analysis --- Linear and Non-Linear Analysis
  --- Impact Analysis
  --- Thermal Analysis
  --- Frequency Analysis
  --- Creep & Fatigue Analysis

• Material Testing --- PVT & CRIMS Data

• Mold & Die --- Pilot production of Mold and Sampling
  --- Mass production of Mold and Commissioning

• Training & Seminar --- Product Training (Basic & Advanced)
  --- Material Testing Training
  --- Basic theory of Plastic Products
  --- Basic theory of Structural Mechanics
Autodesk Moldflow Certification

- Certifying the Student - Professional recognition, Proven proficiency in Moldflow products
- Gets “personal” certification in that product
  - Bronze: Simulation Fundamentals
  - Silver: Three Advanced Simulation courses
- The Moldflow analyst must have a minimum of Moldflow Silver certification.
- Silver Certification in Korea : Sungkyu Kang and David Lee
Autodesk Moldflow Consulting resources

Experience of Moldflow for Automotive

**Conventional Injection Analysis Only for Automotive part**
- Bumper Fascia
- Back-Beam
- Instrument Panel
- Car Audio Front Panel
- Pillar
- Door Garnish
- Wheel Cover
- Radiator Cap
- Side Mirror Housing and Arm
- Air Cleaner Housing
- Battery Box

**Structural Analysis Only for Impact**
- Bumper Back-Beam of V-Car
- Bumper Back-Beam of Y-Car
- Bumper Back-Beam of J-Car
- Bumper Back-Beam of M-Car
- IP System of Y-Car

**Gas Injection Analysis**
- Back-beam for Plastic Bumper System
- Air-con Compressor Cover
HKMC and MOBIS Consulting Items
Exterior Commodities

Moldflow Consulting Items:

1. 범퍼 시스템
2. 헤드 향프
3. 클링 시스템
4. 캐리어
5. 훈 및 레치 어셈블리
6. 오일 클러
7. 와이어 하네스
Interior Commodities

Moldflow Consulting Items

1. कायल क्रोस बाट एक्ट्रिक
2. मेन वायरबिंग
3. हार्ट ब्रॉलर
4. लाइक्स नायट
5. क्राफ्टी शेप्ड मेन एक्ट्रिक
6. क्लास्टर केंजर
7. क्लास्टर पॉवर स्वेच
8. डायमो
9. सेंटरप्लेयर स्वेच एक्ट्रिक
10. ग्लोब्ल बाक्स कंप्लेक्ट
11. साइड एयरवेंट एन्ड एरवेंट
12. फिशिंग घंटा लाइन
13. स्विच मिल इंटरक्टोर
14. एल्टिंग्सन स्विच
Moldflow Structural Alliance:
Autodesk Simulation Mechanical
Material: Supran 1340 (PP+LGF40%)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold Temp</td>
<td>55 °C</td>
</tr>
<tr>
<td>Melt Temp</td>
<td>235 °C</td>
</tr>
<tr>
<td>Injection Time</td>
<td>4 sec</td>
</tr>
<tr>
<td>Packing Time</td>
<td>3 sec</td>
</tr>
<tr>
<td>Cooling Time</td>
<td>40 sec</td>
</tr>
</tbody>
</table>

Mesh: 3D (1,163,810 EA)
Gate: Pin Point

Fill Time / Weld Line

Pressure (at end fill)

Fiber Orientation tensor