新型LED霧燈設計與射出成形研究

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目錄

前言

- 傳統燈具大多以鹵素燈為光源，其缺點有壽命短、光源效率低、溫度高、玻璃外殼易碎、含汞等有毒物質，聚光性不足、耗電量高等問題之外，對環境的損害相對是巨大的，然而另一個重要的新興產品半導體二極體(Light-Emitting Diode, LED)的車燈照明設備，可能取代任何光源，原因是它**具備低耗能(僅約10%)、壽命長(約為傳統燈泡的10倍)、反應速度快(約 330倍)、體積小等優點**，於色彩、亮度、壽命、節能及環保訴求等均較傳統光源更具有發展優勢。
- 高亮度 LED 為現階段相當熱門的車用替代光源，汽機車霧燈最主要的功能是車輛在霧天或者雨天能見度受天氣影響時開啓的車輛燈具，汽車的霧燈起到了提示的作用。**霧燈照明必須具備投射角度光形以及亮度均足夠的兩項前提**，要滿足這兩者，高亮度 LED即可滿足大功率的照明設備。

車用照明燈介紹

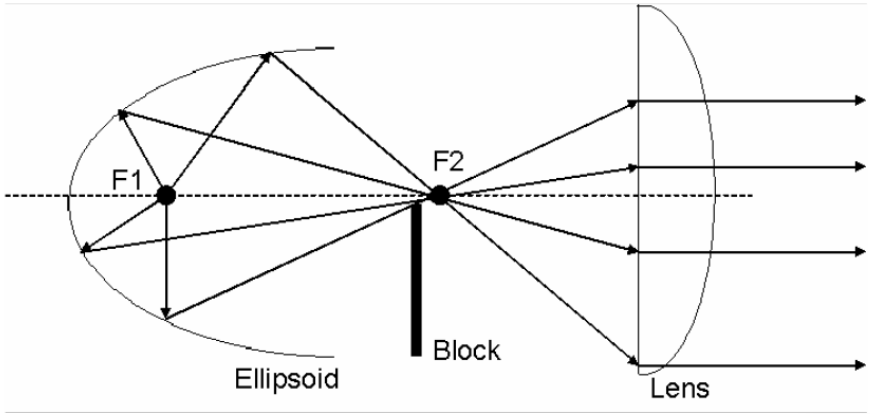
目前使用 LED 當光源應用於燈具設計的方式有二種：**多重反射鏡面車燈(MR , Multi-Reflector) 又稱作反射式車燈以及投射式車燈(Projection System)又稱作透鏡式車燈。**

晶鑽頭燈示意圖

多重反射鏡的製作方式為將一個拋物面切割成許多的方形反射鏡，**每個反射鏡再改變其曲率與旋轉角度，將光線反射到需要的區域，並利用堆疊的方式增強亮度值而組合成需要之光形。**

車用照明燈介紹

- 投射式車燈 (Projection System)，其設計方式為利用橢圓反射面，**將燈源置於橢圓的第一焦點，光線經過反射後集中至第二焦點，在第二焦點的位置放置擋板以製造出需要的截止線光形**，並且再放置一個非球面凸透鏡於擋板前方，其焦點位於擋板位置，使光線能平行射出。



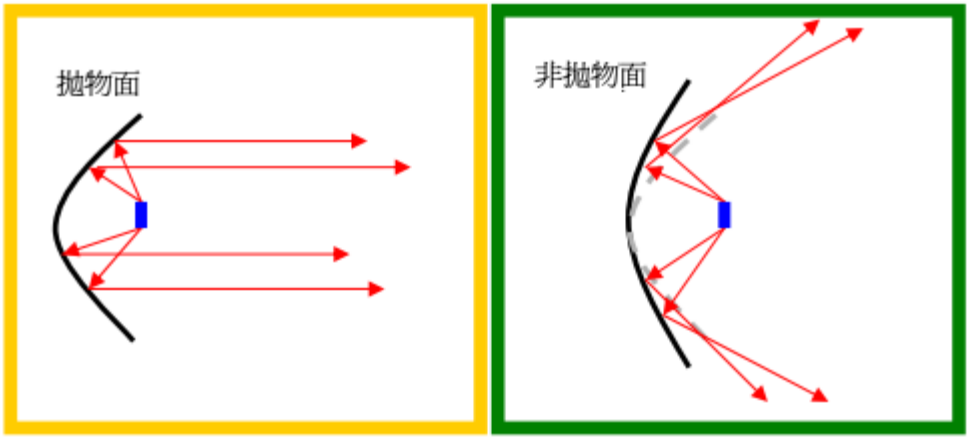
投射式車燈架構圖

研究動機

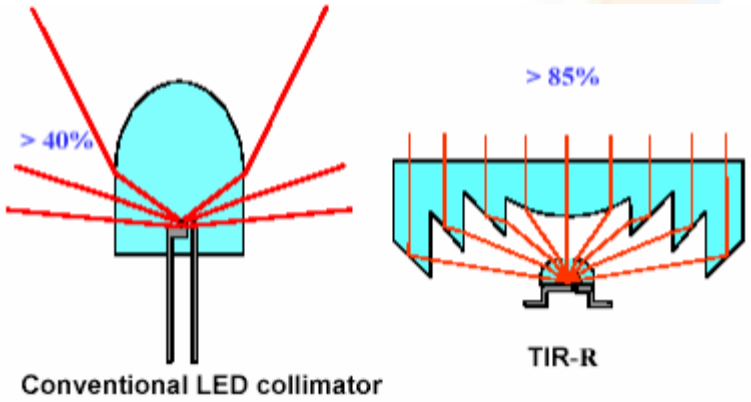
- LED車用霧燈大多使用**投射式**與**反射式**的燈罩設計，但兩種設計方式各有其優缺點。以反射式車燈為例，**光線經過多層反射面造成能量損耗，使投射面的強度減弱**，對能量的使用效率很低;**許多霧燈也沒有符合法規進行光學設計**，容易造成對向駕駛者與前方駕駛，因為眩光造成意外事故。
- 本設計利用多段式的反射罩，並將LED置於燈具中心，發光面朝前方，利用多段式的反射罩來處理LED所發散出不同角度的光線；然而，**一般市售的球面透鏡多為聚焦所用，無法根據法規將光線分佈成一定的需求**，所以設計新穎性的**穿透型光柵結構透鏡**，使光強度的範圍符合歐洲經濟委員會所訂定不同區域之光的分佈強度，並可以穩定**照射光源的亮度和降低眩光**等優點。
- 並針對LED霧燈為稜鏡透鏡實際透過射出成型方式，探討PC料於成型參數下如**複製度**及**翹曲**的影響。

文獻回顧 - 光學設計類

- 彭偉捷[1]於2005年成功設計其車用LED用霧燈雕塑完成的反射罩測試能量效率方面，TIR透鏡頭燈勝過反射式鏡面頭燈。



反射式鏡面頭燈

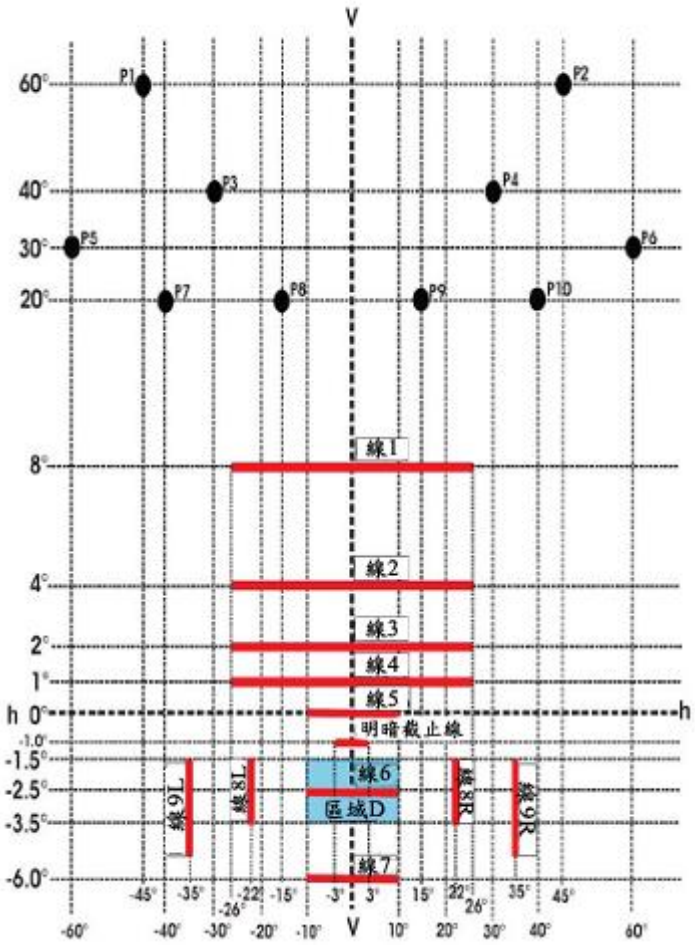


TIR 透鏡(全反射透鏡)

文獻回顧 - 塑膠製造類

- 鄭安益[2]於2009年單眼立體微稜鏡板之製作與檢驗研究中提到射出光學微稜鏡陣列體攝影機中，使用較高的成形溫度有助於成型品的複製度，而降低射出速度可減少剪切稀薄的現象，可使整體密度較為均勻。
- B. Sha [3] 2007以結晶材料及非結晶材料進行微米級的結構進行成型，並以不同的成型溫度以及射出速度探討成型性，發現在較高的成型溫度有助於成型。
- Cheng-Hsien Wu [4] 2006利用田口方法設計實驗參數，並以傳統射出與射出壓縮進行具有Grating結構之透鏡成型。在射出成型(IM)微結構複製度的控制因子為成型溫度，而射出壓縮(ICM)之控制因子為壓縮速度。

ECE R19 CLASS F3車用前霧燈規範



ECE R19 CLASS F3光強度分布圖

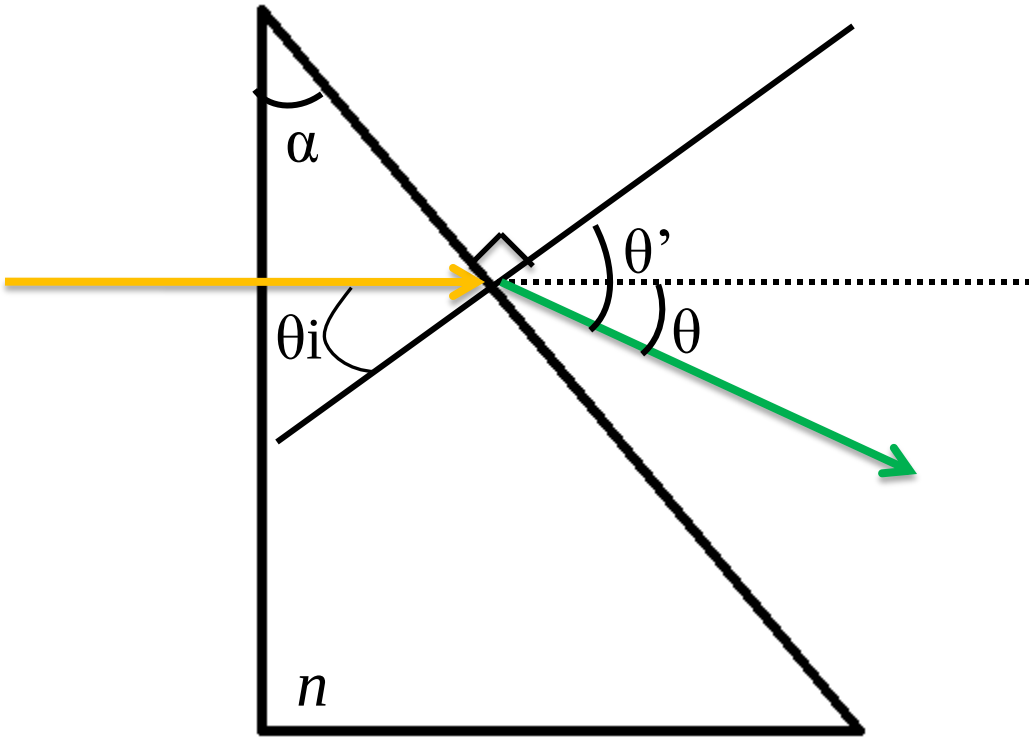
R19 CLASS F3配光要求表

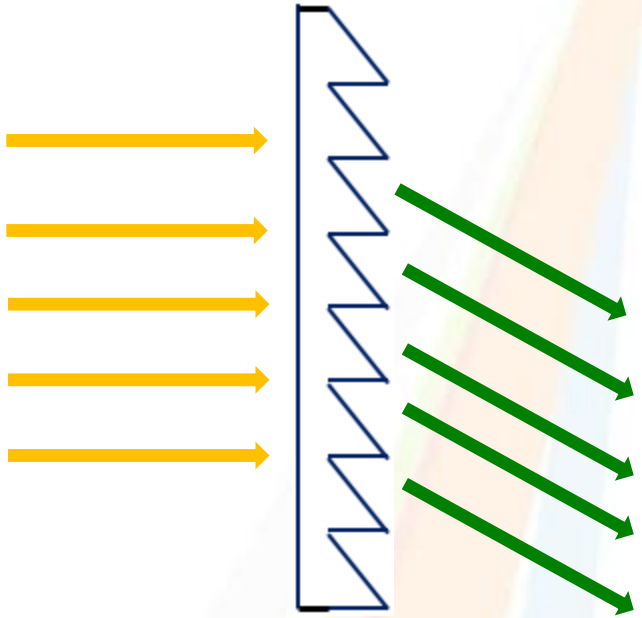
Designated lines or zones	Vertical position */ above h + below h -	Horizontal position */ left of v: - right of v: +	Luminous intensity (in cd)	To comply
Point 1, 2 **/	+ 60°	± 45°	60 max	All points
Point 3, 4 **/	+ 40°	± 30°		
Point 5, 6 **/	+ 30°	± 60°		
Point 7, 10 **/	+ 20°	± 40°		
Point 8, 9 **/	+ 20°	± 15°		
Line 1 **/	+ 8°	- 26° to + 26°	90 max	All line
Line 2 **/	+ 4°	- 26° to + 26°	105 max	All line
Line 3	+ 2°	- 26° to + 26°	170 max	All line
Line 4	+ 1°	- 26° to + 26°	250 max	All line
Line 5	0°	- 10° to + 10°	340 max	All line
Line 6	- 2.5°	- 10° to + 10°	2,000 min	All line
Line 7	- 6.0°	- 10° to + 10°	< 50 per cent of max. on line 6	All line
Line 8L and R ***/	-1.5° to - 3.5°	- 22° and + 22°	800 min	One or more points
Line 9L and R ***/	-1.5° to - 4.5°	- 35° and + 35°	320 min	One or more points
Zone D	- 1° to - 3 °	- 10° to + 10°	8,400 max	Whole zone

*/ The co-ordinates are specified in degrees for an angular web with a vertical polar axis.
**/ See paragraph 6.4.3.4.
***/ See paragraph 6.4.3.2.

前霧燈於25m 處配光要求

Trace pro 光學分析 - 霧燈透鏡設計





光柵光學示意圖

$$n\sin\theta_i = 1\sin\theta'$$

$$\theta = \theta' - \alpha = n\alpha - \alpha = (n-1)\alpha$$

n：材料折射率 θi: 入射角角度

α: 頂角角度　　θ′ :反射角角度

θ: 反射角跟水平線的角度差

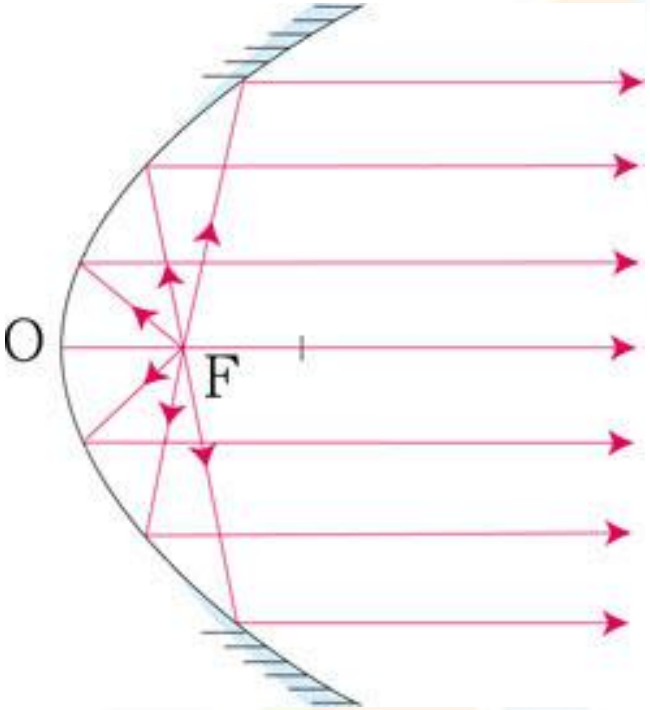
拋物面反射罩

將一拋物線繞著主軸（即對稱軸）旋轉180º，所產生的曲面稱為拋物面，以拋物面作成反射面的鏡子即為拋物面鏡。

1. 拋物面鏡的幾何性質

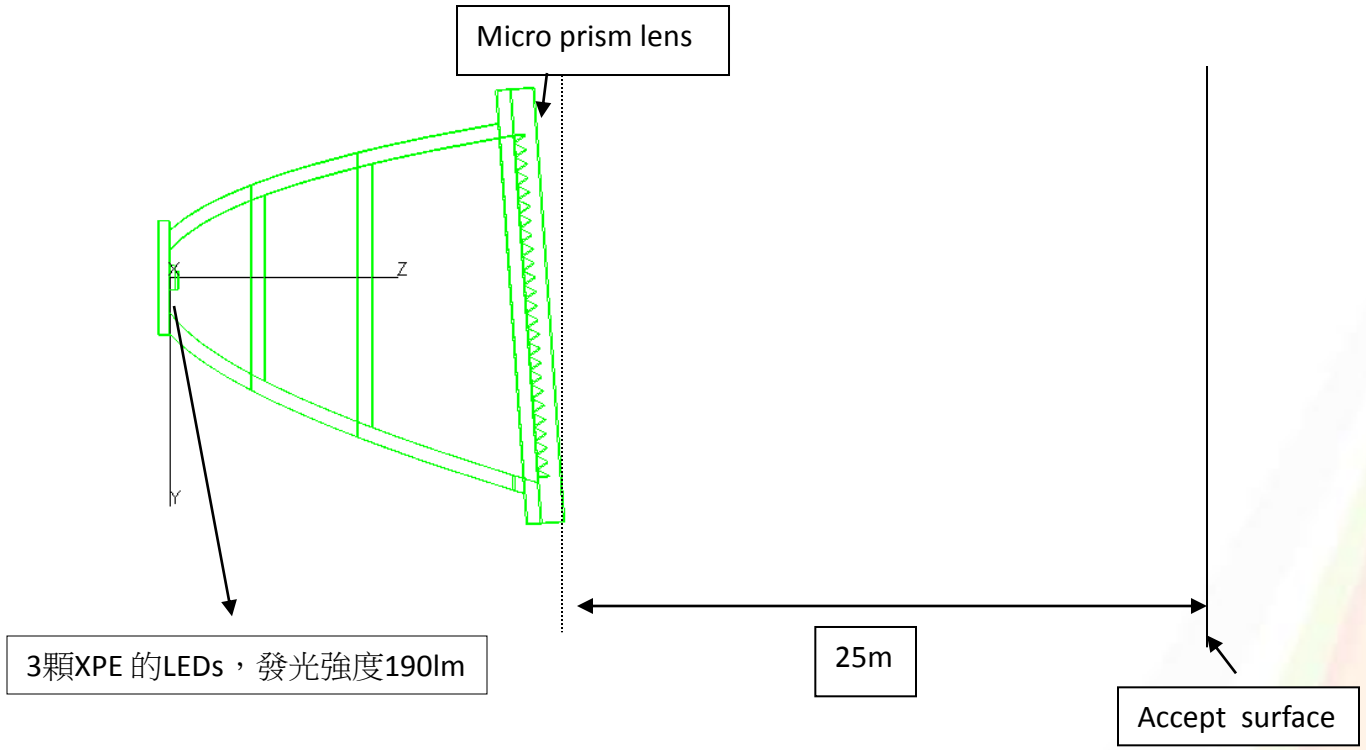
1) 任一平行於主軸的光線入射至拋物面鏡（凹面），其反射光線必定通過拋物線的焦點。

2) 由光行進路徑的可逆性可知，若由拋物面鏡的焦點射出之光線，則經由鏡面反射的光線必定平行於主軸。



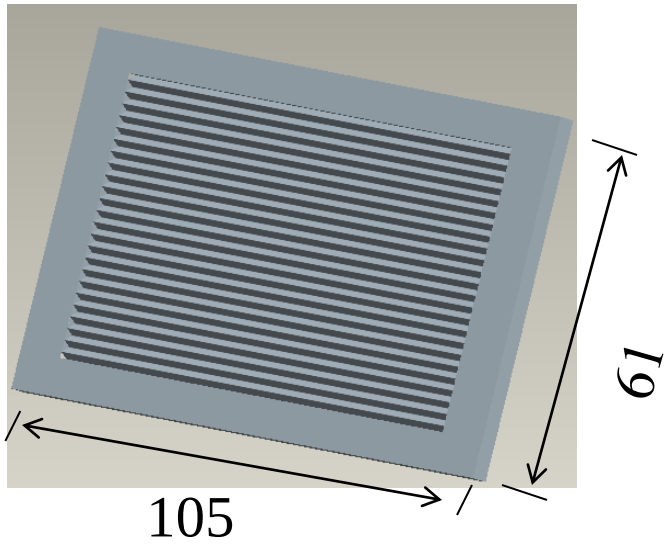
拋物面示意圖

霧燈測試示意圖

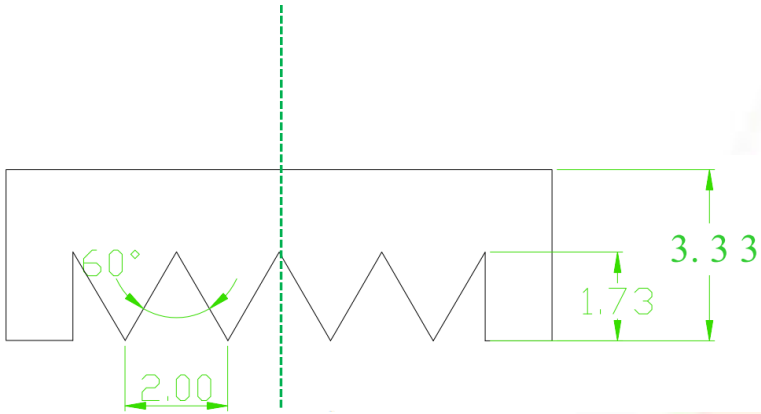


霧燈測試示意圖

Trace pro 光學分析 – 霧燈透鏡設計



稜鏡成品設計圖



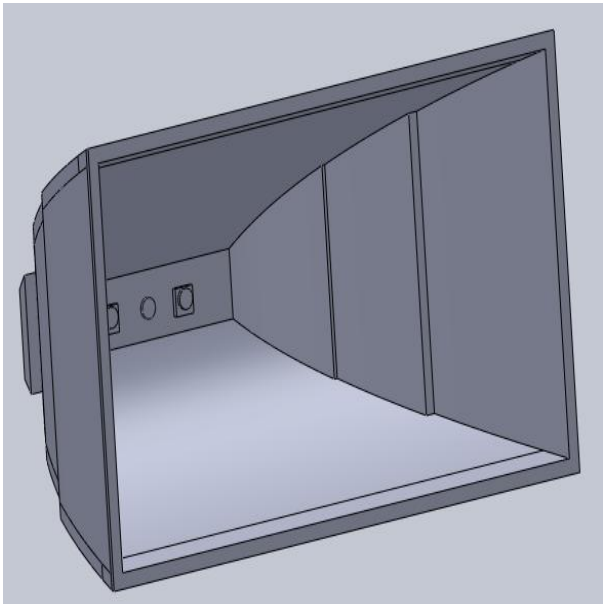
稜鏡微結構尺寸圖

稜鏡設計結果表

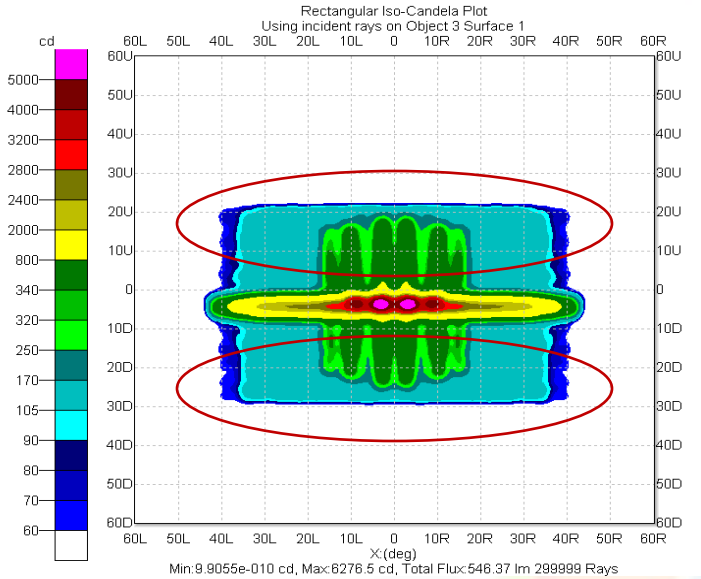
單一個小稜鏡的寬度	W=2.00mm
稜鏡數量	中軸對稱，左右各12個稜鏡
稜鏡的頂角	α=60˚
稜鏡的深度	d=1.73mm

Unit:mm

Trace pro 光學分析 – 反射罩設計



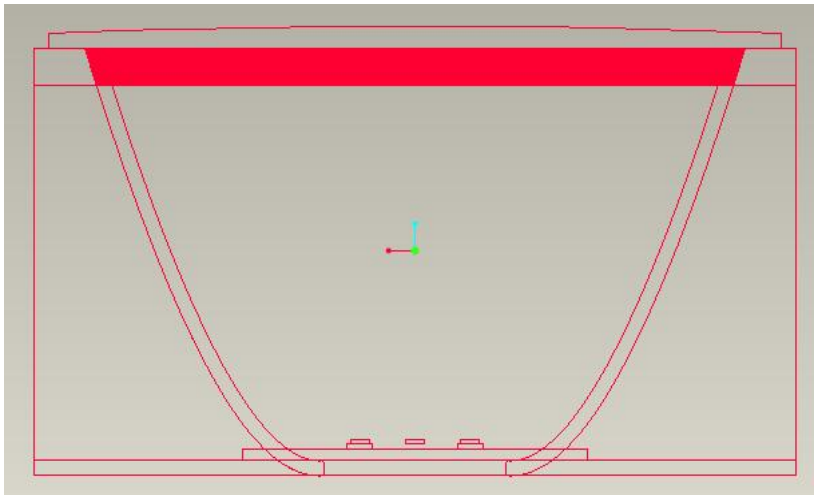
反射罩設計3D示意圖

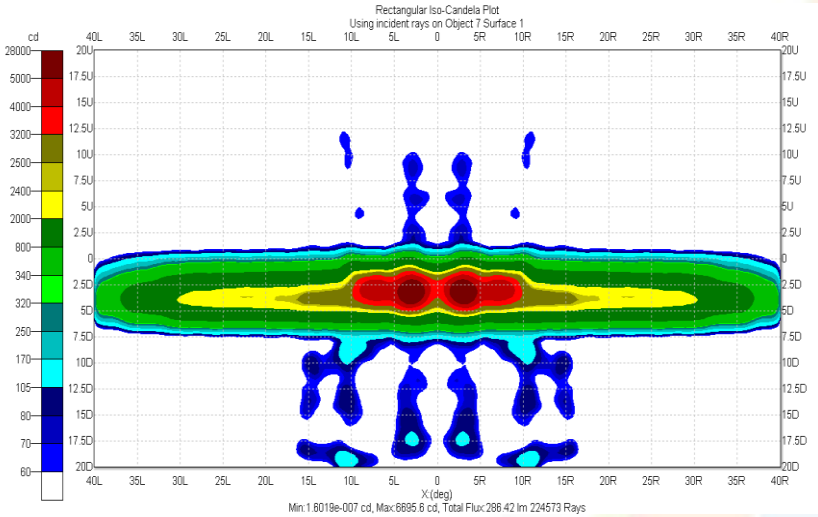


反射罩設計光強度圖

在反射罩方面，光強度集中於垂直+-20度，上下的雜光範圍太大，導致不能符合法規。

光學系統設計與模擬

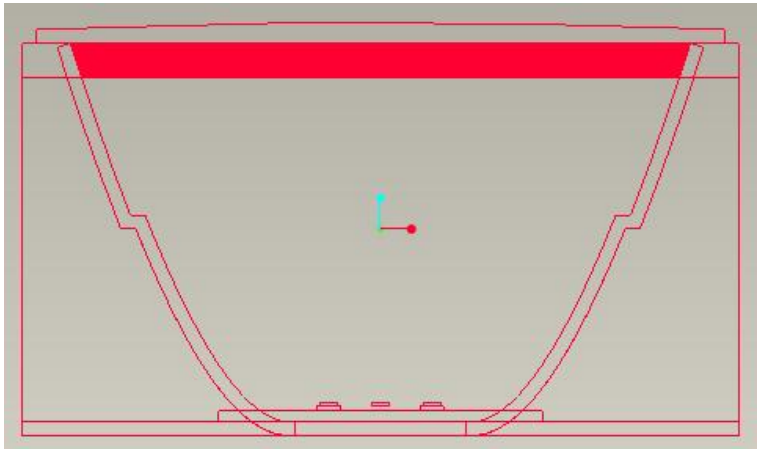


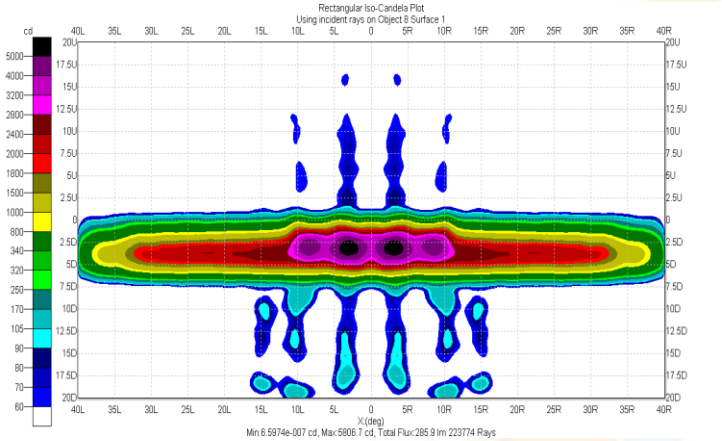


1階反射罩加燈罩示意圖及光強配置圖

1階反射罩上下寬度較大，均勻度較為集中。

光學系統設計與模擬

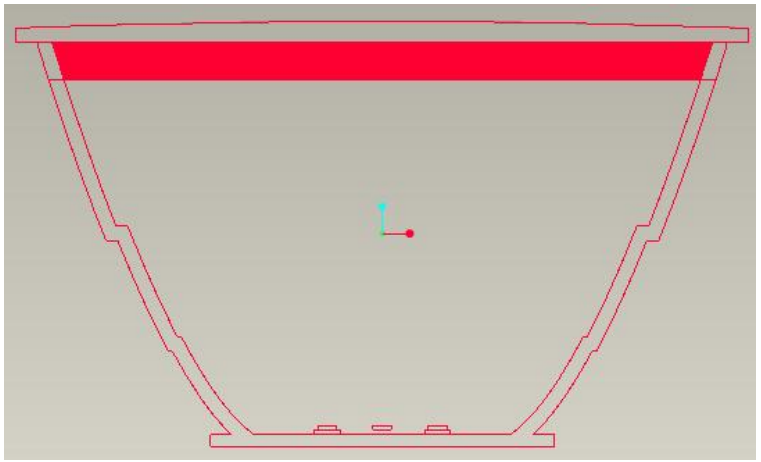


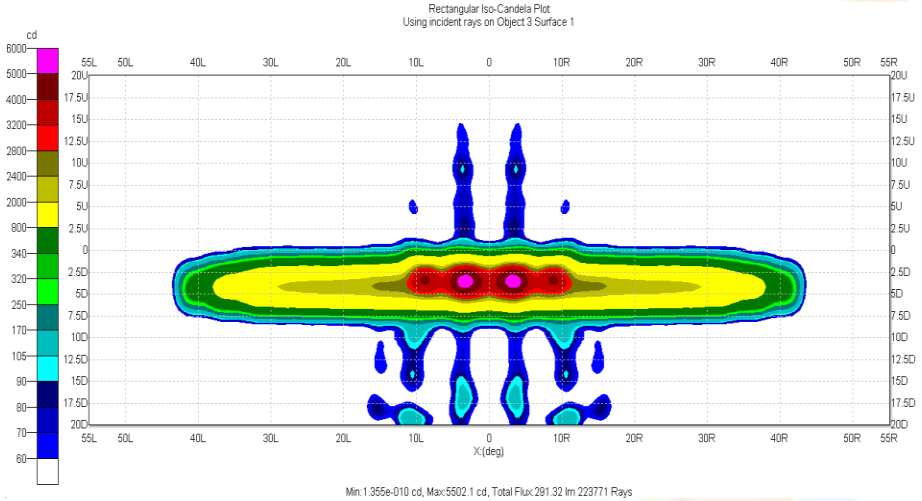


2階反射罩加燈罩示意圖及光強配置圖

2階反射罩上下寬度較為縮小，均勻度較為平均。

光學系統設計與模擬

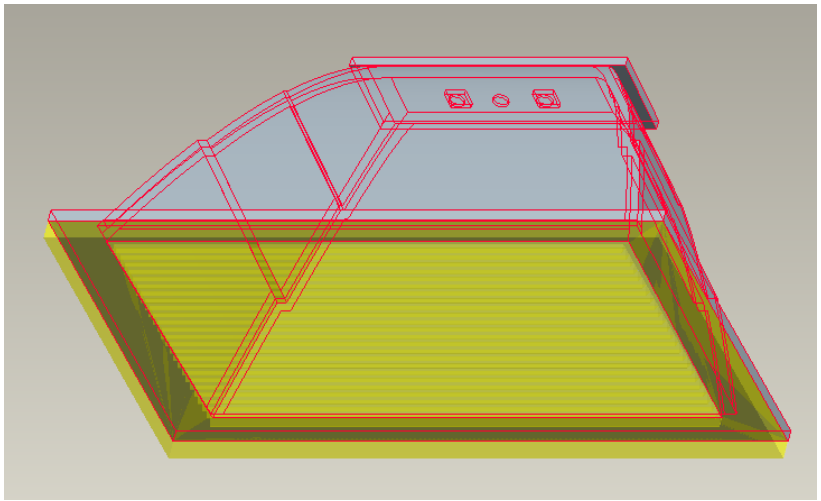


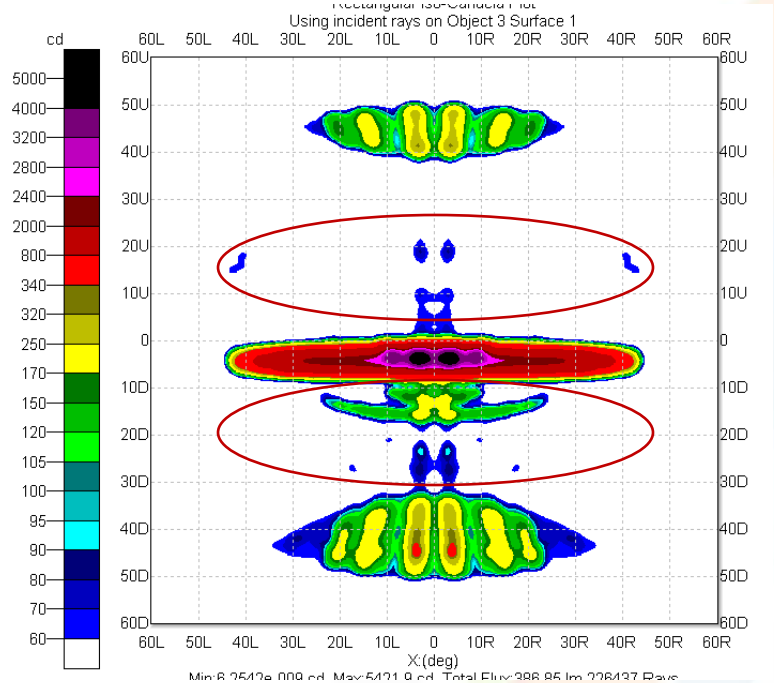


3階反射罩加燈罩示意圖及光強配置圖

3階反射罩上下寬度更為縮小，均勻度更為平均。

Trace pro 光學分析 – 霧燈組合設計

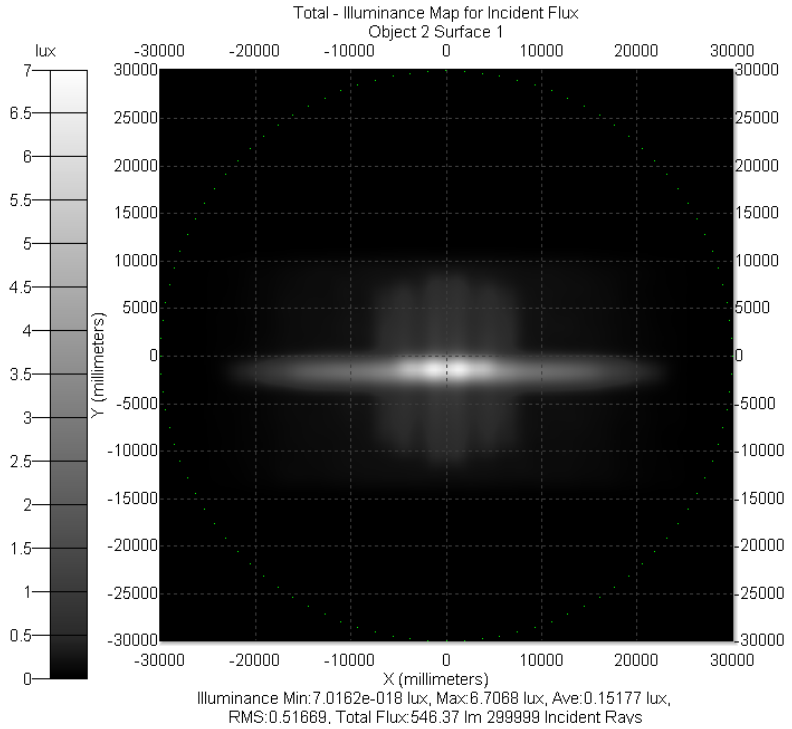




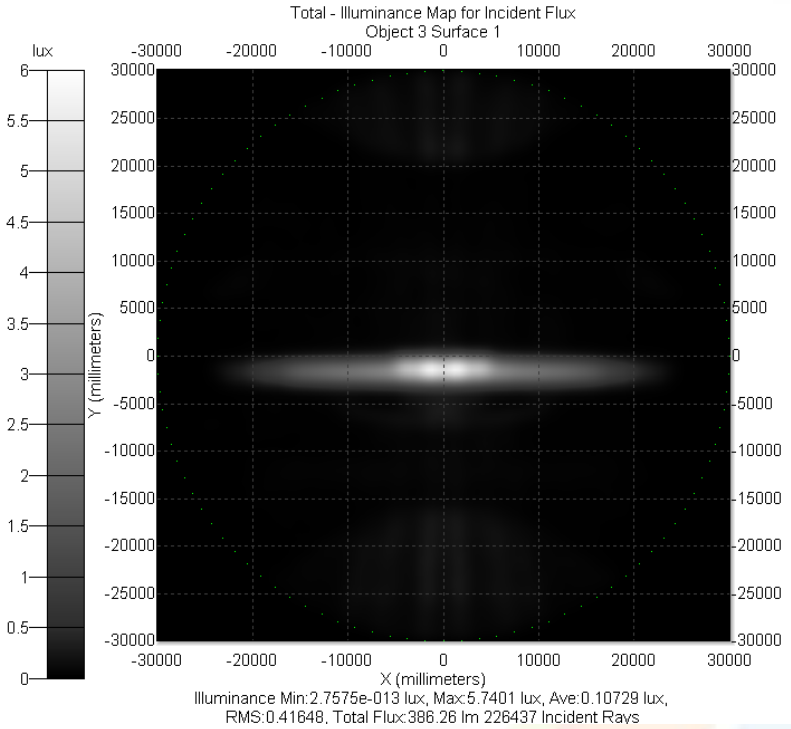
霧燈組合設計3D示意圖　　霧燈組合光強度圖

在霧燈組合設計中，已成功將強光集中0-10度，
上下的雜光亮度已經下降可符合法規之需求。

Trace-pro光照度圖比較分析



反射罩設計光照度圖



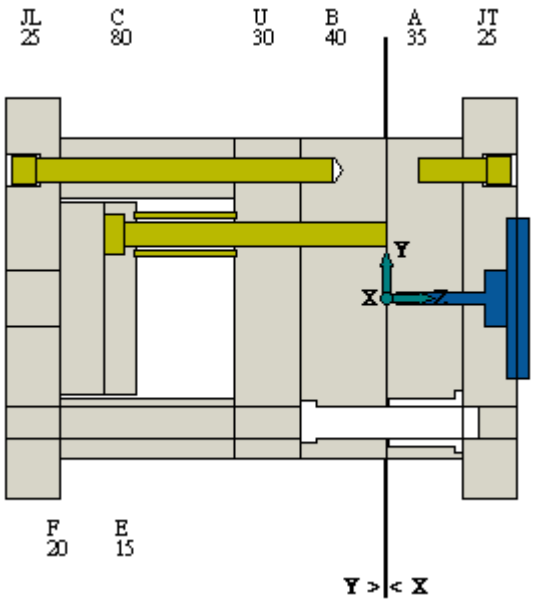
霧燈組合設計光照度圖

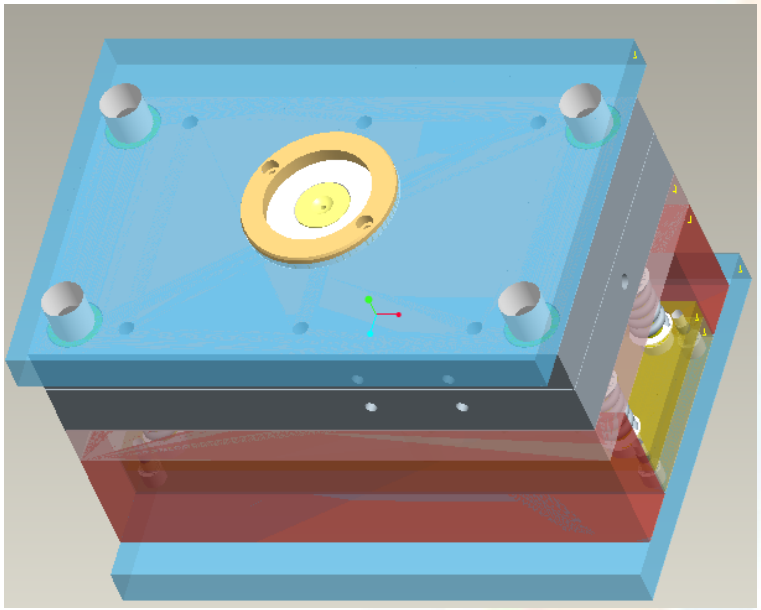
光強度分佈數據

表3 光強度模擬測試數據表

Test point	Measured(cd)	Maximum(cd)	Minimum(cd)
Line1	62.50	90	-
Line2	76.92	105	-
Line3	104.16	170	-
Line4	76.92	250	-
Line5	187.5	340	-
Line6	3200	-	2000
Line8R	1300	-	800
Line8L	1350	-	800
Line9R	1250	-	320
Line9L	1255	-	320

射出成型實驗 - 成型模具設計製作

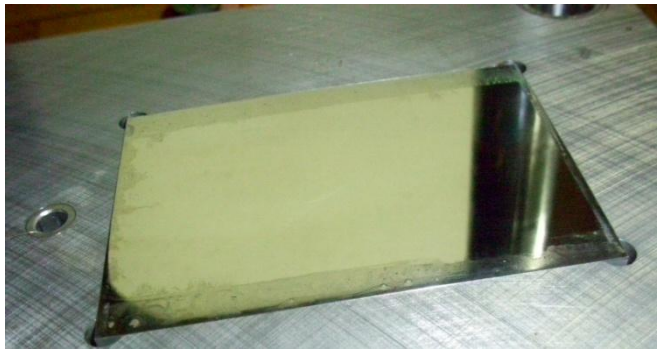


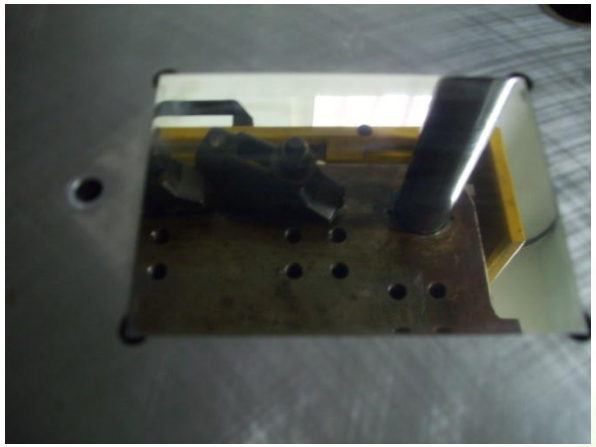


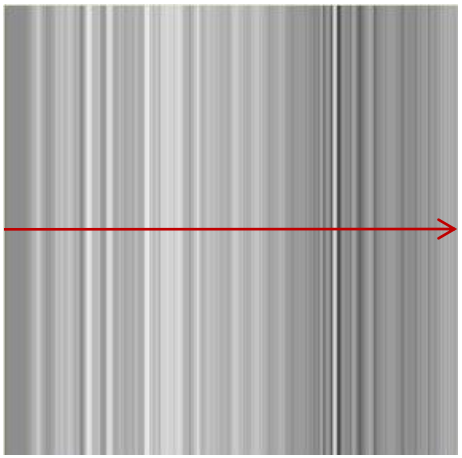
成型模具設計圖

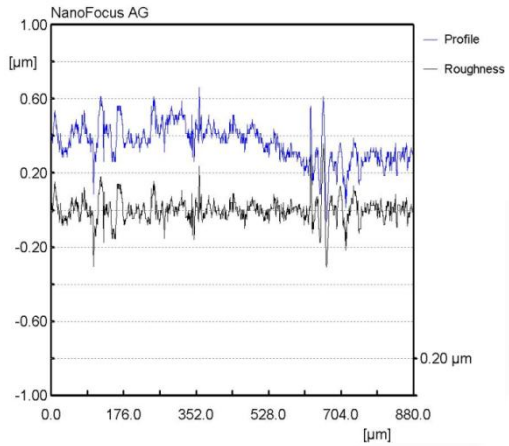
使用模座為喬茂標準模座 - 大水口型式（SA-2035-35×40×80）為兩板模之型式。模具設計採一模一穴之設計型式，冷卻水路採四通直流水路進行冷卻。

母模面量測粗糙度



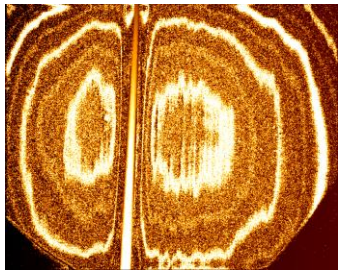


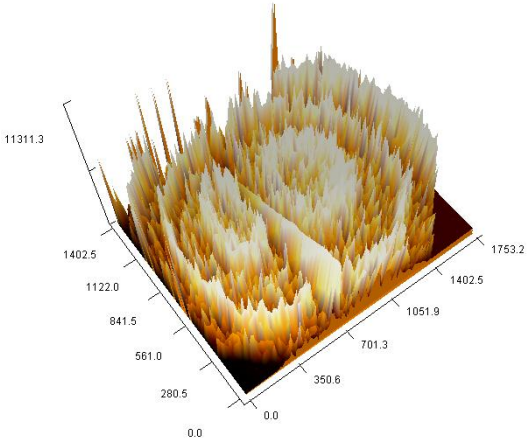


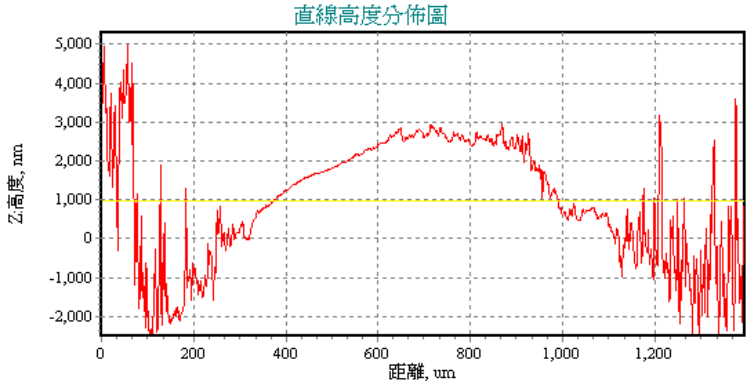


Ra = 0.045 µm

公模仁量測粗糙度







線分析ISO參數（單位：nm）			
Rp	Rc	Rq	RSm
4325	1733	1335.4	259
Rv	Rt	Rsk	Rdq
3521	7846.8	-0.3	68.5
Rz	Ra	Rku	
7846.8	96.83	3.1	

Ra = 0.096 μm

LED霧燈微稜鏡透鏡背景資料

產品介紹

LED霧燈微稜鏡透鏡

厚度：3.33mm

長　　度：105mm

寬　　度：61 mm

使用機台

震雄 SM-50

預測螺桿位置=34.5 mm

Total Volume= 21.8 cc

塑膠材料

PC AD-5503

原始成型條件固定因子

充填時間：0.2 s

模具溫度: 80℃

塑料溫度：285 ℃

冷卻時間：25 s

田口實驗設變因子規畫表

	A	B	C	D
	射出壓力 (%)	保壓壓力 (%)	保壓時間 (s)	射出速度 (%)
Level_1	40	25	6	10
Level_2	45	30	8	15
Level_3	50	35	10	20

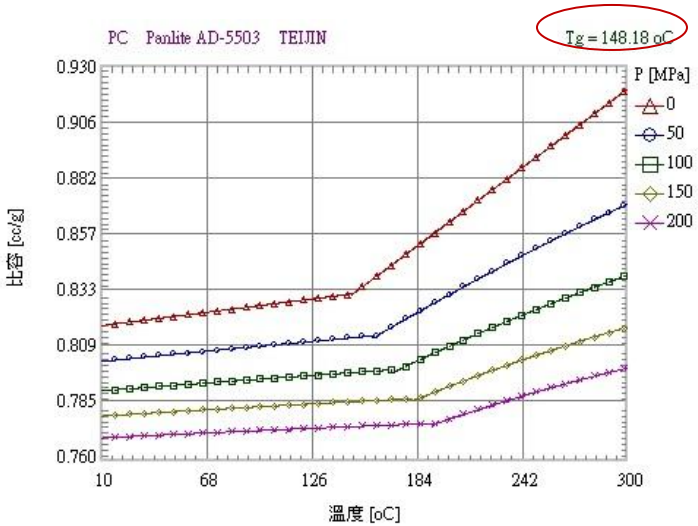
LED霧燈微稜鏡透鏡射出田口設計翹曲度望小

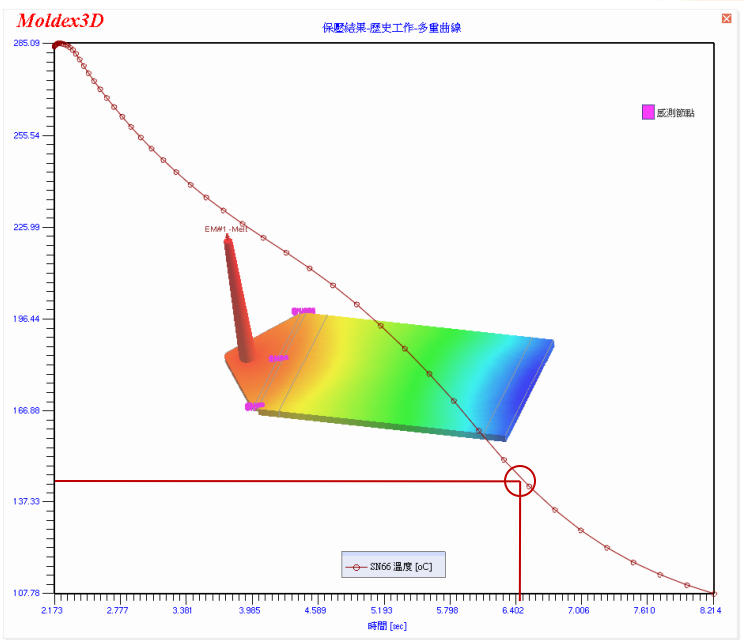
1. 先以實際射出成品初步抓出參數為基準(Level_1)，固定因子為塑料溫度為285 ℃，模具溫度為80 ℃，是依據塑料加工條件表，如下圖，冷卻時間設定為25s，而設變因子為射出壓力、保壓壓力、保壓時間、射出速度。

說明	
材料名稱	PC
材料型號	Panlite AD-5503
製造商	TEIJIN
備註說明	MFI(240,10)=14g/10min ,MVR(300,1.2)=54 cm3/10min ,D=1.2 g/cc
最後修改日期	2009/11/11
加工條件	
塑料溫度 (最低限制)	270 oC
塑料溫度 (一般設定)	285 oC
塑料溫度 (最高限制)	300 oC
模具溫度 (最低限制)	60 oC
模具溫度 (一般設定)	80 oC
模具溫度 (最高限制)	100 oC
頂出溫度	148 oC
固化溫度	168 oC

保壓時間設定

2. 先以Level_1的射出參數定義，保壓時間為澆口凝固時間，大約是4.5秒左右，為了確保澆口凝固，所以保壓時間取6、8、10s，作為3個水準。





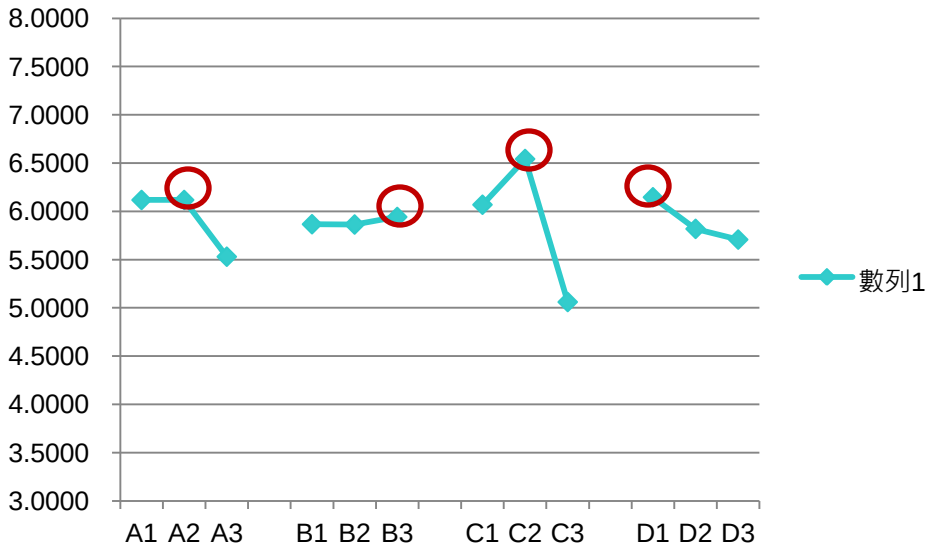
6.674-2.173=4.501s

L9(3⁴)直交表配置與分析數據

模擬值翹曲分析表

EXP.	A	B	C	D	最大值	最小值	Warpage	MSD	S/N
1	1	1	1	1	0.2210	-0.2688	0.4898	0.2399	6.1996
2	1	2	2	2	0.1553	-0.3746	0.5299	0.2808	5.5161
3	1	3	3	3	0.1302	-0.3425	0.4657	0.2169	6.6379
4	2	1	2	3	0.1589	-0.4043	0.5632	0.3172	4.9867
5	2	2	3	1	0.1208	-0.3482	0.4690	0.2200	6.5765
6	2	3	1	2	0.1302	-0.3425	0.4727	0.2234	6.5083
7	3	1	3	2	0.1285	-0.3494	0.4779	0.2284	6.4133
8	3	2	1	3	0.1673	-0.4162	0.5835	0.3405	4.6792
9	3	3	2	1	0.2515	-0.2795	0.5310	0.2820	5.4981

L9(3⁴)S/N比回應表



S/N比	A	B	C	D
Level 1	6.0239	5.8665	6.0687	6.1459
Level 2	6.1179	5.8636	6.5426	5.8185
Level 3	5.5302	5.9418	5.0607	5.7076
Effect	0.5877	0.0782	1.4819	0.4383
Rank	2	4	1	3

A ： Injection Pressure
B ： Holding Pressure
C ： Holding Time
D ： Injection speed

最佳因子組合 ： *A2 B3 C2 D1*

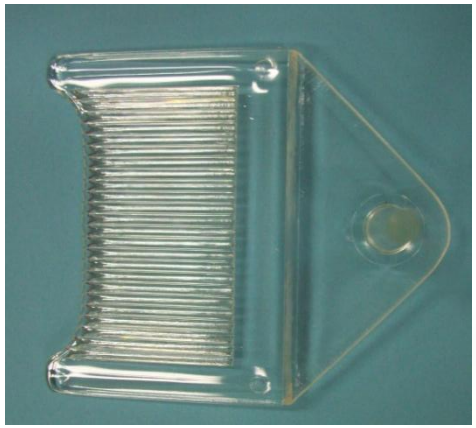
變異數分析

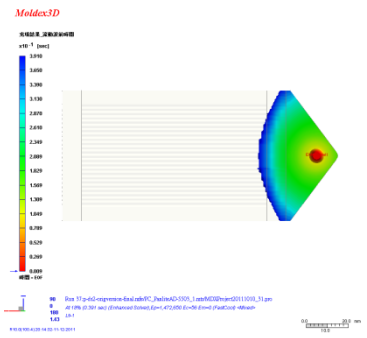
	變動SS	自由度DF	變異V	變異比F	純變動S'	貢獻度%
A	0.5979	2	0.298967	0.298967	0.5979	13.72065
B	0.0118	2	0.005892	0.005892	0.0118	0.270389
C	3.4366	2	1.718283	1.7183	3.4366	78.85812
D	0.3116	2	0.155814	0.1558	0.3116	7.150839
e	0	0				
T	4.3579	8			4.3579	100

主要貢獻因子：最大貢獻因子為 保壓時間，貢獻度為78.86 %
第2貢獻因子為 射出壓力，貢獻度為13.72 %
第3貢獻因子為 射出速度，貢獻度為7.15 %

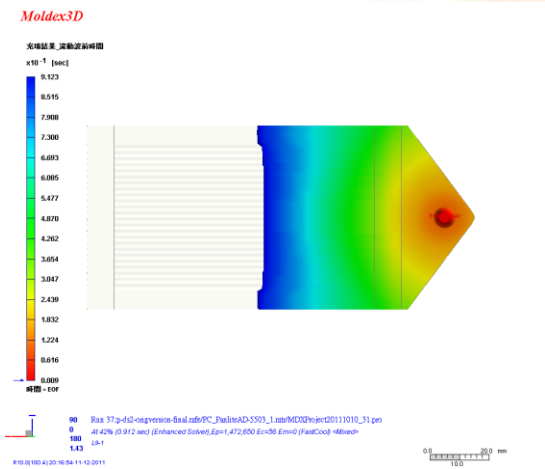
成型參數比較:最佳成型參數A2 B1 C2 D3 翹曲0.4306mm
相較於最差數A2 B2 C3 D1 翹曲0.5835mm

流動實驗比較



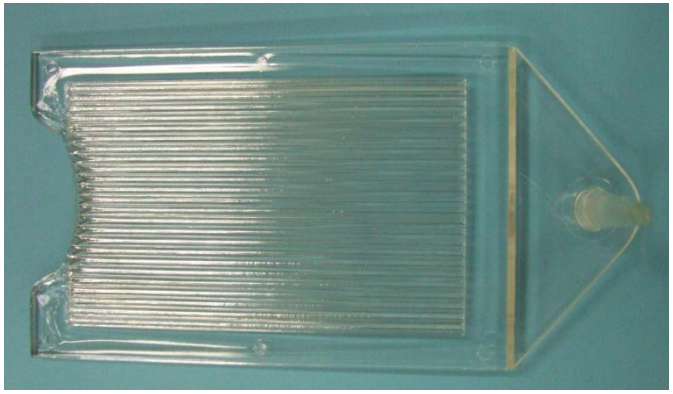


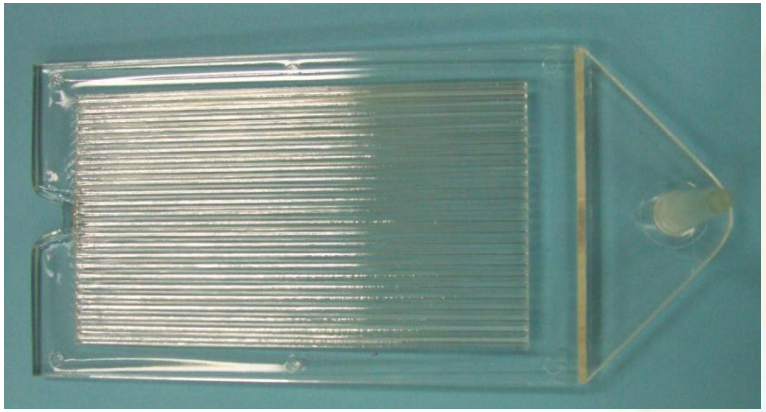
充填18%

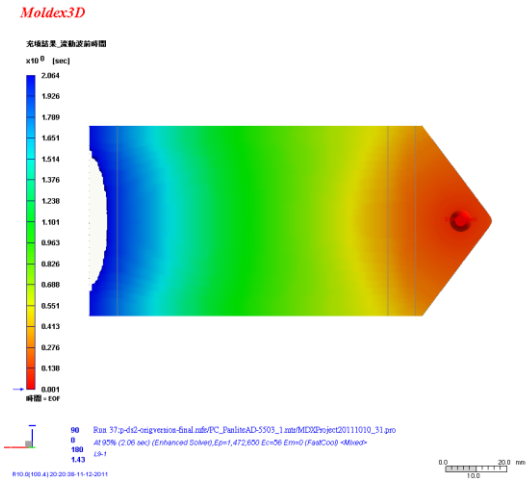


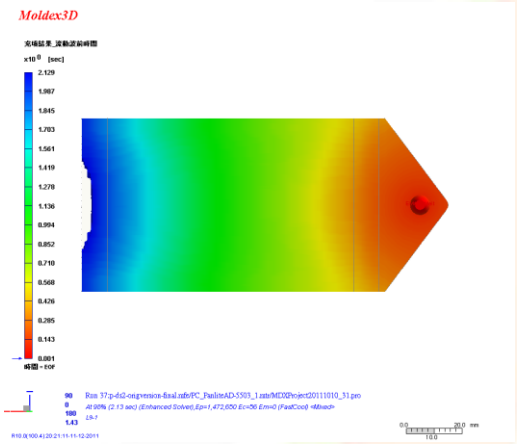
充填42%

流動實驗比較





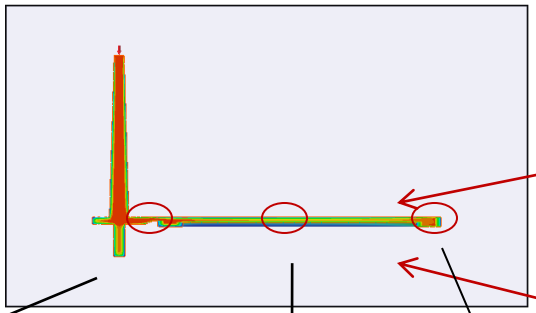




充填95%

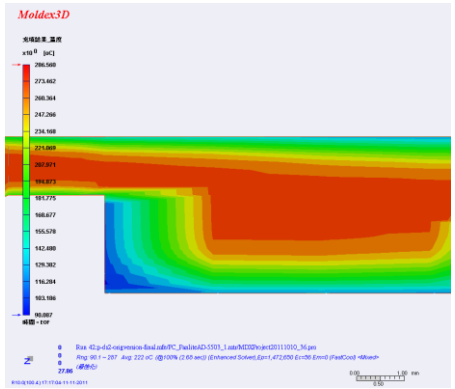
充填98%

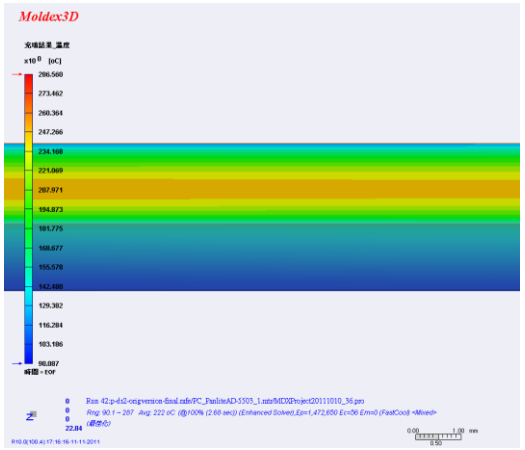
最佳化充填剖面充填結束溫度分佈

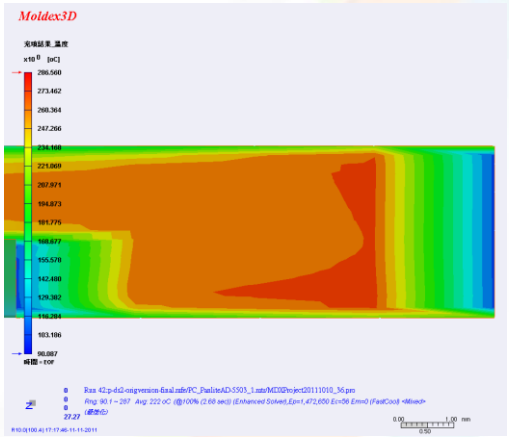


霧燈透鏡平面側

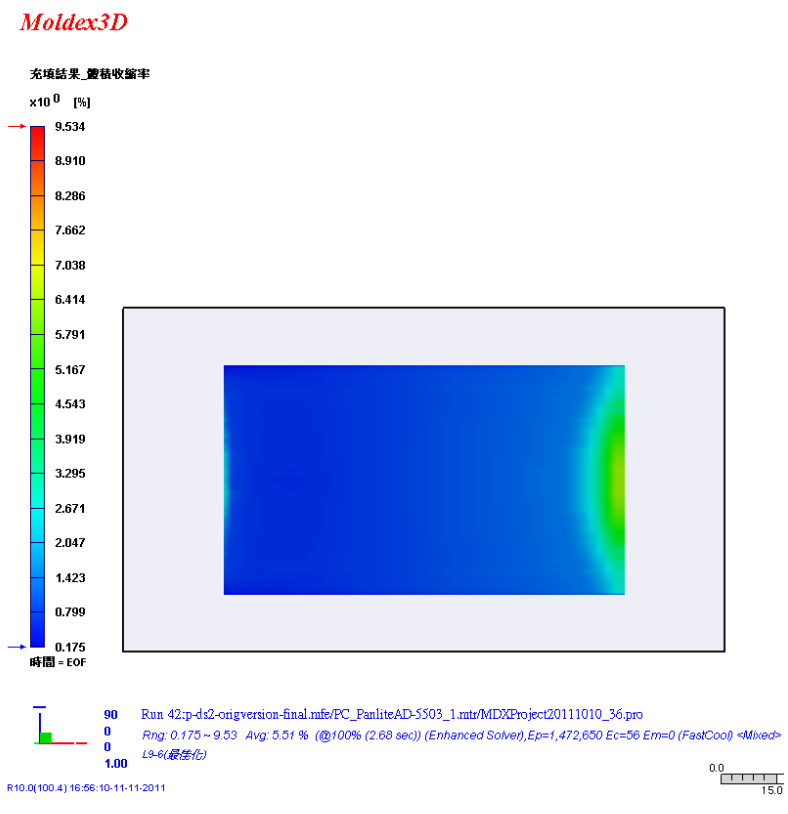
霧燈透鏡結構側



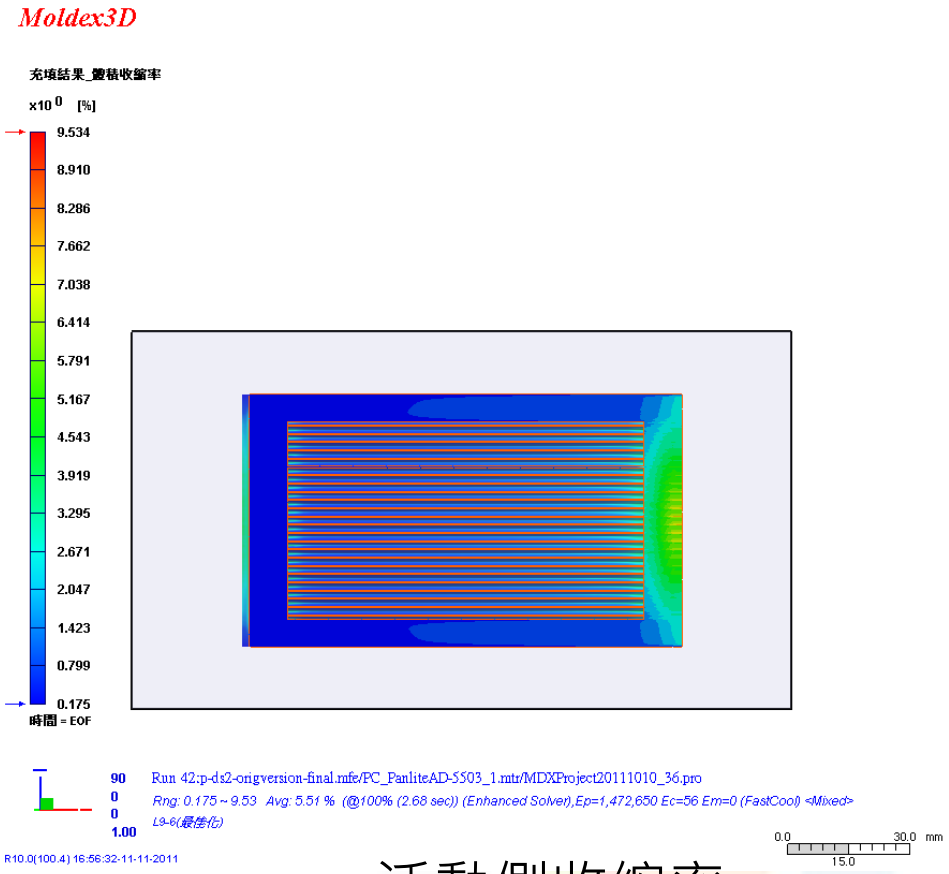




最佳化充填體積收縮率

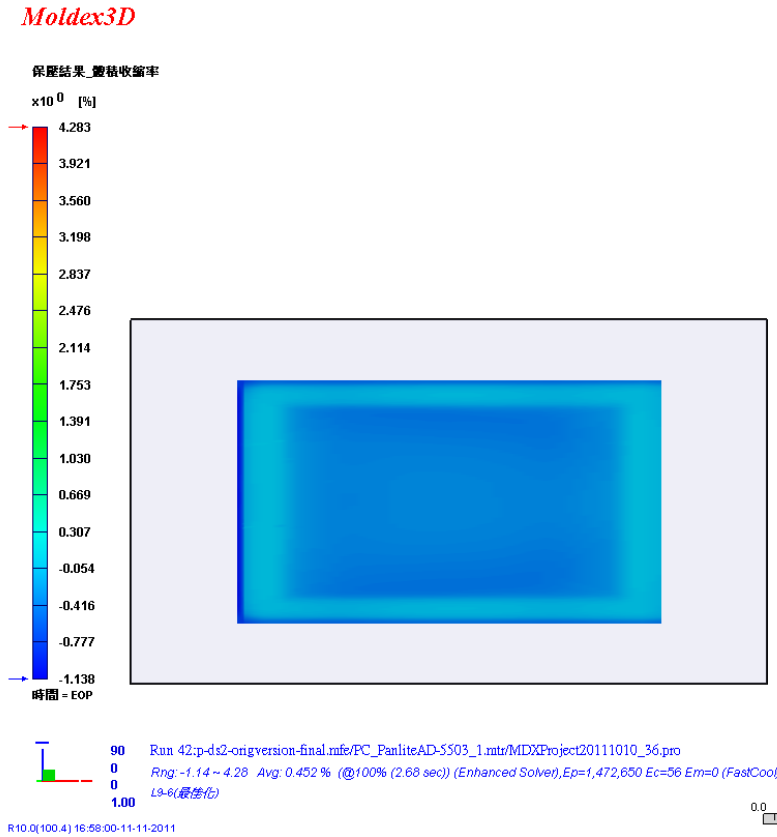


固定側收縮率

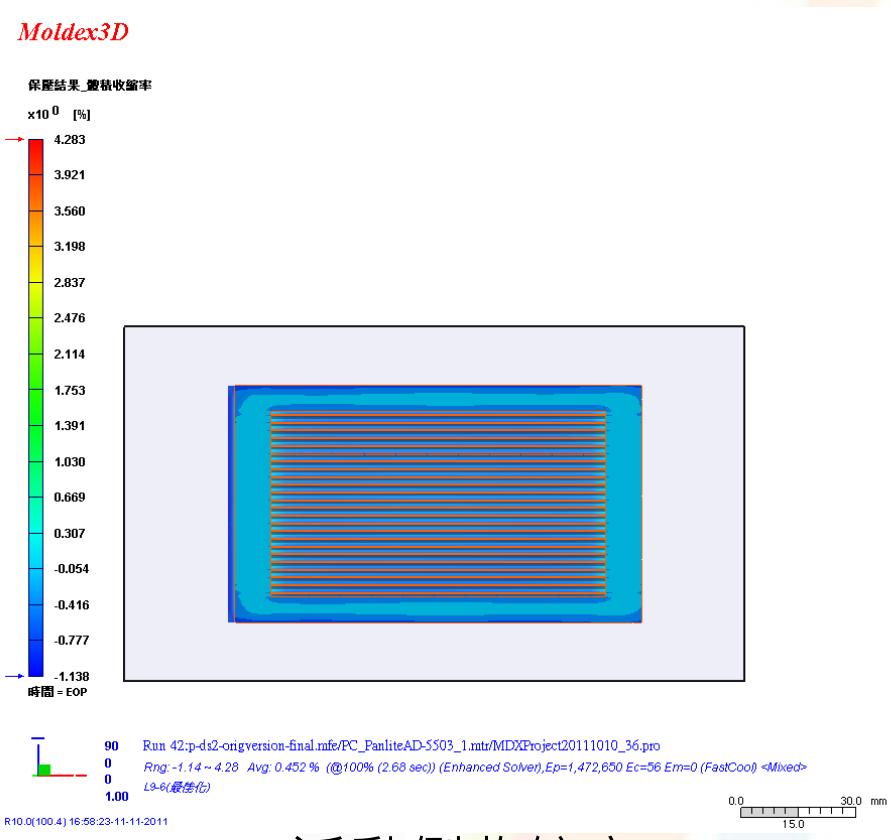


活動側收縮率

最佳化保壓體積收縮率

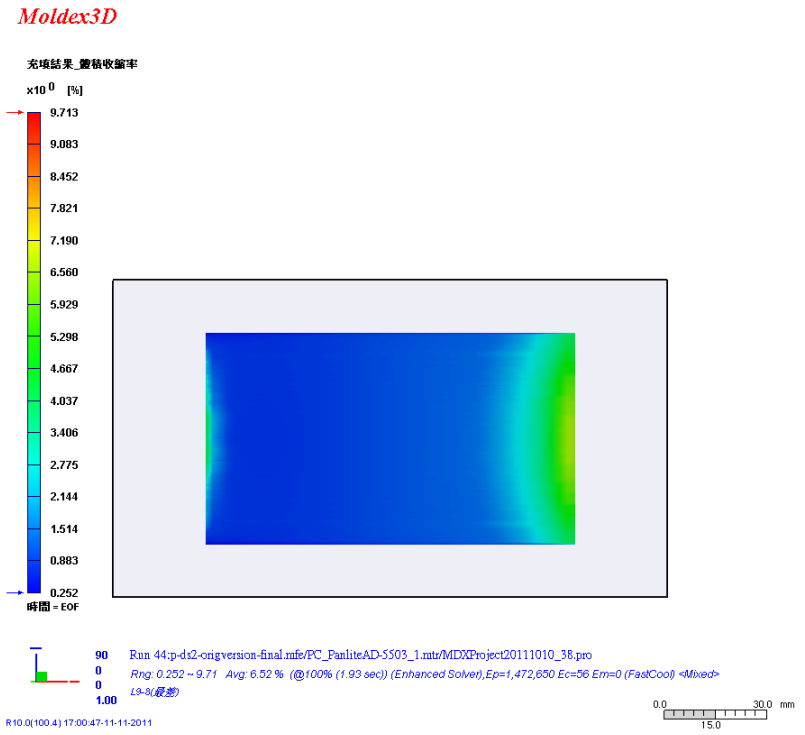


固定側收縮率

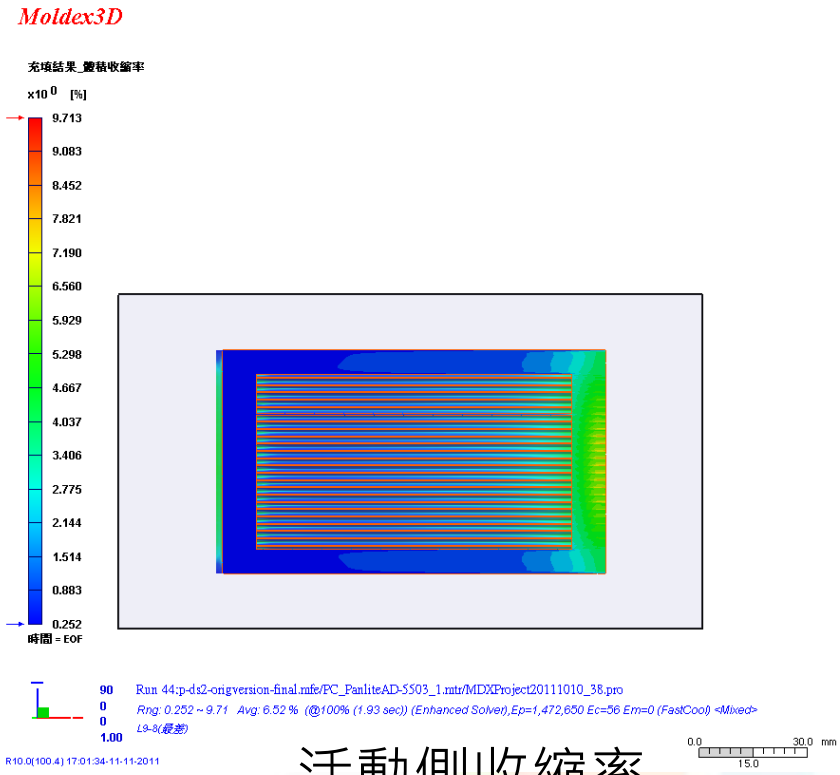


活動側收縮率

最差化充填體積收縮率(L8)

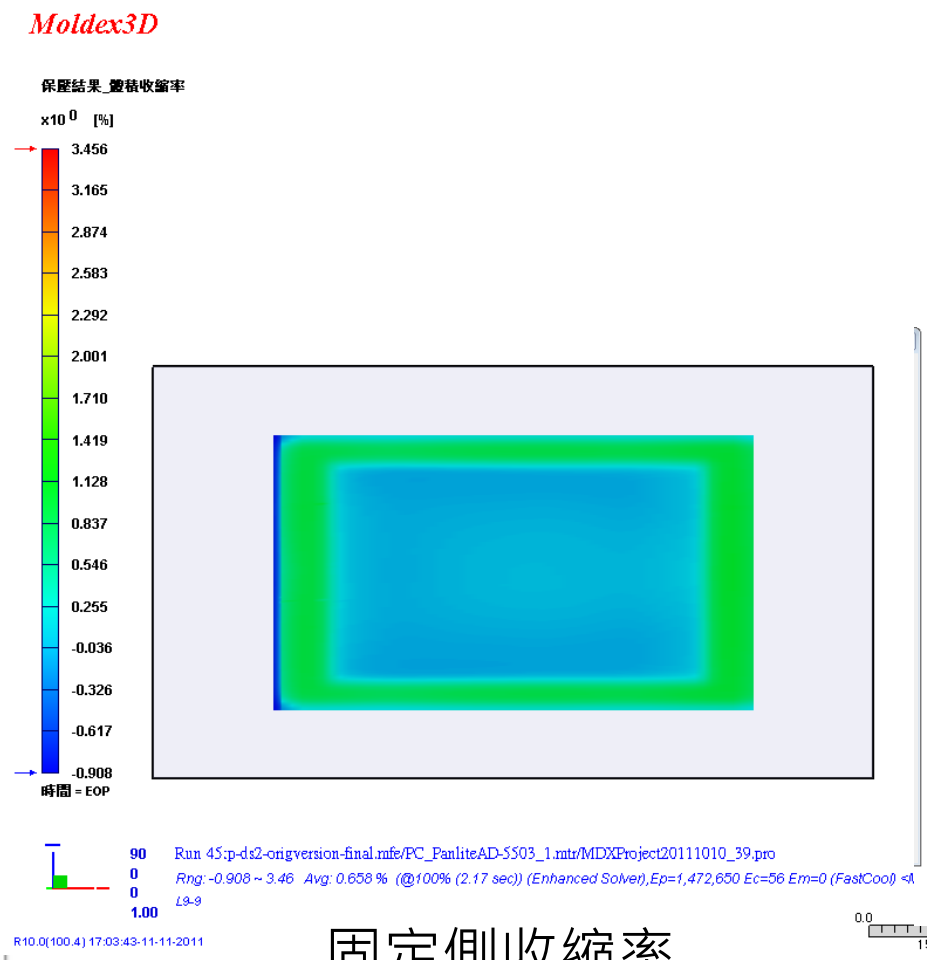


固定側收縮率

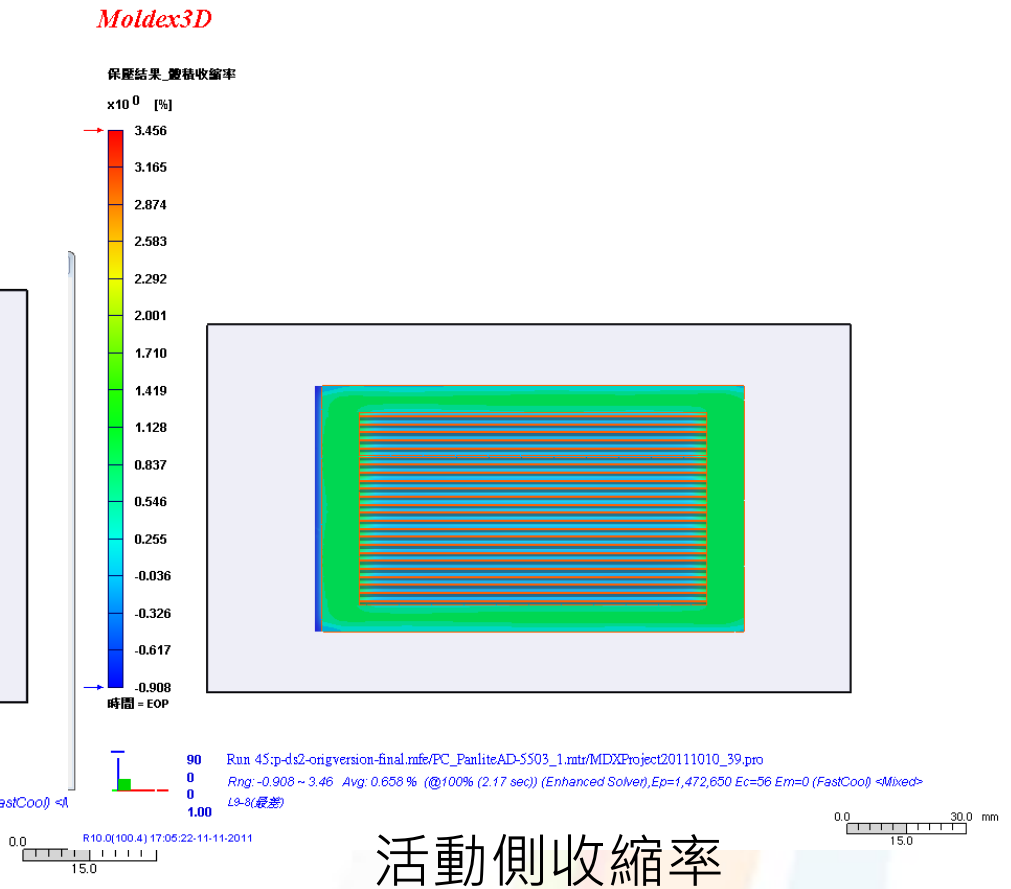


活動側收縮率

最差化保壓體積收縮率(L8)



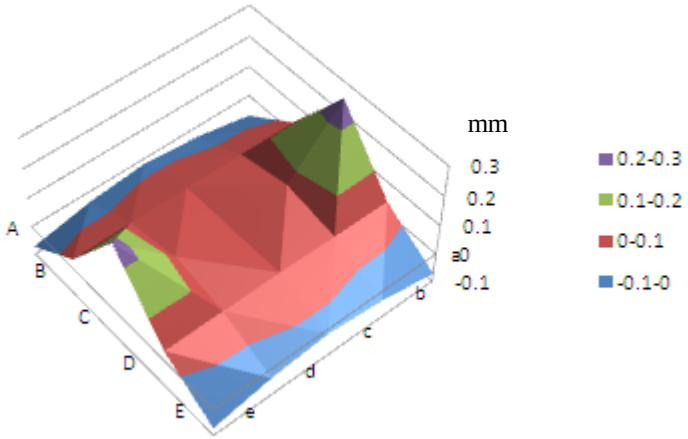
固定側收縮率



活動側收縮率

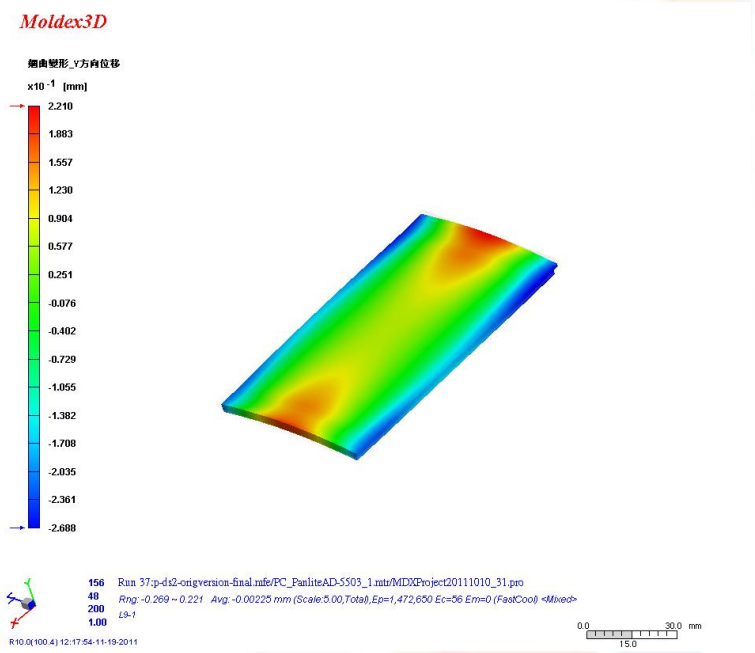
L1

experiment



Warpage:0.321

simulation

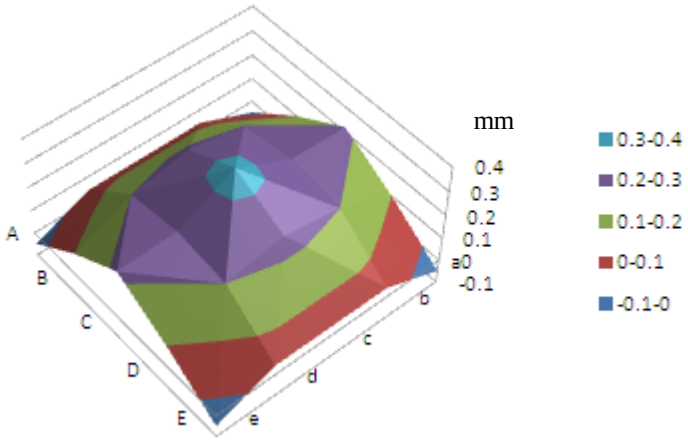


Warpage:0.4989

Unit:mm

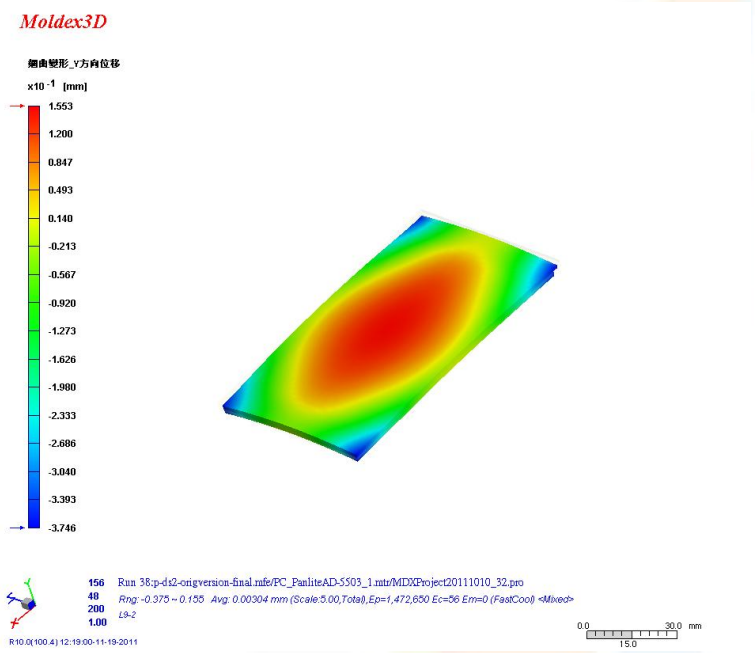
L2

experiment



Warpage:0.389

simulation

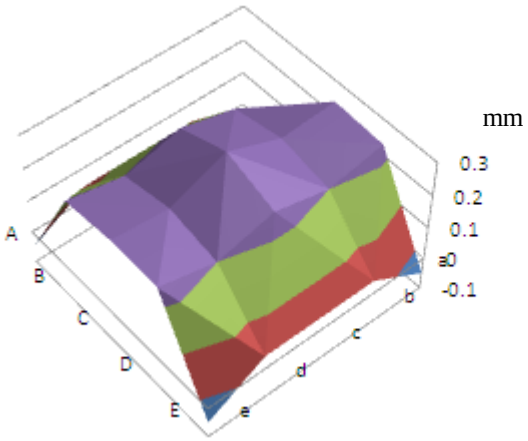


Warpage:0.5299

Unit:mm

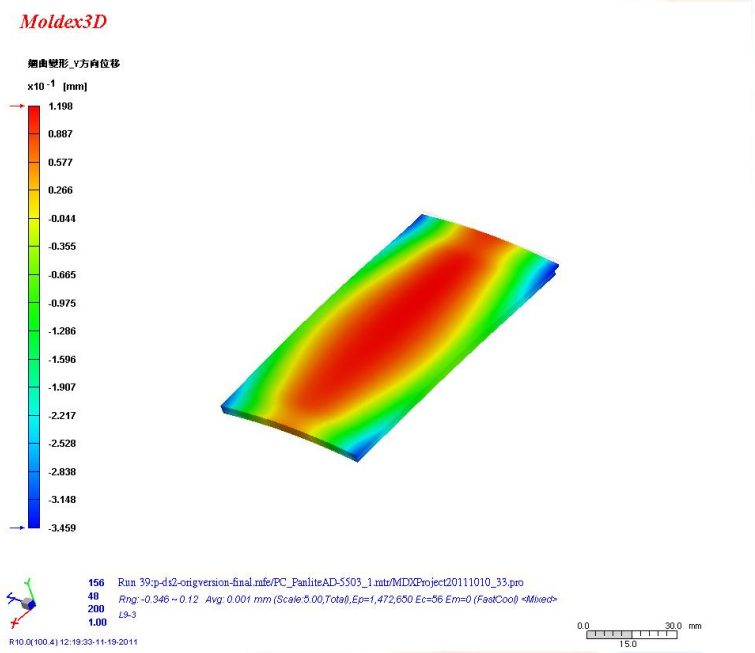
L3

experiment



Warpage:0.341

simulation

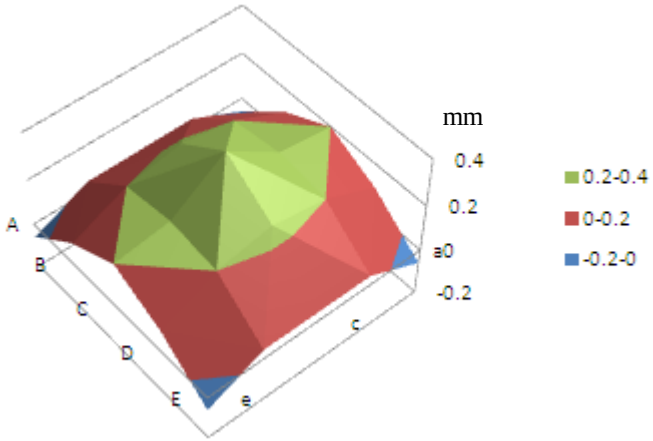


Warpage:0.4657

Unit:mm

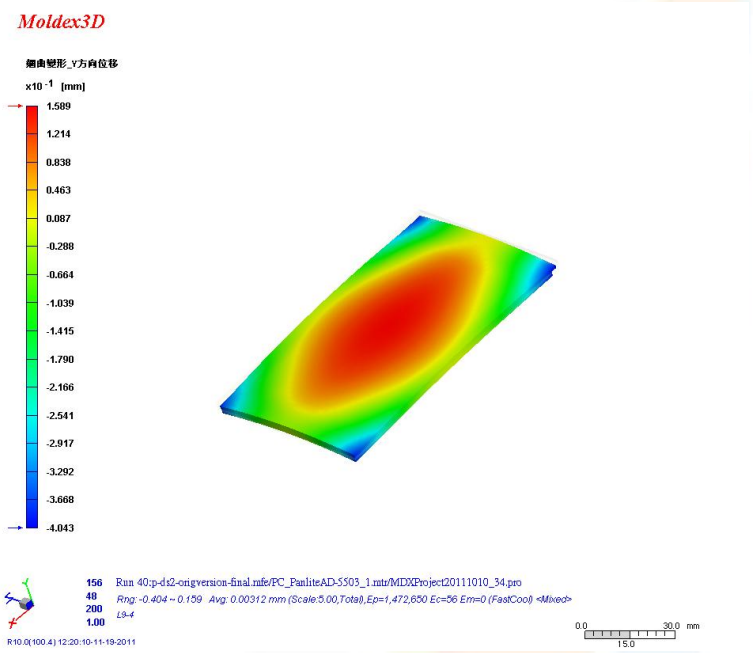
L4

experiment



Warpage:0.438

simulation

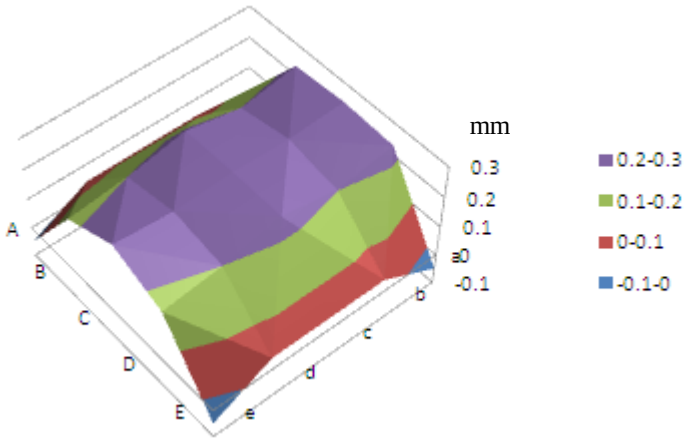


Warpage:0.5632

Unit:mm

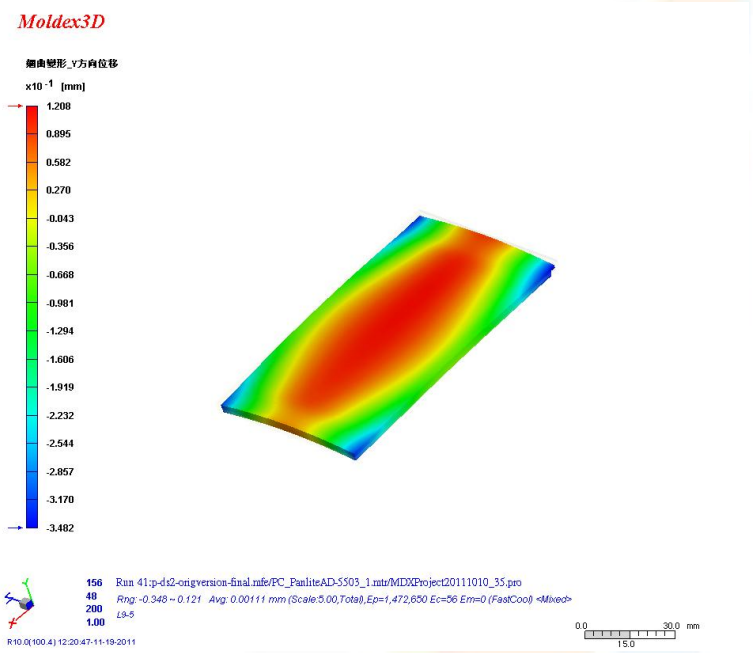
L5

experiment



Warpage:0.287

simulation

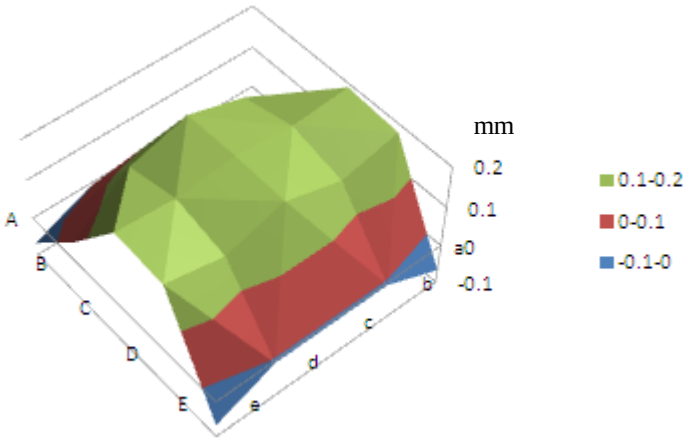


Warpage:0.4690

Unit:mm

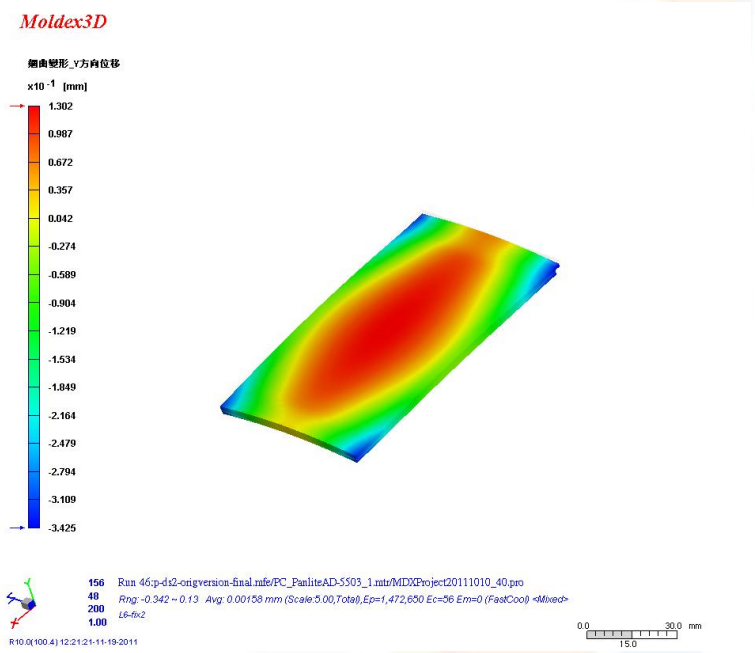
L6

experiment



Warpage:0.260

simulation

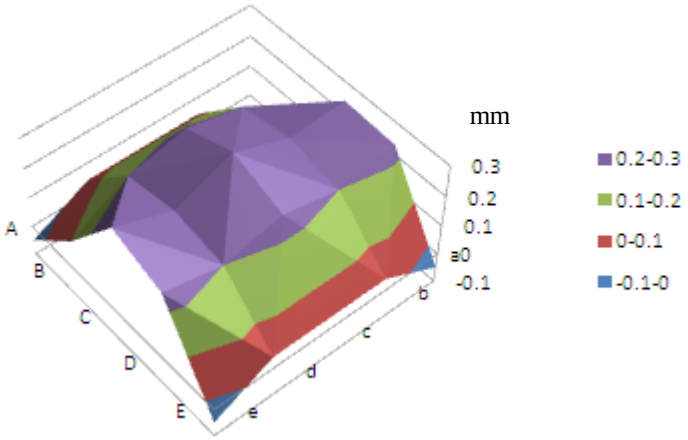


Warpage:0.4727

Unit:mm

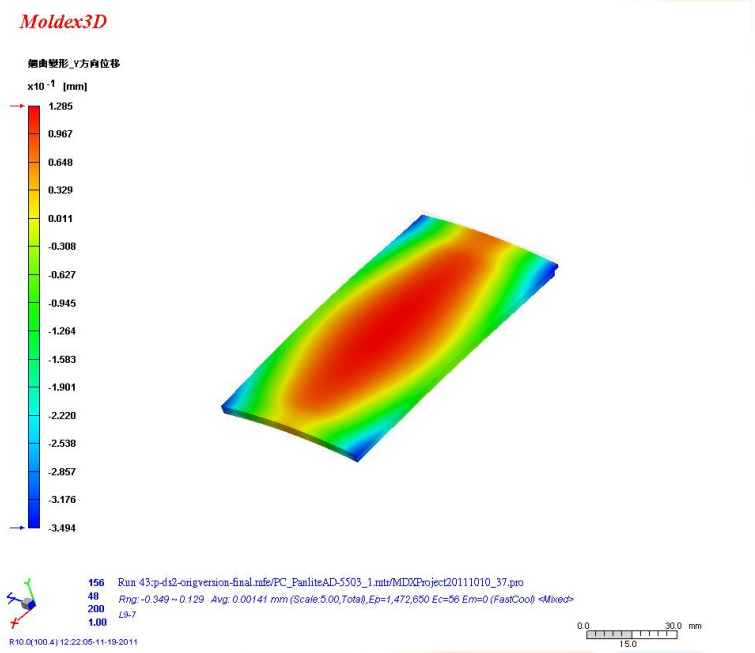
L7

experiment



Warpage:0.348

simulation

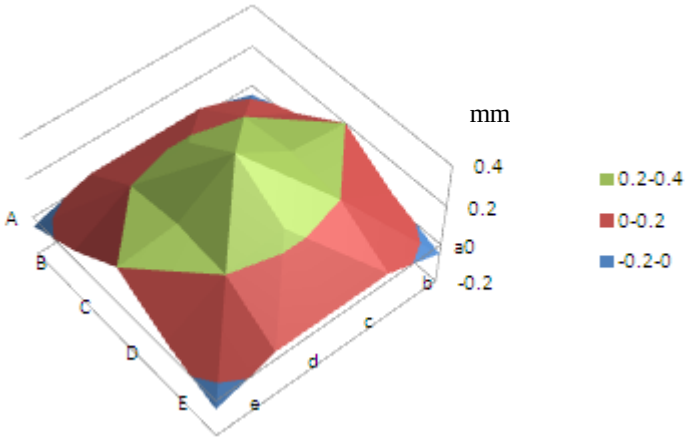


Warpage:0.4779

Unit:mm

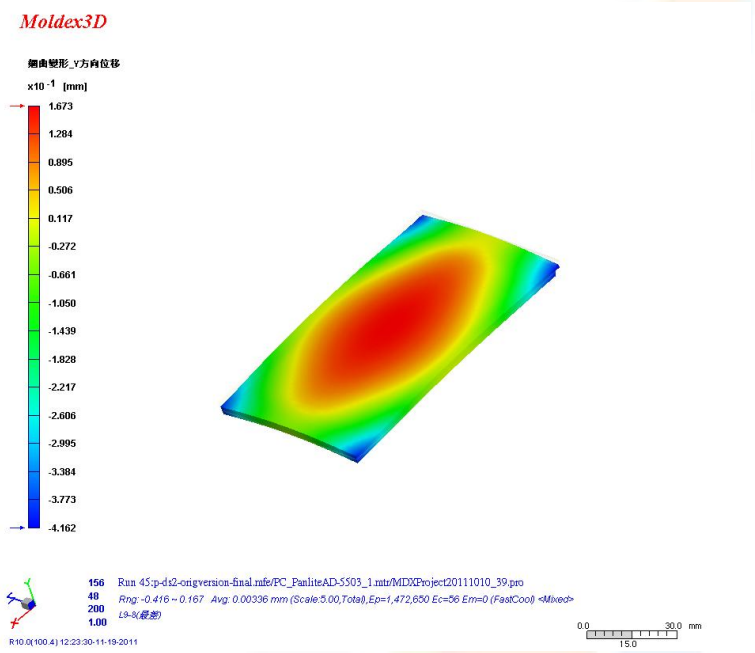
L8(最差)

experiment



Warpage:0.445

simulation

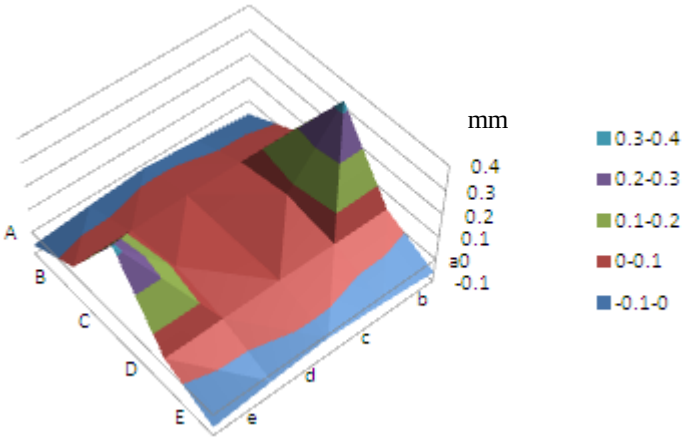


Warpage:0.5835

Unit:mm

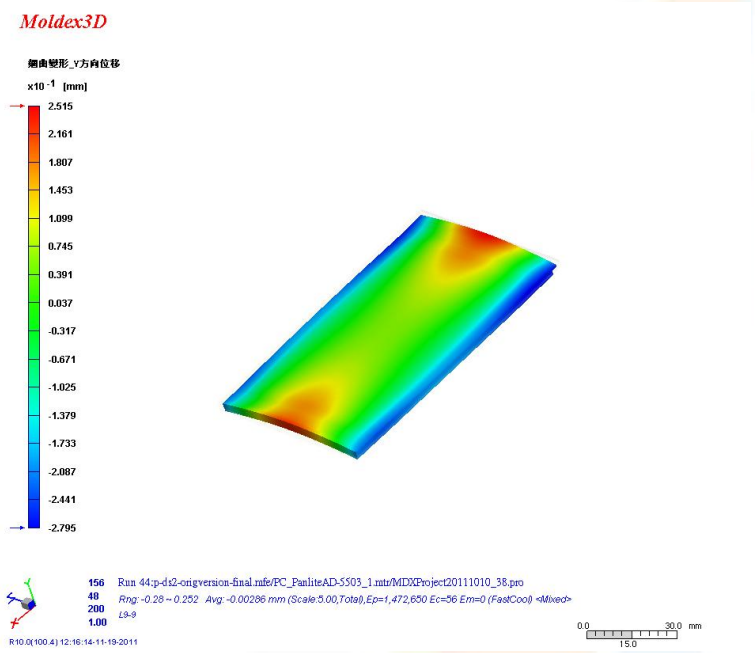
L9

experiment



Warpage:0.386

simulation

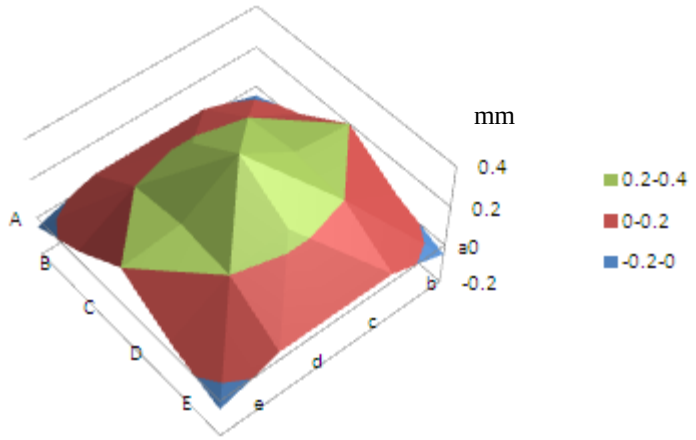


Warpage:0.5310

Unit:mm

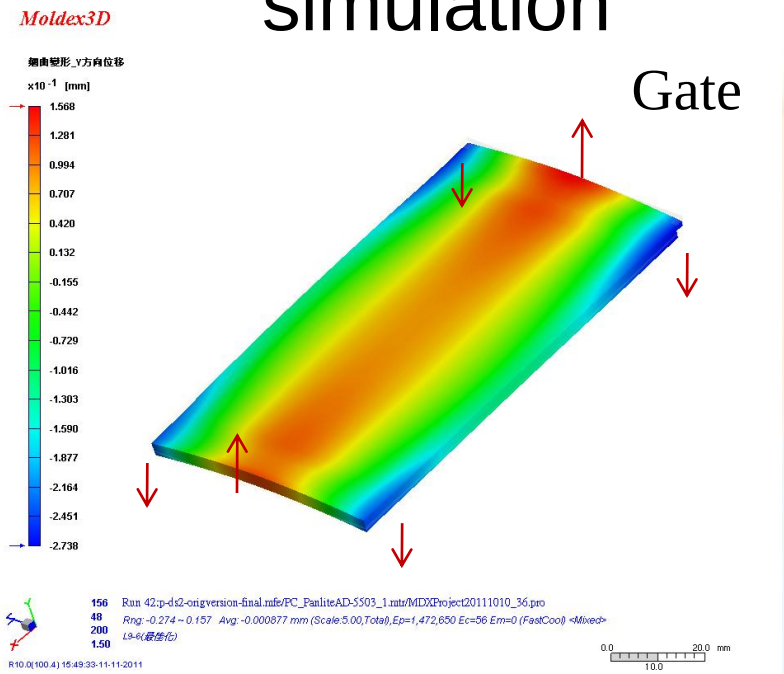
田口實驗最佳成型條件(L10)

experiment



Warpage:0.252

simulation



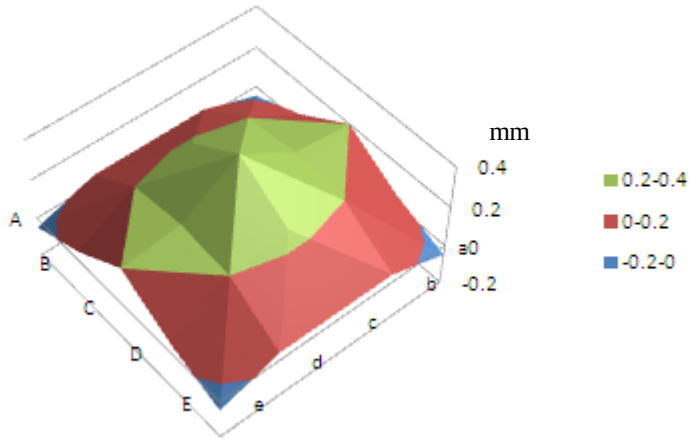
Warpage:0.4306

Unit:mm

Melt temperature （℃）	285	Injection pressure (%)	45	Holding time (sec)	8
Mold temperature （℃）	80	Holding Pressure (%)	35	Cooling time (sec)	25
Injection speed(%)	10				

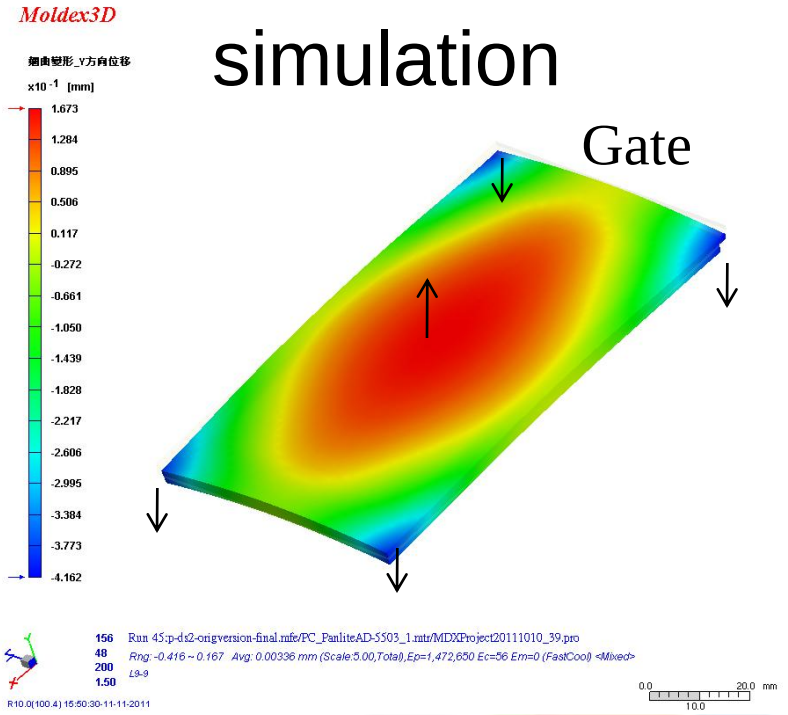
田口實驗最差成型條件(L8)

experiment



Warpage:0.445

simulation

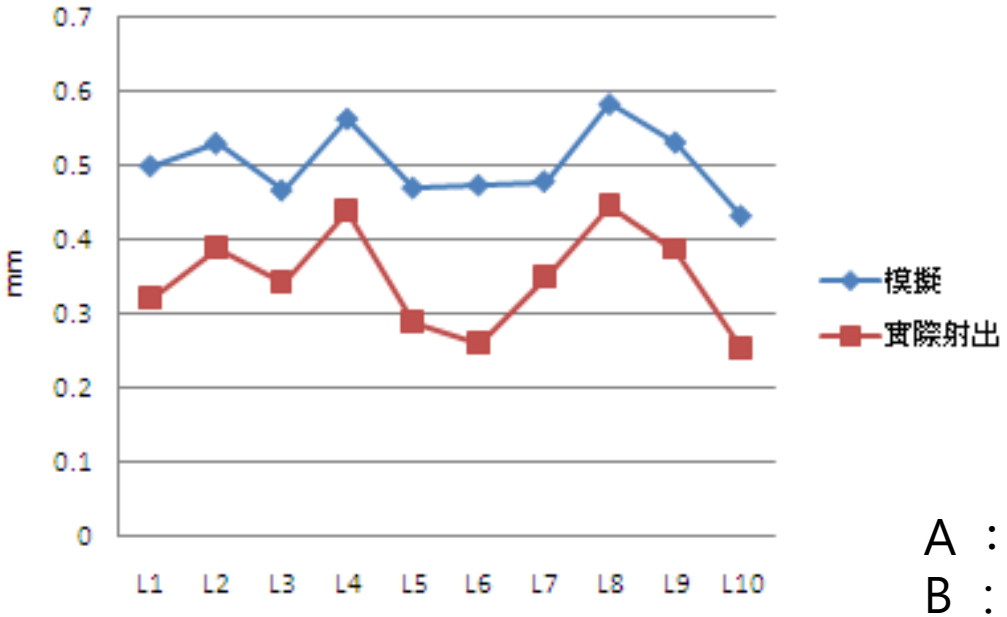


Warpage:0.5835

Unit:mm

Melt temperature （℃）	285	Injection pressure (%)	50	Holding time (sec)	6
Mold temperature （℃）	80	Holding Pressure (%)	30	Cooling time (sec)	25
Injection speed(%)	20				

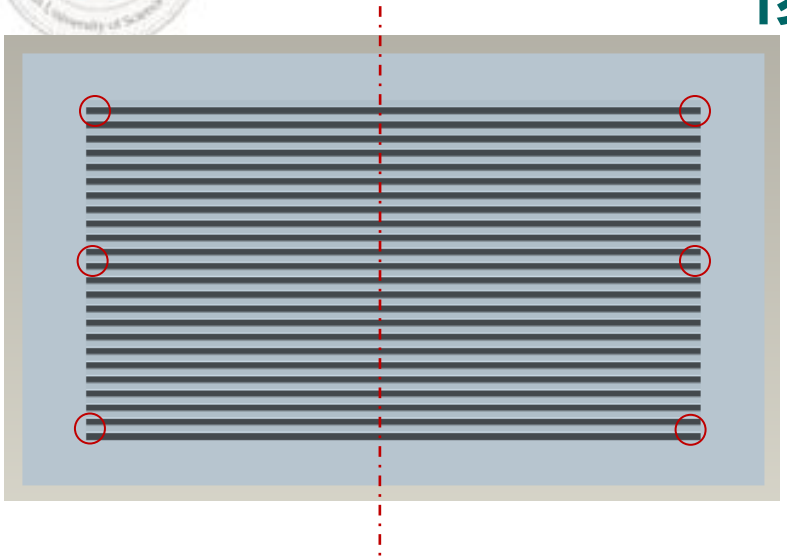
實際翹曲與分析趨勢比較

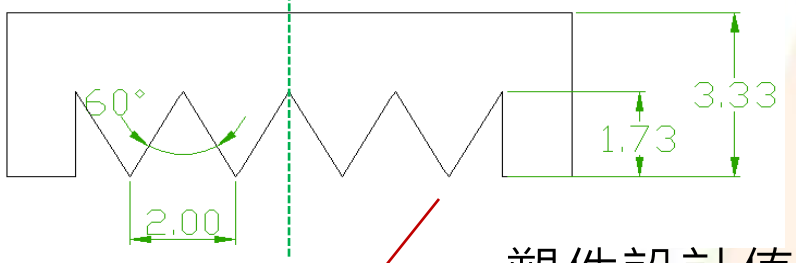


L10為最佳化翹曲量參數:*A2 B3 C2 D1*

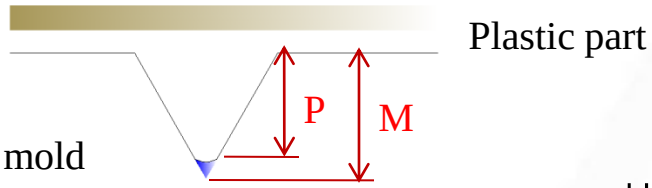
A ： Injection Pressure
B ： Holding Pressure
C ： Holding Time
D ： Injection speed

複製度量測





塑件設計值圖



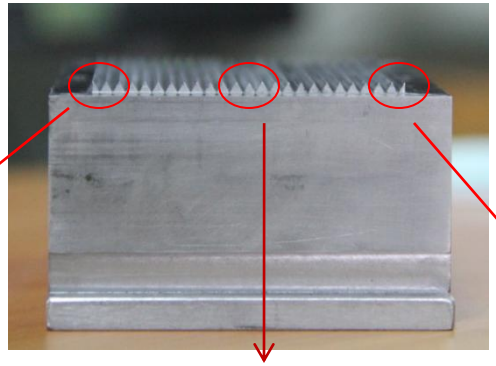
微溝槽成形示意圖

P=塑件三角形高實際量測值
M=模仁三角形高實際值

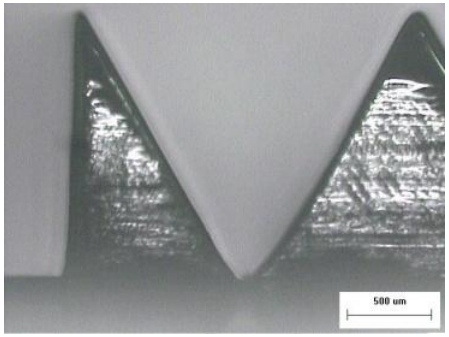
Ps:模仁實際高度值為1.629mm

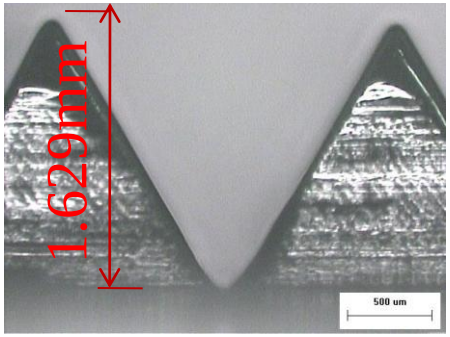
- 複製度= (P/M)*100%

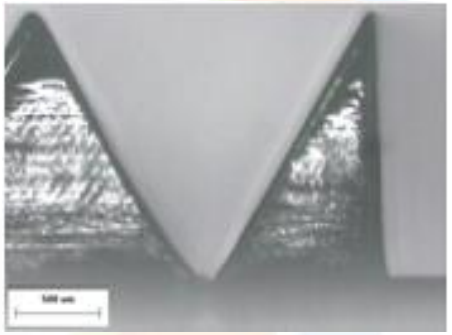
公模仁OM量測



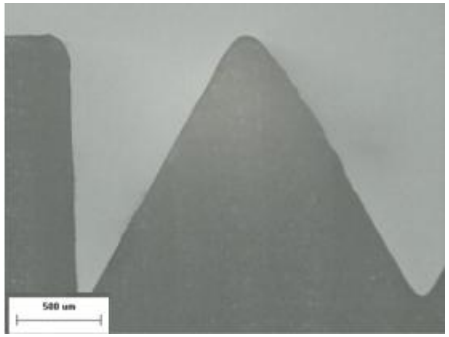
R1=頂角半徑
R2=底角半徑

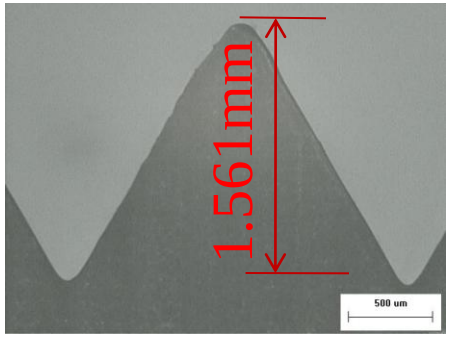


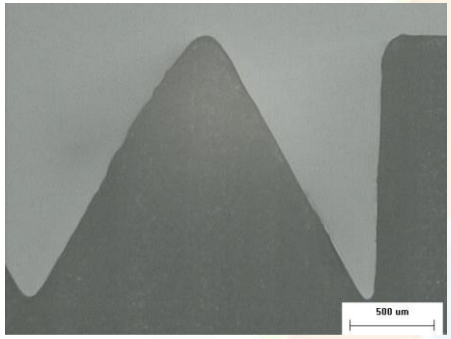




60℃近澆口端稜鏡複製度

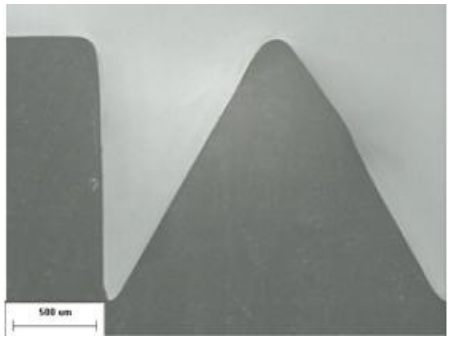


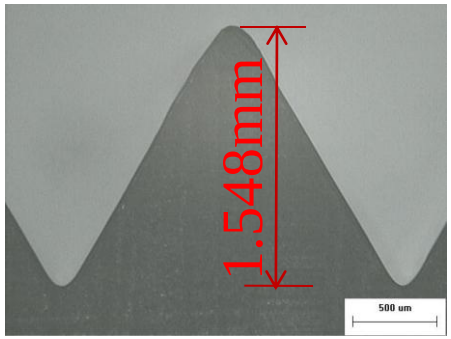


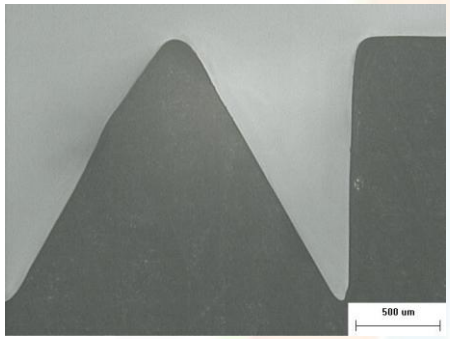


複製度=(1.561/1.629)*100=95.83%

60℃遠澆口端稜鏡複製度

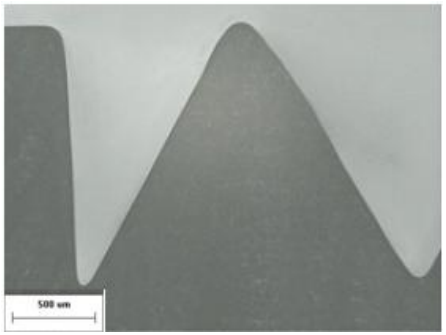


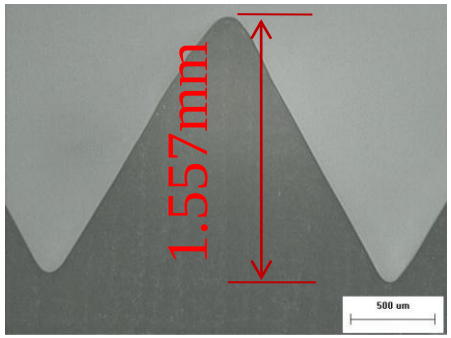


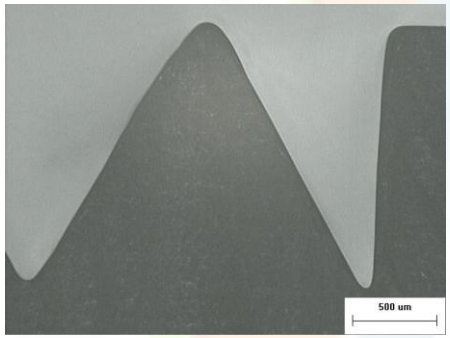


複製度=(1.548/1.629)*100=95%

70 ℃近澆口端稜鏡複製度

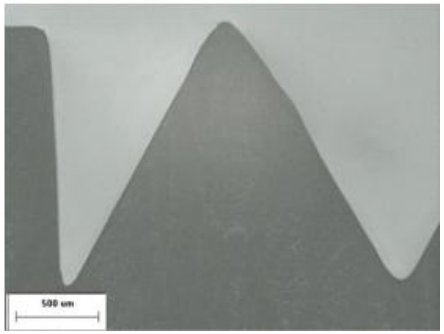


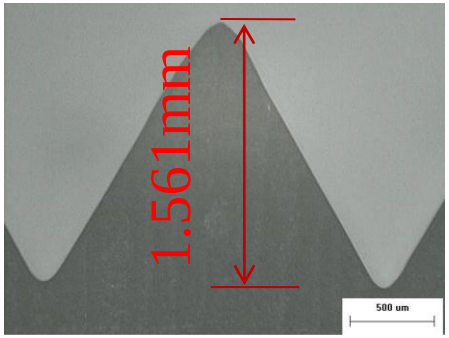


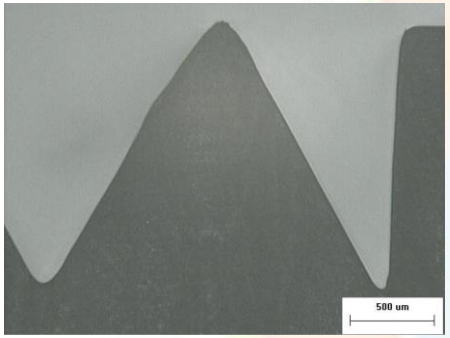


複製度=(1.557/1.629)*100=96.11%

70 ℃遠澆口端稜鏡複製度

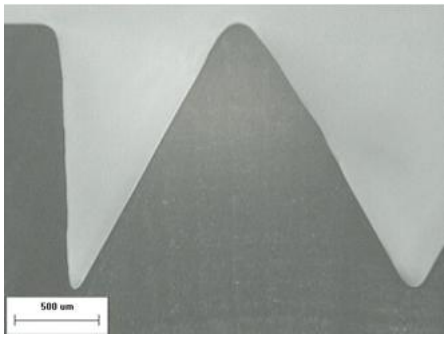


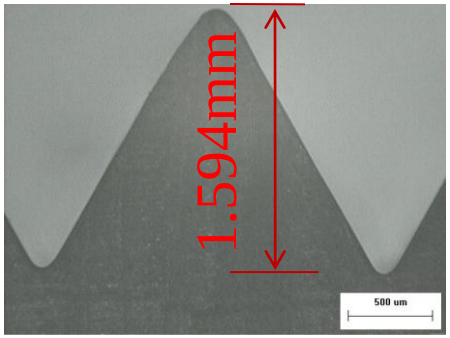


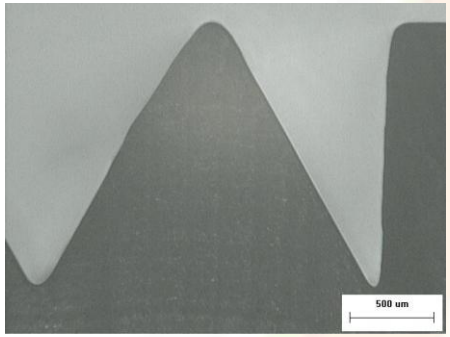


複製度=(1.561/1.629)*100=95.83%

80 ℃近澆口端稜鏡複製度

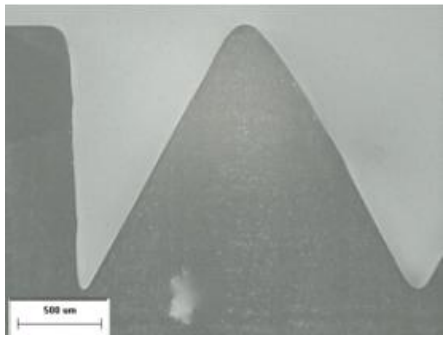


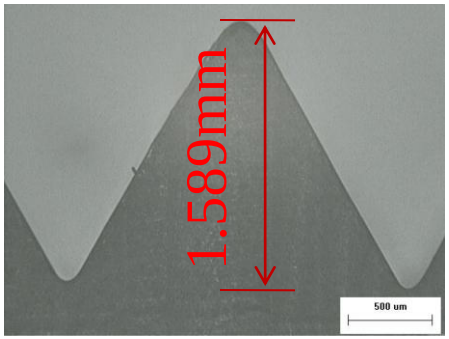


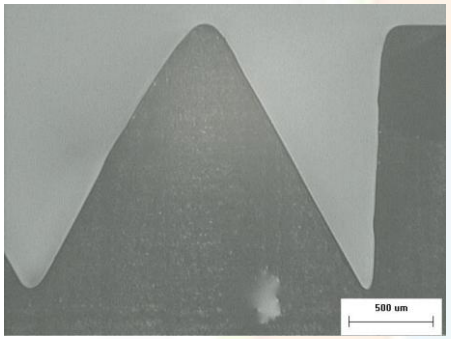


複製度=(1.594/1.629)*100=97.85%

80 ℃遠澆口端稜鏡複製度

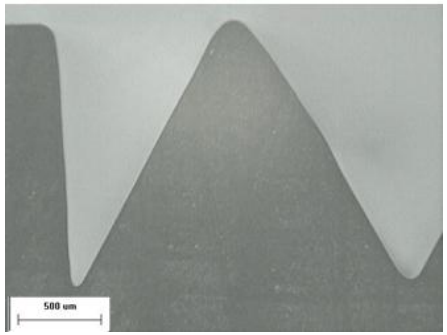


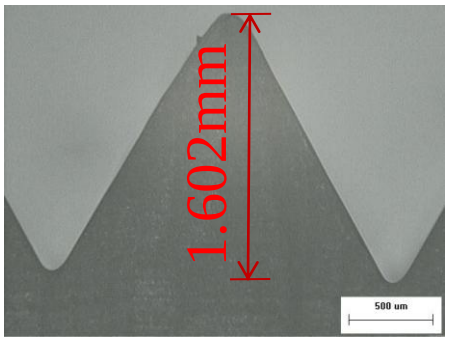


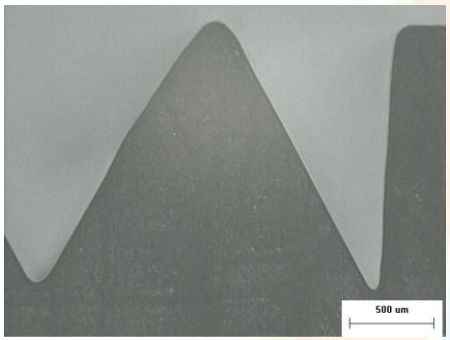


複製度=(1.589/1.629)*100=97.54%

90 ℃近澆口端稜鏡複製度

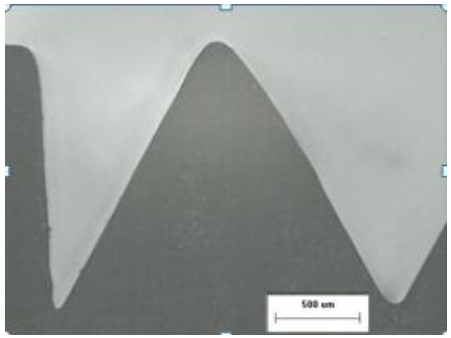


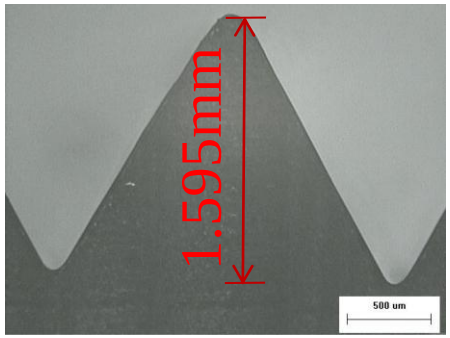


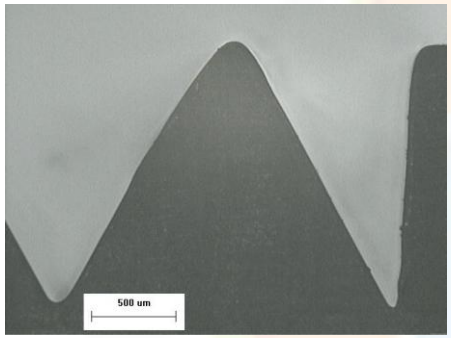


複製度=(1.602/1.629)*100=98.33%

90 ℃遠澆口端稜鏡複製度

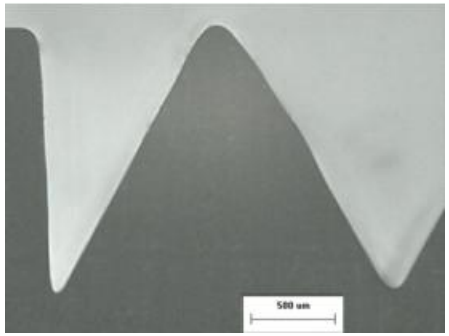


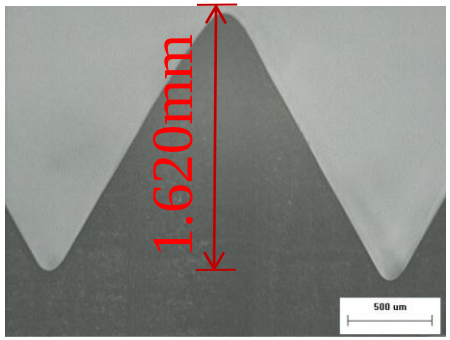


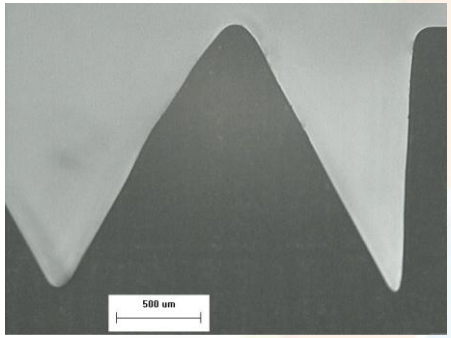


複製度=(1.595/1.629)*100=97.92%

100℃近澆口端稜鏡複製度

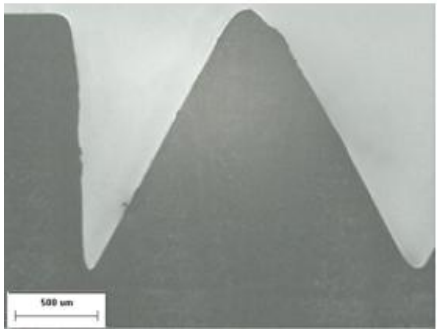


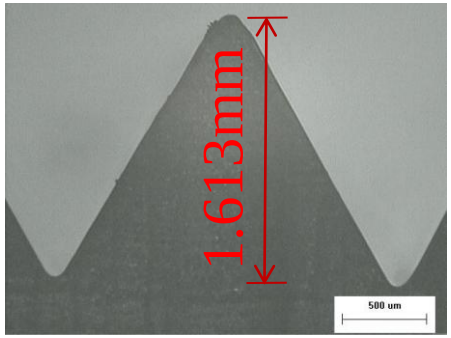


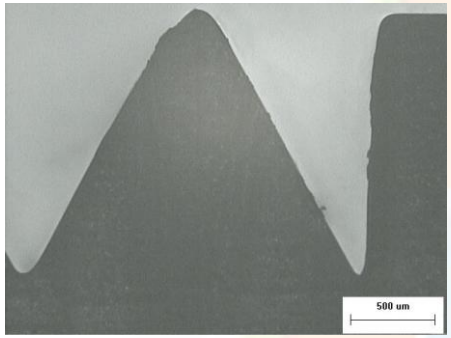


複製度=(1.620/1.629)*100=99.44%

100℃遠澆口端稜鏡複製度

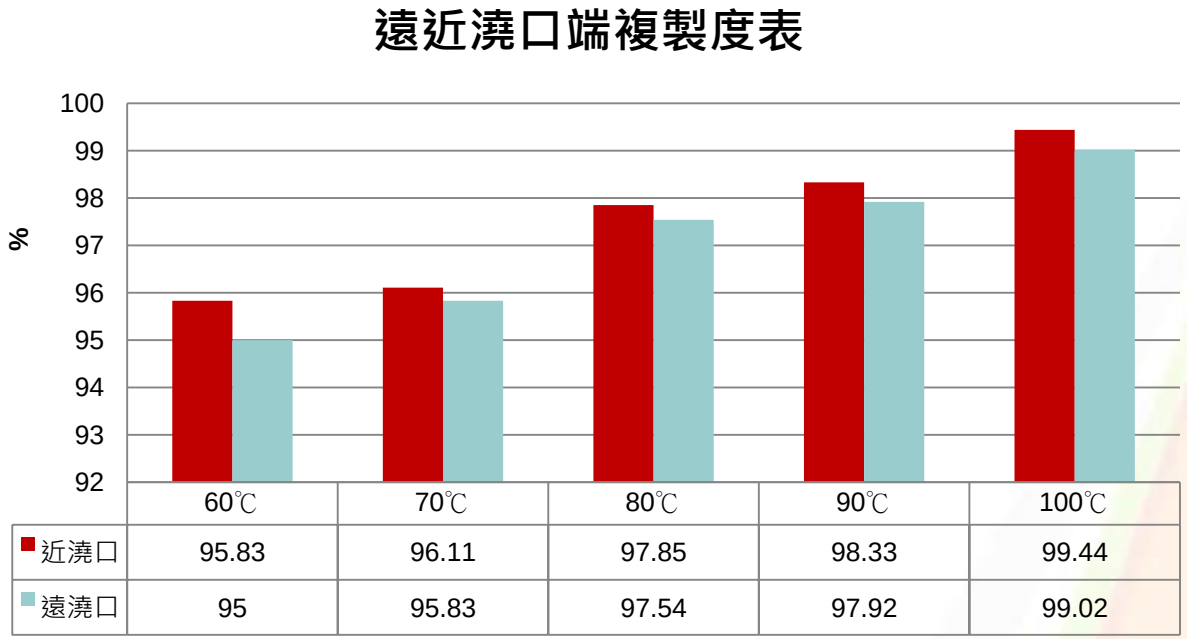






複製度=(1.613/1.629)*100=99.02%

遠近澆口端複製度



	60℃	70℃	80℃	90℃	100℃
近澆口	95.83	96.11	97.85	98.33	99.44
遠澆口	95	95.83	97.54	97.92	99.02

複製度跟模溫關係成正比線性，但當模溫在80℃以上，趨勢趨近於平緩，不論遠近澆口端複製度都大於97.5%以上。

結論

- 光學部分:

1. 成功設計出反射罩和楔型的穿透型繞射光柵結構透鏡燈罩，符合其**ECE R19 F3的規範。**
2. 成功設計出3種不同型式的反射罩，探討其中之差別。
3. 評估最佳化的設計是3階的拋物面反射罩，不論是對於改善 光亮度、均勻性和雜散光，**其中2.5D需要的2000cd以上，此設計可以達到3200cd，是規範的1.6倍。**

- 塑膠製造射出部分:

1. 對於鏡片翹曲量實驗，利用田口法找出影響最大的因子為保壓時間，其次為射出壓力，**實際成功將翹曲量由最差的0.405mm降至最佳的0.252mm。**
2. 複製度方面，複製度跟模溫關係成正比線性，但**當模溫在80℃以上**，趨勢趨近 於平緩，**不論遠近澆口端複製度都大於97.5%以上。**

未來展望

1. 後續可實際做出實體反射罩和leds以及本次的霧燈光柵透鏡，比較光追跡和實際的趨勢。

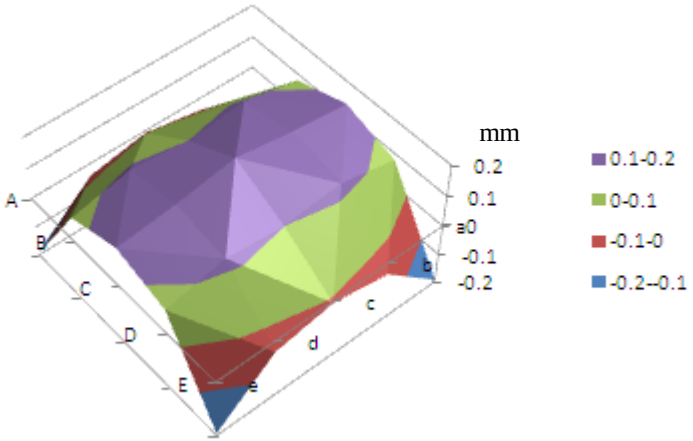
2. 進行雙目標的實驗規畫設計，複製度望大，同時翹曲量望小的最佳化設計。

Thanks for your attention

Polymer Processings Laboratory
National Yunlin University of Science & Technology

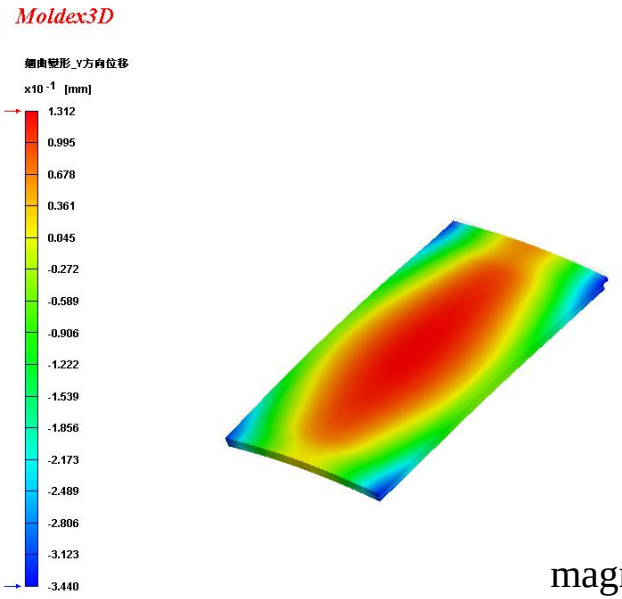
模溫對翹曲度影響-模溫60℃

experiment

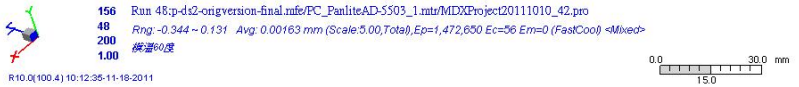


Warpage:0.372

simulation



magnification:5x

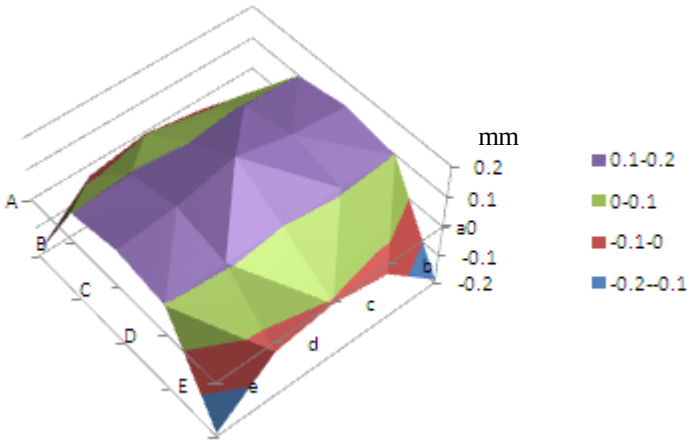


Warpage:0.4752

Unit:mm

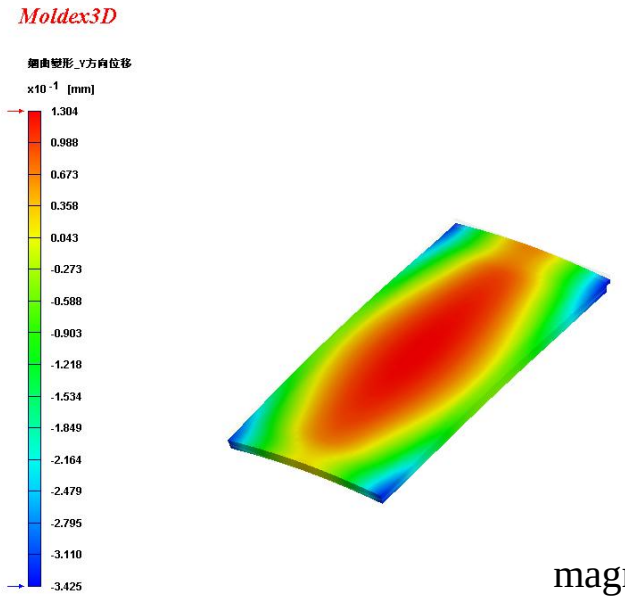
模溫對翹曲度影響-模溫70℃

experiment

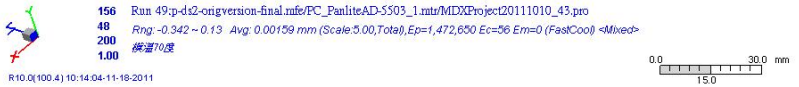


Warpage:0.375

simulation



magnification:5x

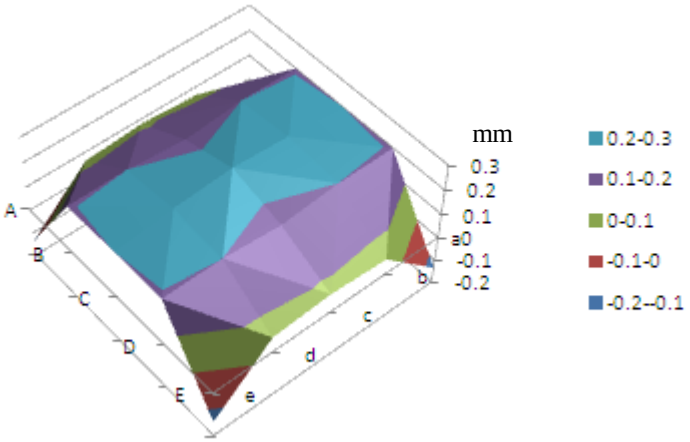


Warpage:0.4729

Unit:mm

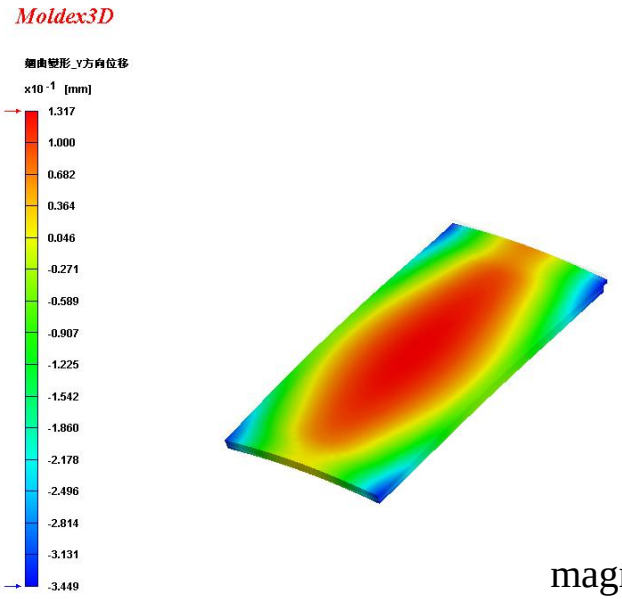
模溫對翹曲度影響-模溫80℃

experiment

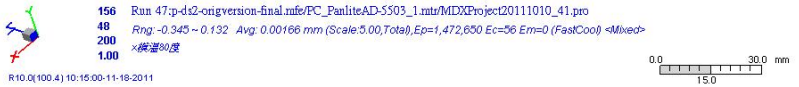


Warpage:0.37

simulation



magnification:5x

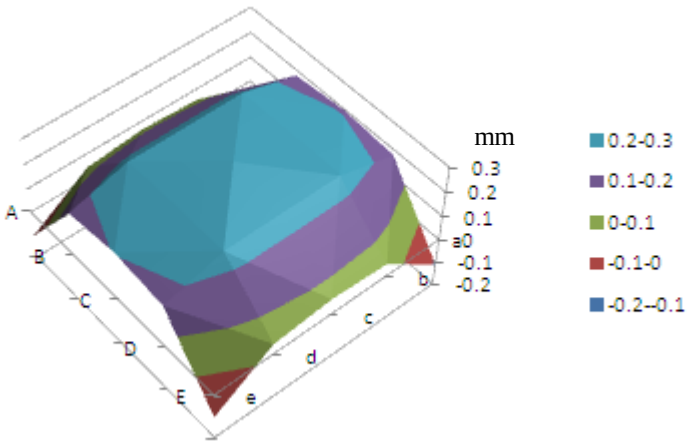


Warpage:0.4766

Unit:mm

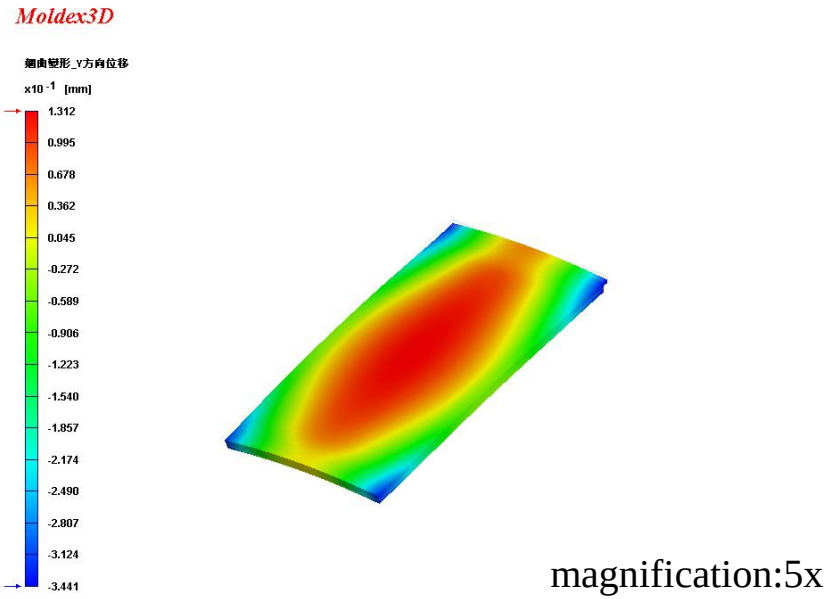
模溫對翹曲度影響-模溫90℃

experiment

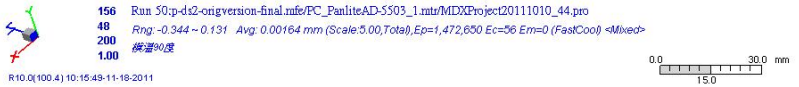


Warpage:0.38

simulation



magnification:5x

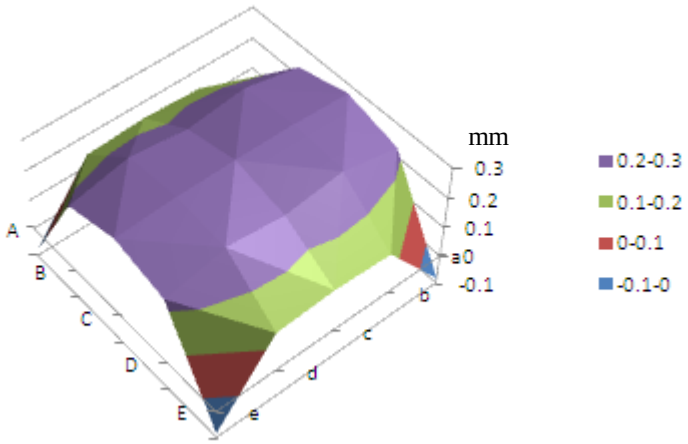


Warpage:0.4753

Unit:mm

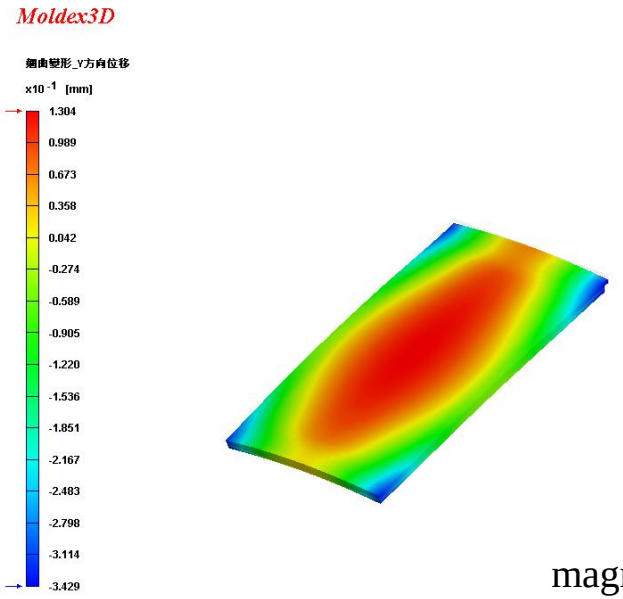
模溫對翹曲度影響-模溫100℃

experiment

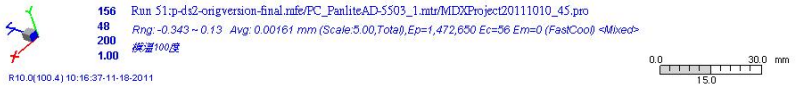


Warpage:0.365

simulation



magnification:5x



Warpage:0.4733

Unit:mm

各模溫影響翹曲量平均data

模溫60℃

X-axis / Z-axis	a	b	c	d	e
A	-0.192	0.08	0.13	0.08	-0.192
B	-0.04	0.12	0.15	0.12	-0.04
C	-0.007	0.1	0.18	0.1	-0.007
D	-0.04	0.12	0.15	0.12	-0.04
E	-0.192	0.08	0.13	0.08	-0.192

Warpage=0.18-(-0.192)=0.372

模溫70℃

X-axis / Z-axis	a	b	c	d	e
A	-0.188	0.099	0.126	0.099	-0.188
B	-0.036	0.108	0.145	0.108	-0.036
C	-0.006	0.098	0.187	0.098	-0.006
D	-0.036	0.108	0.145	0.108	-0.036
E	-0.188	0.099	0.126	0.099	-0.188

Warpage=0.187-(-0.188)=0.375

Unit:mm

各模溫影響翹曲量平均data

模溫80℃

X-axis / Z-axis	a	b	c	d	e
A	-0.135	0.198	0.2	0.198	-0.135
B	0.065	0.2	0.22	0.2	0.065
C	0.08	0.18	0.235	0.18	0.08
D	0.065	0.2	0.22	0.2	0.065
E	-0.135	0.198	0.2	0.198	-0.135

Warpage=0.235-(-0.135)=0.370

模溫90℃

X-axis / Z-axis	a	b	c	d	e
A	-0.112	0.178	0.196	0.178	-0.112
B	0.054	0.239	0.239	0.239	0.054
C	0.066	0.239	0.268	0.239	0.066
D	0.044	0.239	0.239	0.239	0.044
E	-0.102	0.178	0.202	0.178	-0.102

Warpage=0.268-(-0.112)=0.380

Unit:mm

各模溫影響翹曲量平均data

模溫100℃

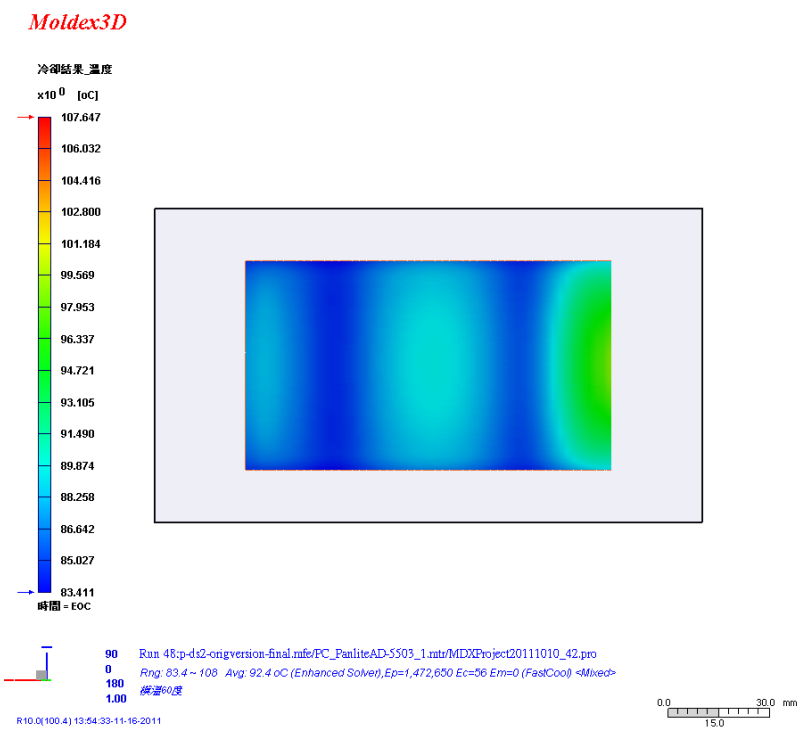
X-axis / Z-axis	a	b	c	d	e
A	-0.083	0.228	0.271	0.228	-0.083
B	0.137	0.267	0.28	0.267	0.137
C	0.147	0.245	0.282	0.245	0.147
D	0.137	0.267	0.28	0.267	0.137
E	-0.083	0.228	0.271	0.228	-0.083

Warpage=0.282-(-0.083)=0.365

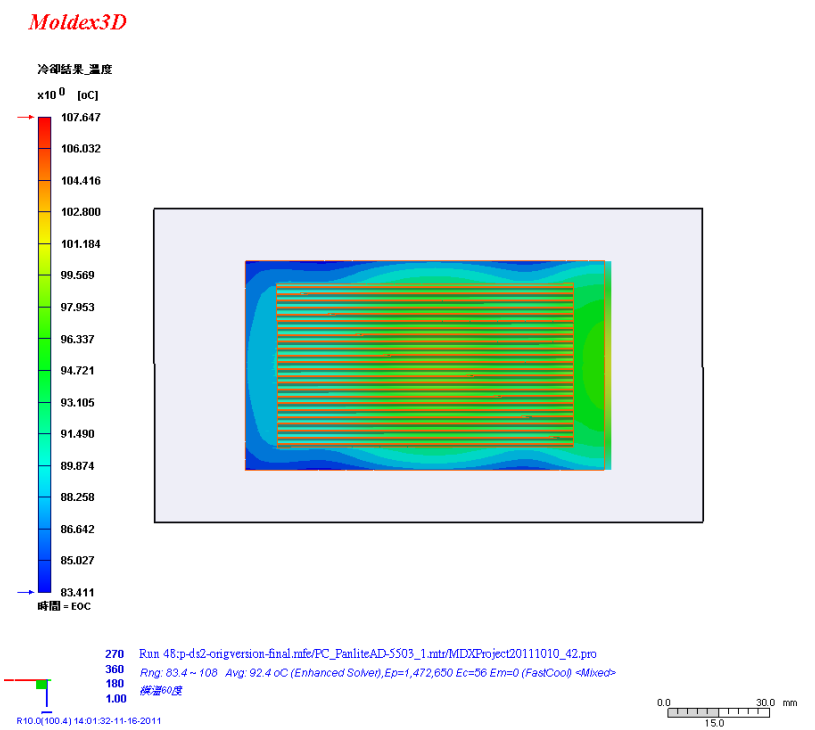
Unit:mm

模溫60℃，冷卻30s後公母模溫度分佈圖

固定測溫度分佈圖

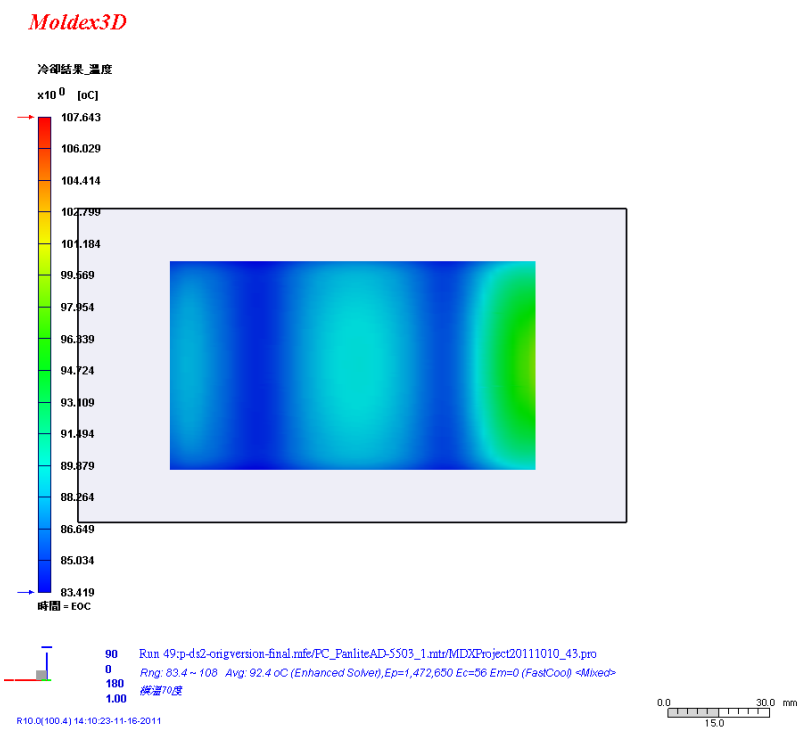


活動測溫度分佈圖

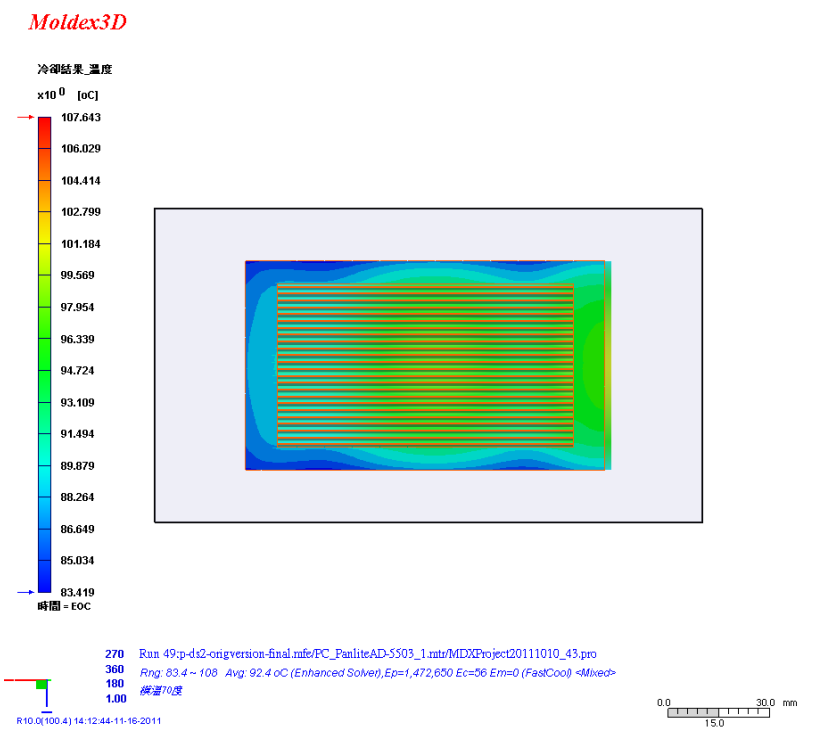


模溫70℃，冷卻30s後公母模溫度分佈圖

固定測溫度分佈圖

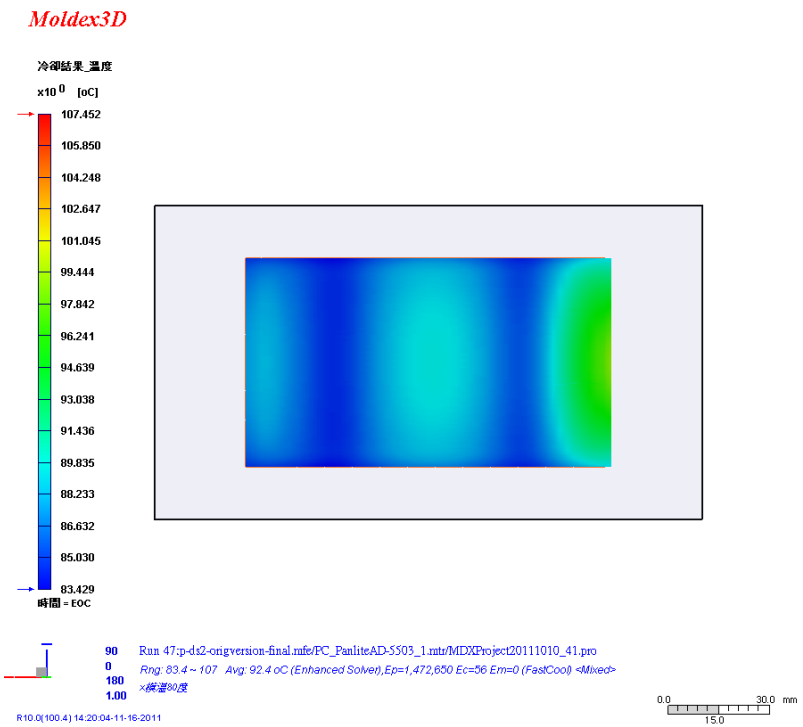


活動測溫度分佈圖

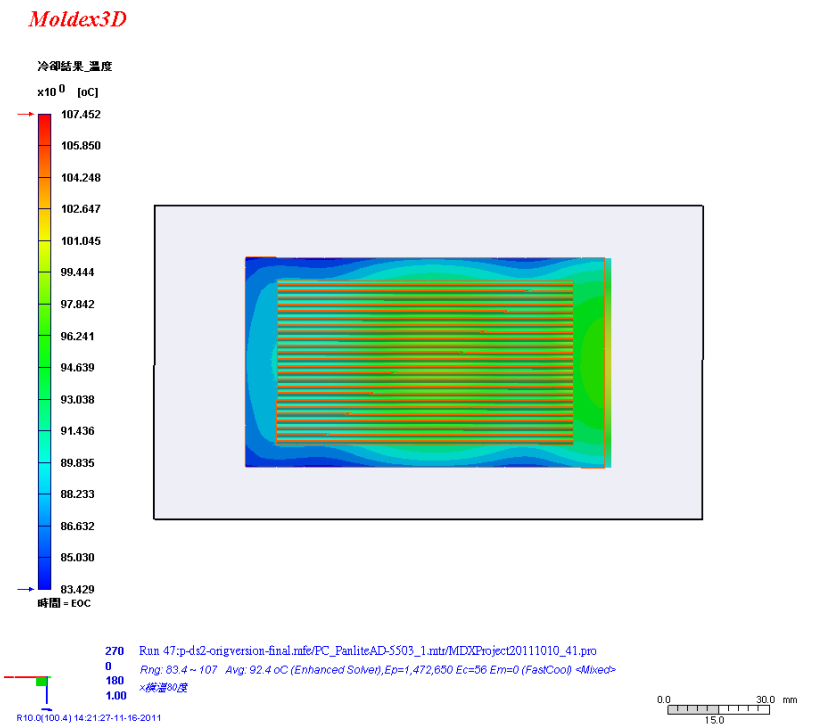


模溫80℃，冷卻30s後公母模溫度分佈圖

固定測溫度分佈圖

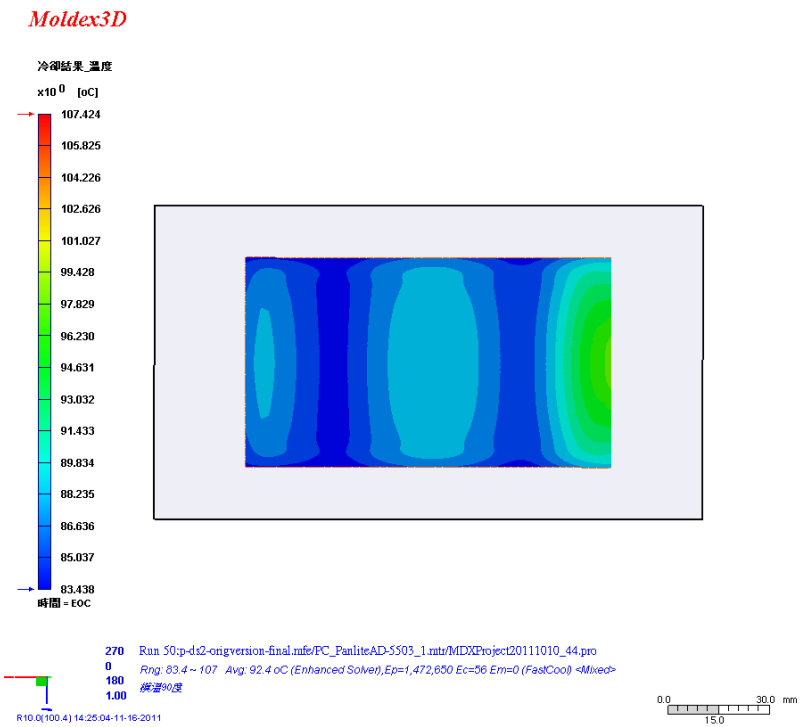


活動測溫度分佈圖

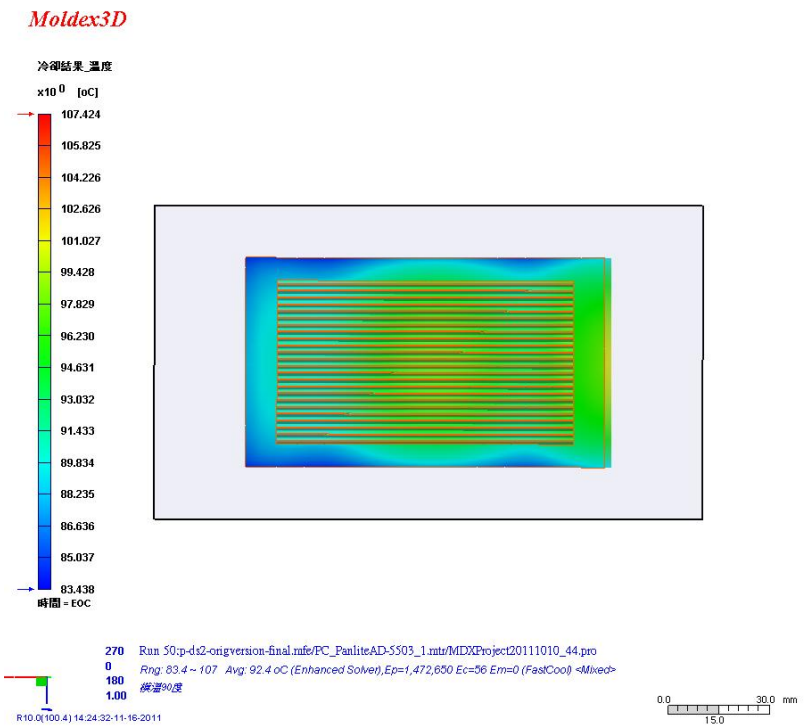


模溫90℃，冷卻30s後公母模溫度分佈圖

固定測溫度分佈圖

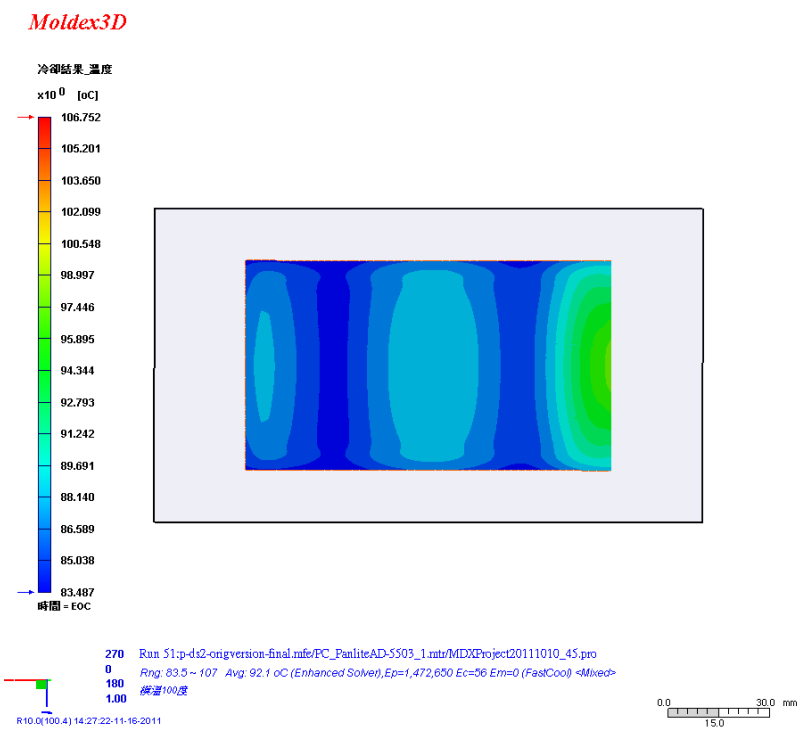


活動測溫度分佈圖

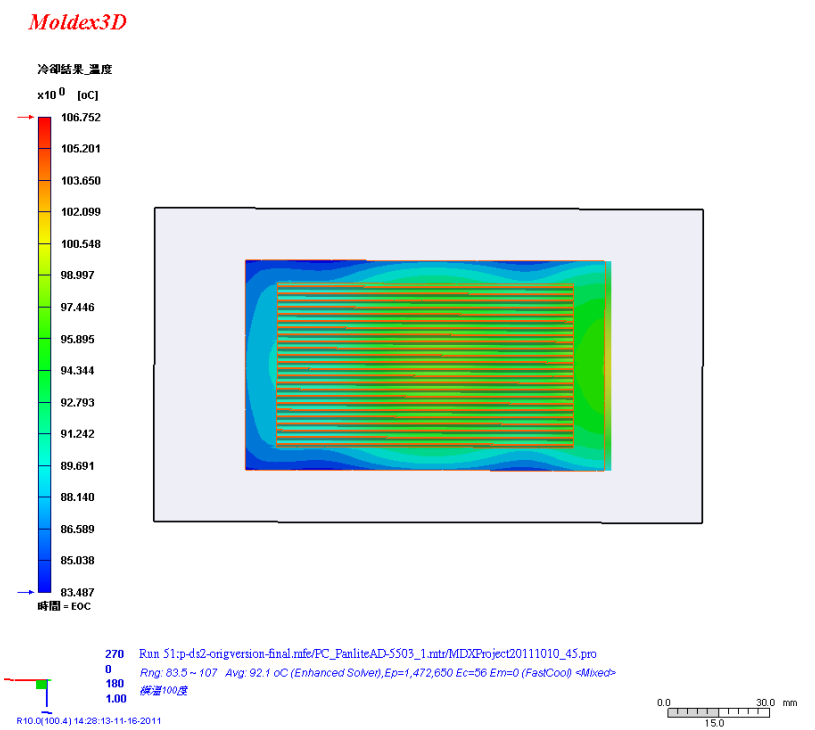


模溫100℃，冷卻30s後公母模溫度分佈圖

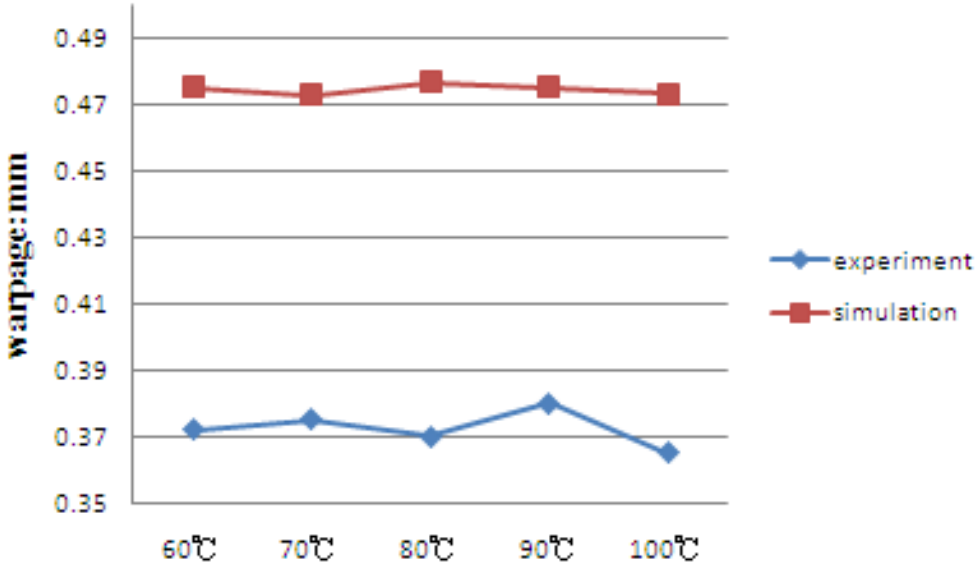
固定測溫度分佈圖



活動測溫度分佈圖



實驗與模擬翹曲比較表



60℃	70℃	80℃	90℃	100℃	
0.372	0.375	0.370	0.380	0.365	experiment
0.4752	0.4729	0.4766	0.4753	0.4733	simulation

模溫對翹曲度影響小結論

1. 不同模溫冷卻後的固定側和活動側模溫分佈，大致上皆相同。
2. 模擬的翹曲量趨近於平緩，而實驗值的翹曲量最大和最小差0.015mm，可以得知其模溫因子影響翹曲量是很小的。