Moldex3D

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

(Report Sample)

Moldex3D 2013 Innovation Talent Award

Showing Your Talent ; Molding Your Innovation

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

CoreTech System Co., Ltd
www.moldex3d.com

Content

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).

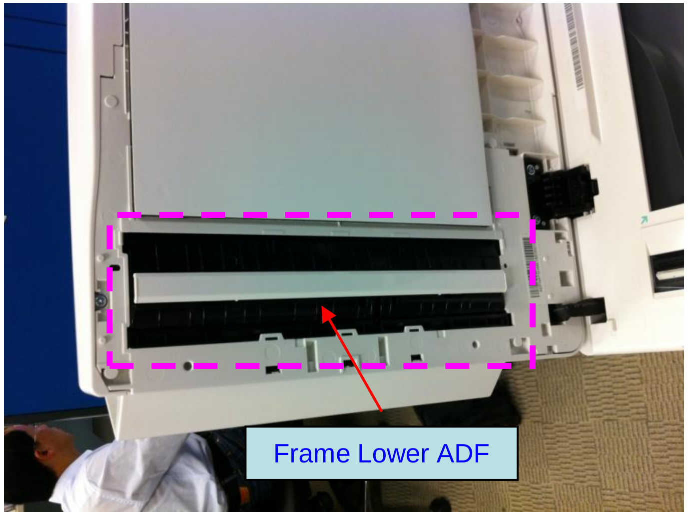
> Lite-On Technology, the parent company of the Lite-On Group, was the first company in Taiwan to produce LEDs. Over the past three decades since its inception, Lite-On has vigorously penetrated the market sectors of computers, digital home products, consumer electronics, communications products, key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

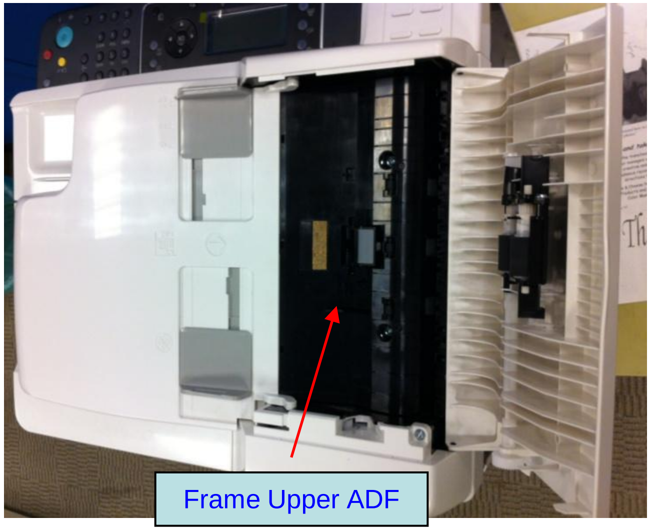
> Lite-On's outstanding research and development and industrial design capabilities provide customers with a wide range of products and services, making Lite-On the best ODM/OEM outsourcing choice for world-class companies.

Product Introduction

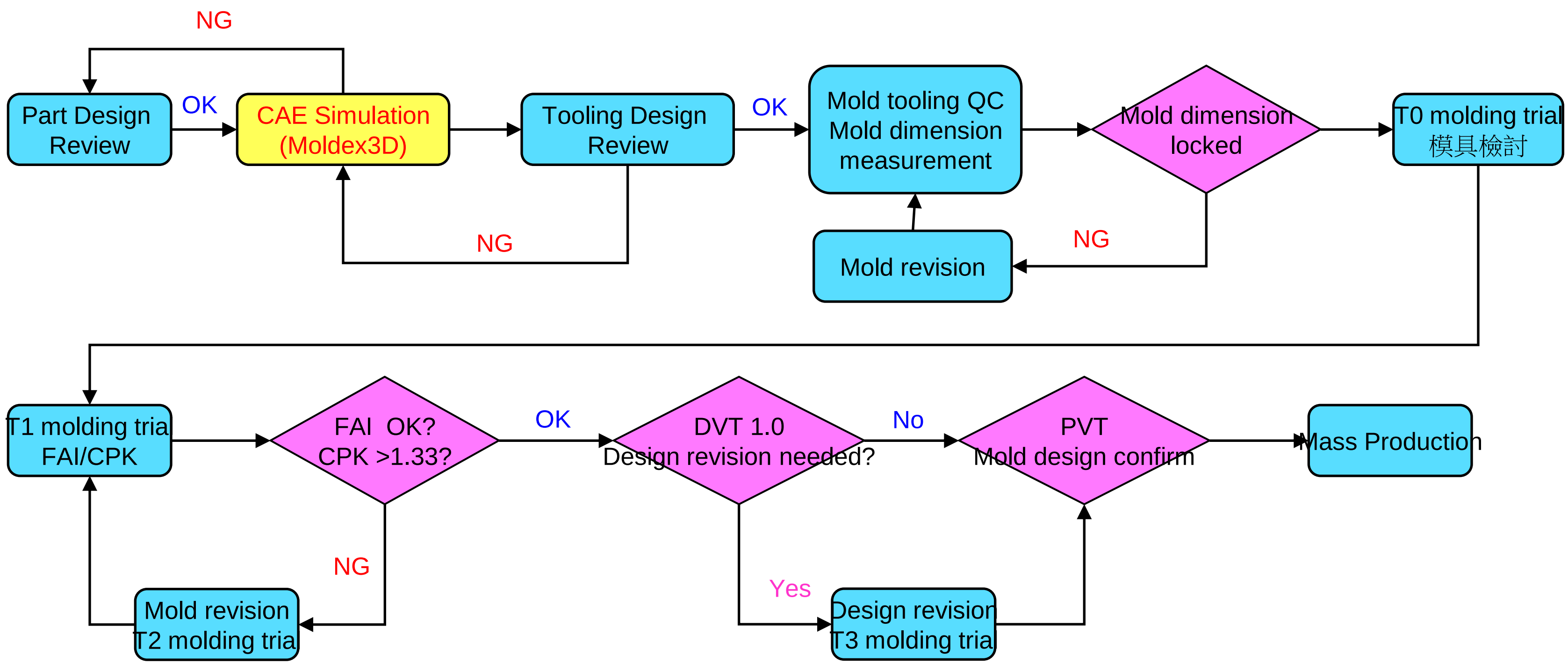
> ADF Scanner is an indispensable device in the office. Its value greatly depends on the scanning speed, quality, stability, reliability, as well as price.

> 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



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?

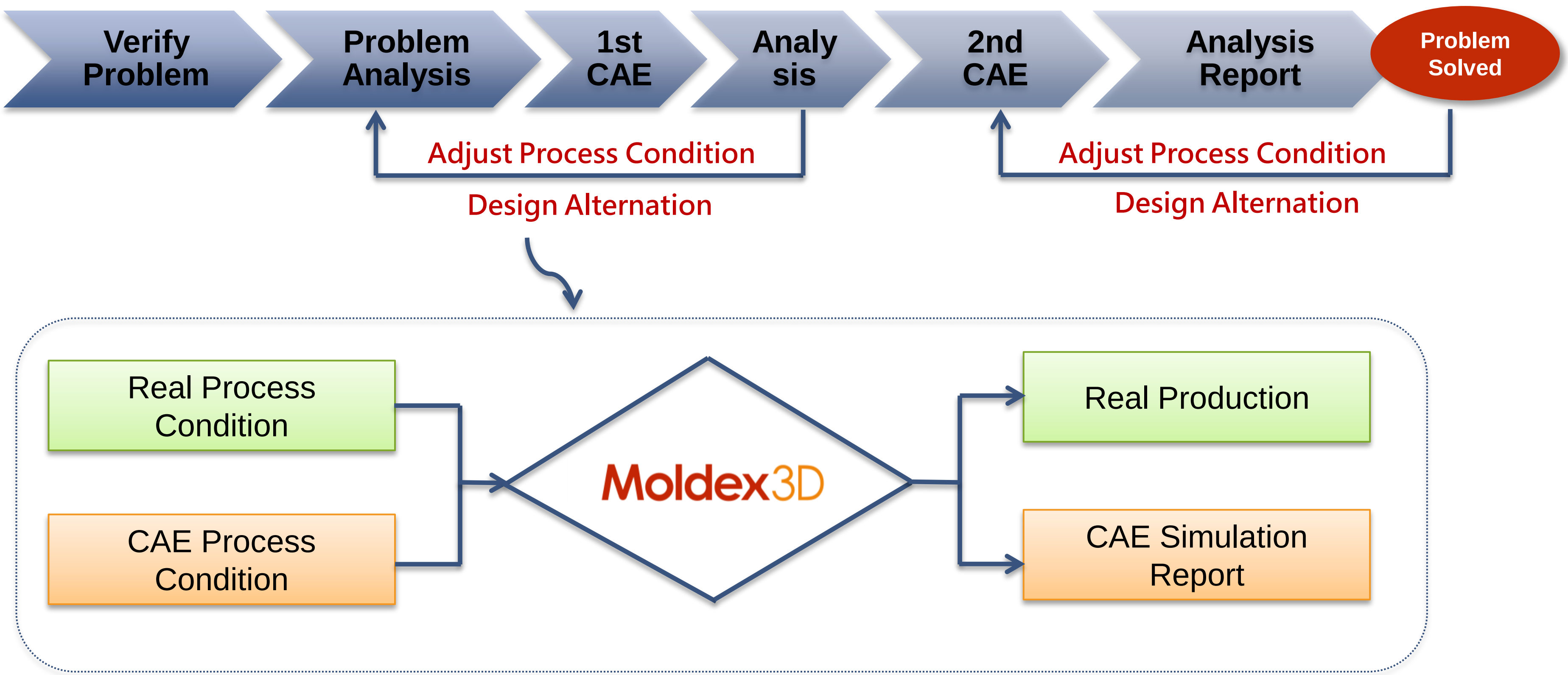
> Problems encountered
  - Z-displacement requirement: <0.3mm
  - Paper jammed situation

> 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.
  - Evaluate feasibility of Gas-Assisted Injection Molding Process implementation and its improvement level for displacement.

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

CAE Application Process



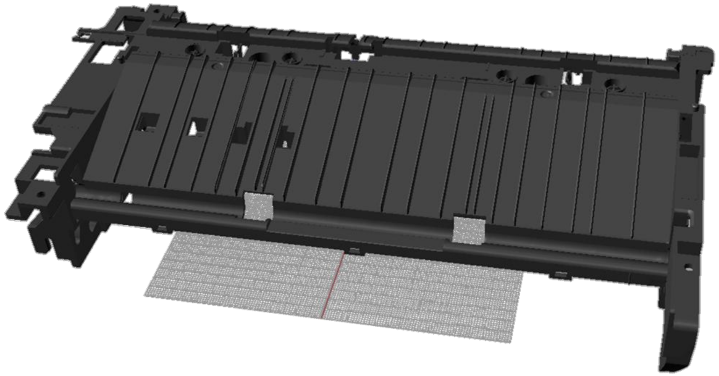
Moldex3D Successful Application Case Study

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 ℃**
  - **Mold Temperature： 80 ℃**



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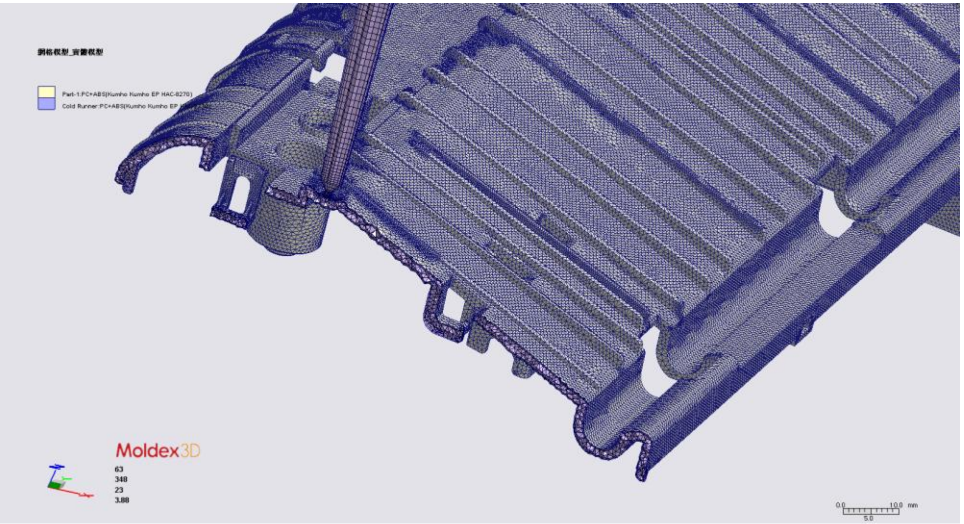
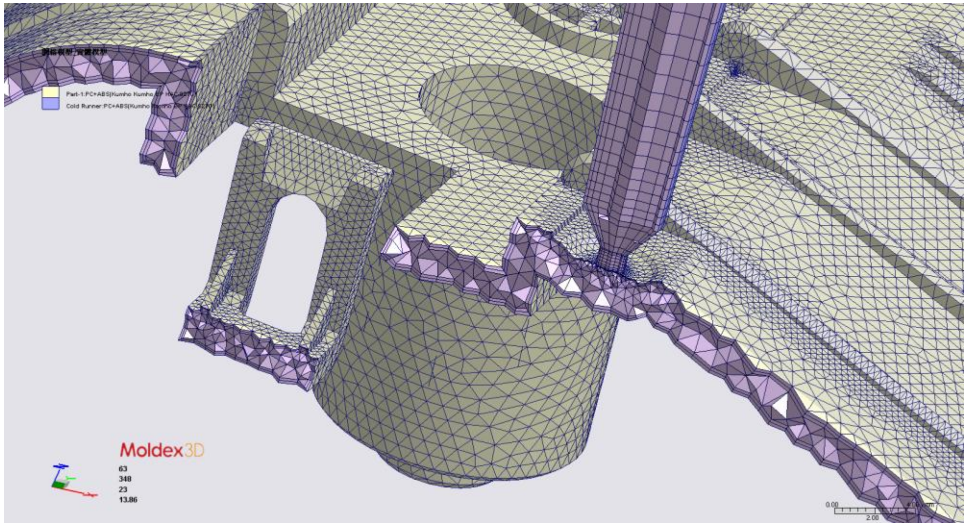
Mesh Model

- 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: 1.2hr
  - Cool: 2 min
  - Warp: 6 min
- Computer Information
  - CPU: Intel Core i7-3930K
  - (6CPU) *2
  - RAM: 32 G *2





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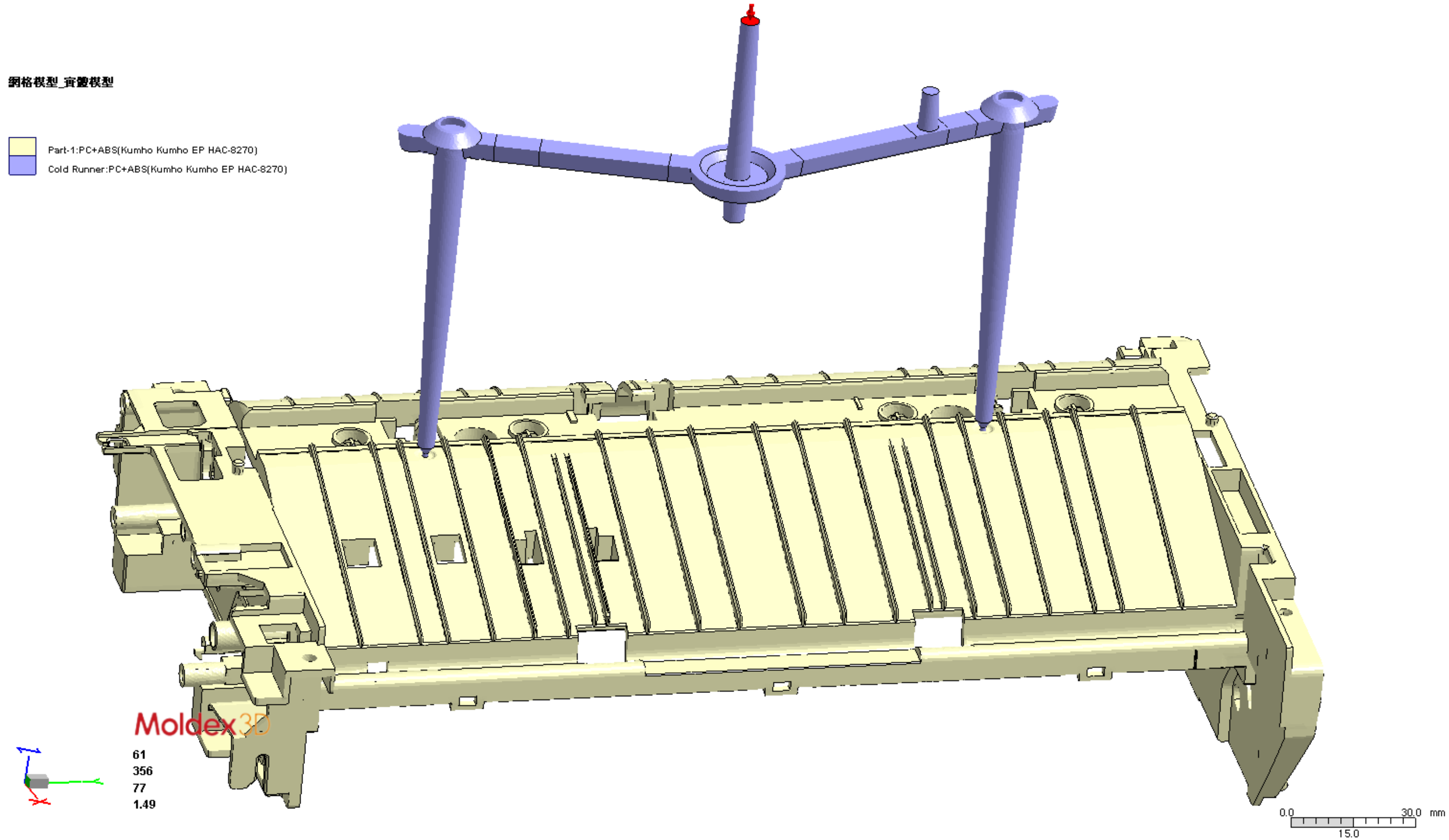
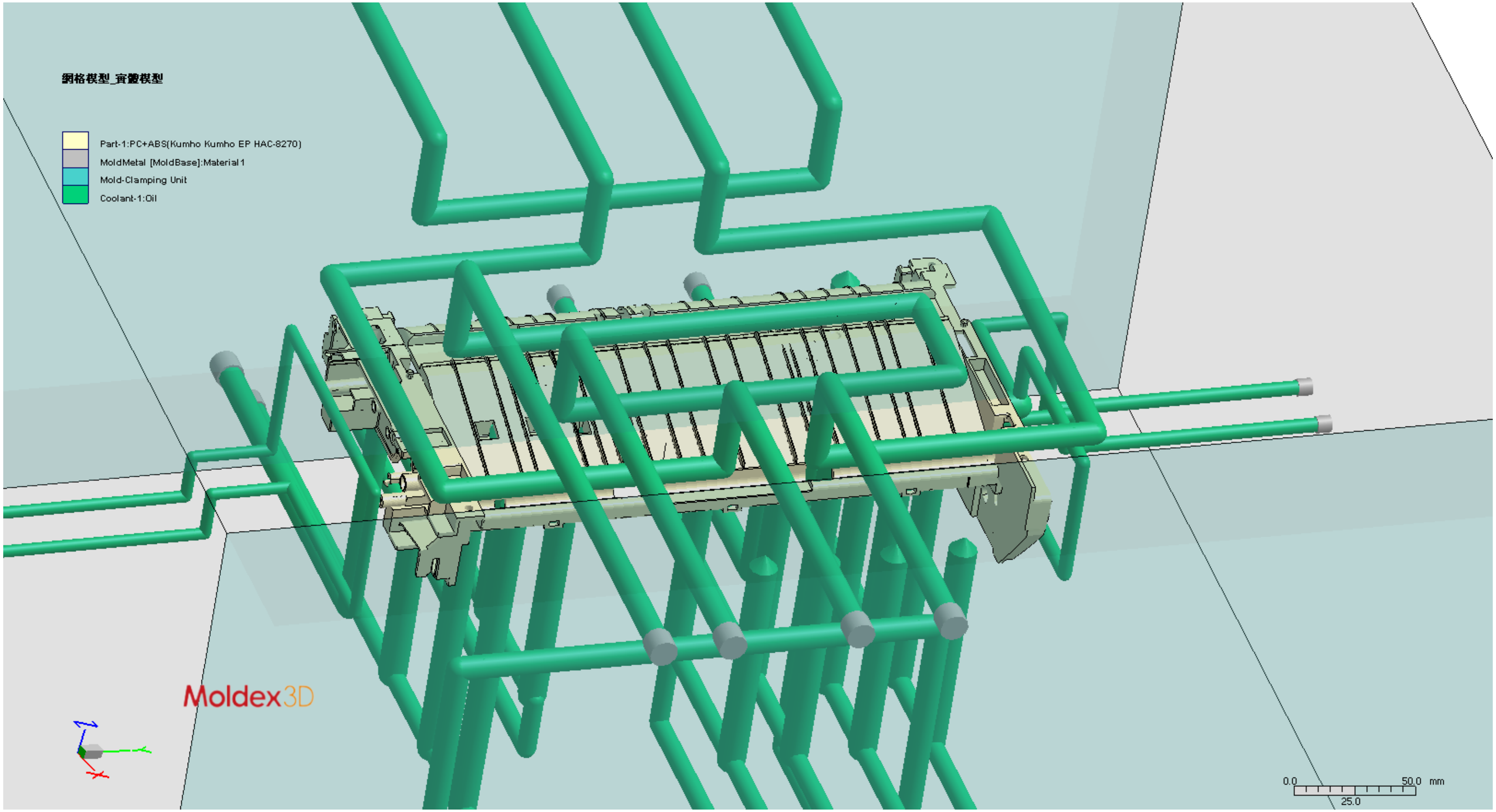
Runner Layout



Cooling Channel Design



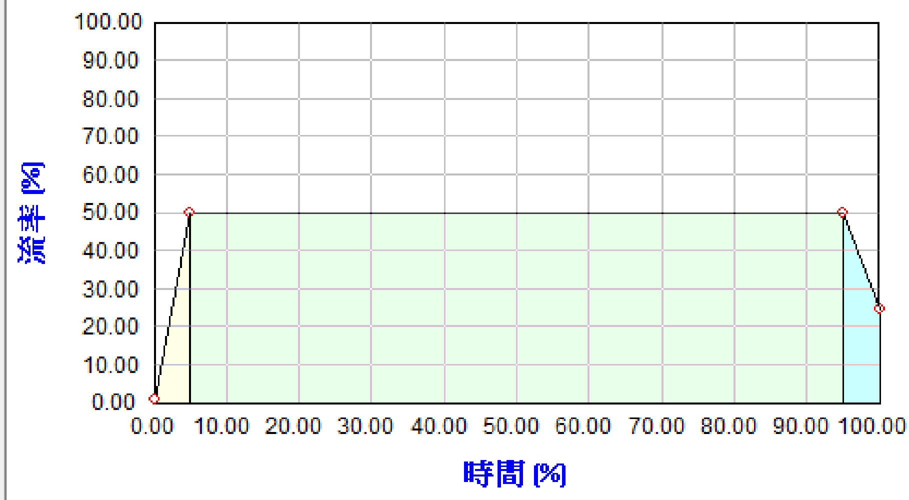
Analysis Items and Contents

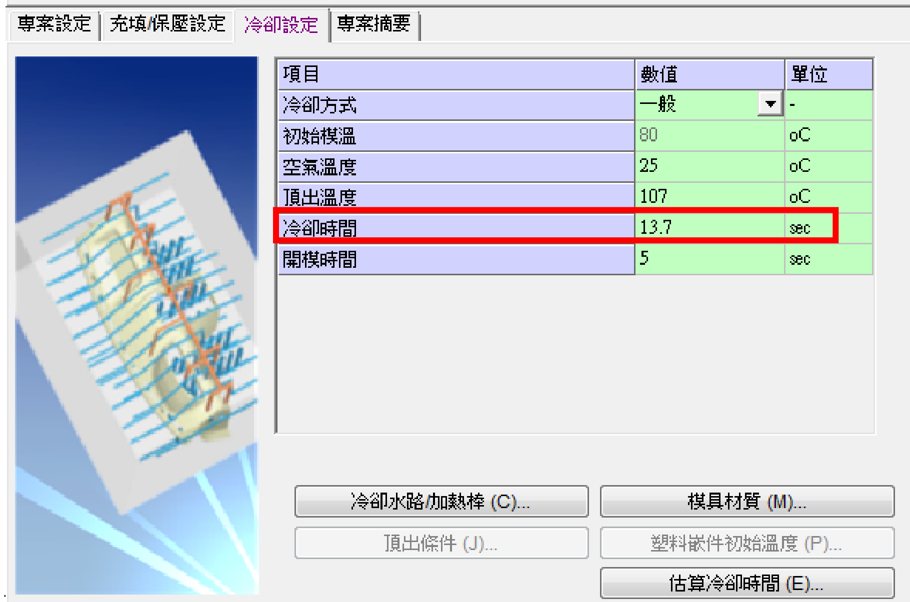
1. Traditional injection molding process
   - **Understand the problems of the original design, inside temperature distribution and displacement.**
2. Parameter adjustment
   - **Explorer how adjusted parameter will affect displacement and evaluate feasibility of the traditional injection molding process.**
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.**

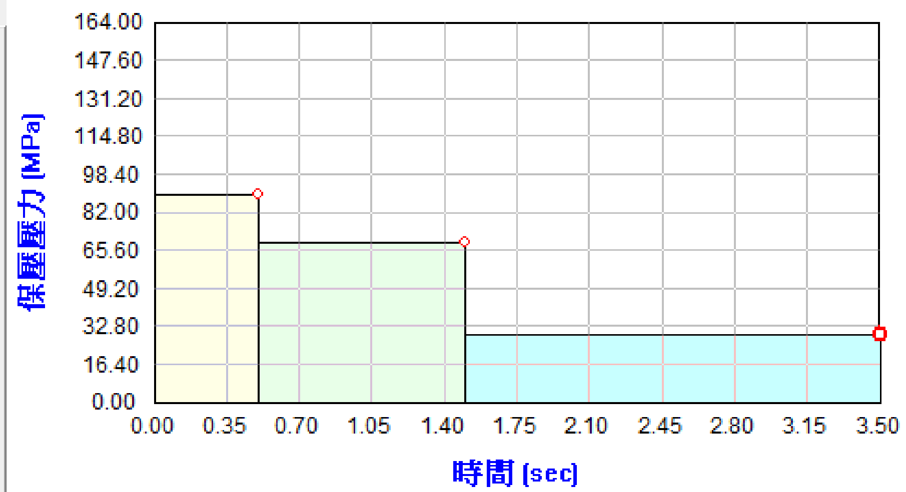
Original Design Analysis and Results Interpretation

Traditional injection molding process

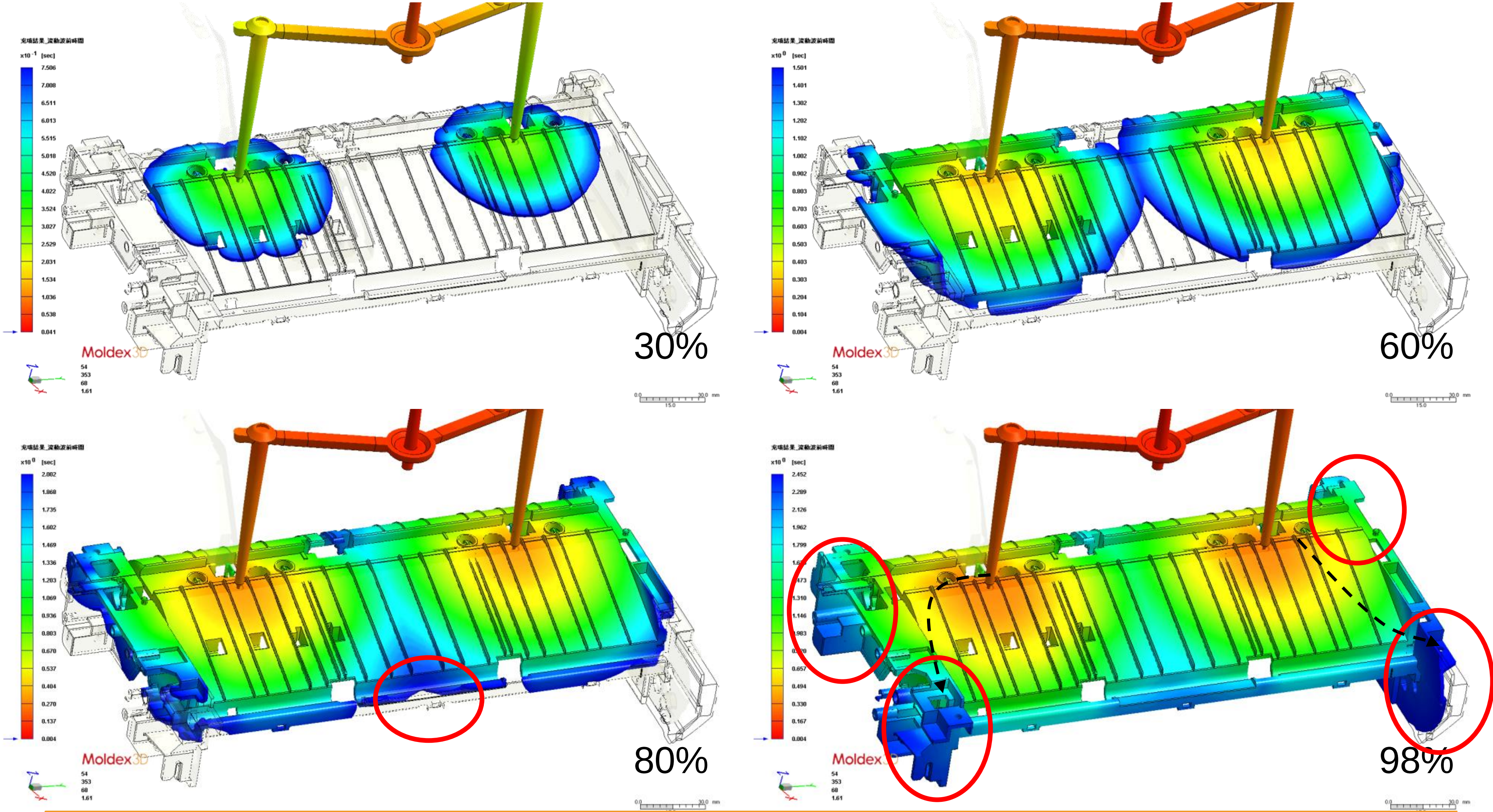
Process Parameter





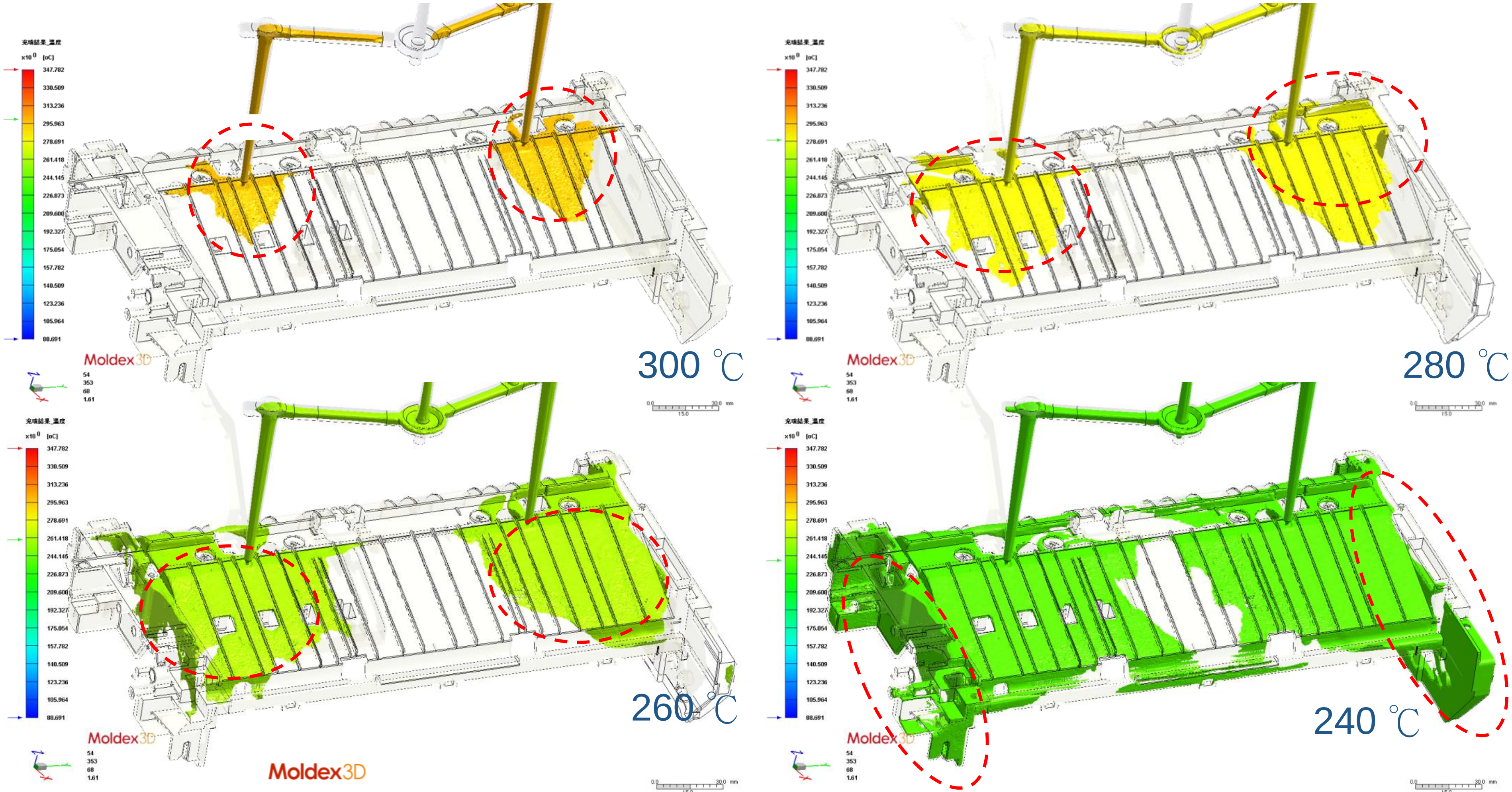


Melt Front Time 30%~98%



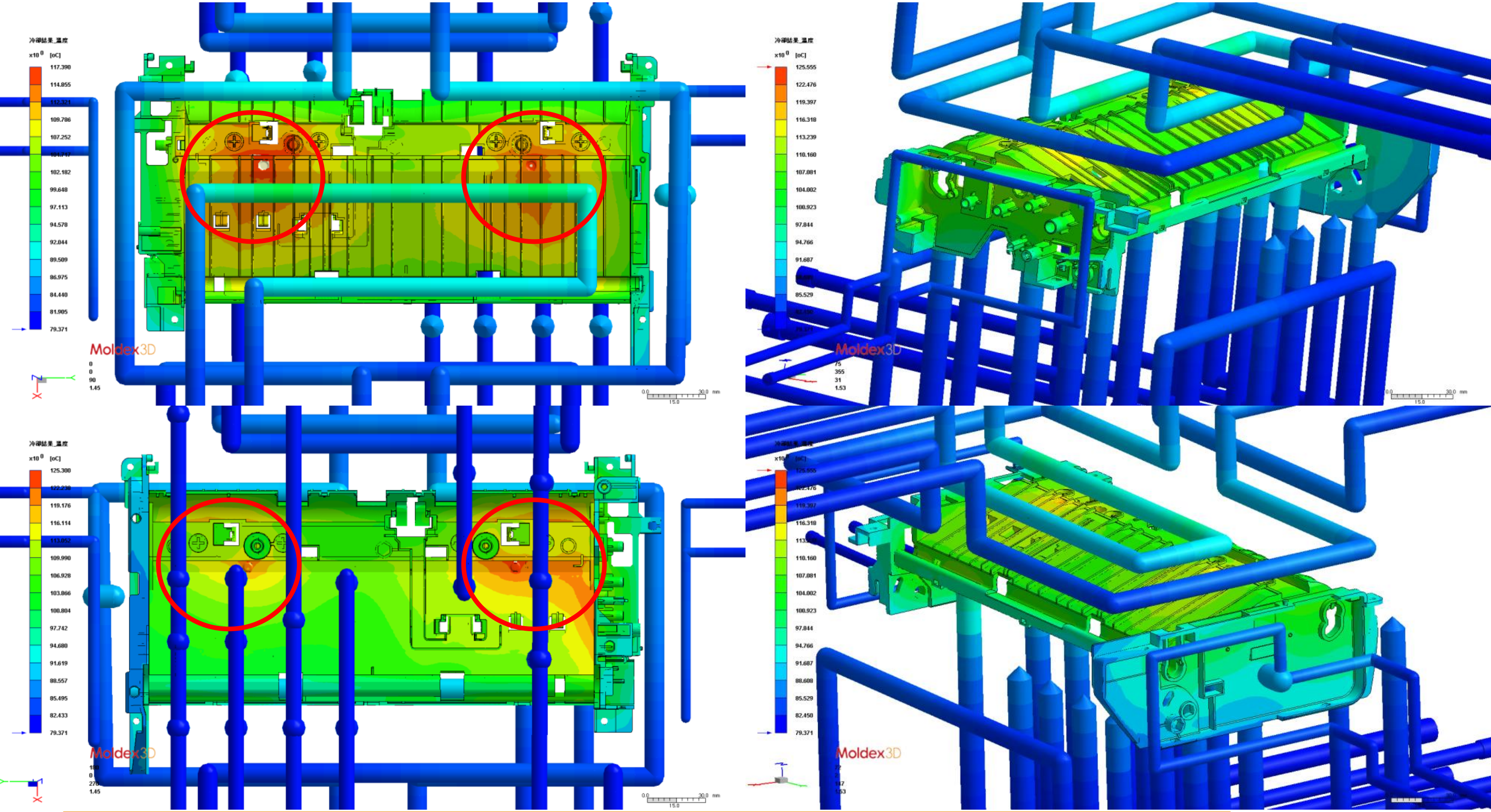
Generally, the end area of filling process has lower pressure due to farther flow length and temperature loss along the way. Therefore, the packing pressure is less than insufficient and will cause higher warpage. From the analysis results above, it can be told that the highlighted part will have more severe warpage or displacement.

Filling Analysis _ Internal Temperature Distribution



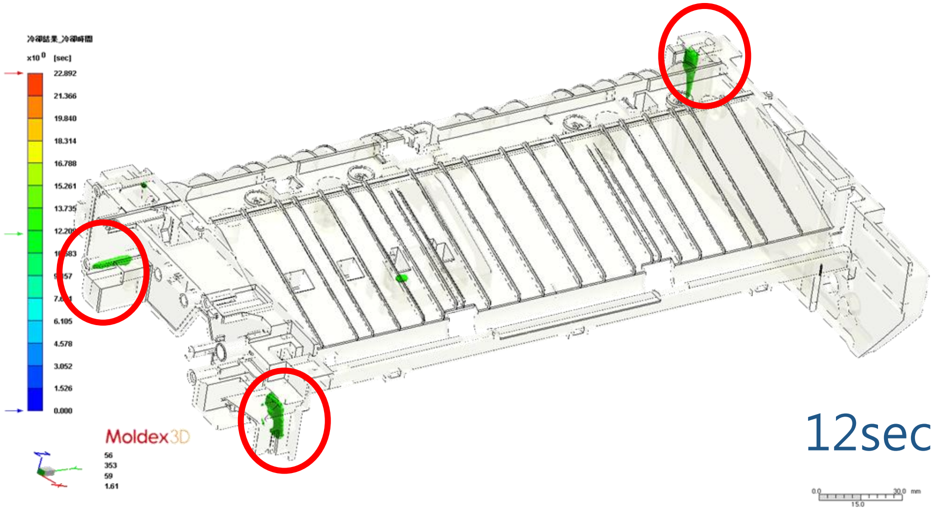
Based on the analysis results, the high temperature areas are mainly distributed around both corner sides and the area around the gates. The middle areas were the first areas starting packing process, therefore the temperature is relatively lower. Therefore, those areas should not be considered for pin location.

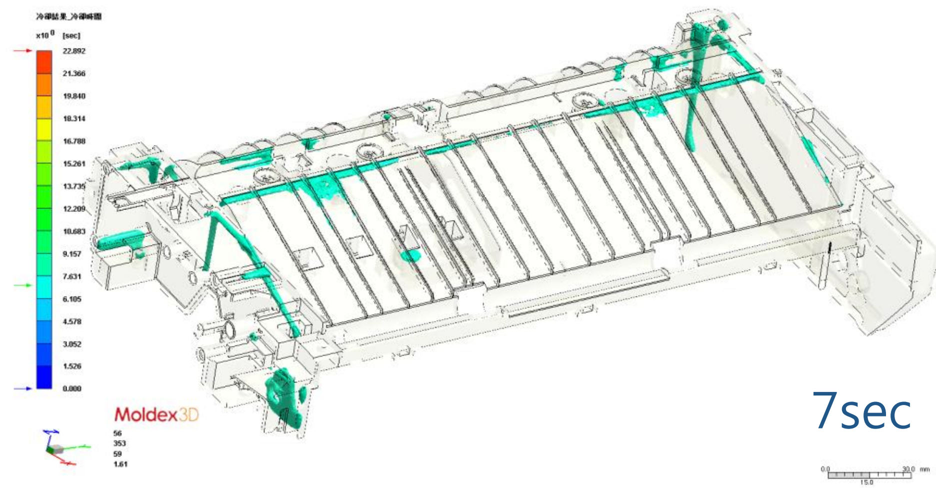
Cooling Analysis _ Temperature Distribution

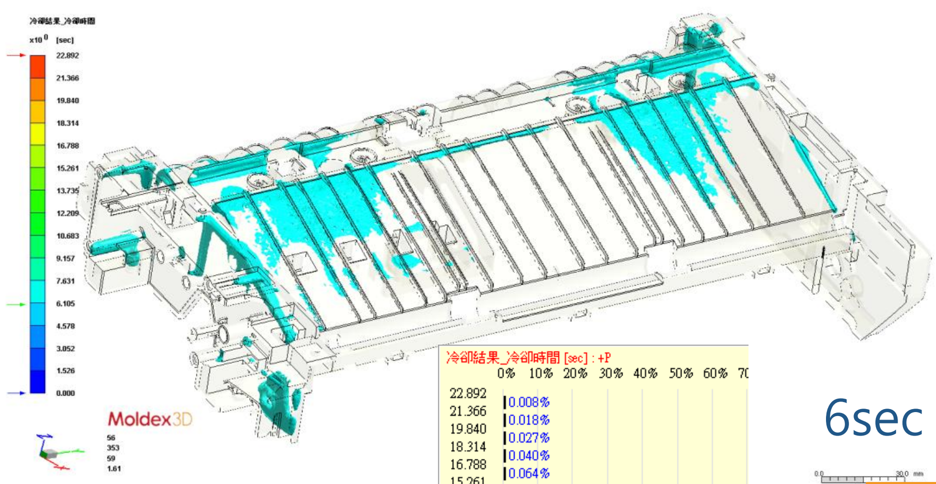


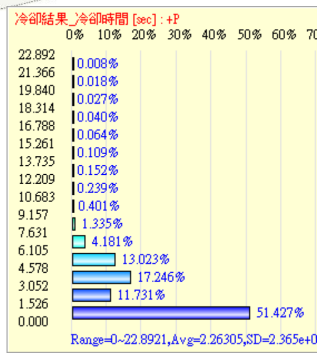
Areas near the gates in the core have heat accumulation problem and the areas around the corner in the cavity have heat accumulation problem.

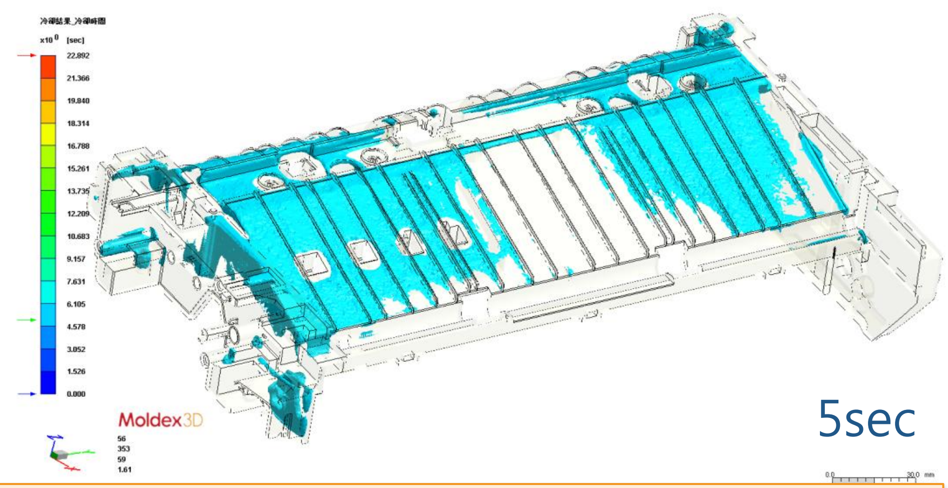
Cooling Analysis _ Cooling Time









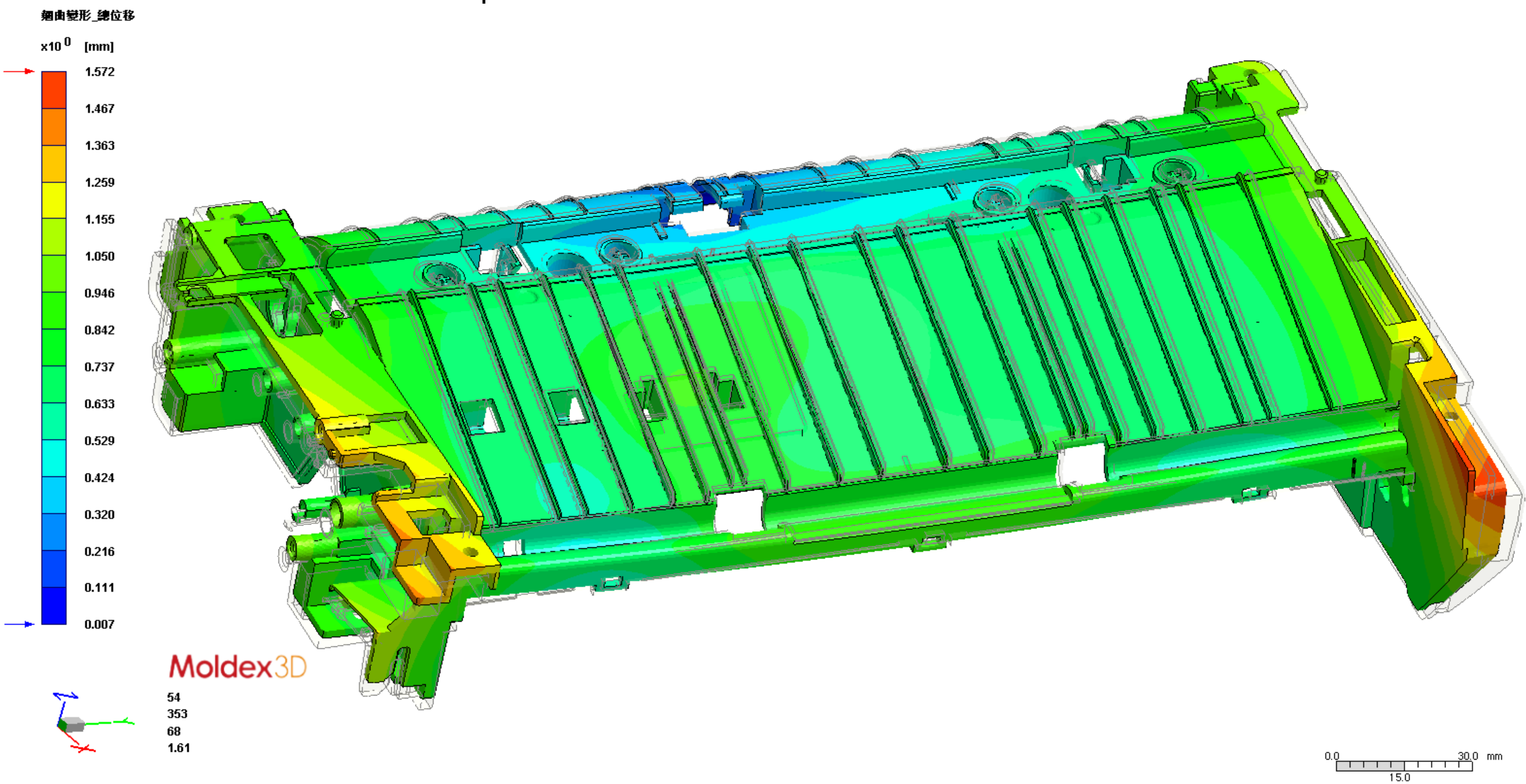


Cooling time usually range between 0~7 sec. Partial areas have longer cooling time, more than 12 seconds because of thicker wall thickness.

Warpage Analysis _ Total Displacement

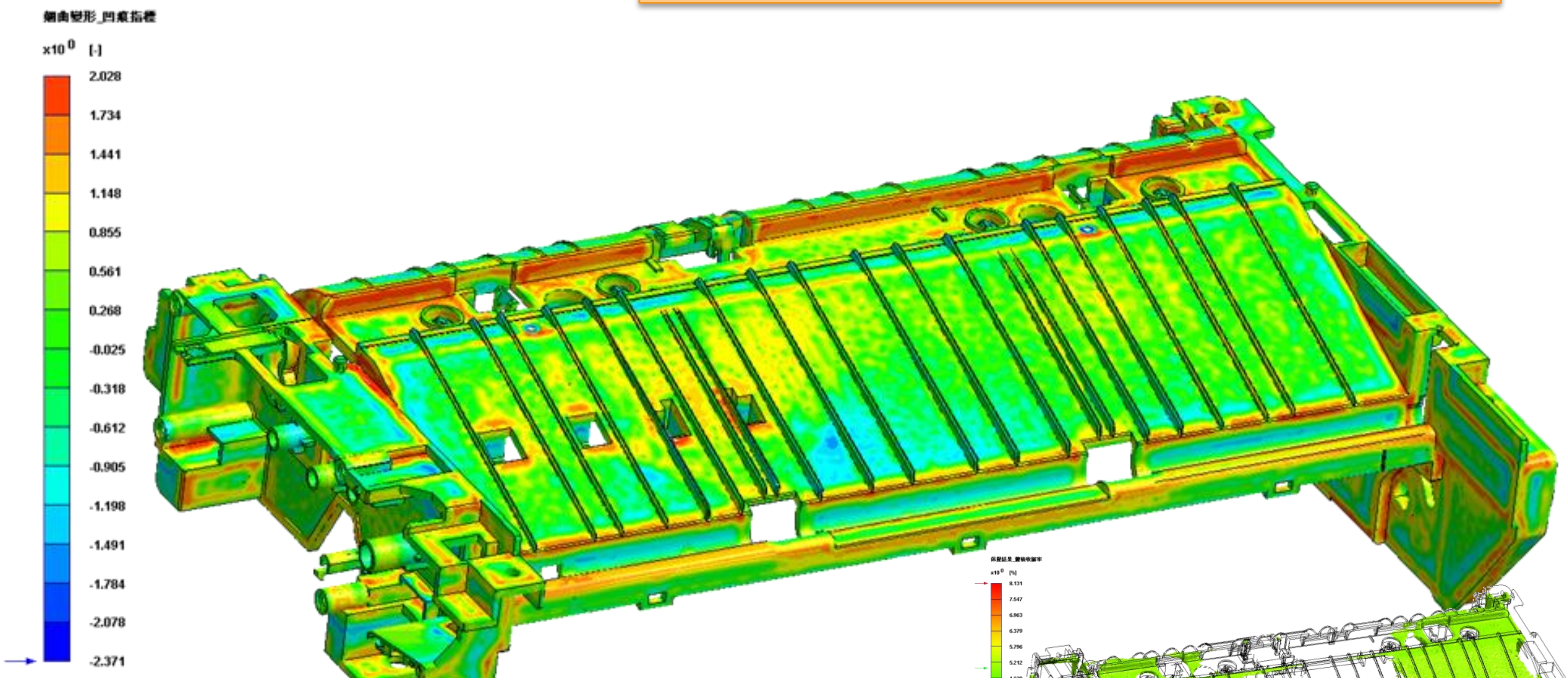
Scale：3X

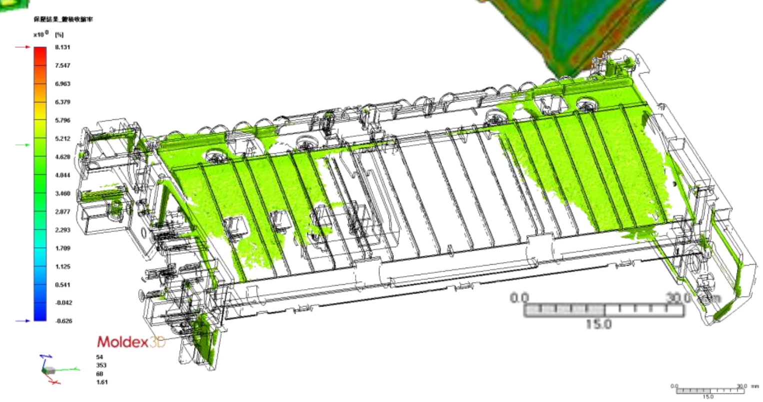
Total Displacement: 0.007mm~1.572mm



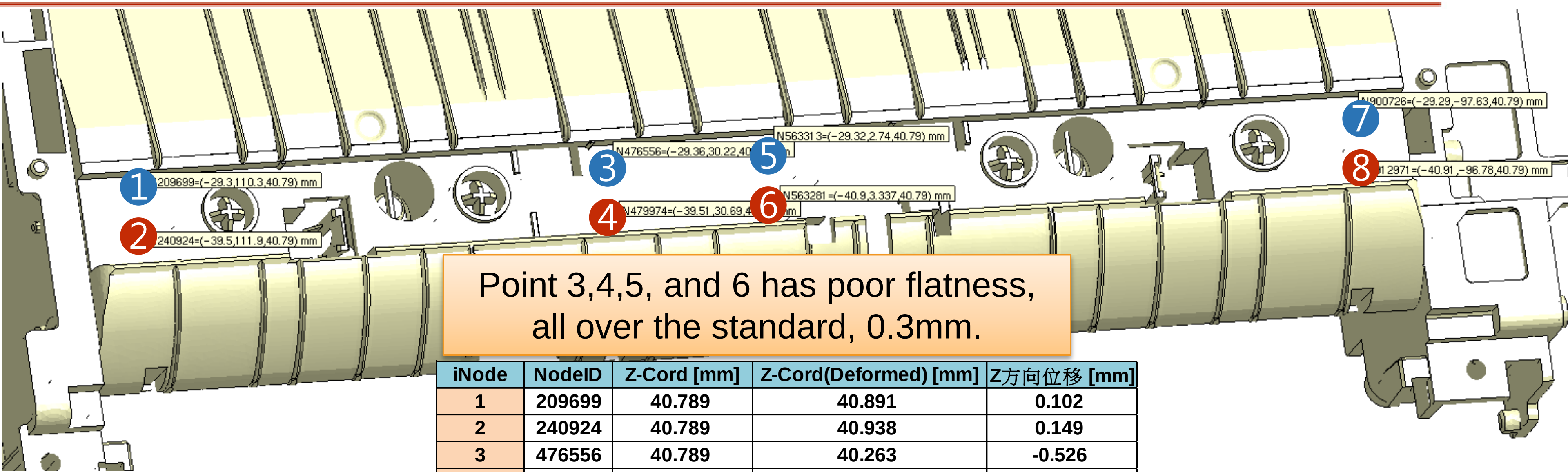
Warpage Analysis _ Sink Mark Index

Product surface has severe shrinkage mark



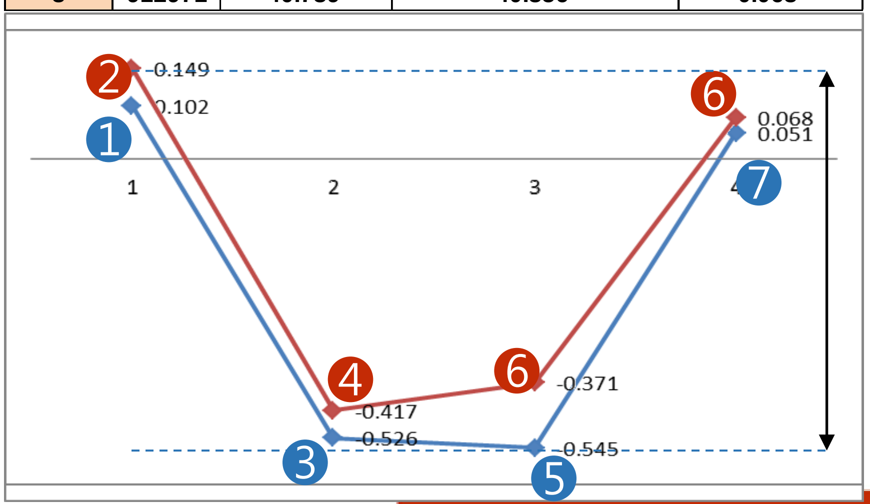


Warpage Analysis _ Node Seeding and Displacement



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

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



The difference between the highest and lowest is about 0.694mm.

Design Alternatives and Simulation Analysis

Process Parameter Adjustment I _ Packing Time

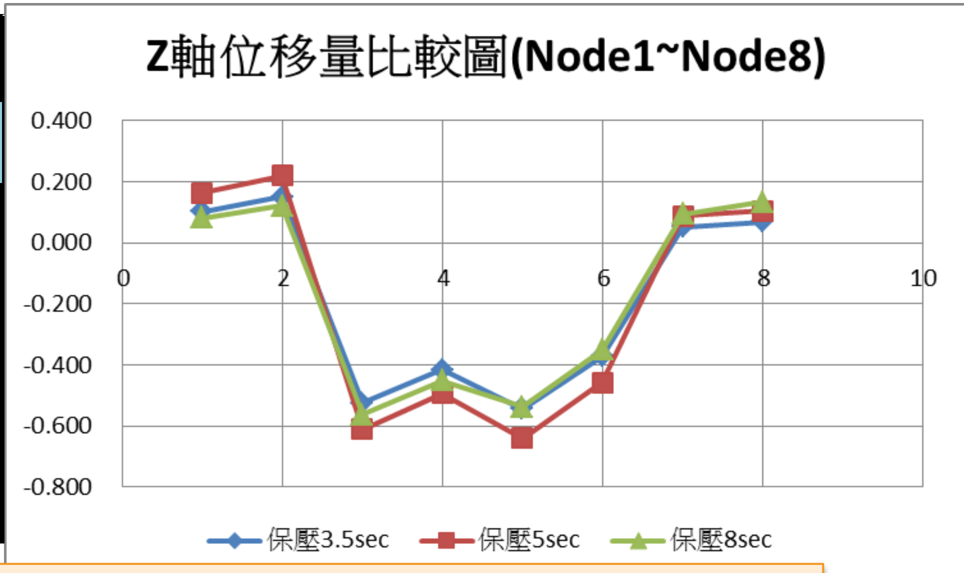
Attempts of Revised Design

- 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.

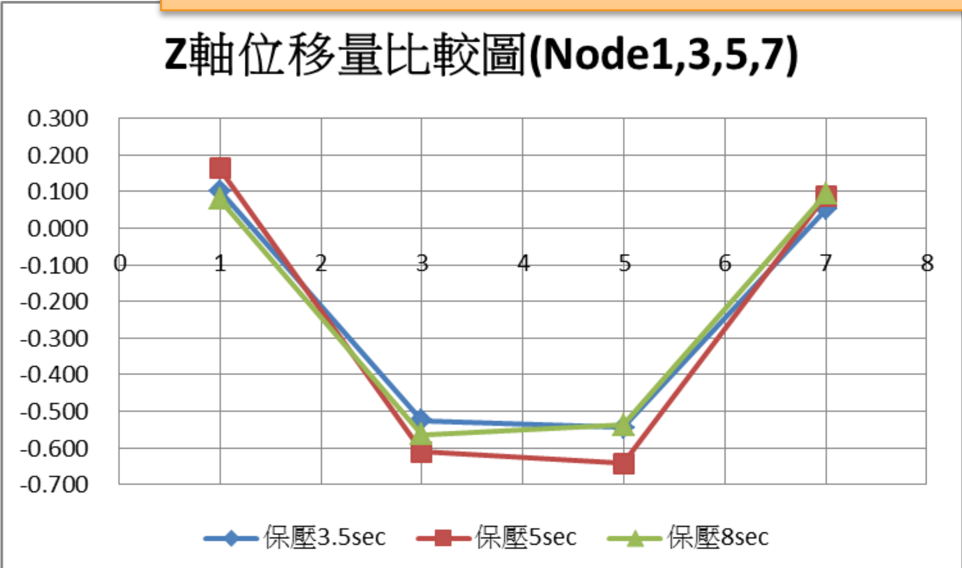
- Revised Design (Without modifying gate location and amount, only parameters are adjusted.
  - Revised Design 1 : Increase packing time from 3.5 sec to 5 sec (average mold temperature is 80 ℃)
  - Revised Design 2 : Increase packing time from 3.5sec to 8sec (average mold temperature is 80 ℃)

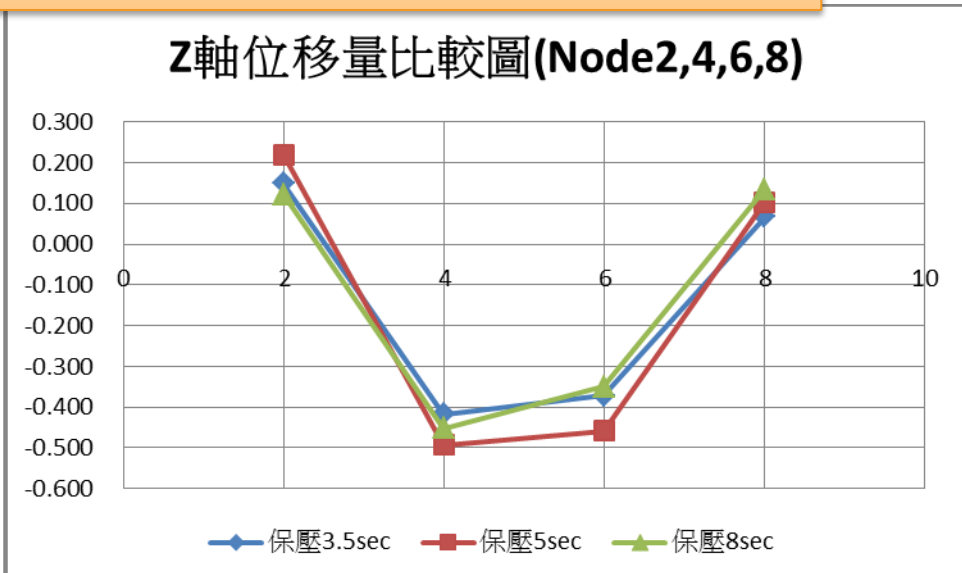
Comparison of Z-Displacement

iNode	NodeID	Z - Displacement [mm]		
		Packing Time 3.5 sec	Packing Time 5 sec	Packing Time 8 sec
1	209699	0.102	0.364	0.080
2	240924	0.149	0.502	0.121
3	476556	-0.526	-1.200	-0.564
4	479974	-0.417	-1.094	-0.452
5	563313	-0.545	-1.185	-0.537
6	563281	-0.371	-0.980	-0.351
7	900726	0.051	0.294	0.093
8	912971	0.068	0.337	0.134



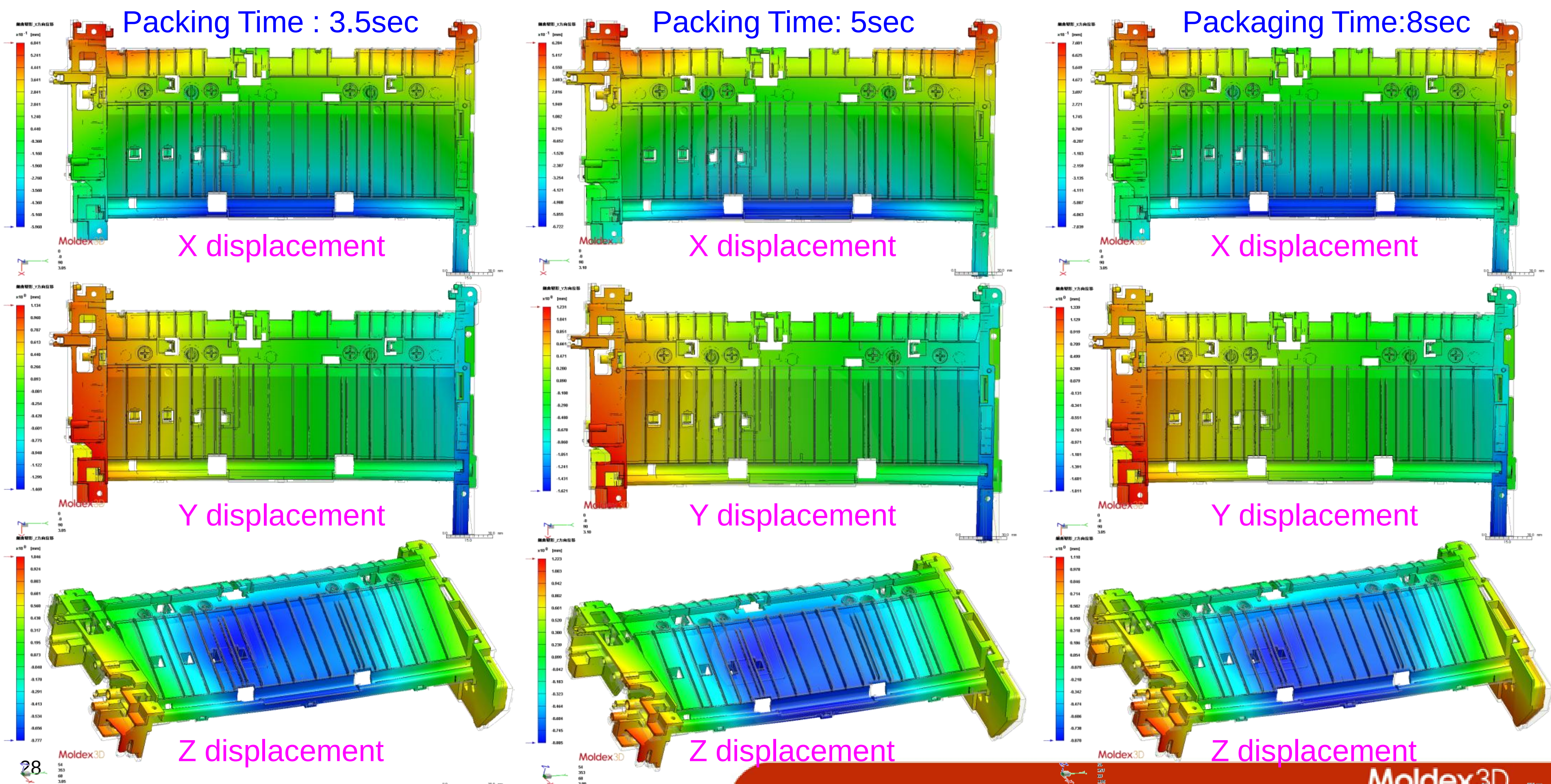
From the graphs, it can be told that packing time of 3.5 sec and packing time of 8 sec have similar results. However, packing time of 5 sec has the worst flatness result.





Comparison of Warpage Displacement

Item	X displacement			Y displacement			Z displacement		
Unit:mm	min	max	total	min	max	total	min	max	total
Packing Time 3.5sec	-0.596	0.604	1.2	-1.469	1.134	2.603	-0.777	1.046	1.823
Packing time 5sec	-0.672	0.628	1.3	-1.621	1.231	2.852	-0.885	1.223	2.108
Packing Ttime 8sec	-0.704	0.76	1.464	-1.811	1.339	3.15	-0.87	1.11	1.98



Design Alternatives and Simulation Analysis

Process Parameter Adjustment II _ Packing Pressure and Coolant Temperature

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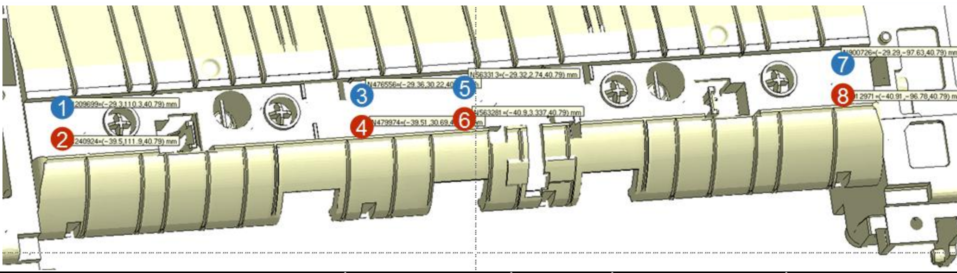
Attempts of Revised Design and Reasons

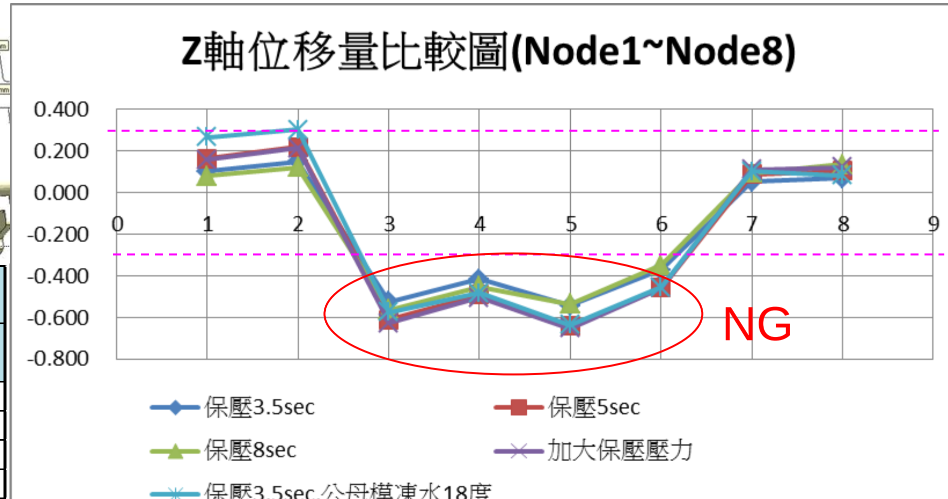
> **Revised Design Introduction**
  - **Based on the results, we can know that increasing packing time has no significant effect on warpage and flatness. Instead the original design with packing time of 3.5 sec has better flatness.**
  - **But their flatness levels are all above 0.3mm, we continue adjust 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℃)**
  - **Revised Design IV: Keep packing time as 3.5 sec and decrease mold temperature to 18℃**

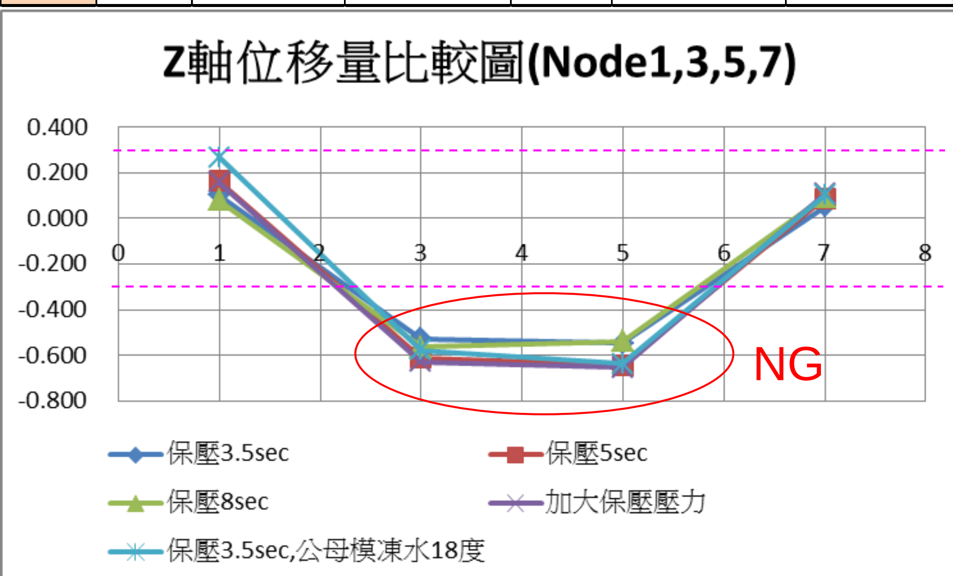
Comparison of Z-Displacement

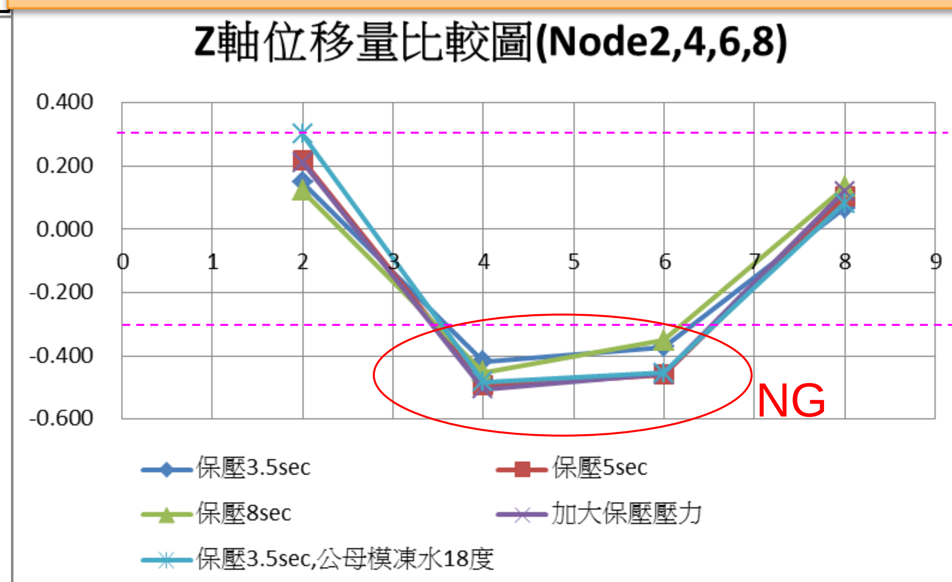


iNode	NodeID	Z方向位移 [mm]				
		保壓3.5sec	保壓5sec	保壓 8sec	加大保壓壓力	保壓3.5sec,公母模凍水18度
1	209699	0.102	0.163	0.080	0.157	0.267
2	240924	0.149	0.220	0.121	0.212	0.301
3	476556	-0.526	-0.611	-0.564	-0.628	-0.576
4	479974	-0.417	-0.493	-0.452	-0.506	-0.483
5	563313	-0.545	-0.642	-0.537	-0.653	-0.637
6	563281	-0.371	-0.459	-0.351	-0.458	-0.455
7	900726	0.051	0.088	0.093	0.109	0.103
8	912971	0.068	0.104	0.134	0.121	0.082



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

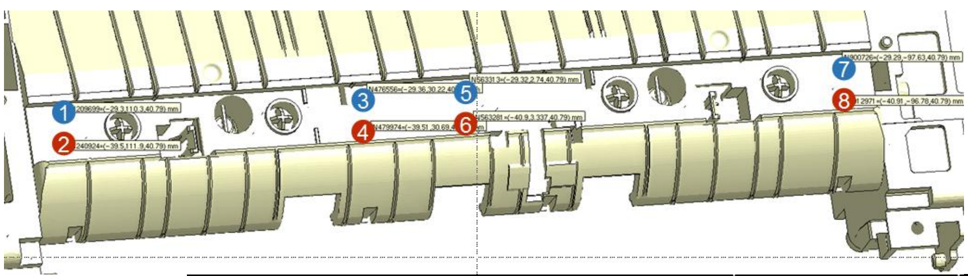




Sum-Up

> 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.



iNode	NodeID	Z方向位移 [mm]				
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2	240924	0.149	0.220	0.121	0.212	0.301
3	476556	-0.526	-0.611	-0.564	-0.628	-0.576
4	479974	-0.417	-0.493	-0.452	-0.506	-0.483
5	563313	-0.545	-0.642	-0.537	-0.653	-0.637
6	563281	-0.371	-0.459	-0.351	-0.458	-0.455
7	900726	0.051	0.088	0.093	0.109	0.103
8	912971	0.068	0.104	0.134	0.121	0.082

項目	X displacement				Y displacement				Z displacement			
單位:mm	min	max	total	改善率	min	max	total	改善率	min	max	total	改善率
保壓3.5sec	-0.596	0.604	1.2		-1.469	1.134	2.603		-0.777	1.046	1.823	
保壓5sec	-0.672	0.628	1.3	-8.33%	-1.621	1.231	2.852	-9.57%	-0.885	1.223	2.108	-15.63%
保壓8sec	-0.704	0.76	1.464	-22.00%	-1.811	1.339	3.15	-21.01%	-0.87	1.11	1.98	-8.61%
加大保壓壓力	-0.689	0.6168	1.3058	-8.82%	-1.707	1.218	2.925	-12.37%	-0.957	1.223	2.18	-19.58%
保壓3.5sec,凍水	-0.5938	0.4188	1.0126	15.62%	-1.229	0.886	2.115	18.75%	-1.011	1.177	2.188	-20.02%

Design Alternatives and Simulation Analysis

Process Parameter Adjustment III _Gas-Assisted Injection Molding Process adoption

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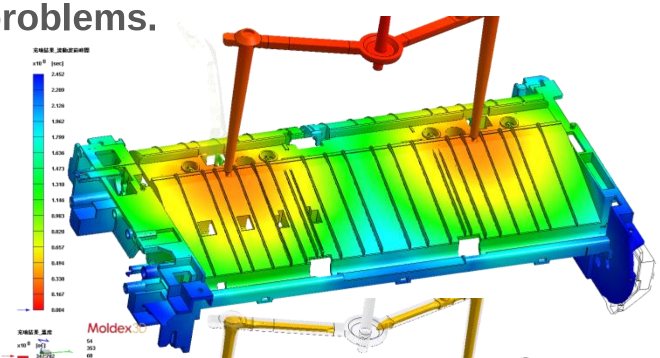
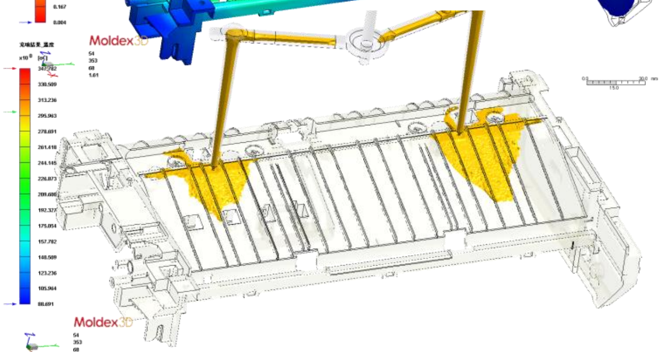
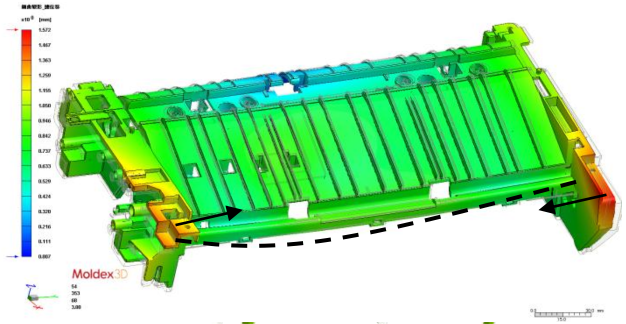
Pin Location Setup and Discussion

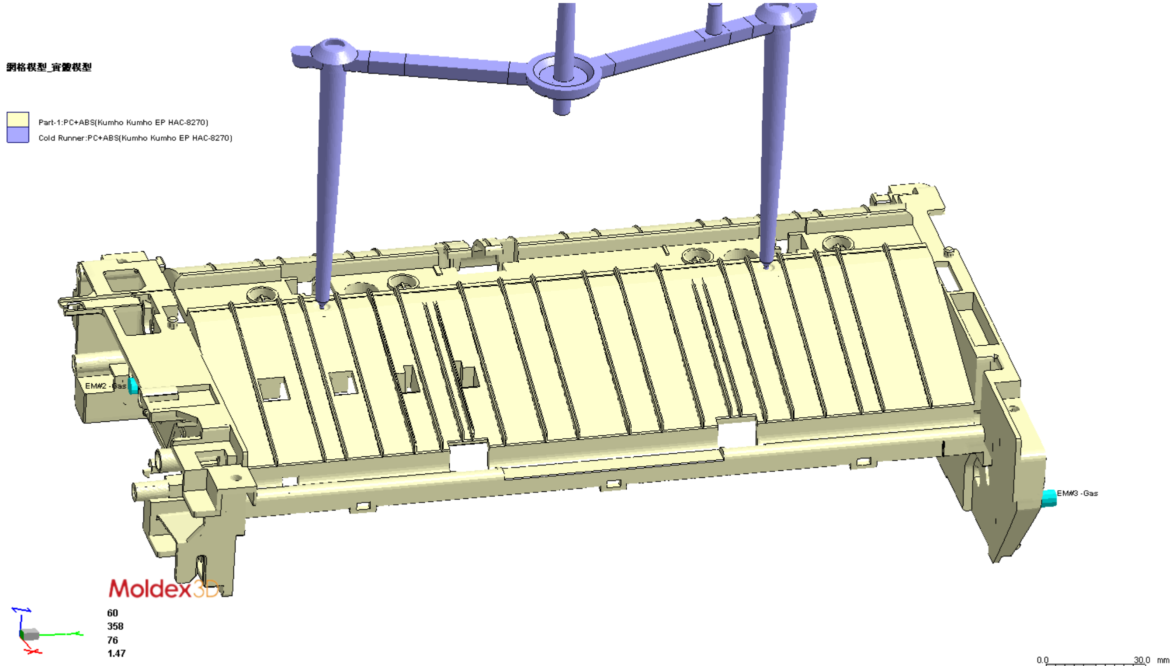
- Information from traditional analysis:
  - Flow imbalance. Middle melt front firstly arrived, then packing and temperature decreasing started. The bottom areas of both left and right sides firstly complete filling process.
  - Higher temperature areas are mainly distributed in the areas around the 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.

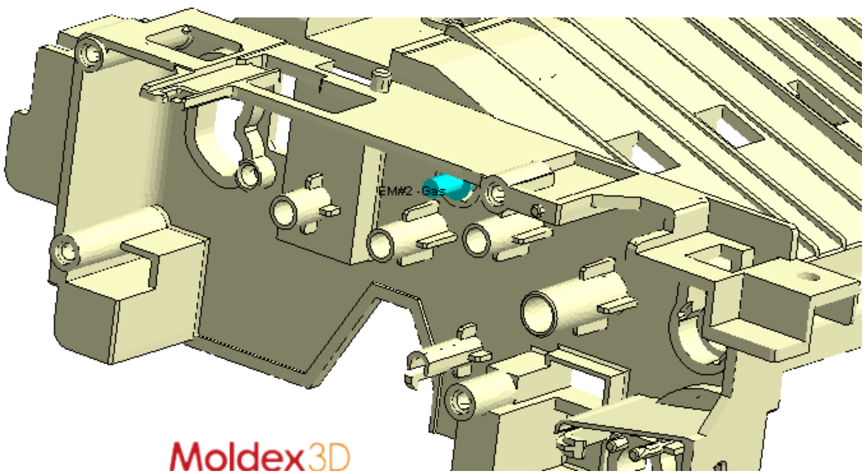


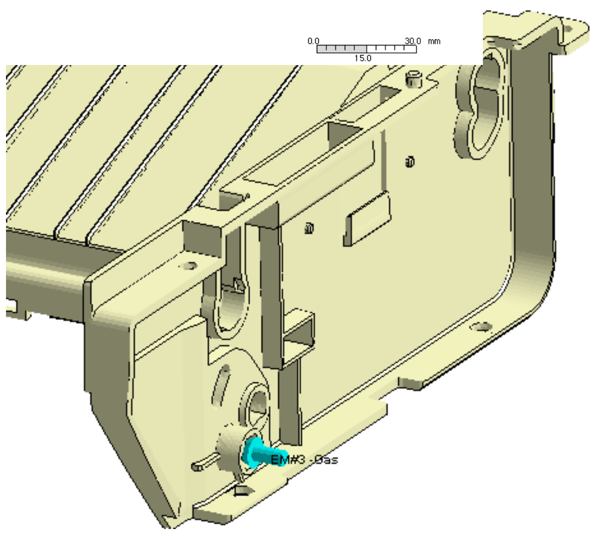




Pin Location Setup

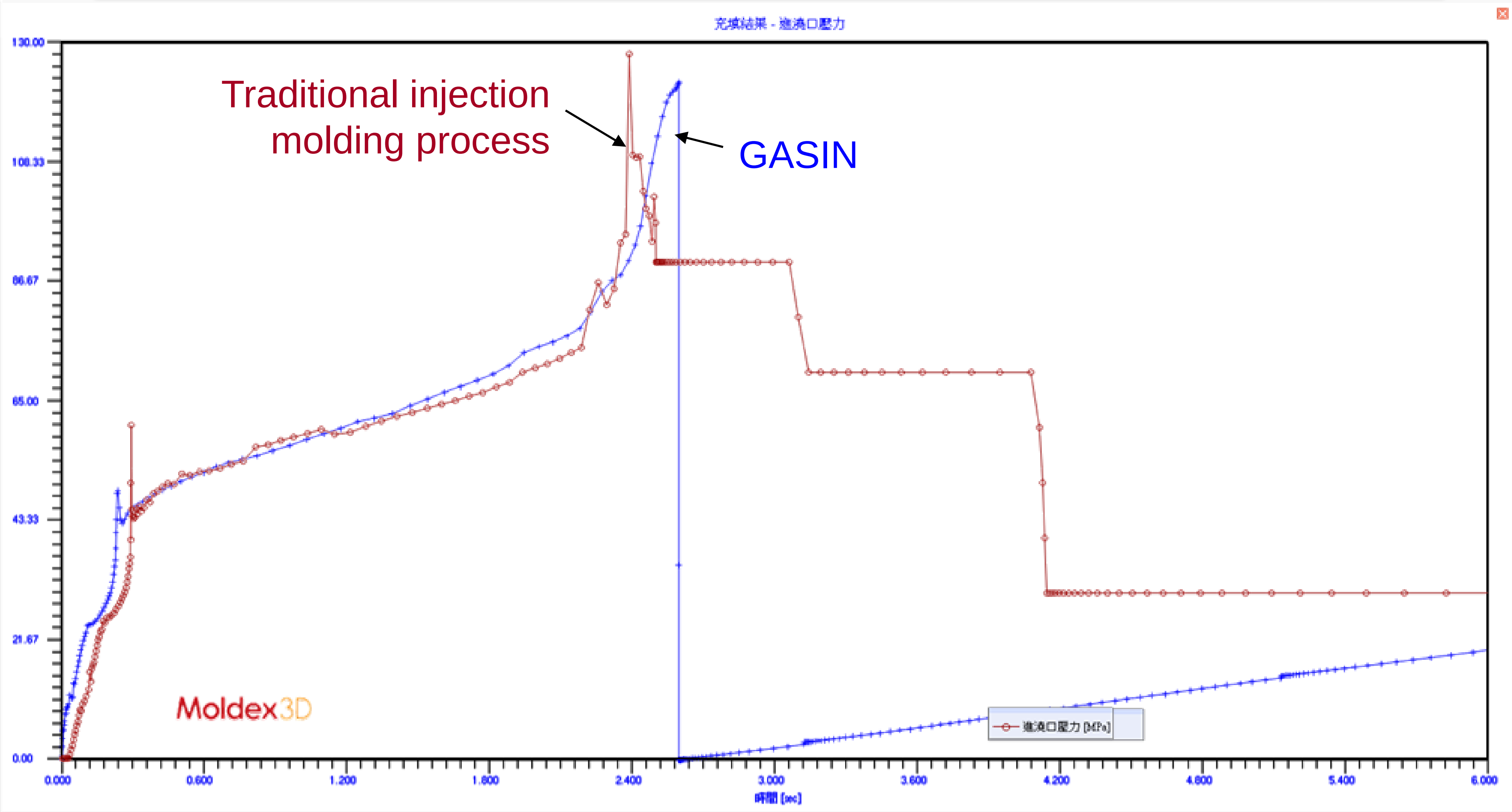






Filling Analysis Result _ Injection Pressure

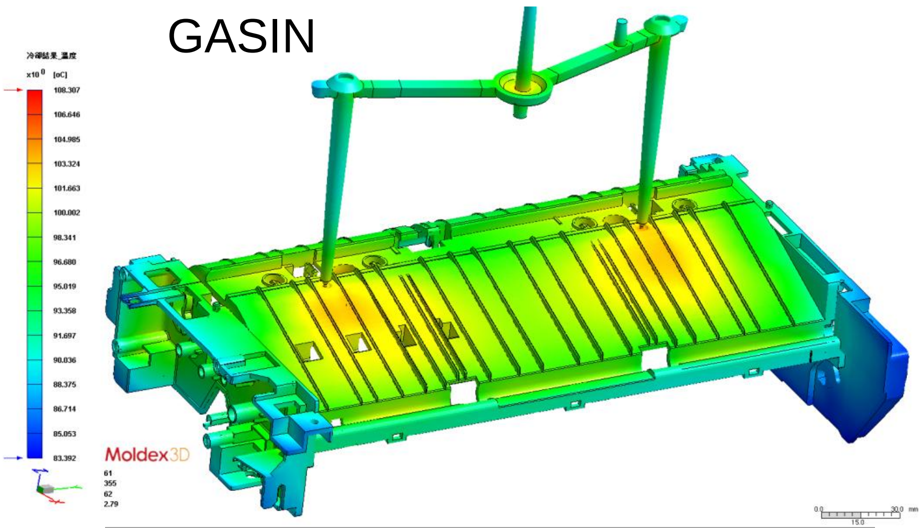
The injection pressure needed with gas assisted injection was way smaller than the pressure needed with traditional injection molding process.



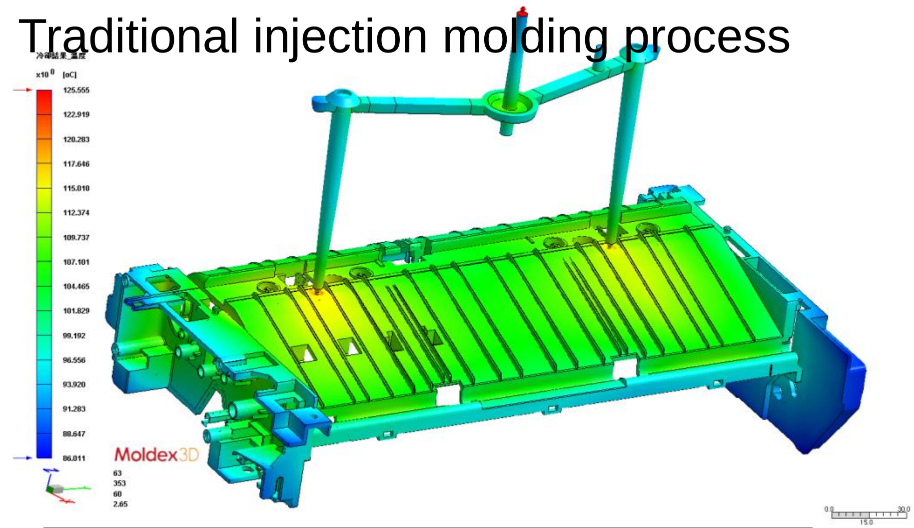
Moldex3D

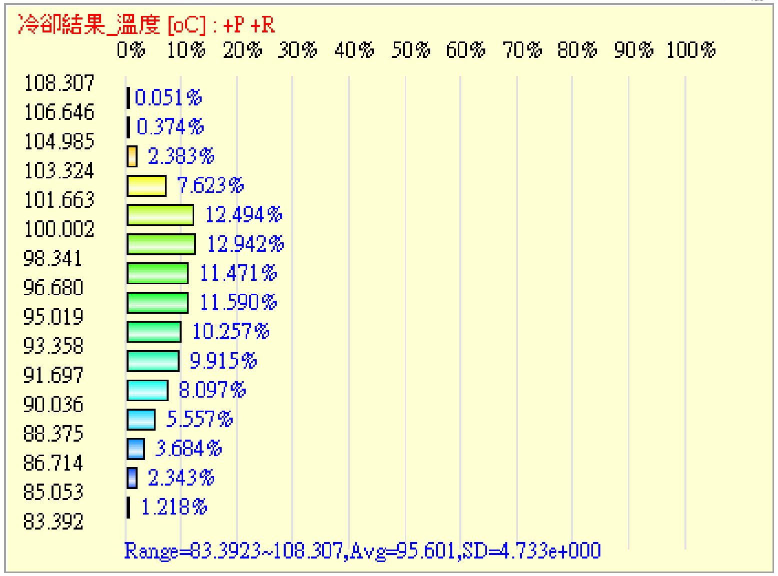
Cooling Analysis Result _ Cooling Temperature

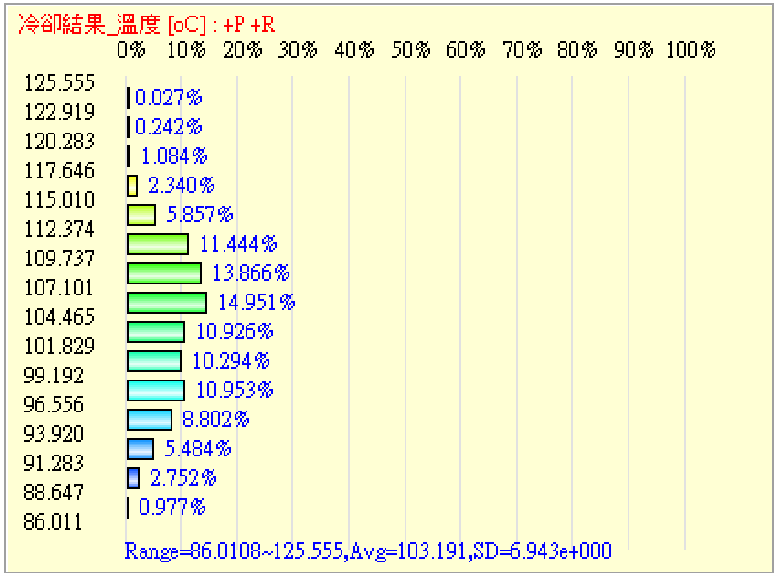
GASIN



Traditional injection molding process



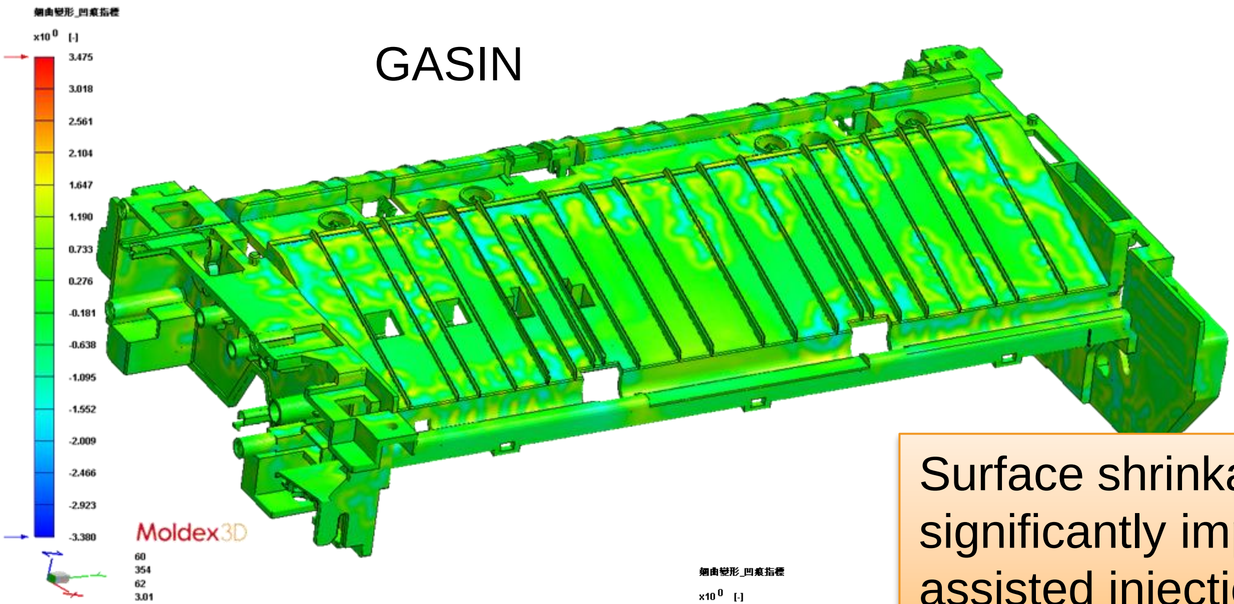




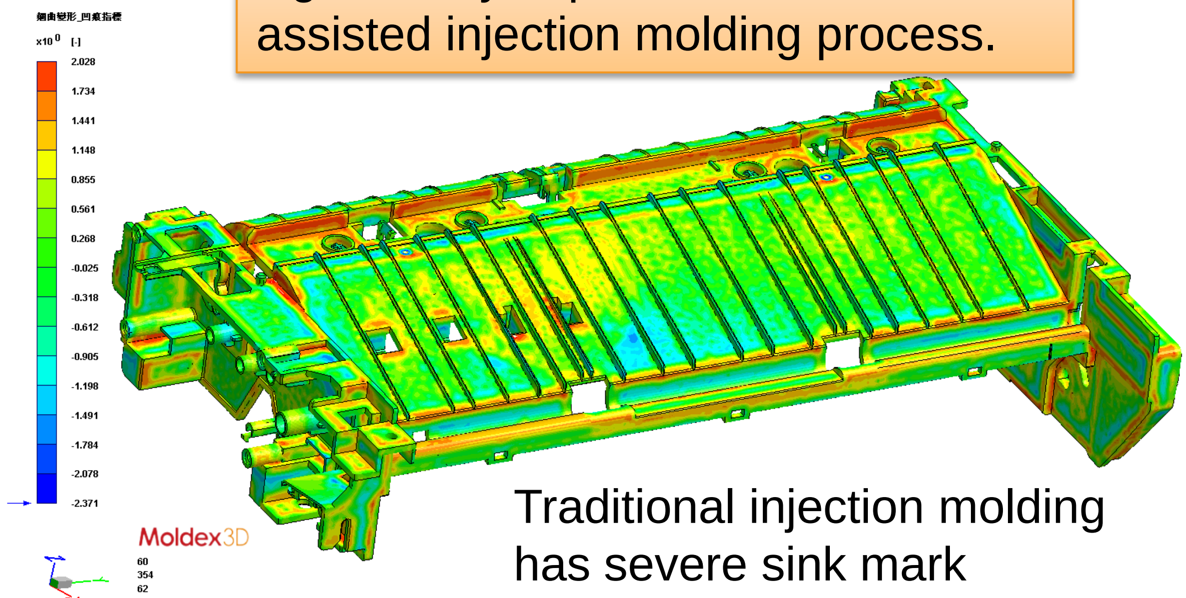
Average temperature distribution ranges between 83℃ and 108℃ with GASIN. On the other hand, average temperature distribution ranges between 86℃ and 125℃, which is about 17℃ higher.

Warpage Analysis Result _ Sink Mark Index

GASIN



Surface shrinkage mark has been significantly improved with Gas-assisted injection molding process.

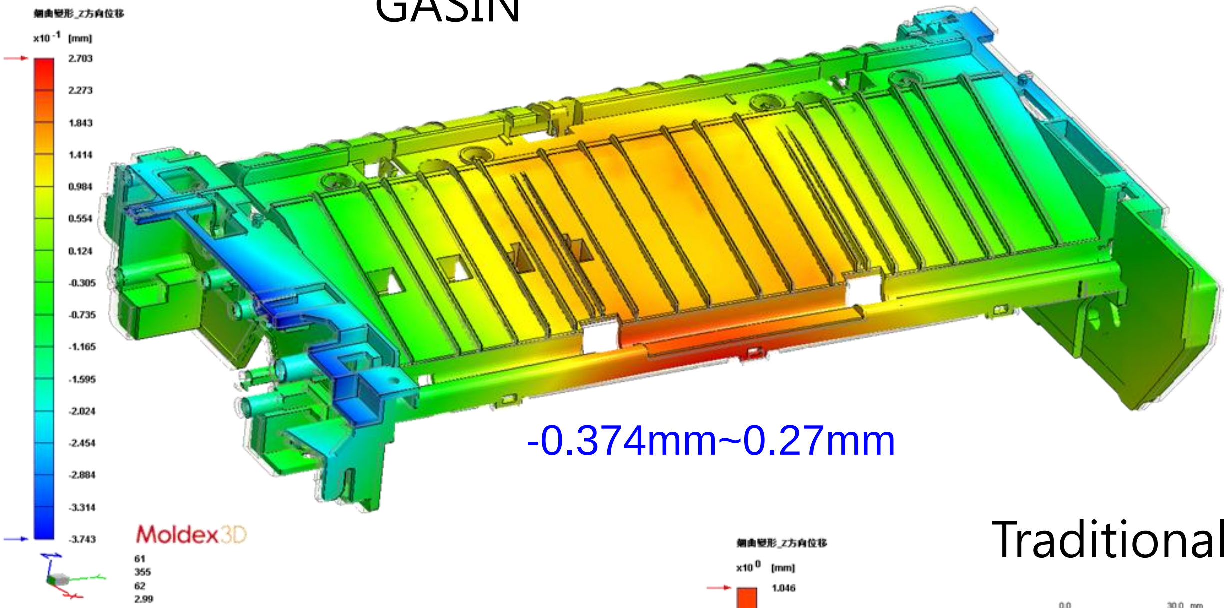


Traditional injection molding has severe sink mark

Warpage Analysis Result _ Z-Displacement

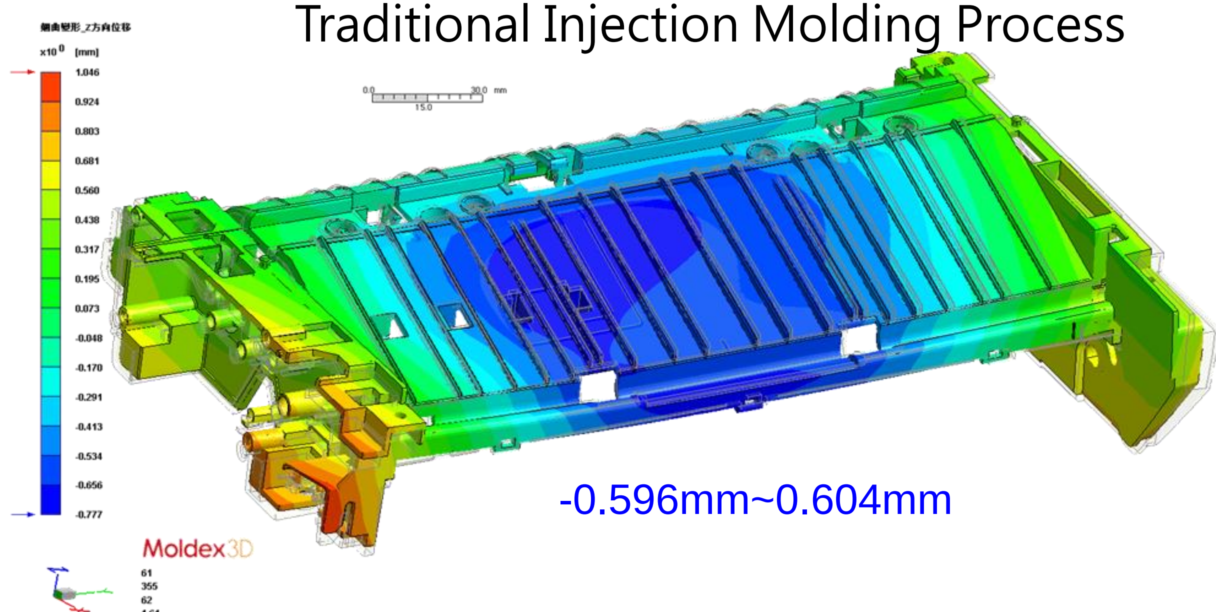
GASIN

Scale: 3X



-0.374mm~0.27mm

Traditional Injection Molding Process

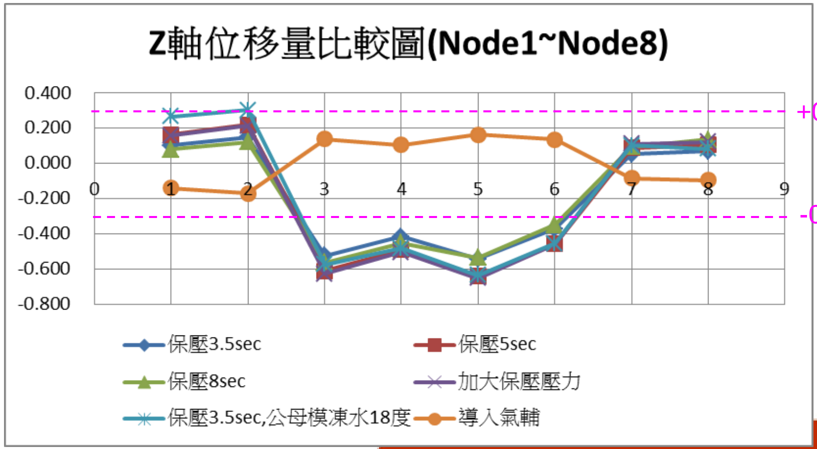


-0.596mm~0.604mm

Comparison of Warpage Analysis Result

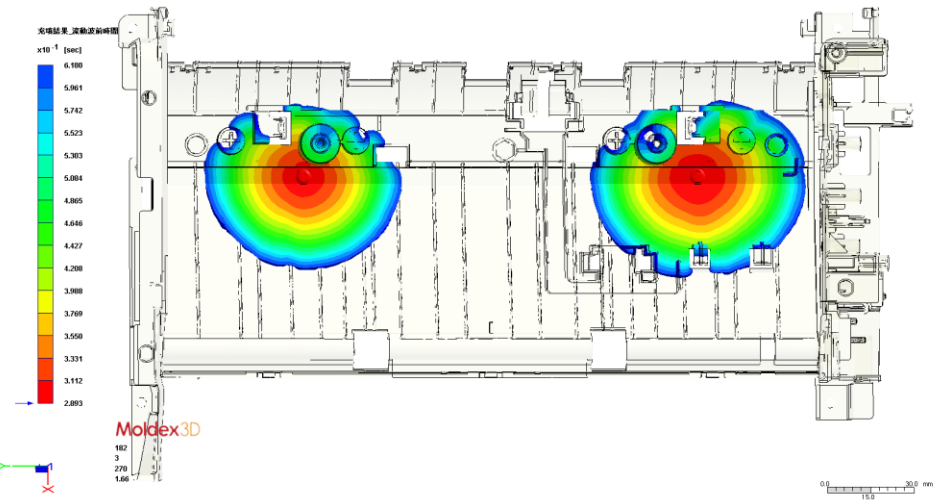
> After implementing Gas-assisted injection molding, overall warpage phenomenon was significantly improved.
  - X-Displacement improve 45%
  - Y-Displacement improve 40%
  - Z-Displacement improve 64%
  - Z-Flatness is within ±0.3mmm and under 0.2mm, which fulfilled the requirement.。

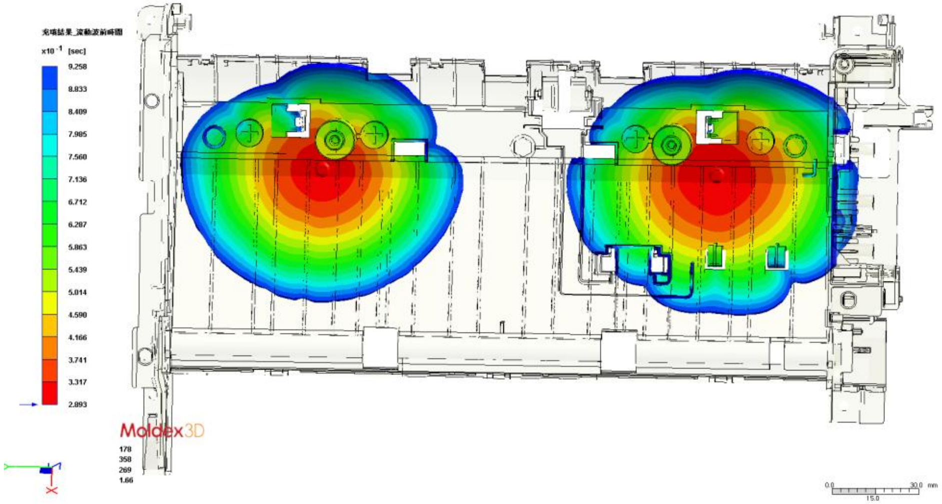
項目	X displacement				Y displacement				Z displacement			
單位:mm	min	max	total	改善率	min	max	total	改善率	min	max	total	改善率
保壓3.5sec	-0.596	0.604	1.2		-1.469	1.134	2.603		-0.777	1.046	1.823	
保壓5sec	-0.672	0.628	1.3	-8.33%	-1.621	1.231	2.852	-9.57%	-0.885	1.223	2.108	-15.63%
保壓8sec	-0.704	0.76	1.464	-22.00%	-1.811	1.339	3.15	-21.01%	-0.87	1.11	1.98	-8.61%
加大保壓壓力	-0.689	0.6168	1.3058	-8.82%	-1.707	1.218	2.925	-12.37%	-0.957	1.223	2.18	-19.58%
保壓3.5sec,凍水	-0.5938	0.4188	1.0126	15.62%	-1.229	0.886	2.115	18.75%	-1.011	1.177	2.188	-20.02%
導入氣輔	-0.368	0.2885	0.6565	45.29%	-0.7723	0.782	1.5543	40.29%	-0.3743	0.2703	0.6446	64.64%



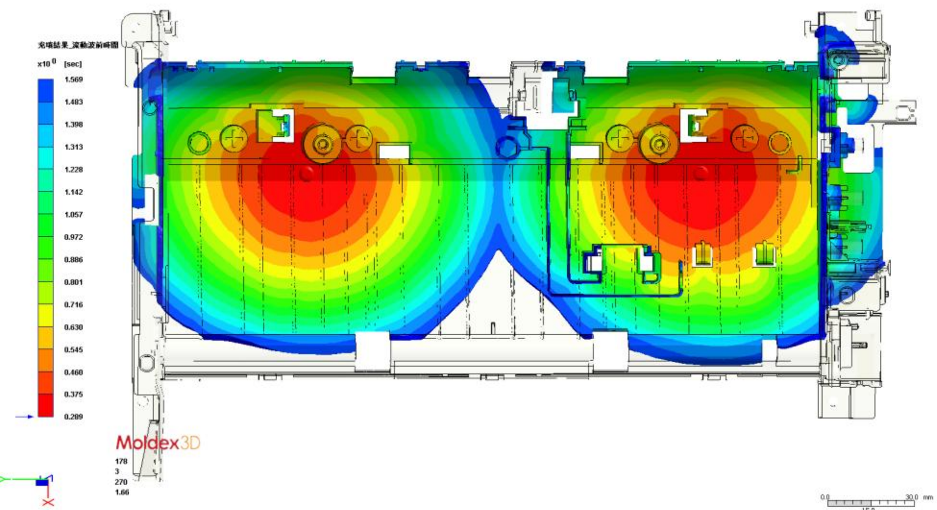
Comparison of Simulation Result and Real Product

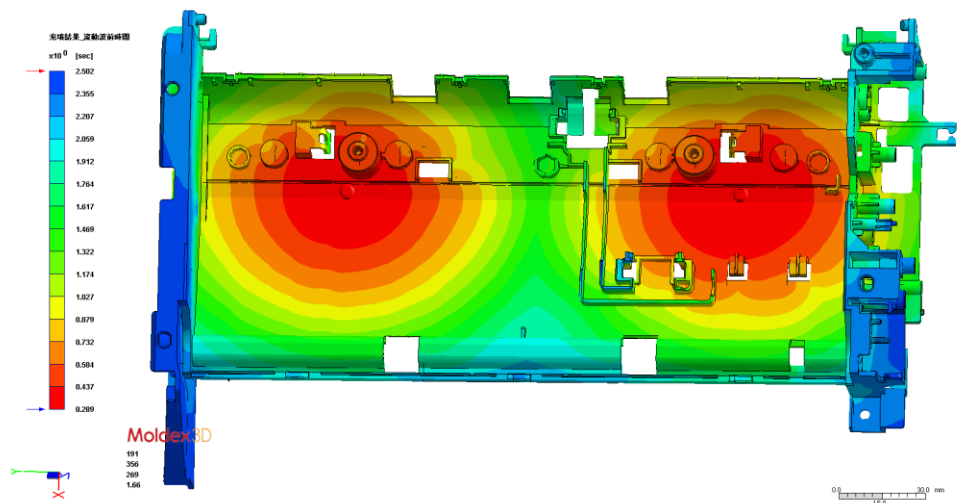
Before Gas Entry _ Comparison of Short Shot Analysis Result I



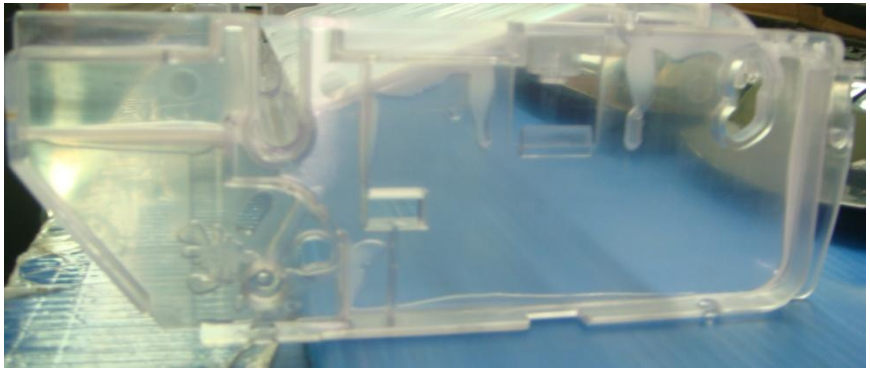


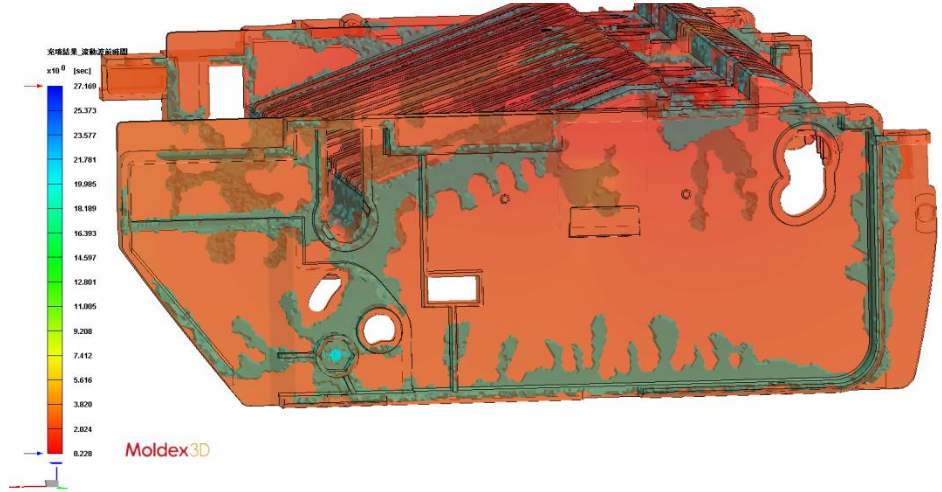
Before Gas Entry _ Comparison of Short Shot Analysis Result II



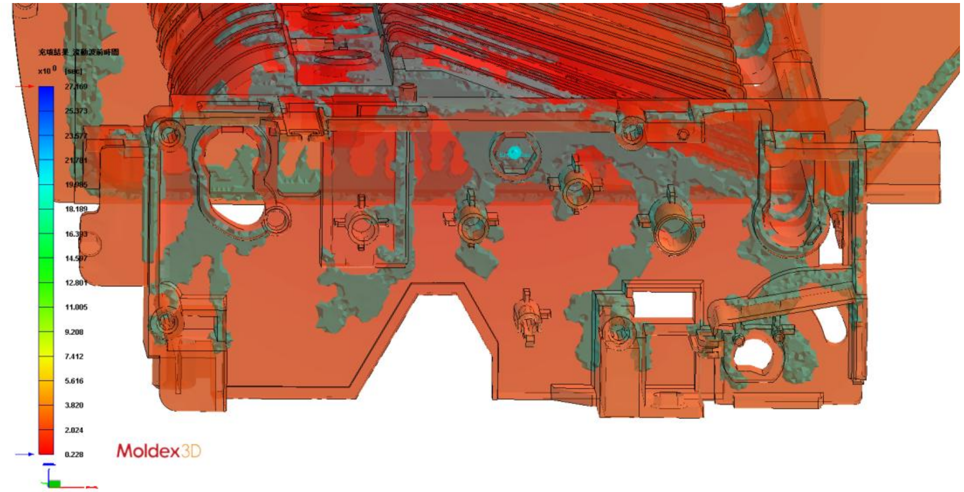


After Gas Entry _ Comparison of Gas Permeation Analysis Result





The simulation analysis results correspond with the short shot result from real mold trial.



Benefit Analysis and Future Application

Moldex3D Application Value Analysis

	Price per iter	Tooling	Machine Cost Rate (USD/min)	Mold Repairing (USD/per time)	Mold Trial (USD/per Time)	Personnel (USD/per day)
Unit:USD	1	22,000	0.2	2,000	200	4

Traditional Injection Molding Process	Filling	Packing		Cooling	Mold Open	Cycle Time
	2.5	3.5		22	10	38
Gas-Assisted Injection Molding Process	Filling	Packing	Gas	Cooling	Mold Open	Cycle Time
	2.5	3.5	10	5	10	31

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

*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!