Warpage Improvement Analysis of ADF Scanner Paper Feeding Mechanism & Moldex3D GASIN Simulation and Verification

(Report Sample)

No. : 001
Company : Lite-on Technology
Contestant : Alan Ting
Content

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- Company & Product Introduction
- Product and Mold Development Process
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Contestant Introduction

> Name: Alan Ting
> Company: Lite-on Technology
> Department: Imaging Department
> Products in-charge: Mold development and production process optimization for Mini Projector、Scanner、Multi-Function Devices, etc.
> Specialties:
  – CAE Simulation
  – Mold and injection process problems solving
Company Introduction

> Lite-On Technology Corporation was founded in 1975 as a producer of LEDs (Light-Emitting Diodes).

> Lite-On Technology, the parent company of the Lite-On Group, was the first company in Taiwan to produce LEDs. Over the past three decades since its inception, Lite-On has vigorously penetrated the market sectors of computers, digital home products, consumer electronics, communications products, key components and sub-systems, and optoelectronic components.

> Lite-On’s outstanding research and development and industrial design capabilities provide customers with a wide range of products and services, making Lite-On the best ODM/OEM outsourcing choice for world-class companies.
Product Introduction

> ADF Scanner is an indispensable device in the office. Its value greatly depends on the scanning speed, quality, stability, reliability, as well as price.

> The movement of ADF Scanner can be divided to four steps: pick up, feed, scan, and eject. The whole process from picking up to ejecting could also influence scanning quality and reliability. Therefore, the flatness of the paper feed tray plays a crucial role in the function of ADF scanner.
Product and Mold Development Process

Part Design
CAE Simulation (Moldex3D)
Tooling Design Review
Mold tooling QC
Mold dimension locked
T0 molding trial

FAI OK? CPK >1.33?
DVT 1.0
Design revision needed?
PVT
Mold design confirm

T1 molding trial
FAI/CPK

Mold revision
T2 molding trial

NG
OK
NG
NG
NG

FAI: first article inspection
CPK: capability of production index
DVT: design verification test
PVT: Production verification testing
Product Development Trend and Challenge

> Development Trend
  – Scan speed is faster
  – Single page scanning became double pages scanning

> Challenge
  – C.I.S (Contact Image Sensor), react speed is not fast enough
  – High speed cause noise
  – Precision requirement is high
  – Flatness<0.3mm

> Common Problems
  – Flow imbalance
  – Weld line
  – Warpage
  – Uneven flatness
Why CAE?

> Problems encountered
  - Z-displacement requirement: <0.3mm
  - Paper jammed situation

> Short-term solution implemented
  - Process Condition Adjustment
    - Increase packing time (3.5, 5 ,8sec)
      - Invalid
    - Increase packing pressure
      - Invalid
    - Adjust cooling channel temperature
      - Only improve X and Y-Displacement but have negative impact on Z-Displacement

> Why utilize CAE Simulation Analysis
  - Utilize CAE Simulation Analysis to identify product potential problems.
  - Evaluate if traditional injection molding could improve product displacement.
  - The location of the pin in Traditional Gas-Assisted Injection Molding process usually depends on try and error method. Impropriate pin location will affect air permeability results.

> Expected results and objects
  - Decrease Z-Displacement to under 0.3mm
  - Evaluate proper pin location
  - Improve future warpage problem
  - Shorten molding cycle time
  - Decrease injection pressure and clamping force
CAE Application Process

- Verify Problem
- Problem Analysis
- 1st CAE Analysis
- 2nd CAE
- Analysis Report

Adjust Process Condition
Design Alternation

Real Process Condition
CAE Process Condition

Real Production
CAE Simulation Report

Problem Solved
Moldex3D Successful Application Case Study
Background

> **Product Size**
  - Length : 280 mm
  - Width : 160mm
  - Height : 60 mm
  - Thickness : 2 mm

> **Material**
  - PC+ABS

> **Process Condition**
  - Filling Time : 2.5 Sec
  - Melt Temperature : 260 °C
  - Mold Temperature : 80 °C
Mesh Model

> Mesh Type
  – BLM Solid Mesh

> Mesh Count
  – Part Mesh: 2,655,008
  – Cold Runner Mesh: 121,913

> CPU CPU Time (4.2hr)
  – Flow: 2.9 hr
  – Pack: 1.2 hr
  – Cool: 2 min
  – Warp: 6 min

> Computer Information
  – CPU: Intel Core i7-3930K
  – (6CPU) * 2
  – RAM: 32 G * 2
Runner Layout
Cooling Channel Design
Analysis Items and Contents

1. Traditional injection molding process
   - Understand the problems of the original design, inside temperature distribution and displacement.

2. Parameter adjustment
   - Explore how adjusted parameter will affect displacement and evaluate feasibility of the traditional injection molding process.

3. Gas-Assisted Injection Molding Process adoption
   - Utilize Gas-Assisted Injection Molding Process to evaluate pin location and air penetration area range.

4. Warpage and Displacement Comparison
   - Compare displacement analysis results before and after implementing Gas-Assisted Injection Molding Process and evaluate its feasibility.

5. Mold trial comparison
   - Compare analysis results and mold trial results.
Original Design Analysis and Results Interpretation

Traditional injection molding process
Generally, the end area of filling process has lower pressure due to farther flow length and temperature loss along the way. Therefore, the packing pressure is less than insufficient and will cause higher warpage. From the analysis results above, it can be told that the highlighted part will have more severe warpage or displacement.
Based on the analysis results, the high temperature areas are mainly distributed around both corner sides and the area around the gates. The middle areas were the first areas starting packing process, therefore the temperature is relatively lower. Therefore, those areas should not be considered for pin location.
Areas near the gates in the core have heat accumulation problem and the areas around the corner in the cavity have heat accumulation problem.
Cooling Analysis _ Cooling Time

Cooling time usually range between 0~7 sec. Partial areas have longer cooling time, more than 12 seconds because of thicker wall thickness.
Warpage Analysis _ Total Displacement

Total Displacement: 0.007mm~1.572mm

Scale: 3X
Warpage Analysis _ Sink Mark Index

Product surface has severe shrinkage mark
Warpage Analysis _ Node Seeding and Displacement

Point 3, 4, 5, and 6 has poor flatness, all over the standard, 0.3mm.

<table>
<thead>
<tr>
<th>iNode</th>
<th>NodeID</th>
<th>Z-Cord [mm]</th>
<th>Z-Cord(Deformed) [mm]</th>
<th>Z方向位移 [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>209699</td>
<td>40.789</td>
<td>40.891</td>
<td>0.102</td>
</tr>
<tr>
<td>2</td>
<td>240924</td>
<td>40.789</td>
<td>40.938</td>
<td>0.149</td>
</tr>
<tr>
<td>3</td>
<td>476556</td>
<td>40.789</td>
<td>40.263</td>
<td>-0.526</td>
</tr>
<tr>
<td>4</td>
<td>479974</td>
<td>40.789</td>
<td>40.372</td>
<td>-0.417</td>
</tr>
<tr>
<td>5</td>
<td>563313</td>
<td>40.789</td>
<td>40.244</td>
<td>-0.545</td>
</tr>
<tr>
<td>6</td>
<td>563281</td>
<td>40.789</td>
<td>40.417</td>
<td>-0.371</td>
</tr>
<tr>
<td>7</td>
<td>900726</td>
<td>40.789</td>
<td>40.840</td>
<td>0.051</td>
</tr>
<tr>
<td>8</td>
<td>912971</td>
<td>40.789</td>
<td>40.856</td>
<td>0.068</td>
</tr>
</tbody>
</table>

The difference between the highest and lowest is about 0.694mm.
Design Alternatives and Simulation Analysis

Process Parameter Adjustment I _ Packing Time
Attempts of Revised Design

> Issues with original design
  > Flow imbalance (without moving gate location)
  > The areas near the gates and the end of filling have higher volumetric shrinkage because of higher temperature.
    • Adjusted packing pressure to decrease volumetric shrinkage.
  > Areas near the gates in the mold have heat accumulation phenomenon
    • Adjusted mold temperature to improve heat accumulation phenomenon.

> Revised Design (Without modifying gate location and amount, only parameters are adjusted.
  > Revised Design 1 : Increase packing time from 3.5 sec to 5 sec (average mold temperature is 80 °C)
  > Revised Design 2 : Increase packing time from 3.5sec to 8sec (average mold temperature is 80 °C)
Comparison of Z-Displacement

From the graphs, it can be told that packing time of 3.5 sec and packing time of 8 sec have similar results. However, packing time of 5 sec has the worst flatness result.
Comparison of Warpage Displacement

<table>
<thead>
<tr>
<th>Item</th>
<th>X displacement</th>
<th></th>
<th>Y displacement</th>
<th></th>
<th>Z displacement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit:mm</td>
<td>min</td>
<td>max</td>
<td>total</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>Packing Time 3.5sec</td>
<td></td>
<td>-0.596</td>
<td>0.604</td>
<td>1.2</td>
<td>-1.469</td>
<td>1.134</td>
</tr>
<tr>
<td>Packing time 5sec</td>
<td></td>
<td>-0.672</td>
<td>0.628</td>
<td>1.3</td>
<td>-1.621</td>
<td>1.231</td>
</tr>
<tr>
<td>Packaging Time 8sec</td>
<td></td>
<td>-0.704</td>
<td>0.76</td>
<td>1.464</td>
<td>-1.811</td>
<td>1.339</td>
</tr>
</tbody>
</table>

Packing Time: 3.5sec

Packing Time: 5sec

Packaging Time: 8sec
Design Alternatives and Simulation Analysis

Process Parameter Adjustment II _ Packing Pressure and Coolant Temperature
Attempts of Revised Design and Reasons

> **Revised Design Introduction**
  - Based on the results, we can know that increasing packing time has no significant effect on warpage and flatness. Instead the original design with packing time of 3.5 sec has better flatness.
  - But their flatness levels are all above 0.3mm, we continue adjust packaging pressure and cooling channel temperature.

> **Revised Design**
  - Revised Design III: Keep packing time as 3.5 sec and increase packing pressure (mold temperature is 80°C)
  - Revised Design IV: Keep packing time as 3.5 sec and decrease mold temperature to 18°C
Comparison of Z-Displacement

### Table: Z Direction Displacement [mm]

<table>
<thead>
<tr>
<th>iNode</th>
<th>NodeID</th>
<th>Z方向位移 [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>保壓3.5sec</td>
</tr>
<tr>
<td>1</td>
<td>209699</td>
<td>0.102</td>
</tr>
<tr>
<td>2</td>
<td>240924</td>
<td>0.149</td>
</tr>
<tr>
<td>3</td>
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</tr>
<tr>
<td>7</td>
<td>900726</td>
<td>0.051</td>
</tr>
<tr>
<td>8</td>
<td>912971</td>
<td>0.068</td>
</tr>
</tbody>
</table>

Increasing packing pressure and adjusting mold temperature have no significant effect on the flatness.
Sum-Up

Through different process parameter adjustments, we have concluded:

- Increasing packing time does not improve warpage and flatness but increase cycle time. Therefore, packing time of 3.5 sec is relatively better.

- Increasing packing pressure does not improve warpage and flatness and has similar results with packing time of 5 sec. Therefore, this revised design will not be adopted.

- Changing coolant to frozen water with 18 ℃ slightly improve X and Y displacements but has worse Z displacement. In addition, it does not improve flatness.

- Traditional injection molding process cannot satisfy requirement on warpage. Its yield rate and surface shrinkage mark is severe, not only effecting delivery time but also dissatisfy customers' needs.

- As the traditional injection molding process cannot fulfill the requirement of flatness being under 0.3mm, we tried to implement gas-assisted injection molding process to improve the problems.
Design Alternatives and Simulation Analysis

Process Parameter Adjustment III Gas-Assisted Injection Molding Process adoption
Pin Location Setup and Discussion

- Information from traditional analysis:
  - Flow imbalance. Middle melt front firstly arrived, then packing and temperature decreasing started. The bottom areas of both left and right sides firstly complete filling process.
  - Higher temperature areas are mainly distributed in the areas around the runner and gate. Especially, the areas around the gate have the highest temperature.
  - Areas on both sides have bigger warpage. In addition, middle area has higher displacement so that the requirements for flatness was not fulfilled.

- As gas penetrate toward the area which is higher temperature and lower pressure, higher temperature is distributed at the areas around the gate, where is the direction the gas will be penetrating toward. Therefore, we decided to locate the pin in the areas with lower temperature, leading gas to penetrate toward the areas with higher temperature. Further, to improve warpage problems.
Pin Location Setup
The injection pressure needed with gas assisted injection was way smaller than the pressure needed with traditional injection molding process.
Average temperature distribution ranges between 83°C and 108°C with GASIN. On the other hand, average temperature distribution ranges between 86°C and 125°C, which is about 17°C higher.
Surface shrinkage mark has been significantly improved with Gas-assisted injection molding process.

Traditional injection molding has severe sink mark.
Warpage Analysis Result _ Z-Displacement

GASIN

-0.374mm~0.27mm

Scale: 3X

Traditional Injection Molding Process

-0.596mm~0.604mm
Comparison of Warpage Analysis Result

- After implementing Gas-assisted injection molding, overall warpage phenomenon was significantly improved.
  - X-Displacement improve 45%
  - Y-Displacement improve 40%
  - Z-Displacement improve 64%
  - Z-Flatness is within ±0.3mmm and under 0.2mm, which fulfilled the requirement.

<table>
<thead>
<tr>
<th>項目</th>
<th>X displacement</th>
<th>Y displacement</th>
<th>Z displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>單位:mm</td>
<td>min</td>
<td>max</td>
<td>total</td>
</tr>
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<td>保壓3.5sec</td>
<td>-0.596</td>
<td>0.604</td>
<td>1.2</td>
</tr>
<tr>
<td>保壓5sec</td>
<td>-0.672</td>
<td>0.628</td>
<td>1.3</td>
</tr>
<tr>
<td>保壓8sec</td>
<td>-0.704</td>
<td>0.76</td>
<td>1.464</td>
</tr>
<tr>
<td>加大保壓壓力</td>
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<td>0.6168</td>
<td>1.3058</td>
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<td>導入氣輔</td>
<td>-0.368</td>
<td>0.2885</td>
<td>0.6565</td>
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</tbody>
</table>

Z軸位移量比較圖(Node1~Node8)
Comparison of Simulation Result and Real Product
Before Gas Entry _ Comparison of Short Shot Analysis Result I
Before Gas Entry _ Comparison of Short Shot Analysis Result II
After Gas Entry _ Comparison of Gas Permeation Analysis Result

The simulation analysis results correspond with the short shot result from real mold trial.
Benefit Analysis and Future Application
## Moldex3D Application Value Analysis

<table>
<thead>
<tr>
<th>Price per item</th>
<th>Tooling</th>
<th>Machine Cost Rate (USD/min)</th>
<th>Mold Repairing (USD/per time)</th>
<th>Mold Trial (USD/per Time)</th>
<th>Personnel (USD/per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit:USD</td>
<td>1</td>
<td>22,000</td>
<td>0.2</td>
<td>2,000</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Traditional Injection Molding Process

<table>
<thead>
<tr>
<th>Item</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle time</td>
<td>((38-31)/38=0.18) · Cycle time decreases 18%</td>
</tr>
<tr>
<td>Price per time</td>
<td>• Cost for each cycle = Cycle time * Machine cost rate</td>
</tr>
<tr>
<td></td>
<td>• Cost with cycle time decreasing 18% = Cycle time * 18% * Machine cost rate</td>
</tr>
<tr>
<td></td>
<td>• Total savings with cycle time decreasing 18% = 18% * Machine cost rate * Product Number Forecast</td>
</tr>
<tr>
<td></td>
<td>If monthly product is 10,000 Pcs · total savings per year = 31 * 0.18 * 0.2 * 10,000 * 12 = 133,920 USD (\approx) 3,883,680 NTD</td>
</tr>
<tr>
<td>Trial cost</td>
<td>Mold trial decreases 4 times per month</td>
</tr>
<tr>
<td></td>
<td>Trial cost per time is 200 USD · so total savings per year = 4 * 200 * 12 = 9,600 USD (\approx) 278,400 NTD</td>
</tr>
<tr>
<td>Personnel cost</td>
<td>2~3 people are needed and cost for one personnel per day is 4 USD</td>
</tr>
<tr>
<td></td>
<td>12 * 4 * 3 * 4 = 576 USD (\approx) 16,704 NTD</td>
</tr>
<tr>
<td>Time cost</td>
<td>Working time decreases from 4 days to 1 day. Total savings = 3 * 12 = 36 working days per year</td>
</tr>
<tr>
<td>Yield Rate</td>
<td>Increase from 0 % to 99%</td>
</tr>
<tr>
<td>Total Savings</td>
<td>133,920 + 9,600 + 576 = 144,096 USD (\approx) 4,178,784 NTD</td>
</tr>
</tbody>
</table>

### Gas-Assisted Injection Molding Process

<table>
<thead>
<tr>
<th>Traditional Injection Molding Process</th>
<th>Filling</th>
<th>Packing</th>
<th>Cooling</th>
<th>Mold Open</th>
<th>Cycle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filling</td>
<td>2.5</td>
<td>3.5</td>
<td>22</td>
<td>10</td>
<td>38</td>
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<tr>
<td>Packing</td>
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<tr>
<td>Cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mold Open</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Estimated number only for reference.
Moldex3D Future Application

> Future Application
  > To utilize Moldex3D as a platform between client and molding manufacture for better and more complete communication. Further, to find out the best product design
  > To apply Moldex3D on hot runner or RHCM designs.
  > To increase product quality and higher productivity.

> Future Study Direction
  > Optimization of pin location
  > Optimization of pin pressure and time
  > Hot Runner Temperature Control
  > Variotherm
Thank you for your attention!