midas NFX-CFD

CFD_標準教學系列

熱分析2-接觸熱阻

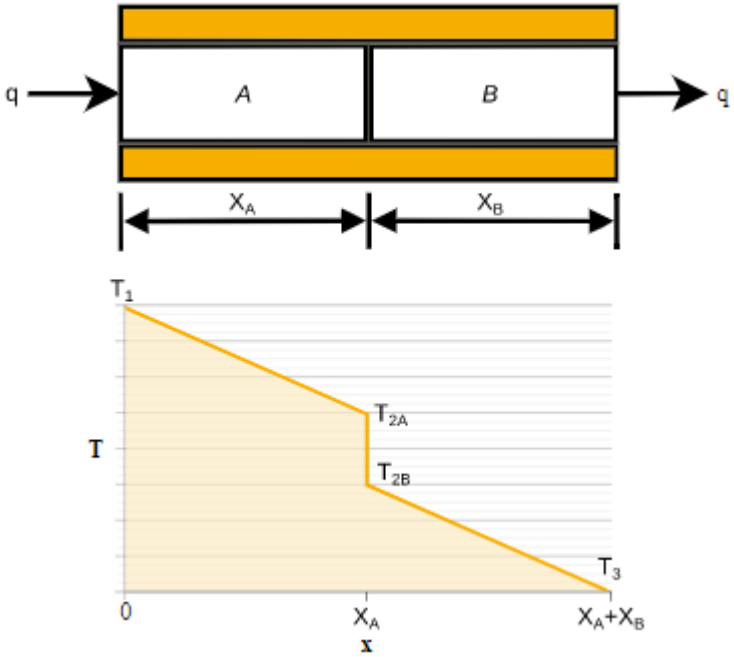
台灣邁達斯

MIDAS

接觸熱阻
(Thermal Contact Resistance)

當二個固體相接觸熱會由較高溫的物體流到較低溫的物體，二個固體的溫度分佈大致如圖所示。其中在接觸面上有明顯的溫度落差，這就是二個接觸面之間接觸熱阻造成的影響。
接觸熱阻定義為溫度差和介面平均熱流的比例。

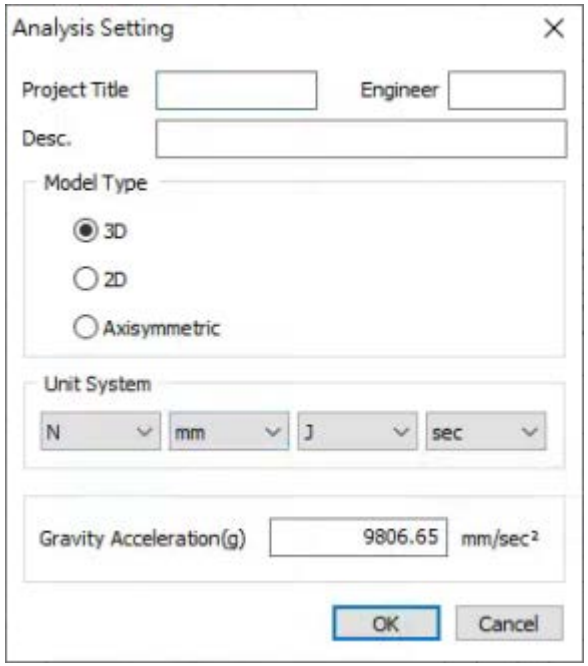
$$q = \frac{T_1 - T_3}{\Delta x_A/(k_A A) + 1/(h_c A) + \Delta x_B/(k_B A)}$$

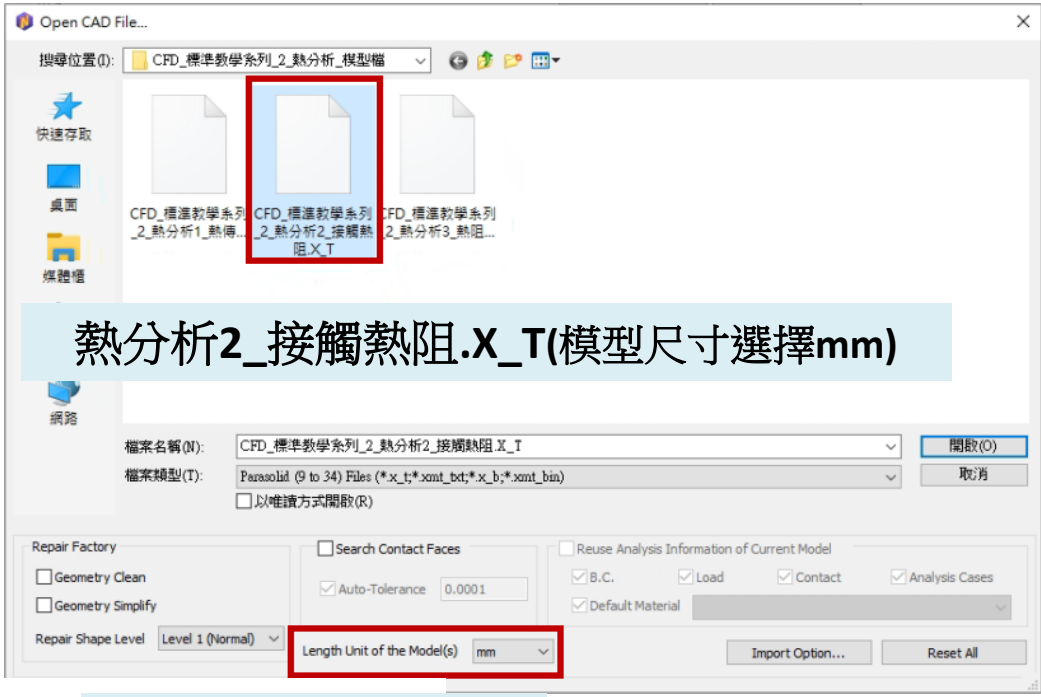


q:為熱流
K_A和K_B:熱傳導率
A:截面積
h_c:接觸熱導率
接觸熱阻:1/h_c(接觸熱導率倒數)

Reference
https://zh.wikipedia.org/wiki/接觸熱導

環境&模型匯入

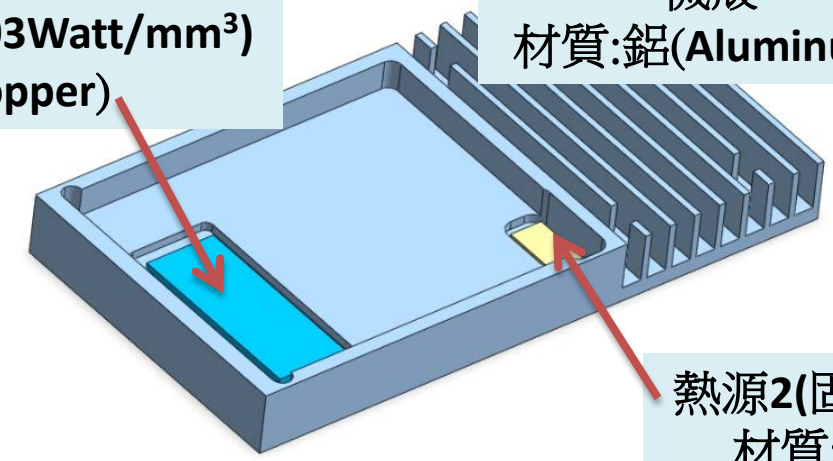




熱分析2_接觸熱阻.X_T(模型尺寸選擇mm)

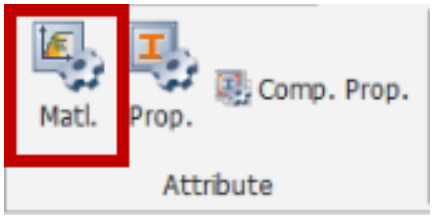
熱源1(發熱量0.003Watt/mm³)
材質:銅(Copper)

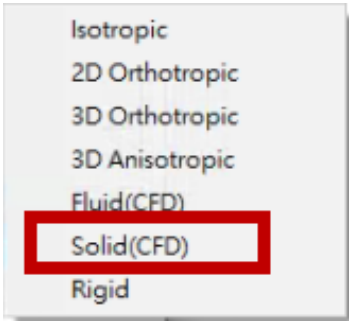
機殼
材質:鋁(Aluminum)



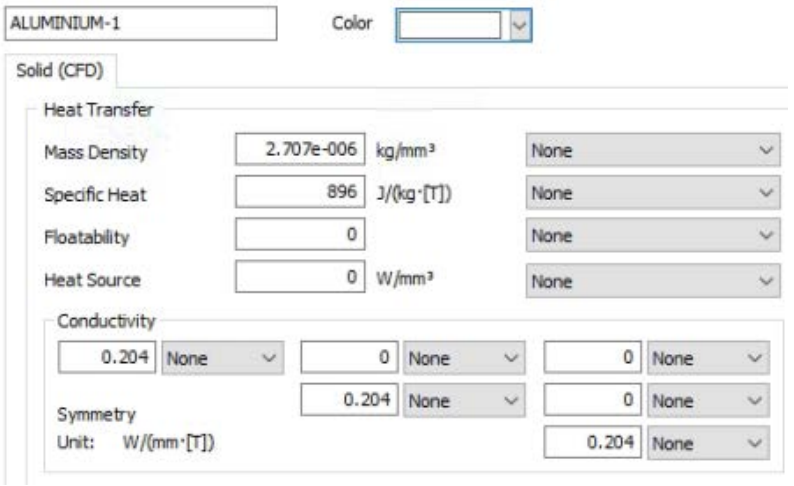
熱源2(固定溫度80 ℃)
材質:銅(Copper)

材料

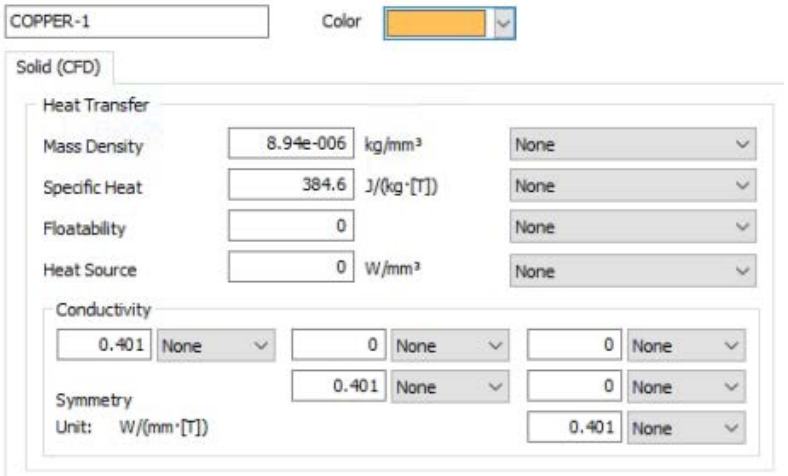




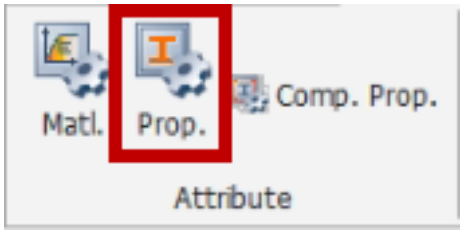
新增Aluminum材料

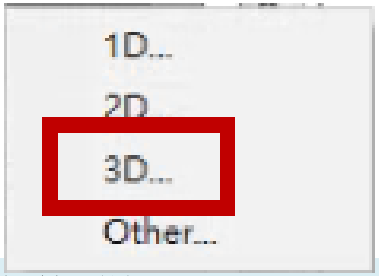


新增Copper材料



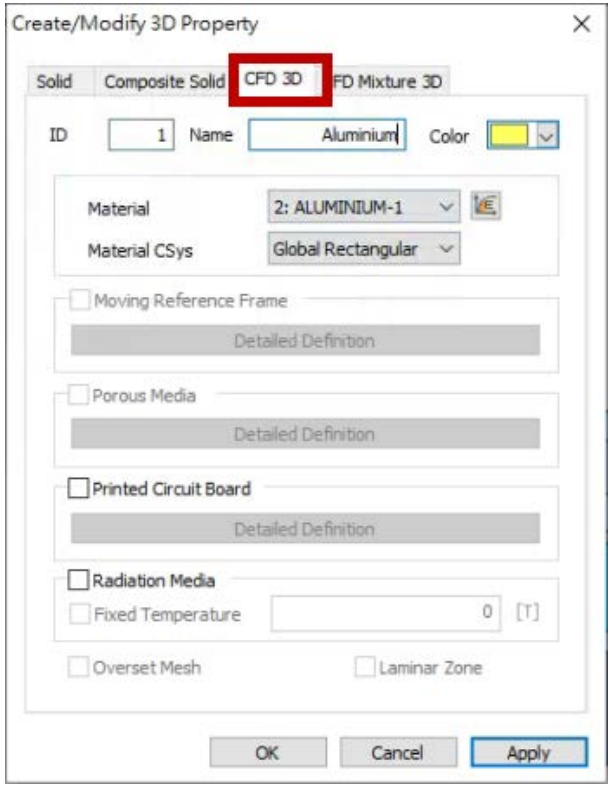
屬性



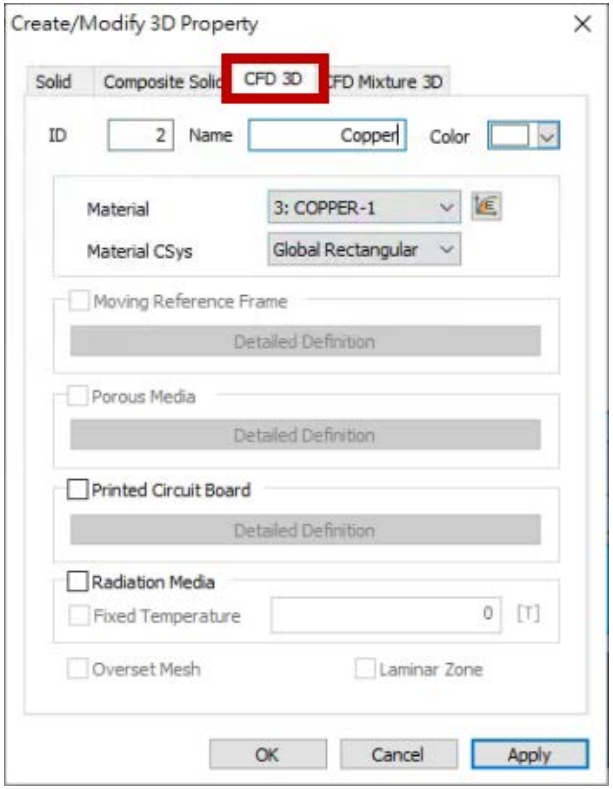


屬性選取Solid

新增Aluminum屬性



新增Copper屬性



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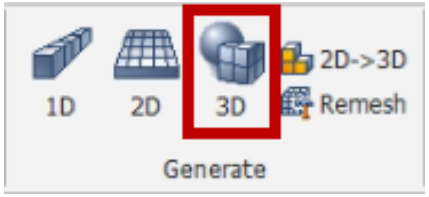
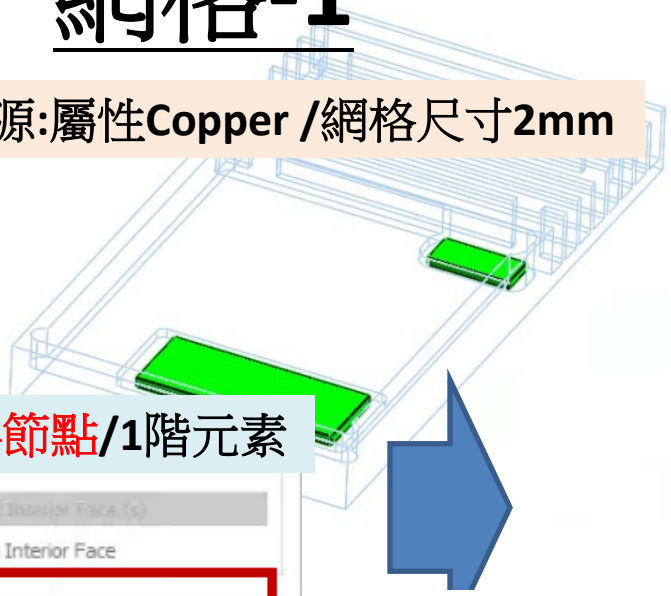
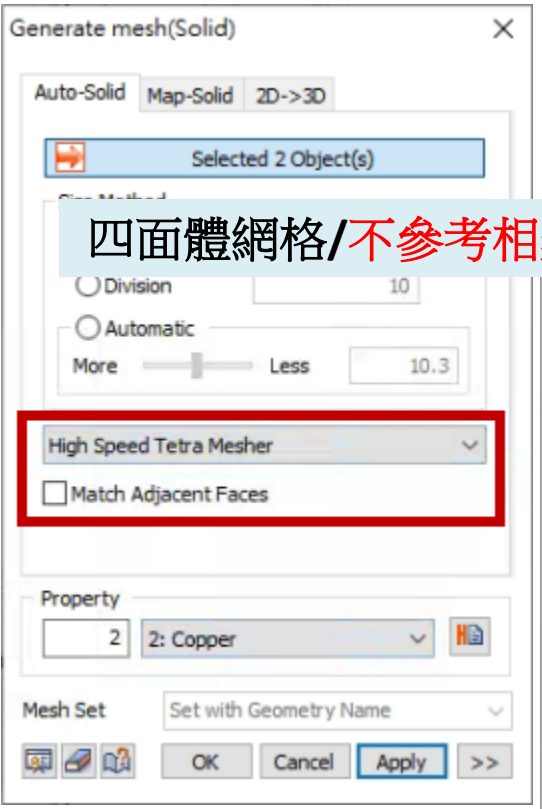
網格-1

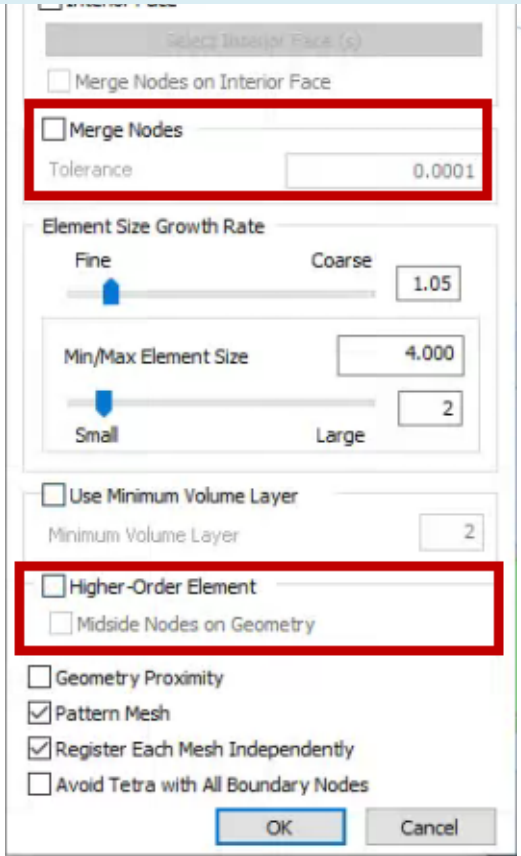


熱源:屬性Copper /網格尺寸2mm



四面體網格/不參考相鄰面/不共節點/1階元素





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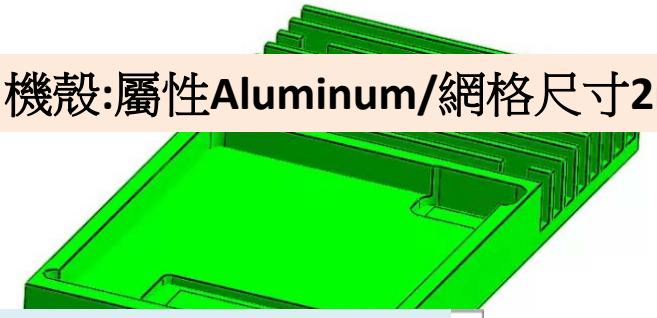
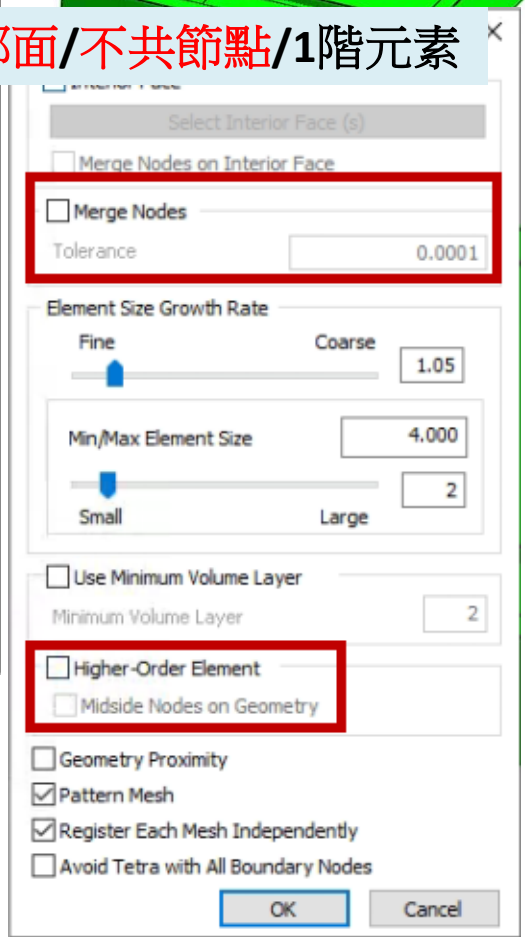
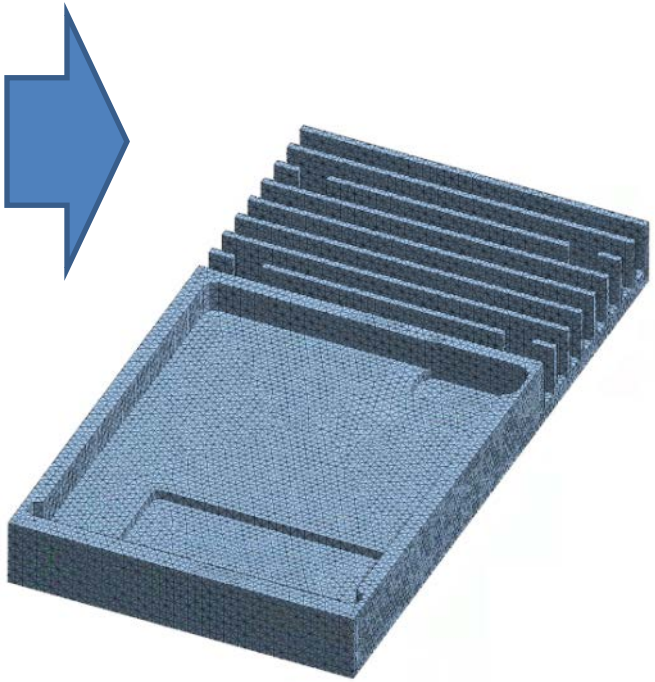
網格-2

機殼:屬性Aluminum/網格尺寸2mm

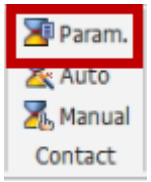


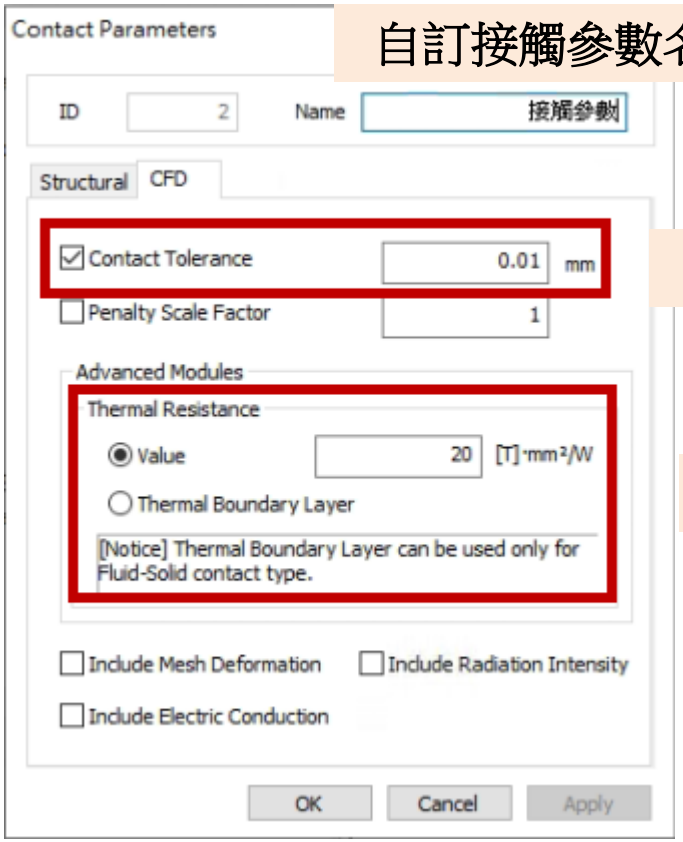
四面體網格/不參考相鄰面/不共節點/1階元素





接觸參數



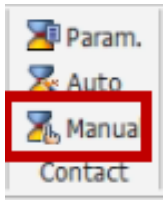


自訂接觸參數名稱

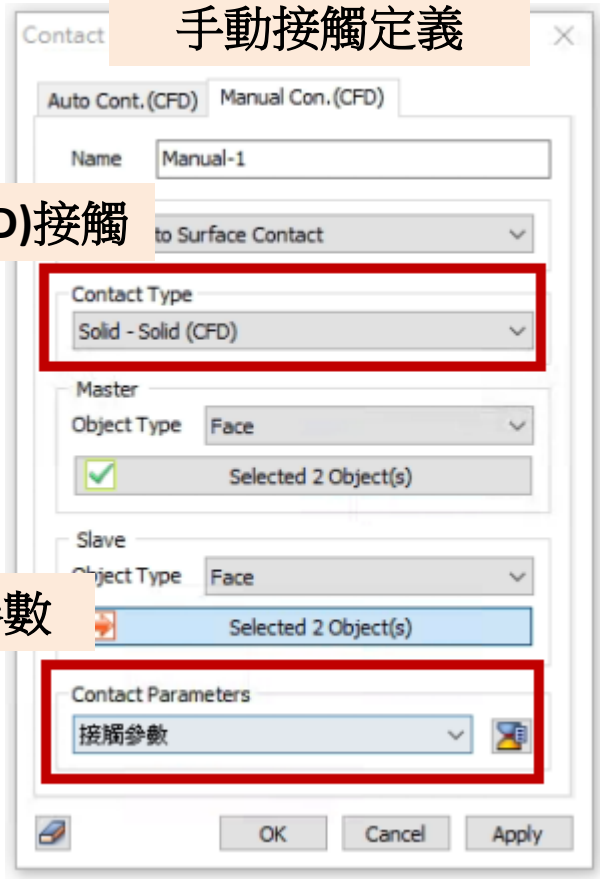
勾選允許接觸間隙

假設接觸熱阻20 (K-mm²/W)

接觸定義



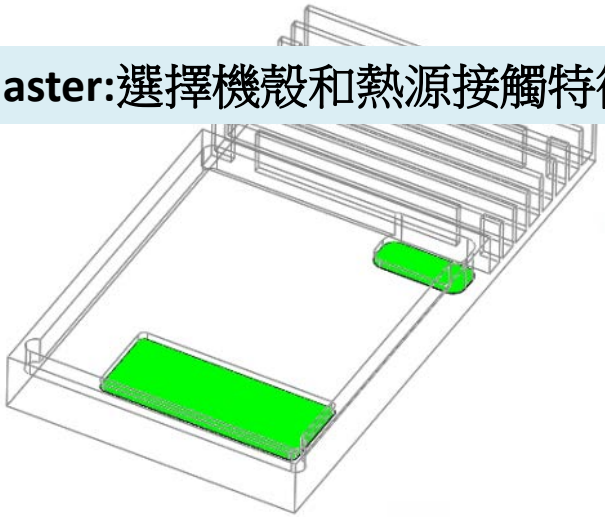
手動接觸定義



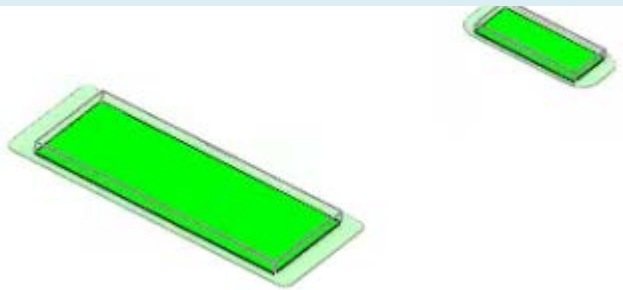
Solid-Solid(CFD)接觸

指定接觸參數

Master:選擇機殼和熱源接觸特徵

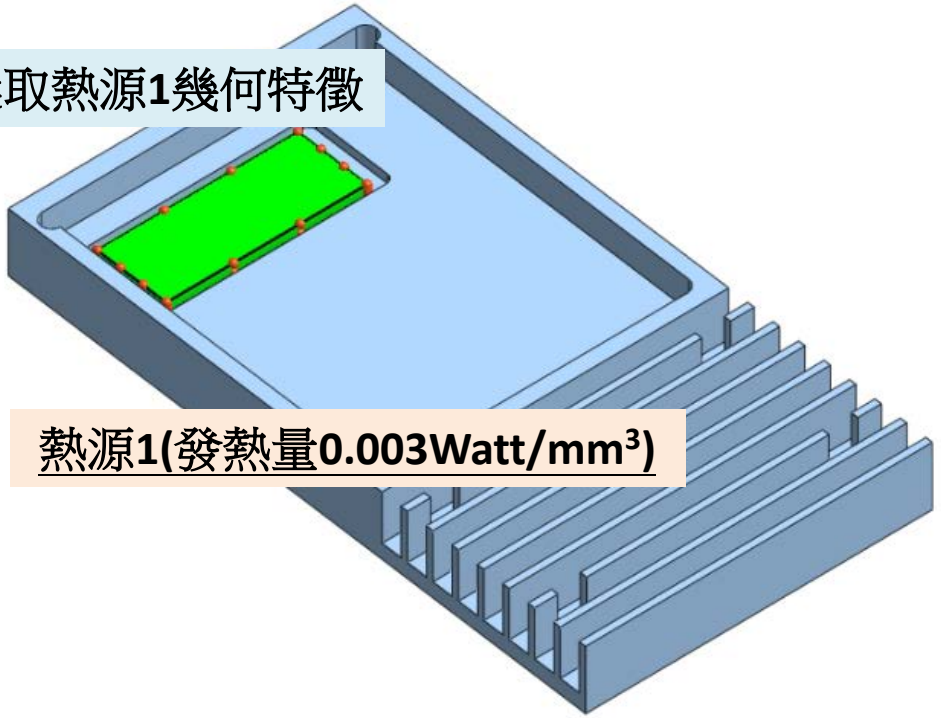


Slave:選擇熱源和機殼接觸特徵



熱源1-發熱量

使用Part選取熱源1幾何特徵

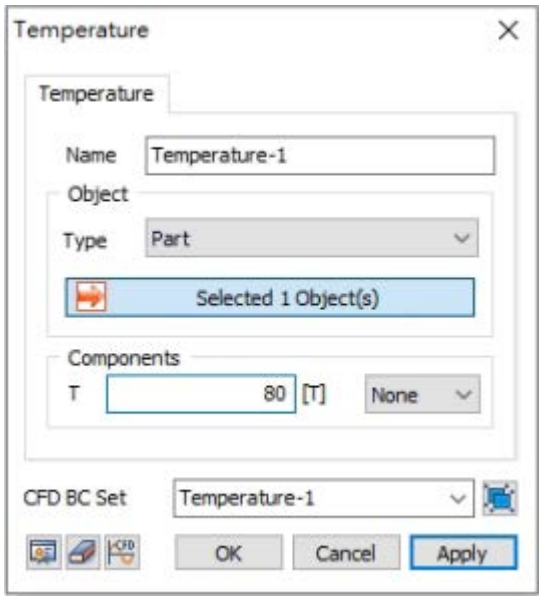


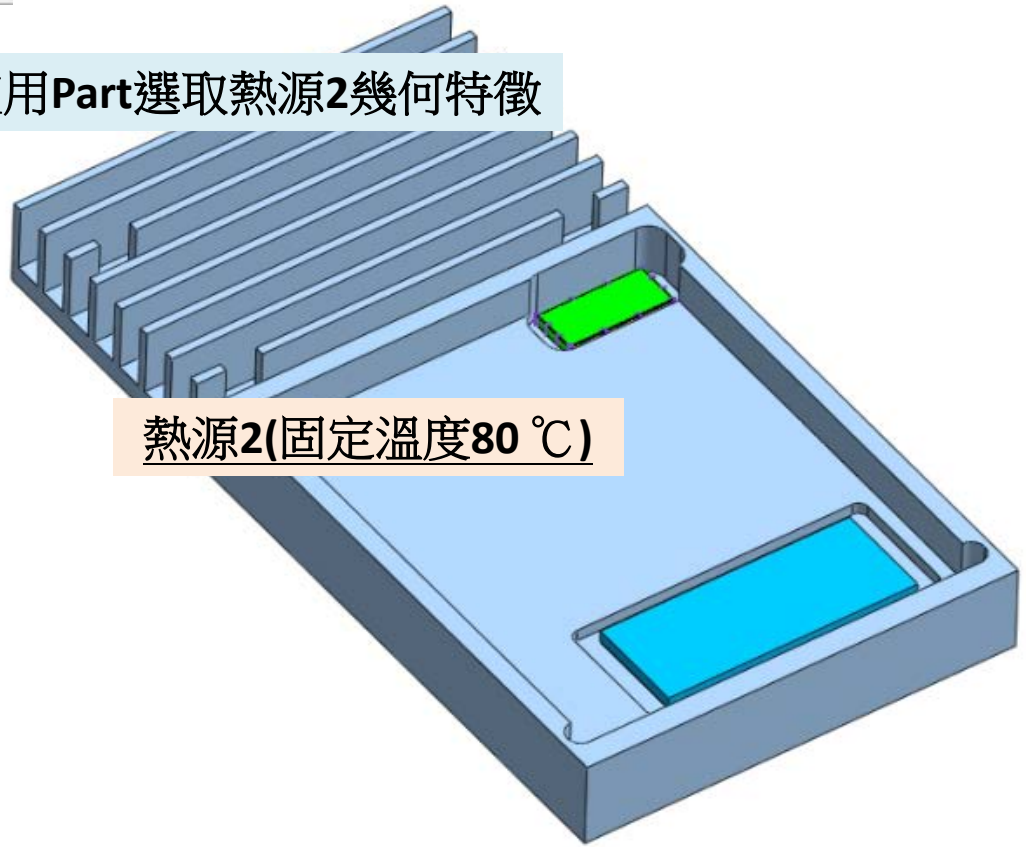
熱源1(發熱量0.003Watt/mm³)

註:不同邊界&載荷建議使用不同集合名稱。

熱源2-溫度

使用Part選取熱源2幾何特徵



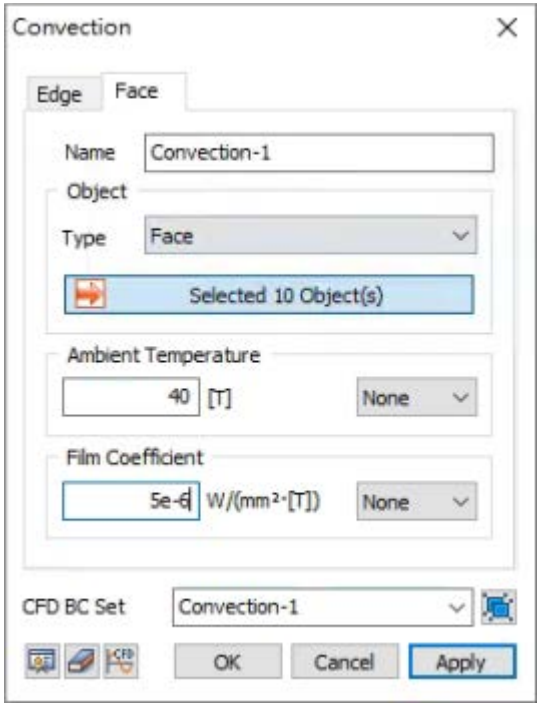


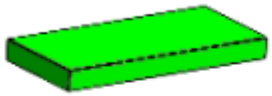
熱源2(固定溫度80 ℃)

註:不同邊界&載荷建議使用不同集合名稱。

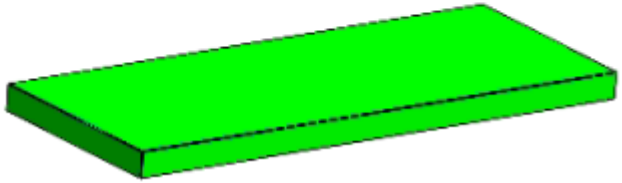
熱對流-1

環境溫度:40 ℃
熱對流係數:5×10^{-6} (W/mm^2 ℃)





施加在空氣與結構接觸特徵

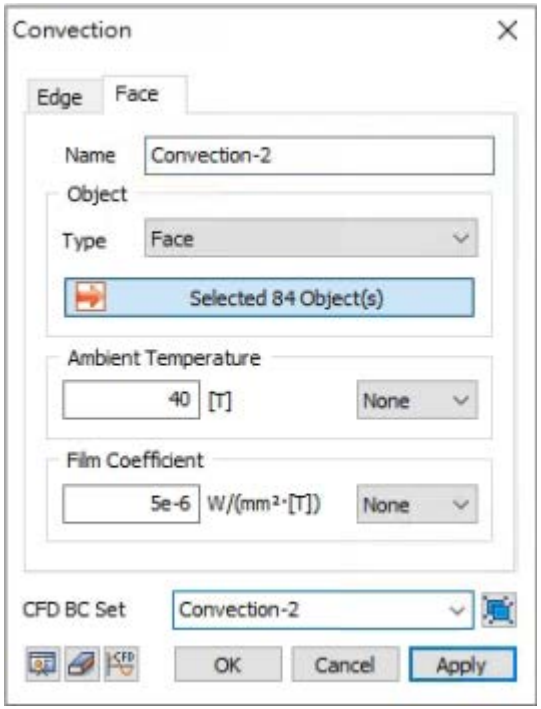


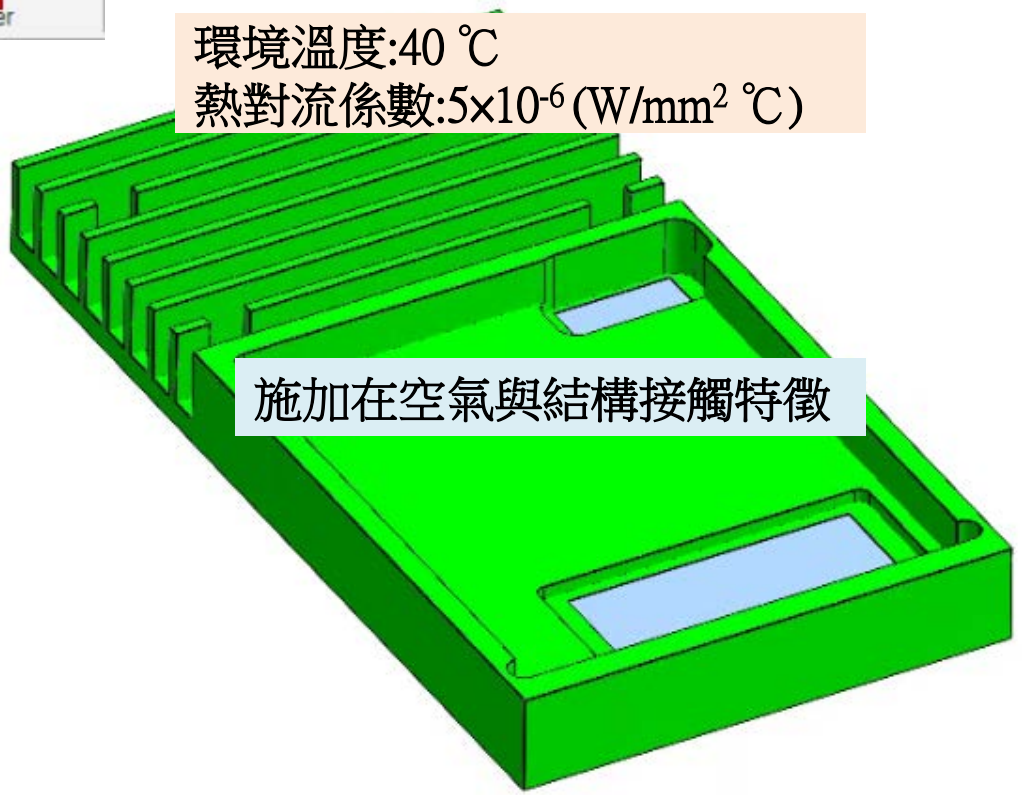
一般空氣熱對流係數
1.自然對流: 3×10^{-6} ~ 12×10^{-6} (W/mm^2 ℃)
2.強制對流: 10×10^{-6} ~ 100×10^{-6} (W/mm^2 ℃)

註1:幾何間的接觸面不用考慮空氣熱對流。
註2:不同邊界&載荷建議使用不同集合名稱。

熱對流-2

環境溫度:40 ℃
熱對流係數:5×10^{-6} (W/mm^2 ℃)



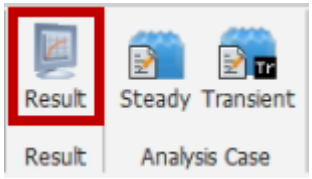


施加在空氣與結構接觸特徵

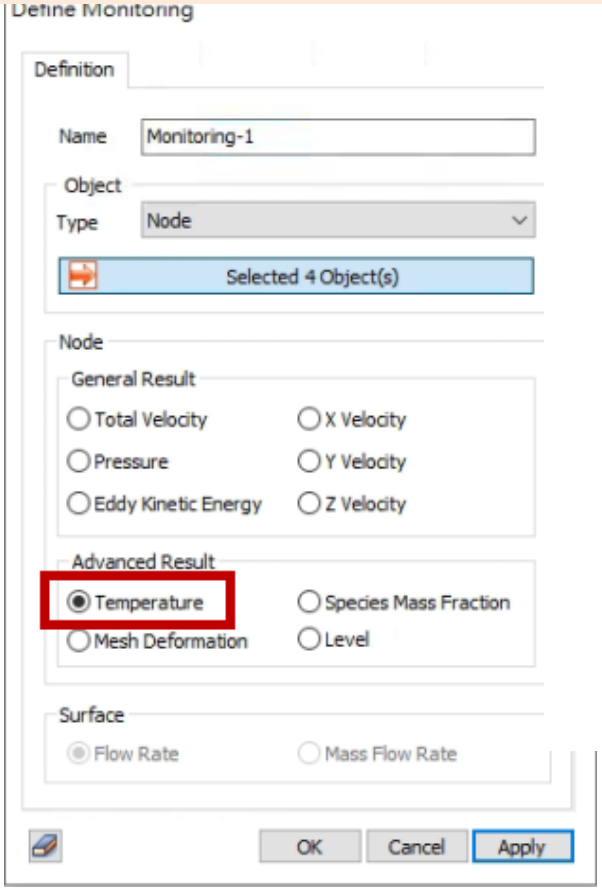
一般空氣熱對流係數
1.自然對流: 3 ×10^{-6} ~12 ×10^{-6} (W/mm^2 ℃)
2.強制對流: 10 ×10^{-6} ~100×10^{-6} (W/mm^2 ℃)

註1:幾何間的接觸面不用考慮空氣熱對流。
註2:不同邊界&載荷建議使用不同集合名稱。

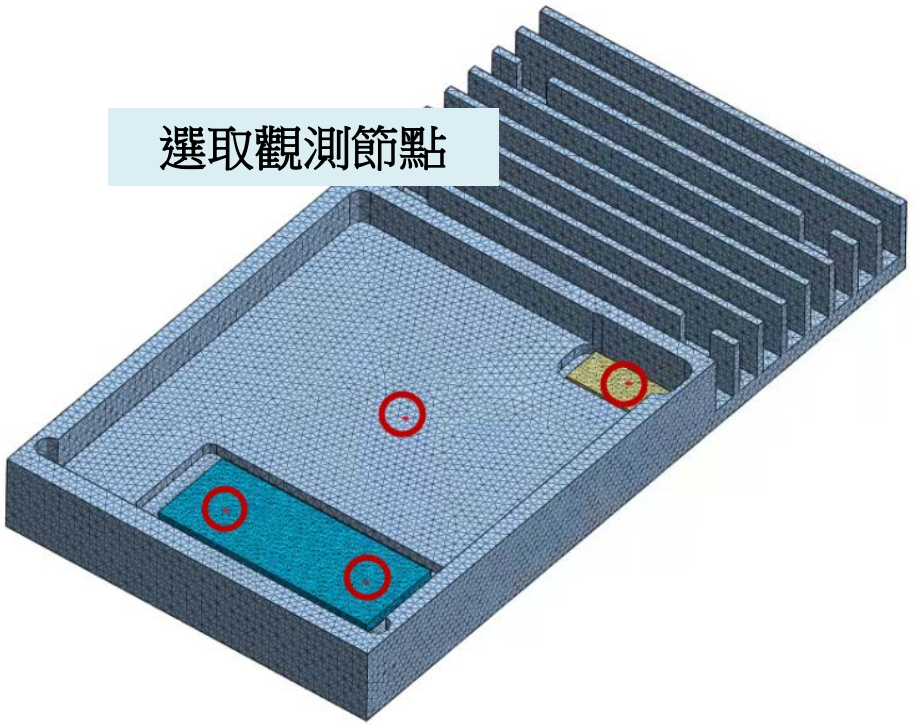
觀測點



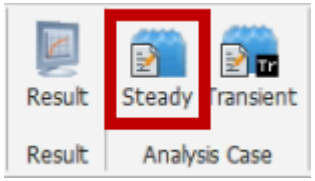
輸出特定節點數據同時能協助判斷收斂穩定



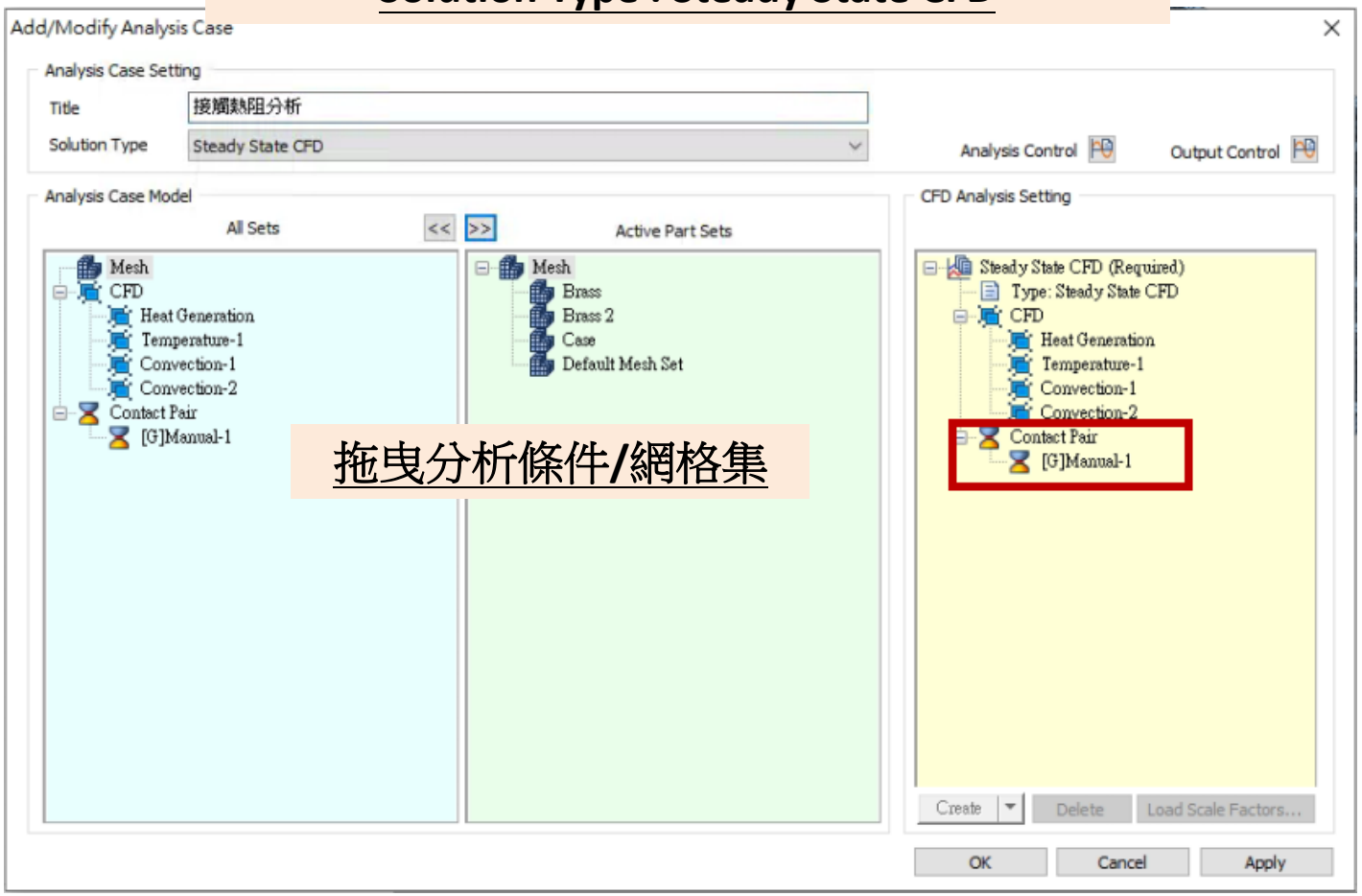
選取觀測節點



接觸熱阻分析-1



Solution Type : Steady State CFD



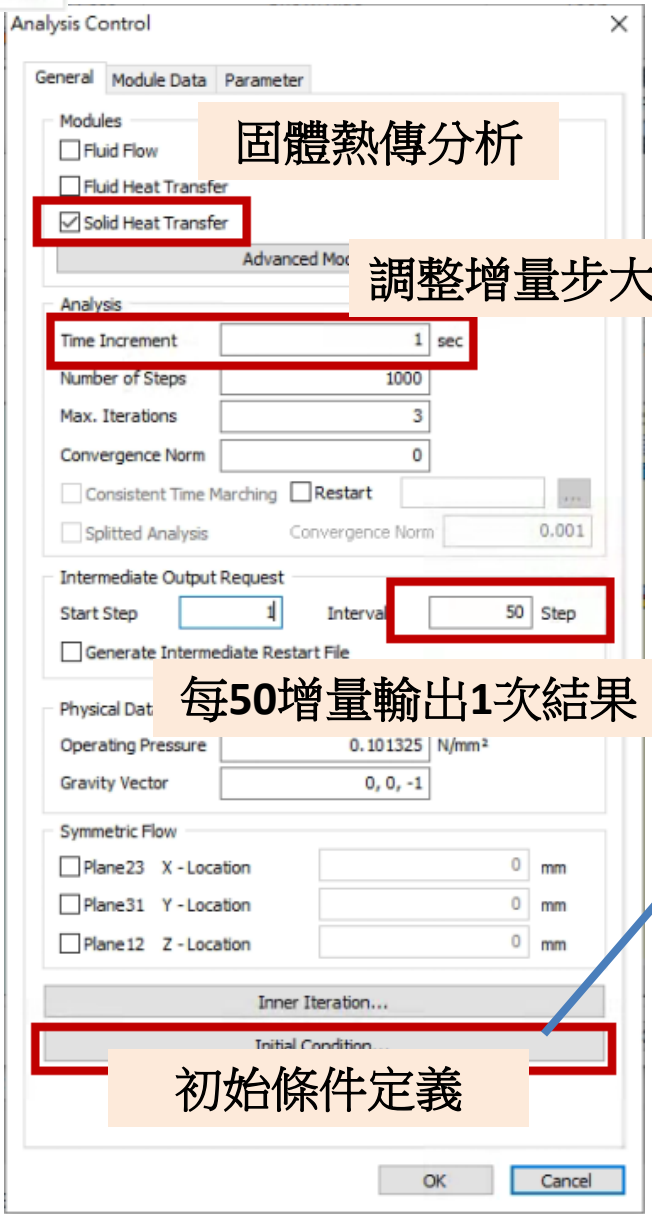
拖曳分析條件/網格集

midas NFX-CFD

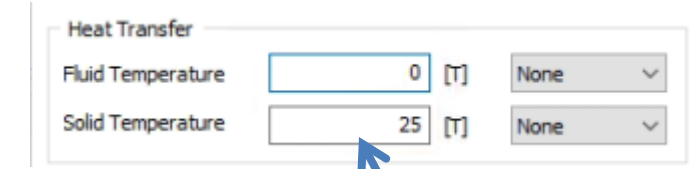
接觸熱阻分析-2

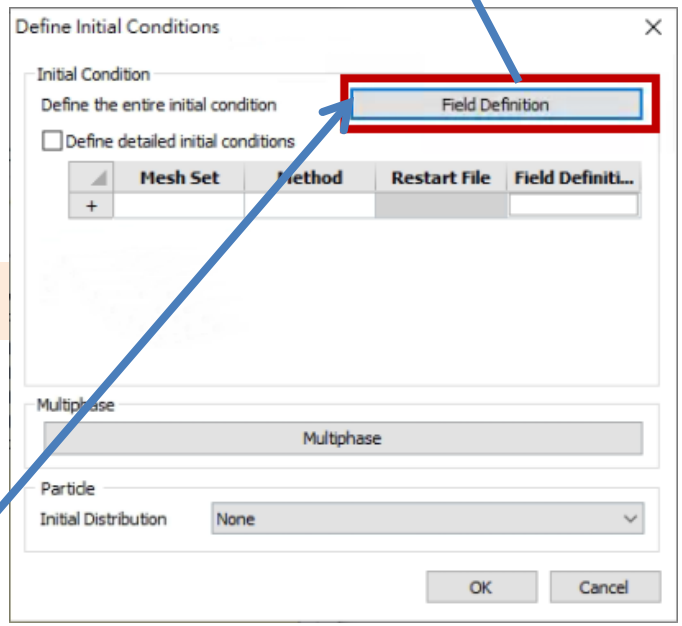
Analysis Control | Output Control

分析工況定義



初始溫度25 ℃

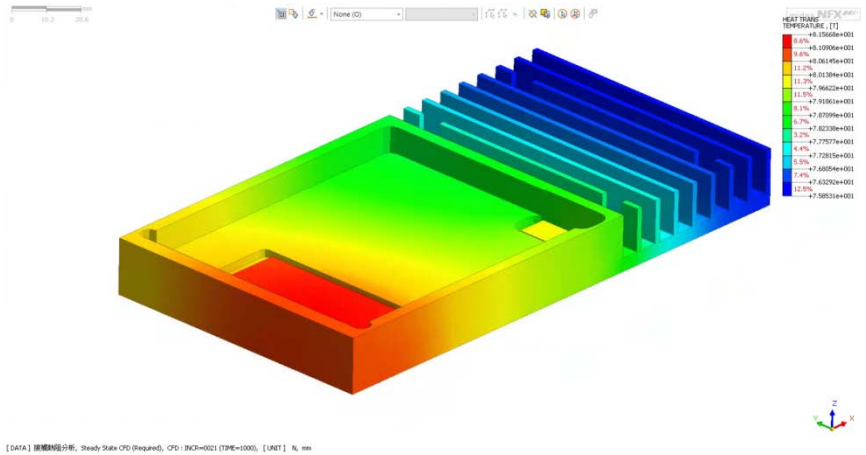




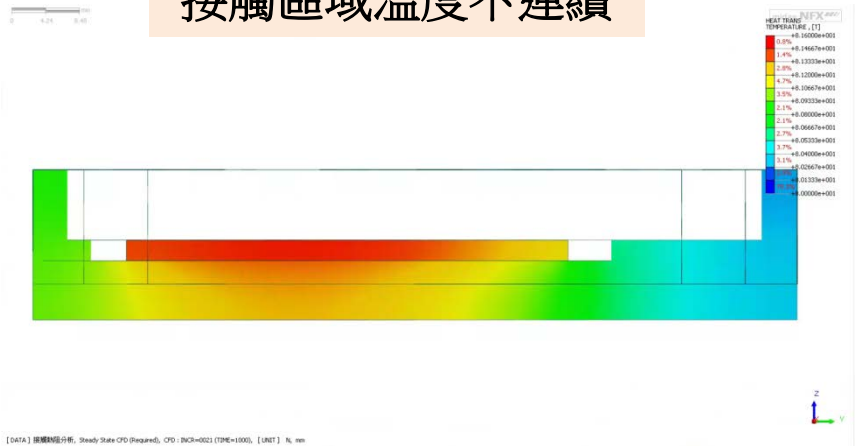
分析結果

(最後増量步)

Temperature(℃)



接觸區域溫度不連續



midas NFX-CFD

CFD_標準教學系列

熱分析6-日照分析

台灣邁達斯

MIDAS

分析說明

環境

地表溫度20 ℃

建物/樹木初始溫度:25 ℃

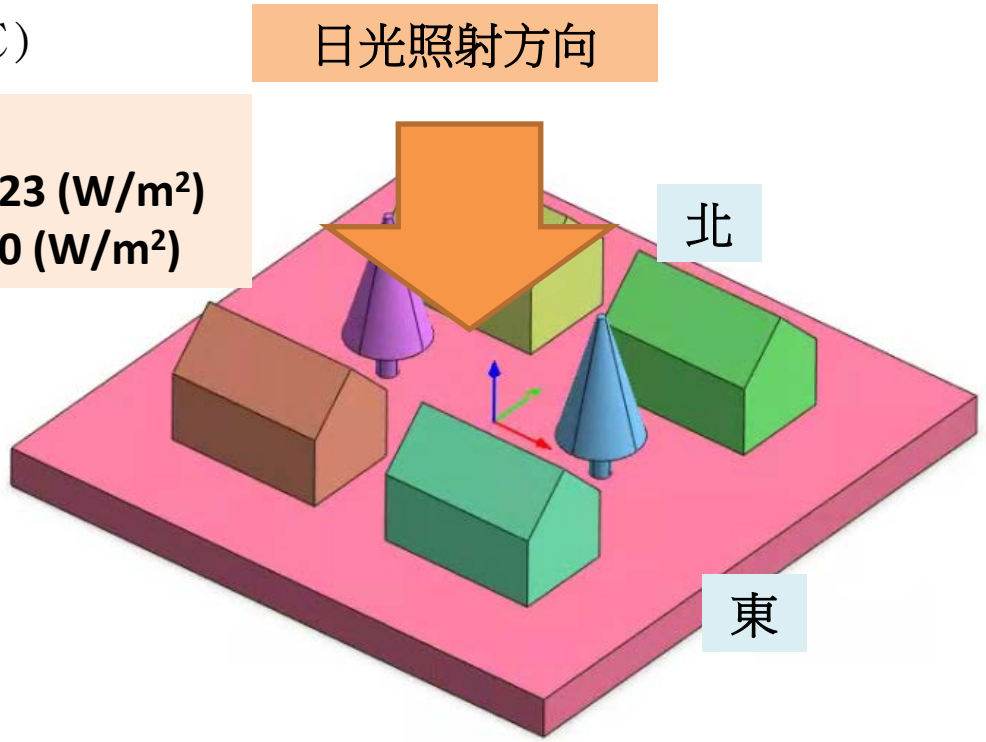
熱對流環境溫度28 ℃

熱對流係數:20(W/m² ℃)

陽光照射

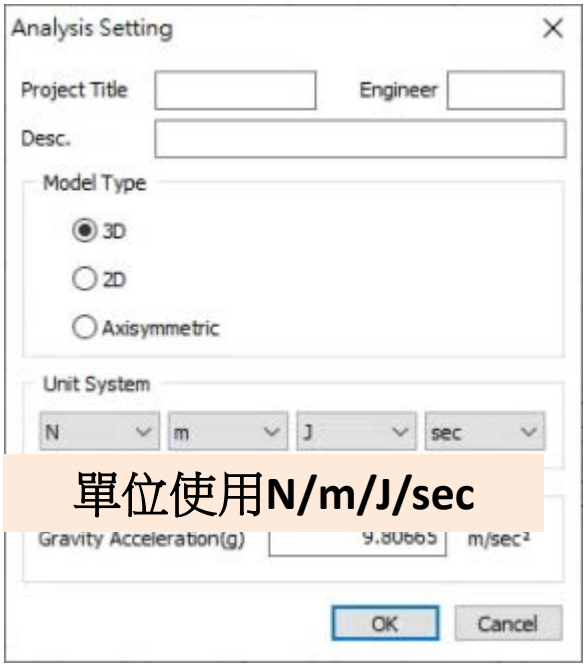
太陽能(直射)輻射熱:1423 (W/m²)

太陽能(漫射)輻射熱:200 (W/m²)

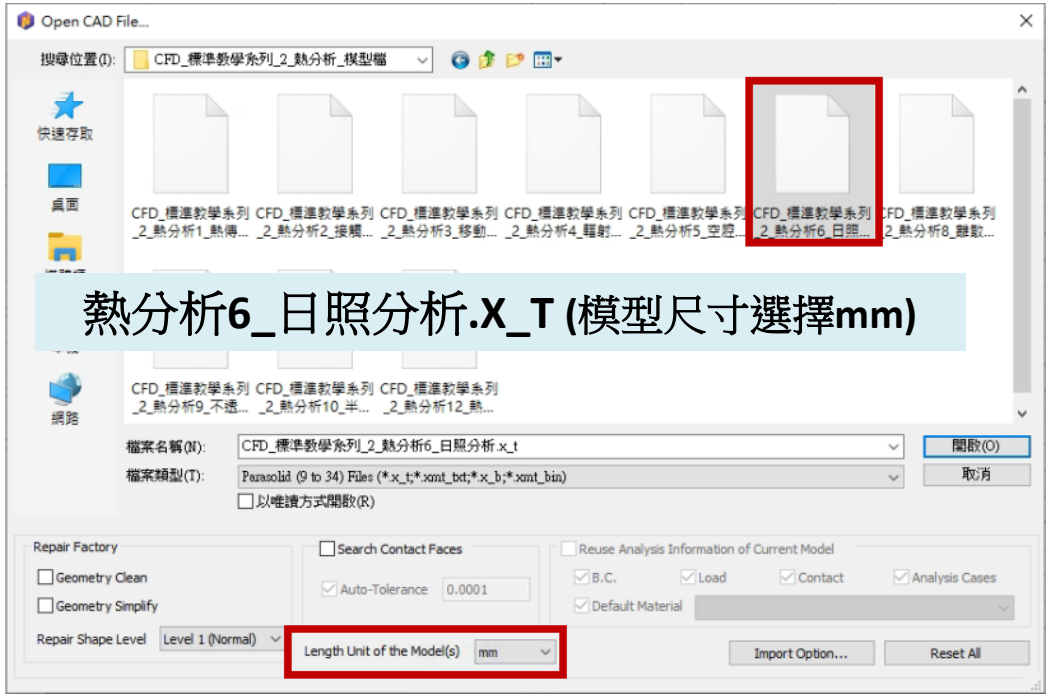


註:範例採假設條件並使用軟體預設參數。

環境 &模型匯入

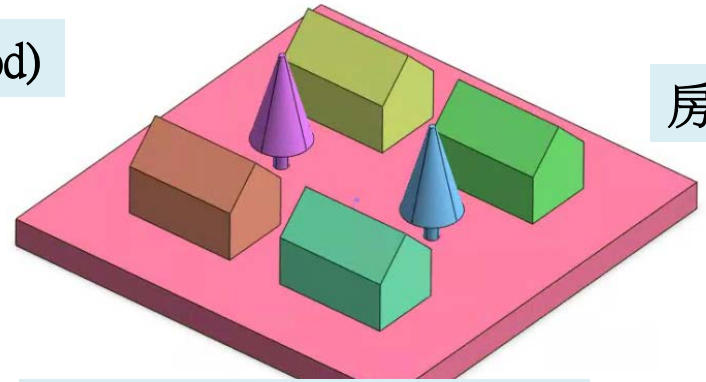


單位使用N/m/J/sec



熱分析6_日照分析.X_T (模型尺寸選擇mm)

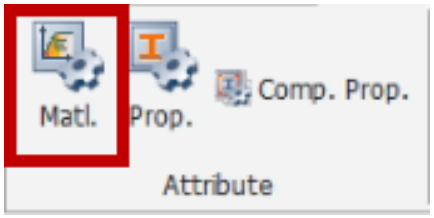
樹木:木(Wood)

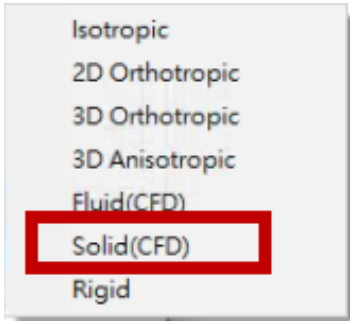


房屋:混泥土(Concrete)

地面:混泥土(Concrete)

材料

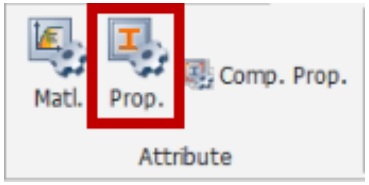


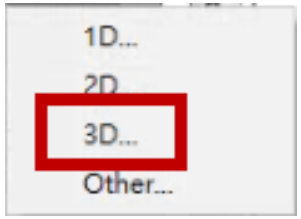


新增Concrete材料

新增Wood材料

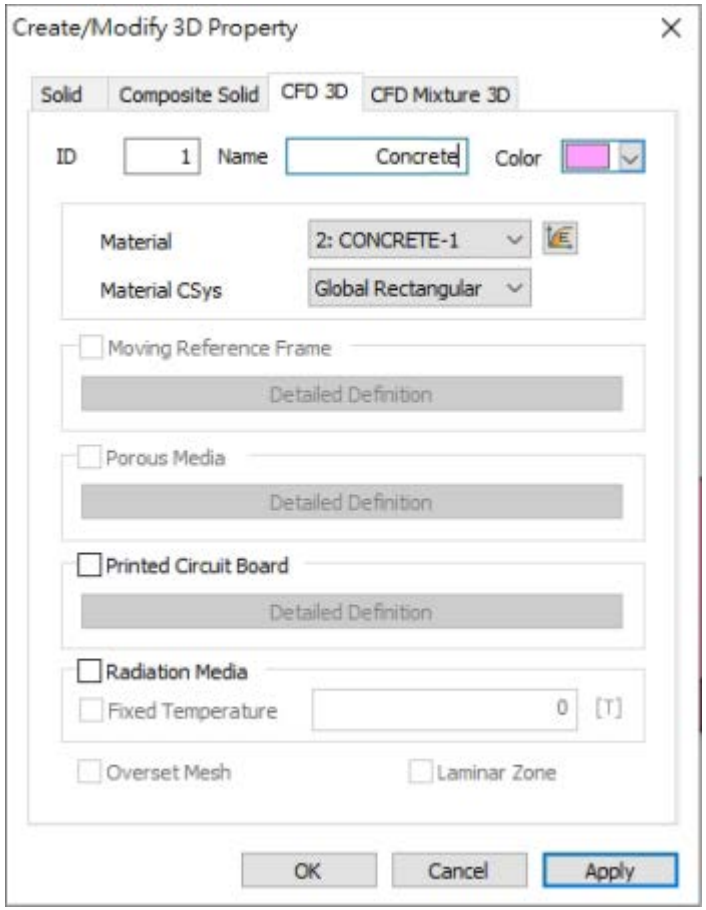
屬性



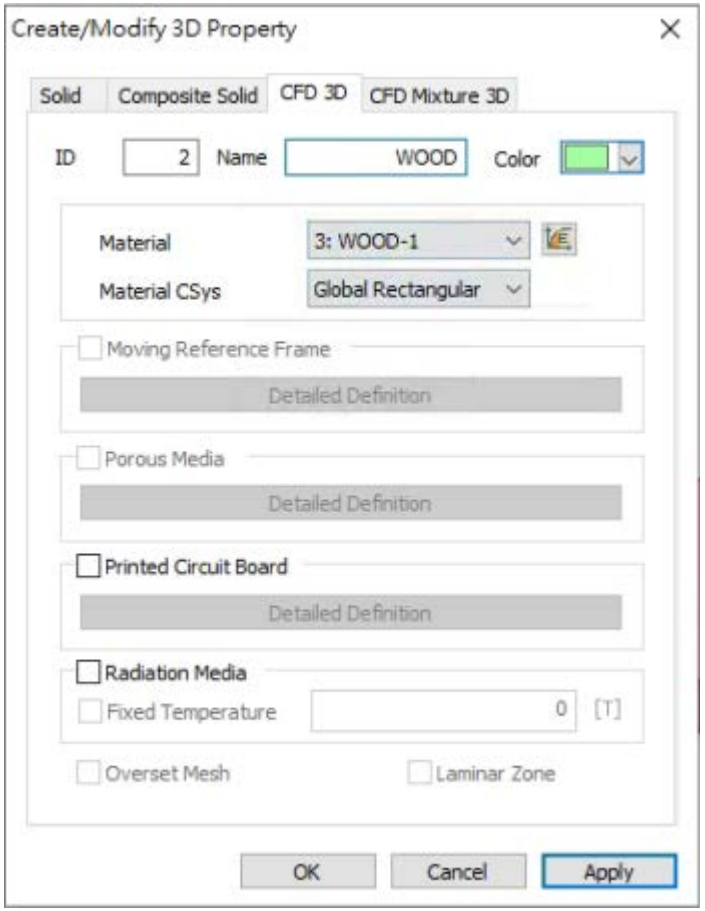


屬性選取Solid

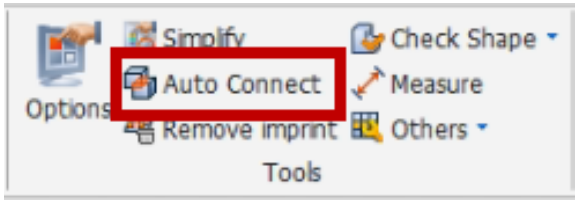
新增Concrete屬性



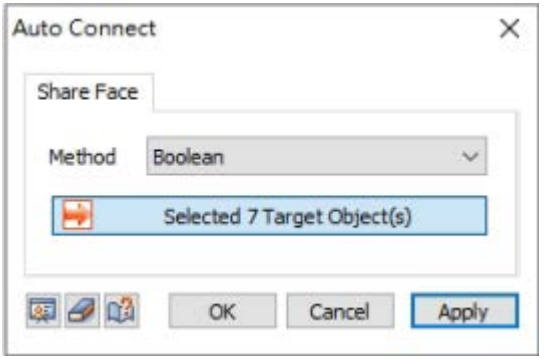
新增Wood屬性

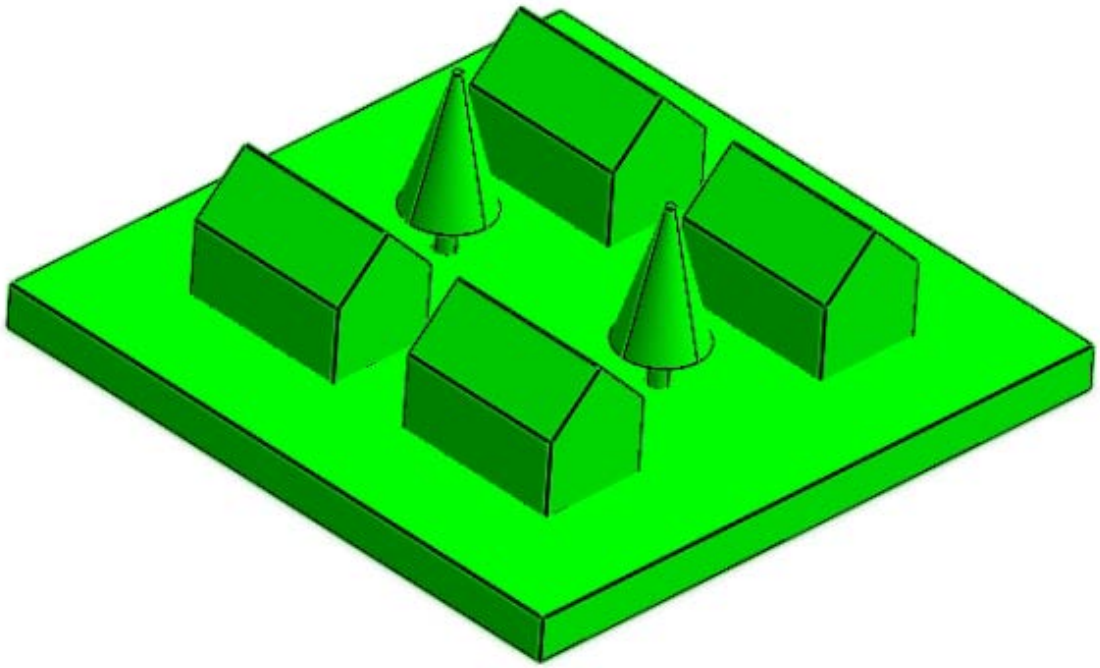


相鄰面特徵

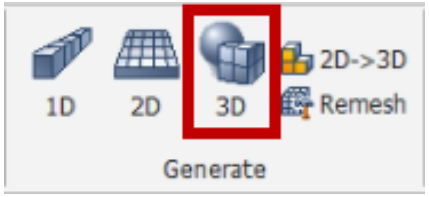


選取所有幾何特徵

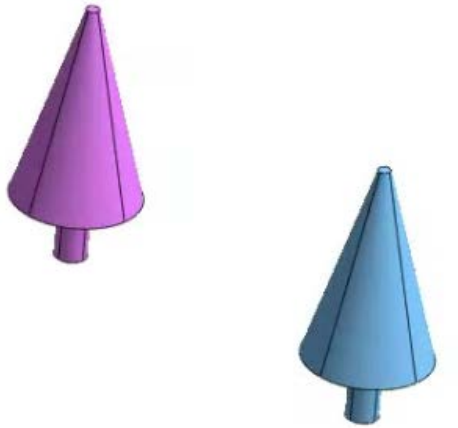




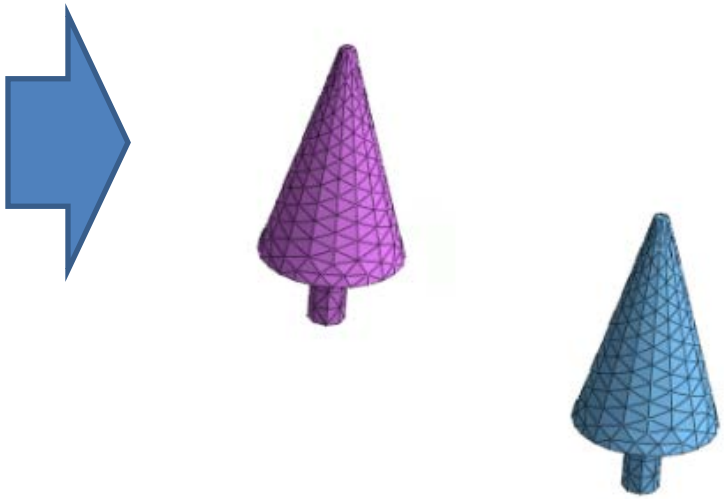
網格-樹木



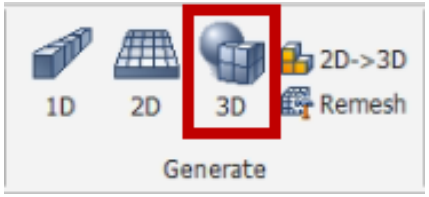
燈具:屬性Wood/網格尺寸0.5



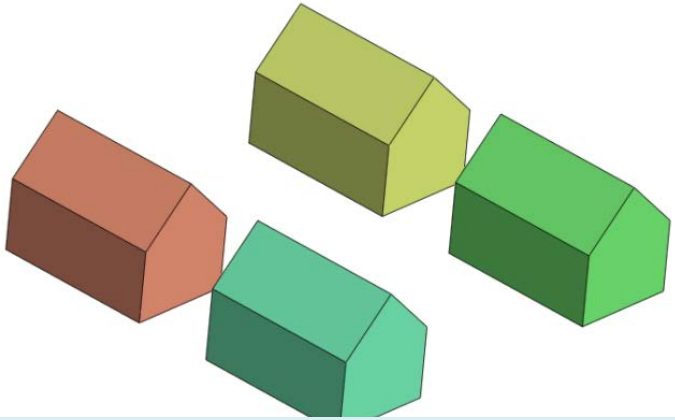
四面體網格/參考相鄰面/共節點/1階元素



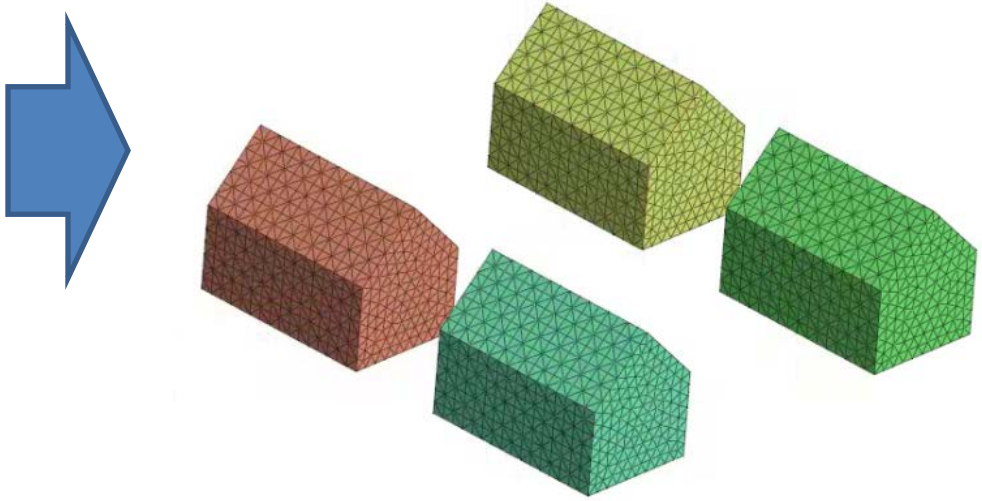
網格-房屋



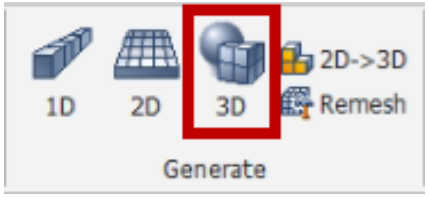
燈具:屬性Concrete /網格尺寸0.5



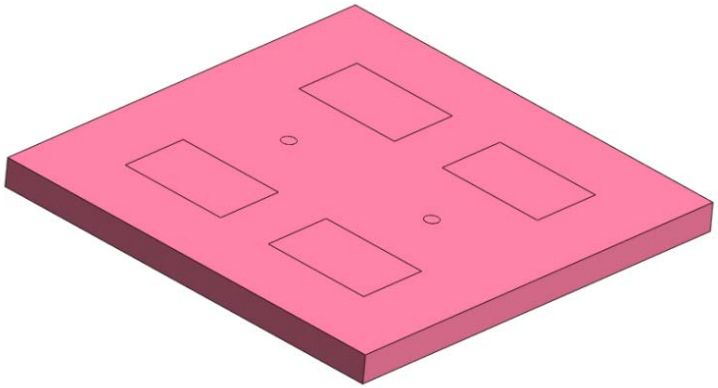
四面體網格/參考相鄰面/共節點/1階元素



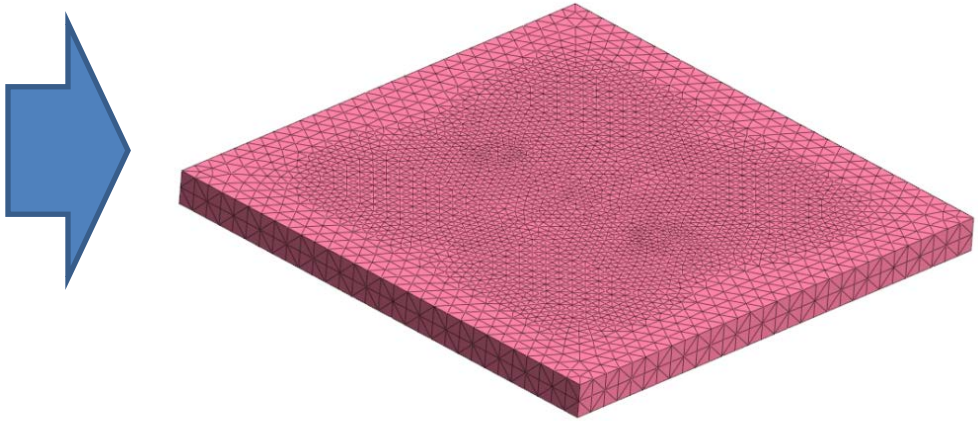
網格-地表



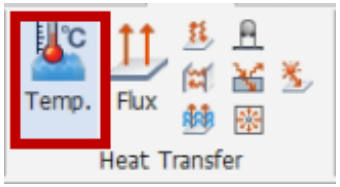
燈具:屬性Concrete /網格尺寸1



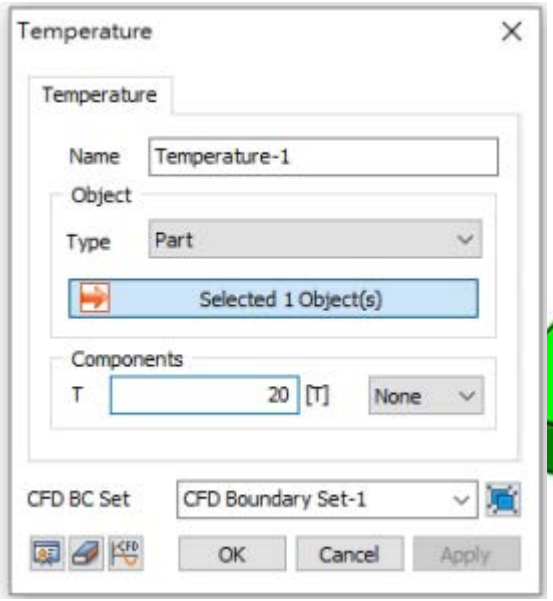
四面體網格/參考相鄰面/共節點/1階元素

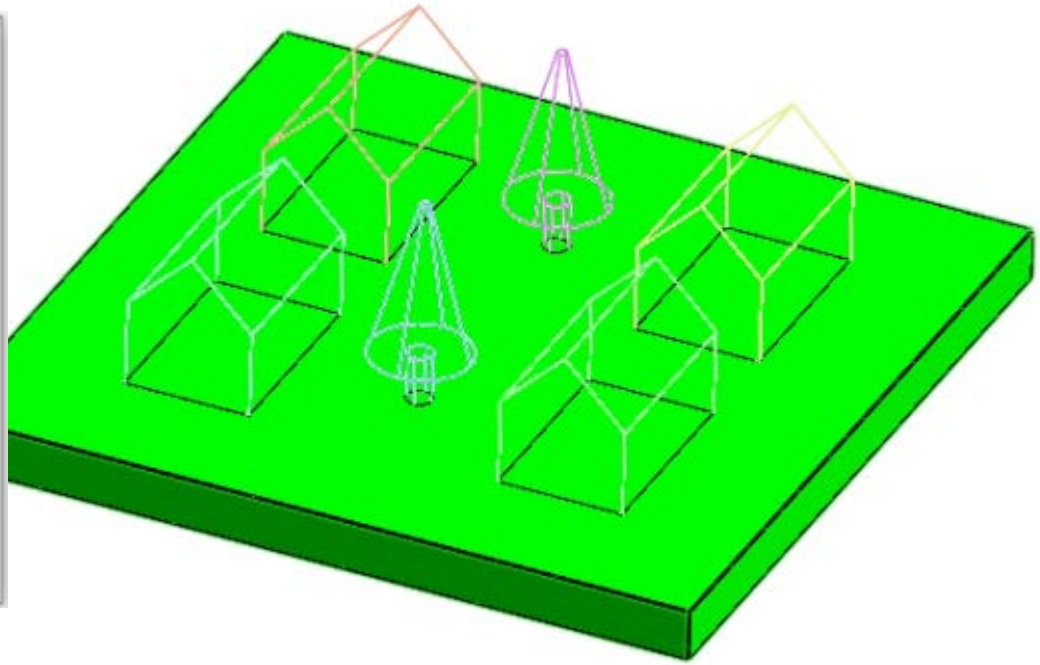


溫度-地表

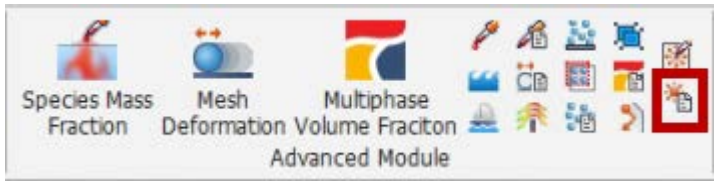


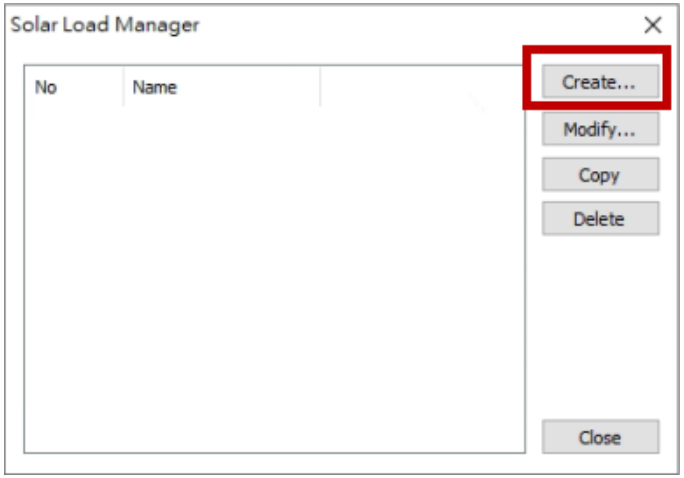
地表溫度維持20 ℃

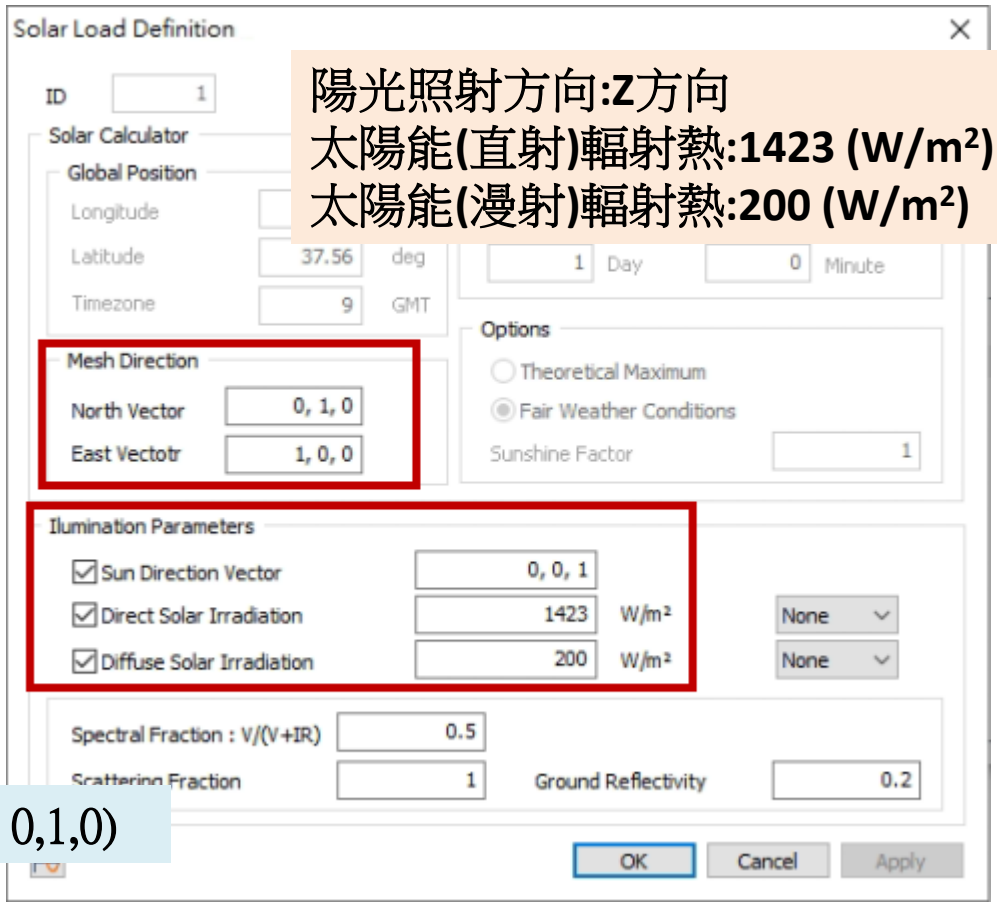




日照-照射方向

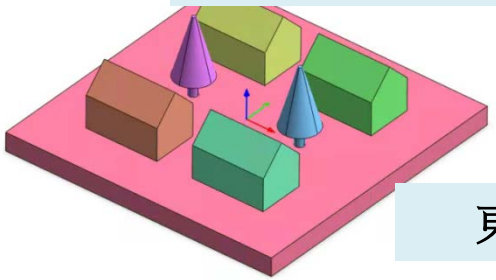






陽光照射方向:Z方向
太陽能(直射)輻射熱:1423 (W/m²)
太陽能(漫射)輻射熱:200 (W/m²)

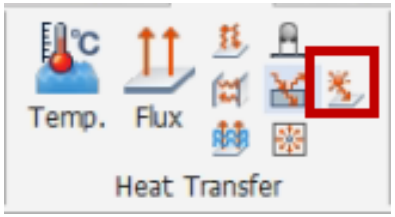
北(North Vector : 0,1,0)

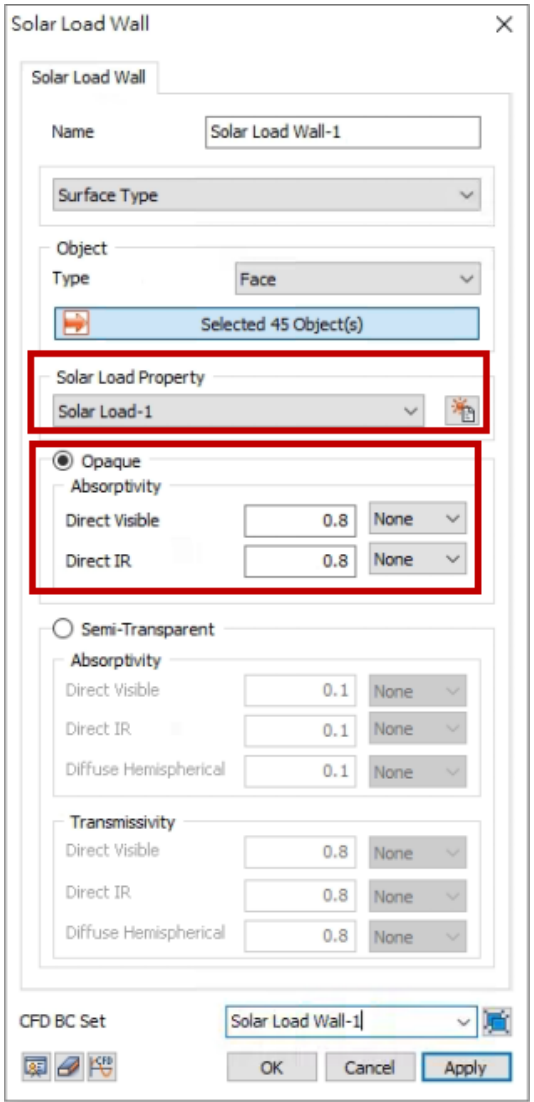


東(East Vector:1,0,0)

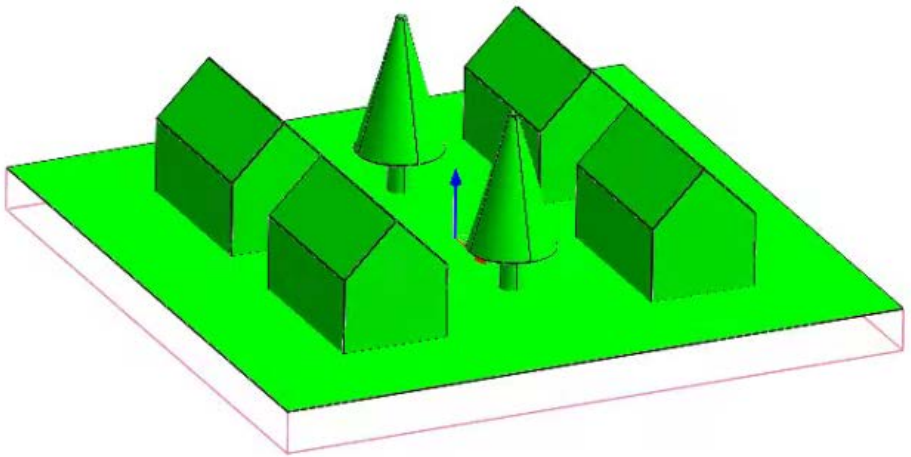
midas NFX-CFD

日照-照射區域



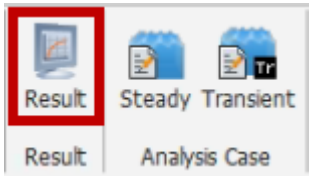


選取日照區域幾何特徵
(全部視為非透明特徵)

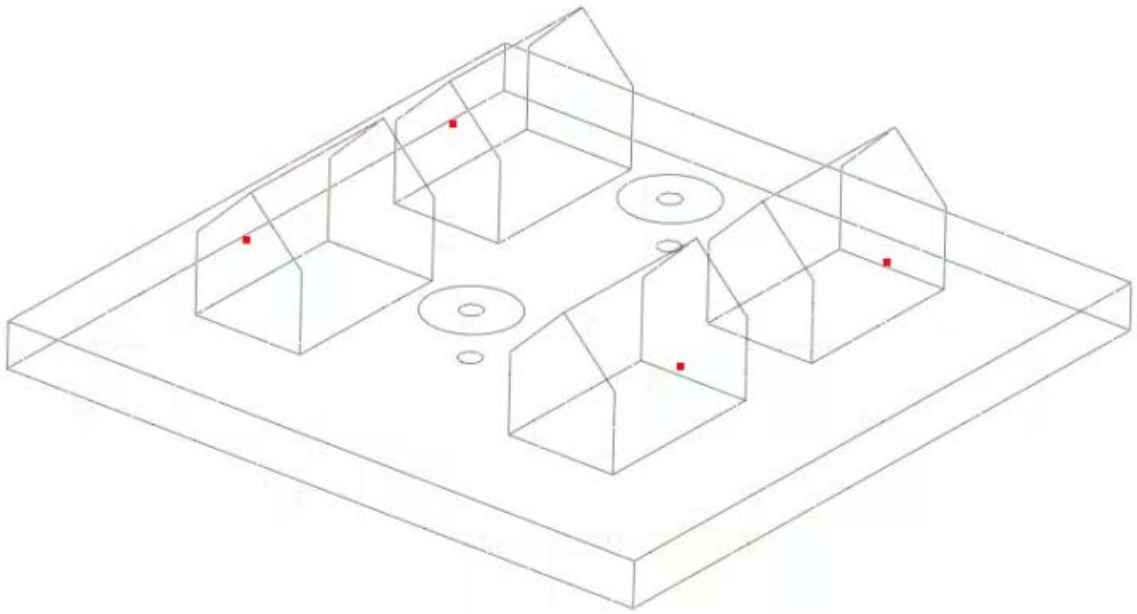


吸收率(Absorptivity) α
直接照射可見光:0.8
直接照射經外線:0.8

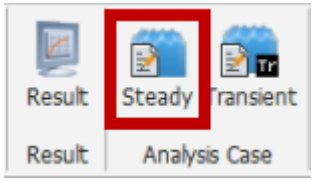
觀測點



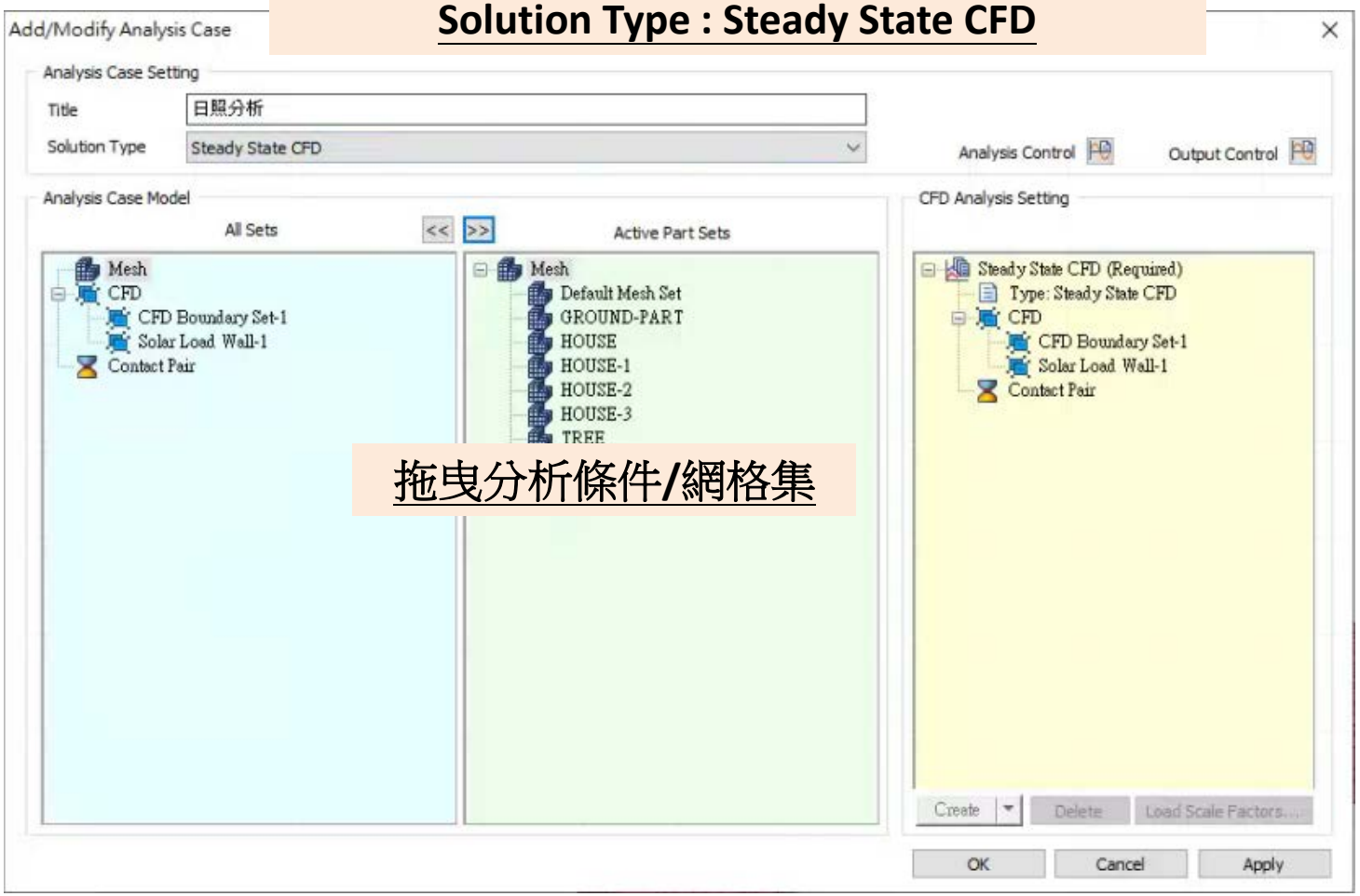
輸出特定節點數據同時能協助判斷收斂穩定



日照分析-1



Solution Type : Steady State CFD

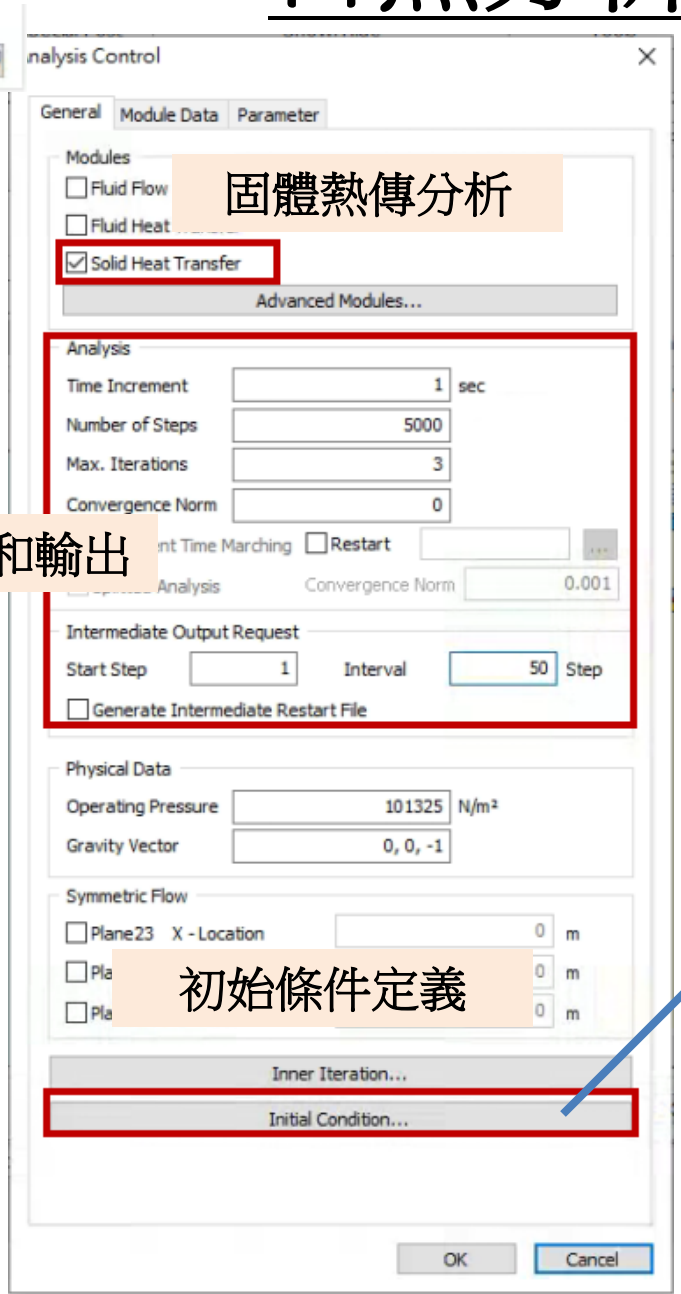


拖曳分析條件/網格集

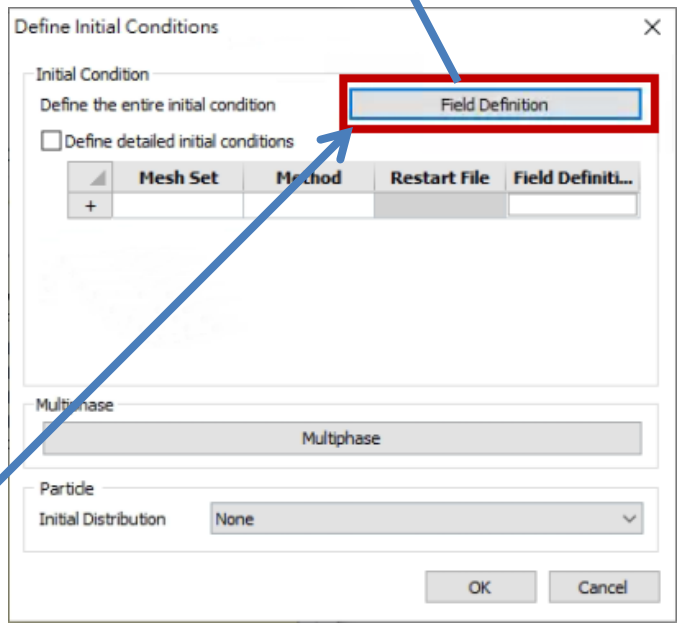
日照分析-2

Analysis Control　Output Control

分析工況定義

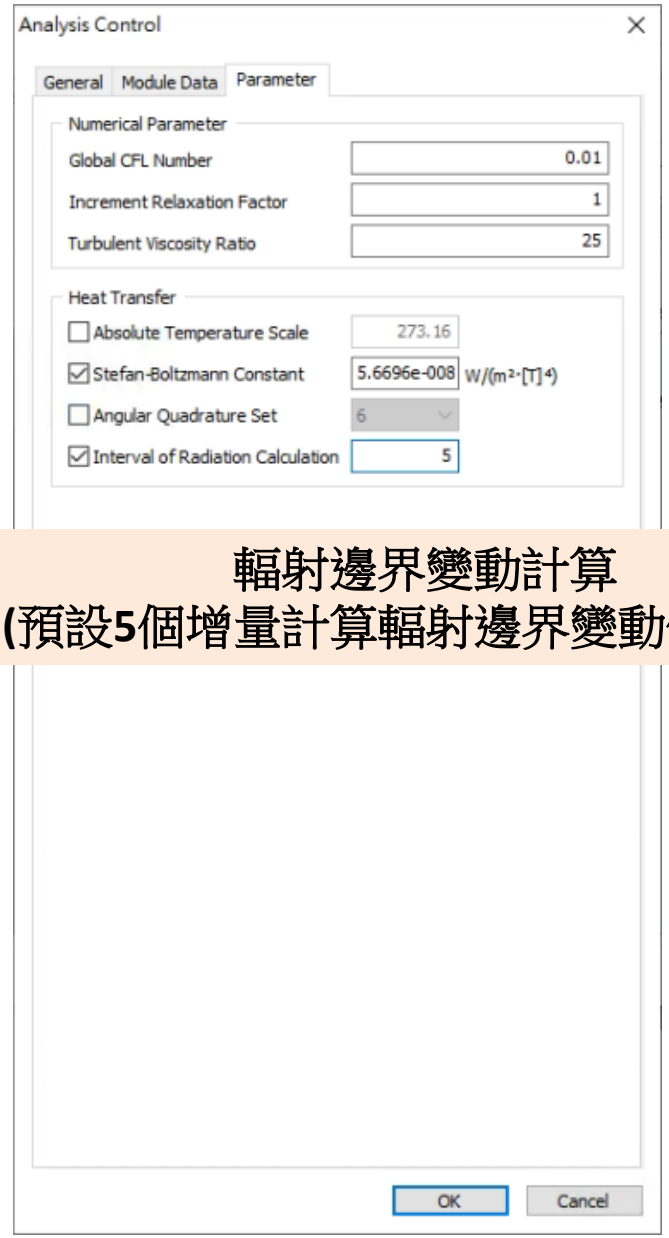


初始溫度25 ℃



日照分析-3

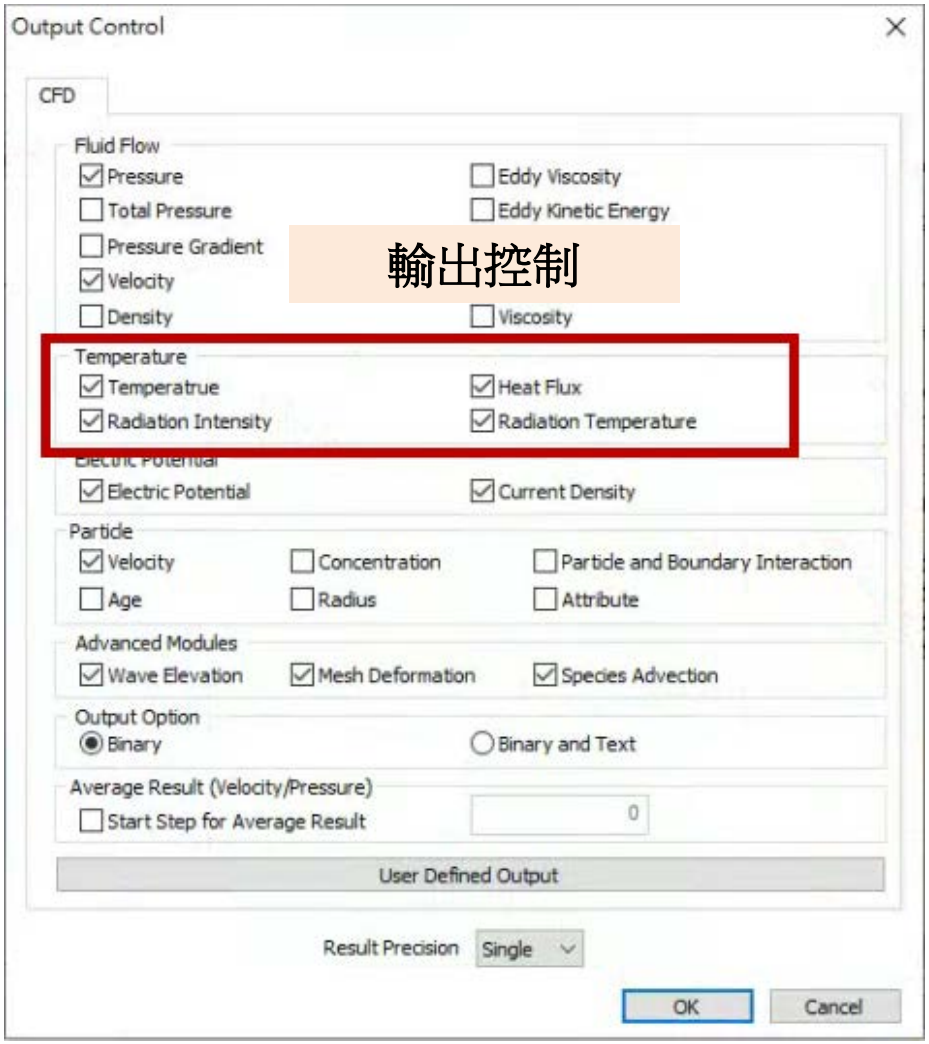
分析工況定義



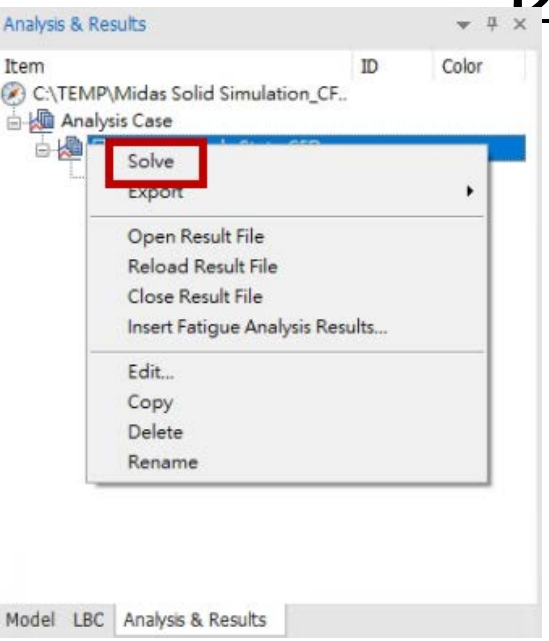
輻射邊界變動計算
(預設5個增量計算輻射邊界變動條件1次)

日照分析-4

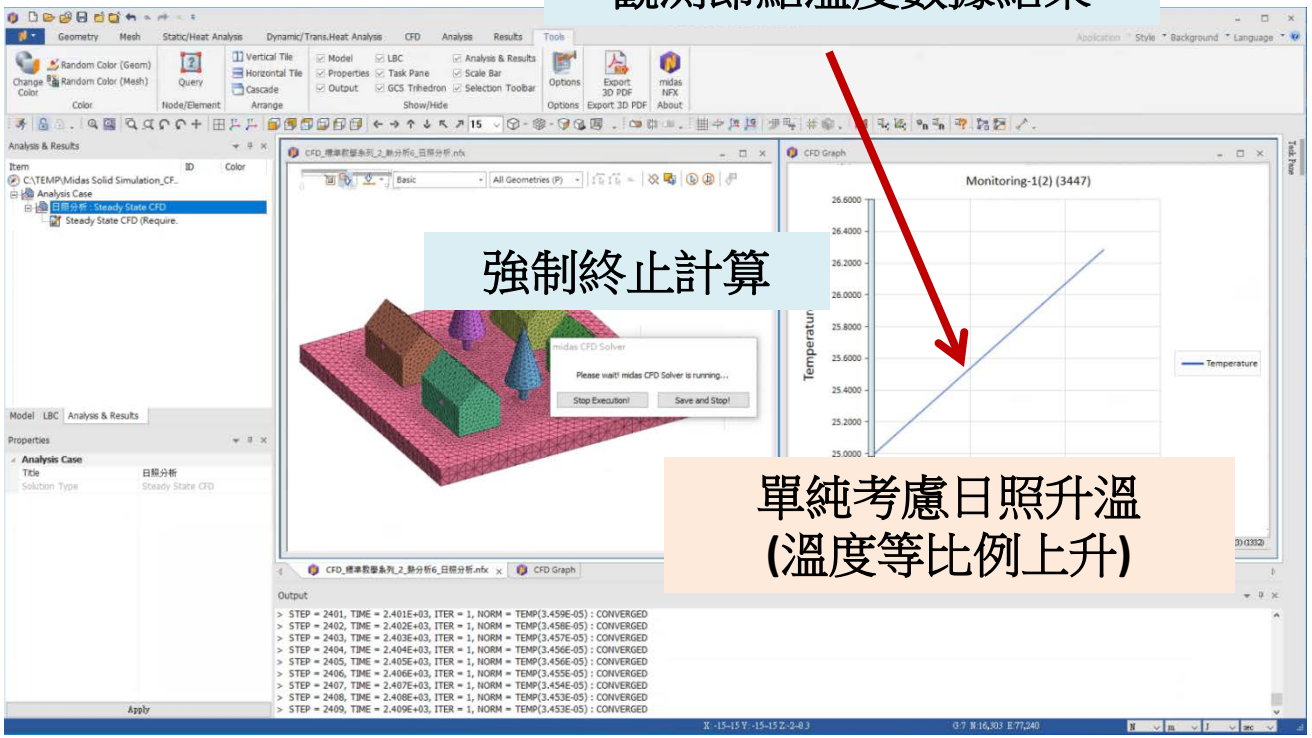
Analysis Control | Output Control



執行計算&分析結果



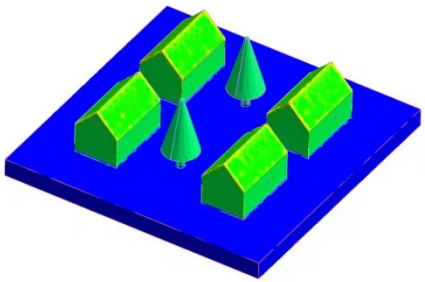
觀測節點溫度數據結果



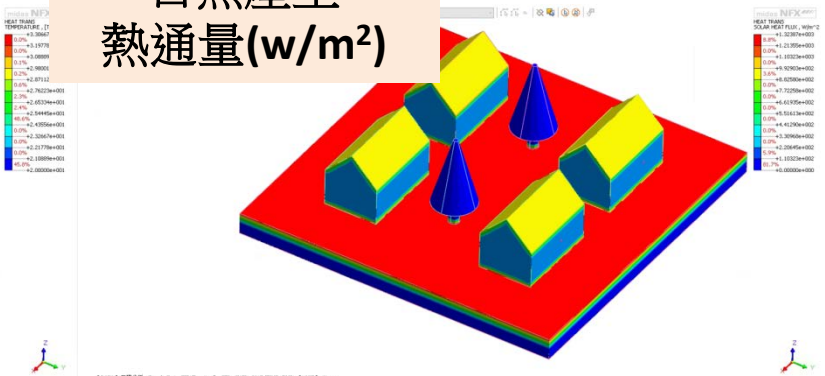
強制終止計算

單純考慮日照升溫
(溫度等比例上升)

溫度(℃)

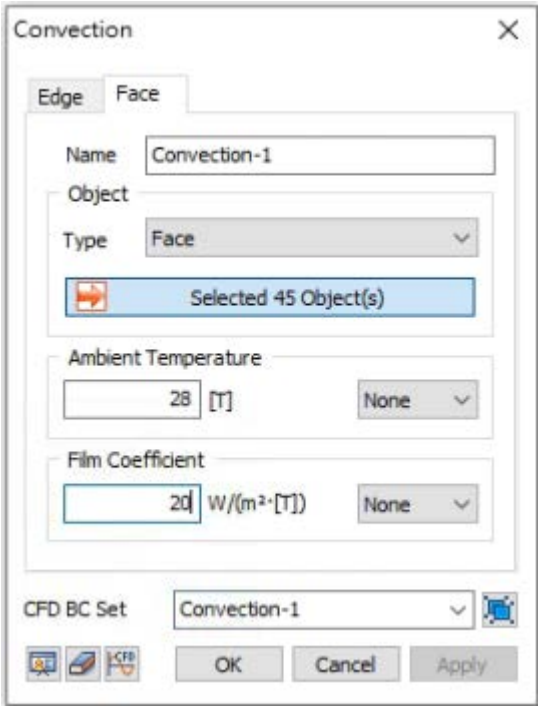


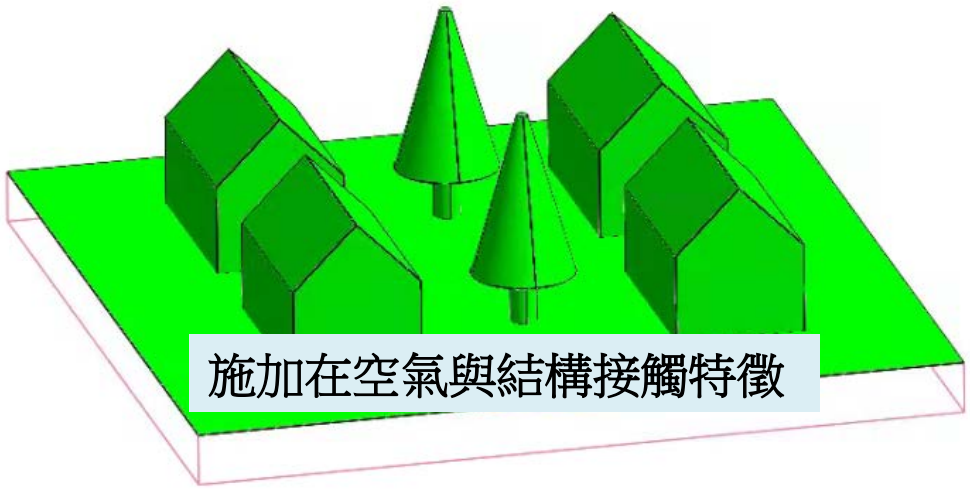
日照產生
熱通量(w/m²)



熱對流

環境溫度:28℃
熱對流係數:20(W/m^2 ℃)

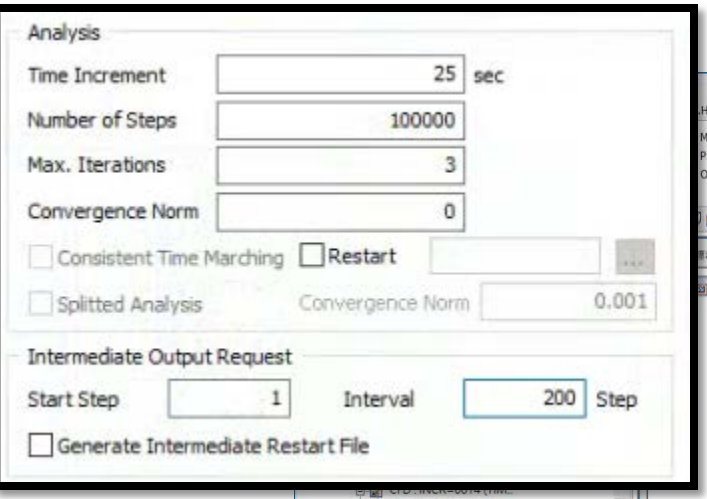


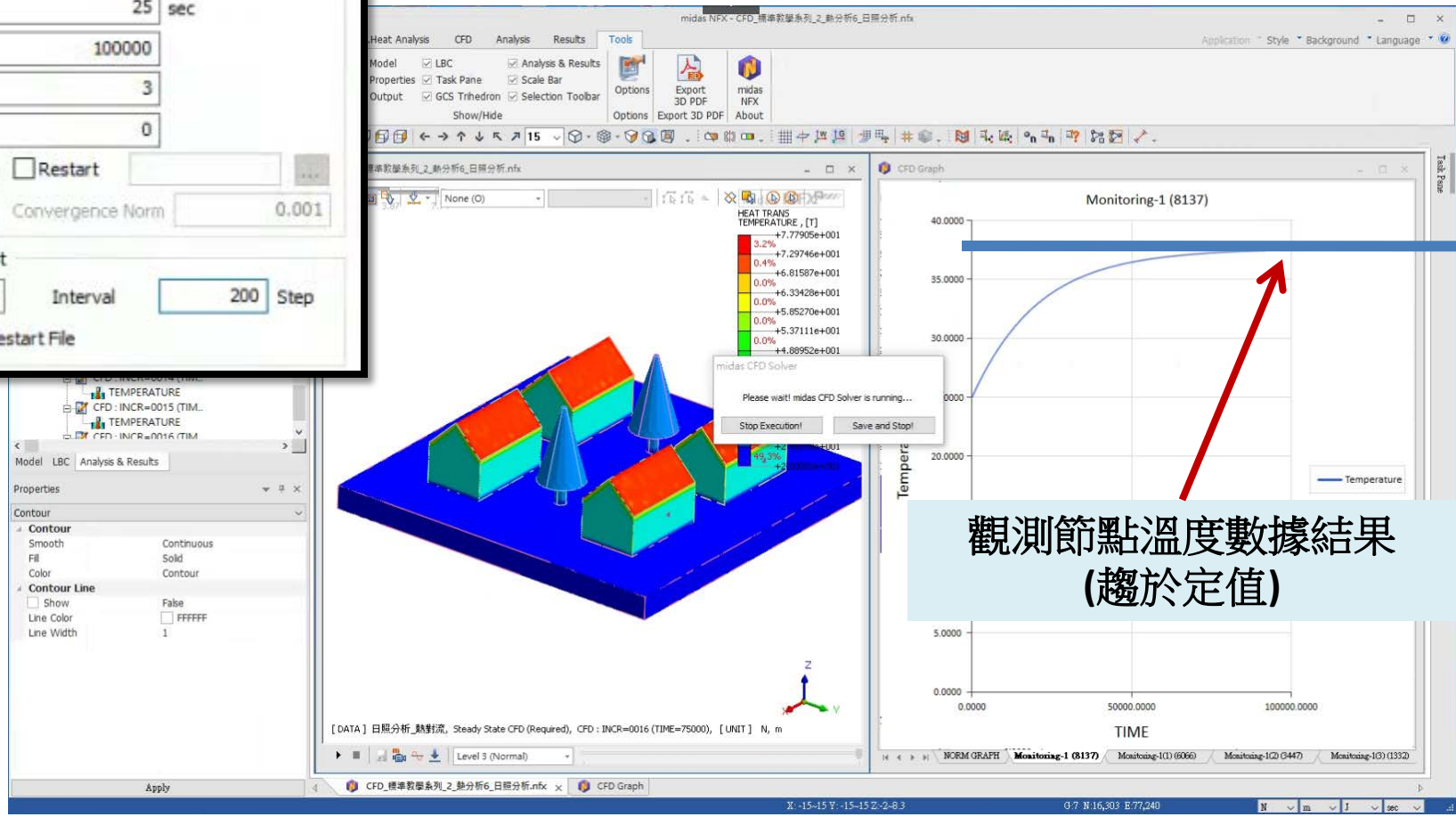


註1:幾何間的接觸面不用考慮空氣熱對流。
註2:不同邊界&載荷建議使用不同集合名稱。

日照分析+熱對流

調整增量和輸出

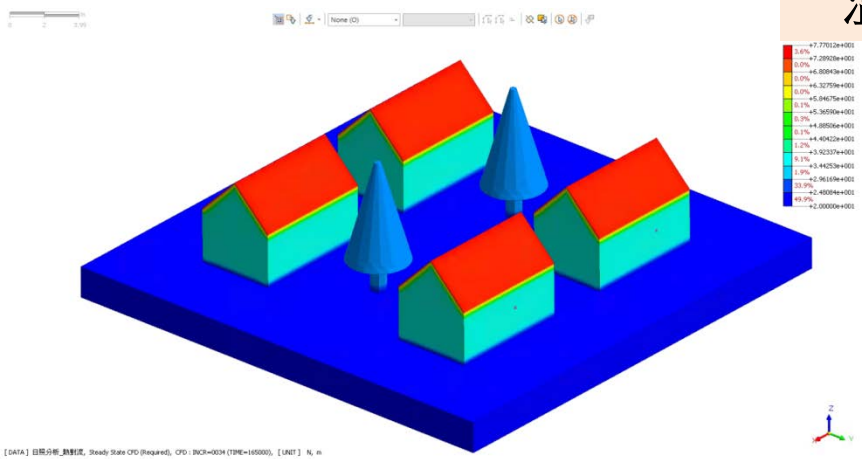


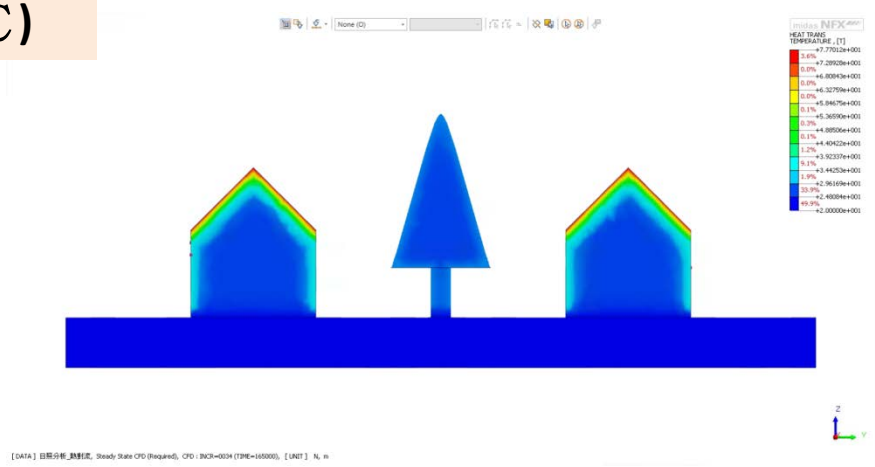


觀測節點溫度數據結果
(趨於定值)

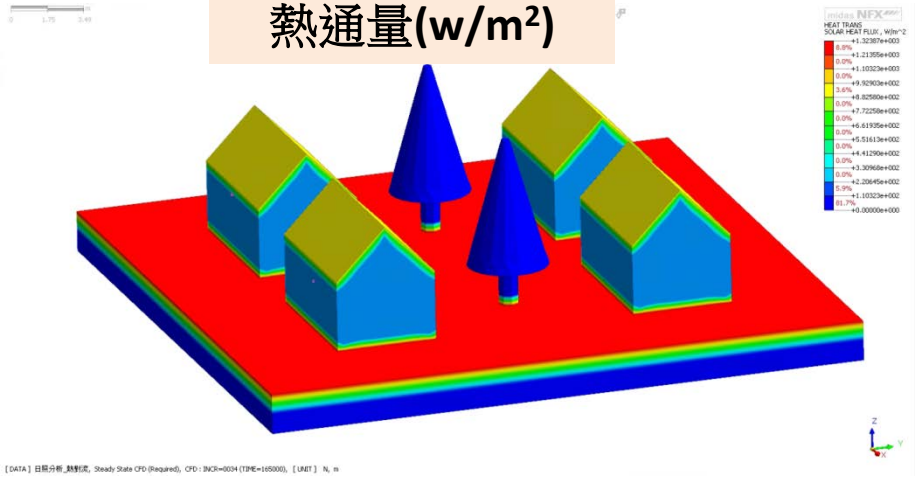
分析結果
(考慮熱對流)

溫度(℃)

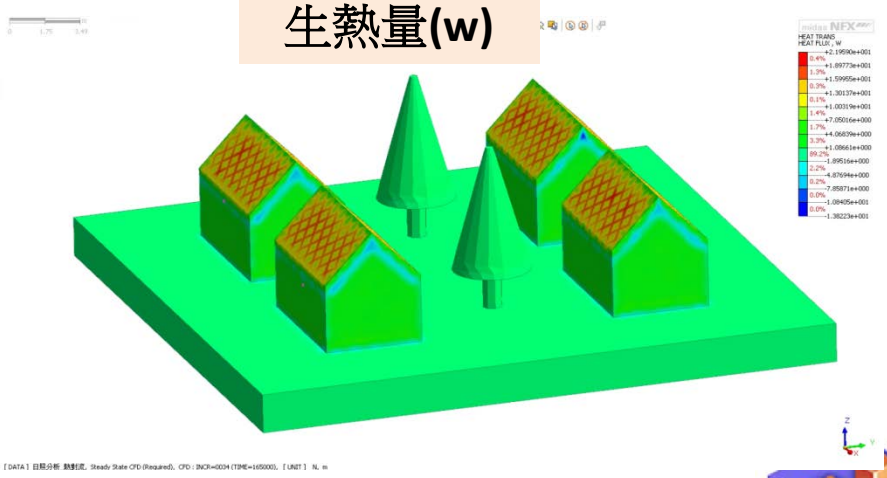




日照產生
熱通量(w/m²)



生熱量(w)



midas NFX-CFD

CFD_標準教學系列

熱分析7-日照分析經緯度

台灣邁達斯

MIDAS

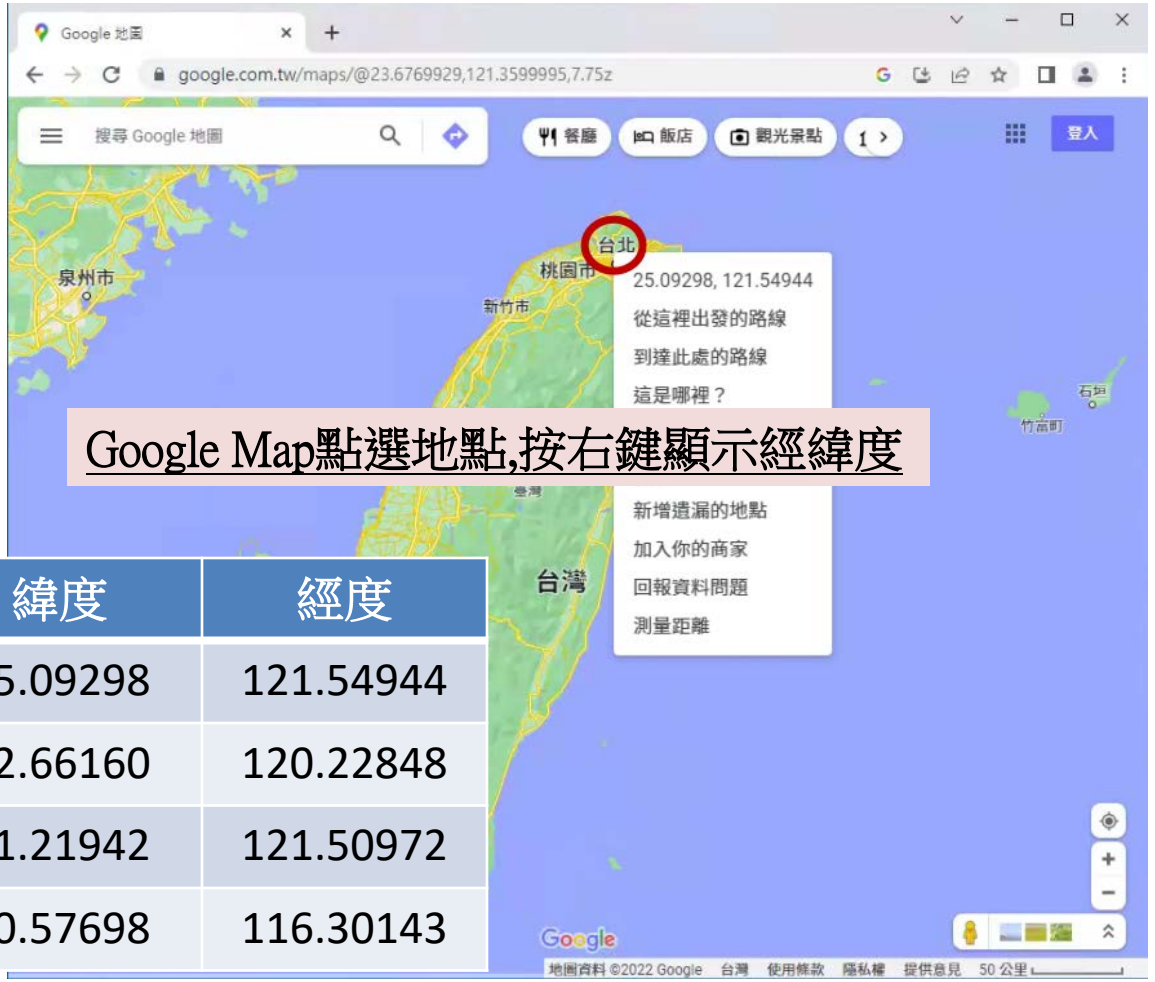
格林威治標準時間GMT

(Greenwich Mean Time)

經緯度

(Greenwich Mean Time)

https://www.google.com.tw/maps/



Google Map點選地點,按右鍵顯示經緯度

地點	緯度	經度
台北	25.09298	121.54944
高雄	22.66160	120.22848
上海	31.21942	121.50972
北京	40.57698	116.30143

midas NFX-CFD

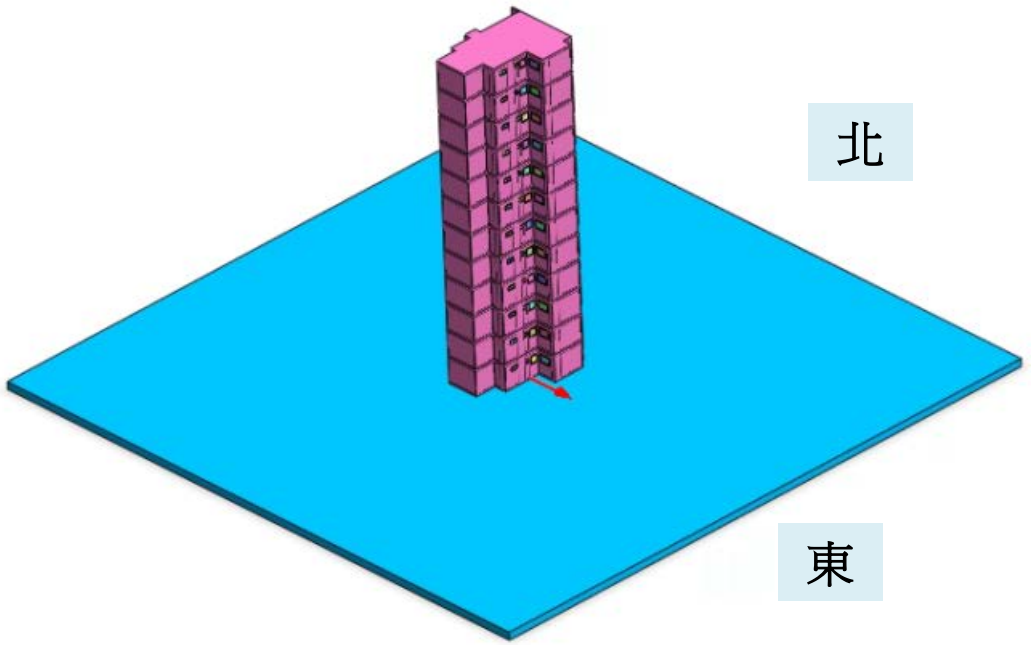
分析說明

地點
台北121°38′E, 25°2′N

時區
台灣 GMT+8

夏至
2023年6月21日 星期三

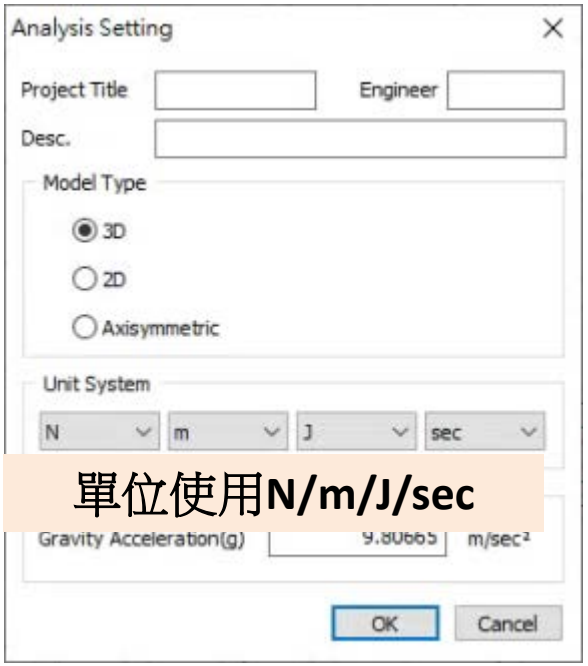
日光照射時間
中午12:00



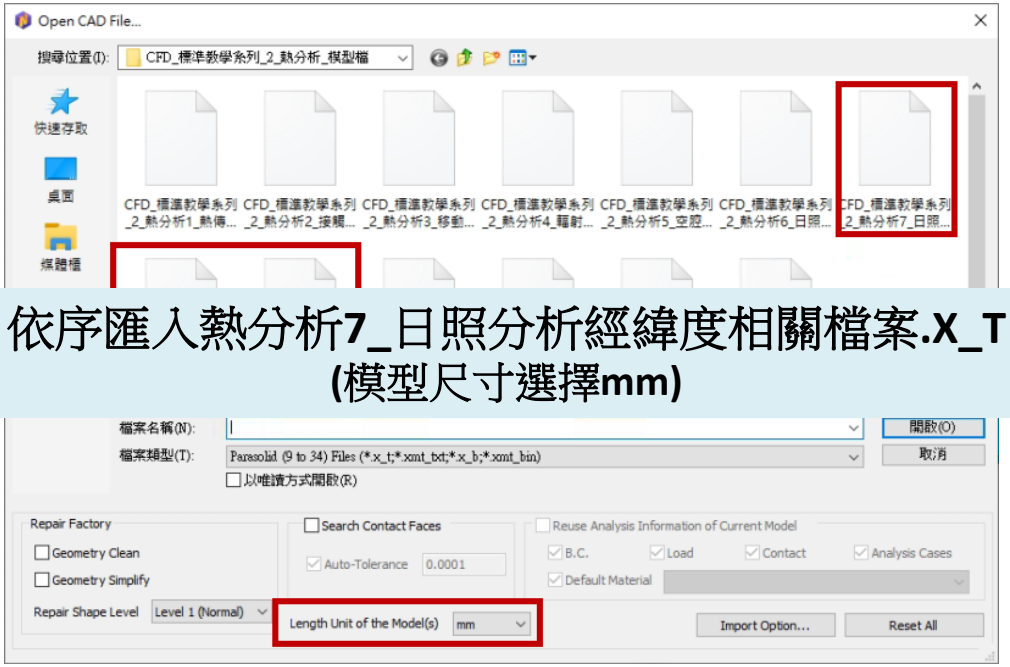
環境
地表溫度20 ℃
建物初始溫度:25 ℃
熱對流環境溫度28 ℃
熱對流係數:20(W/m2 ℃)

註:範例採假設條件並使用軟體預設參數。

環境 &模型匯入

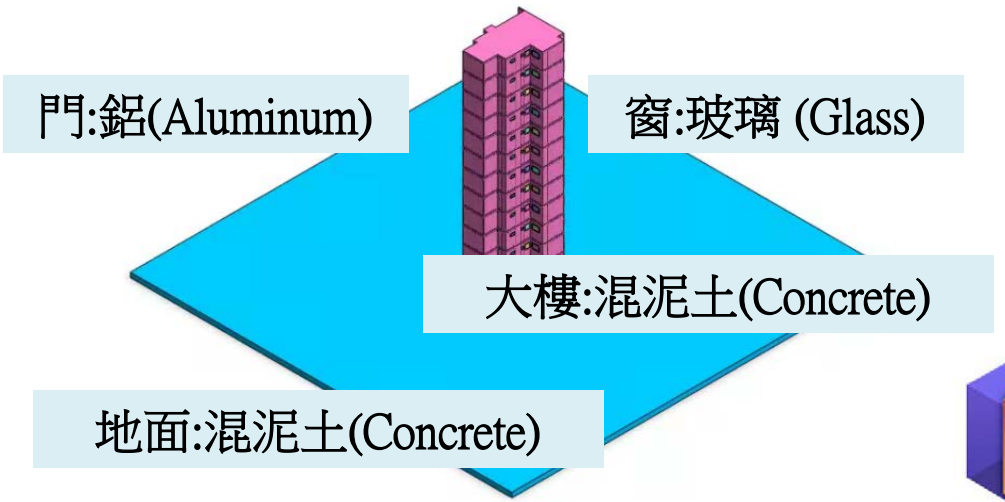


單位使用N/m/J/sec

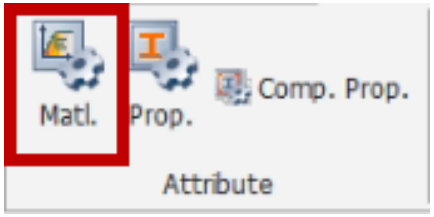


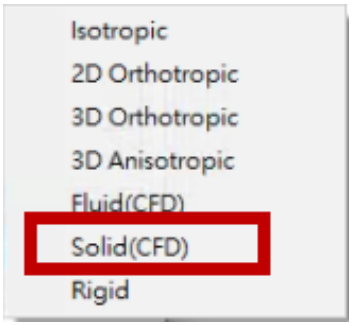
依序匯入熱分析7_日照分析經緯度相關檔案.X_T
(模型尺寸選擇mm)

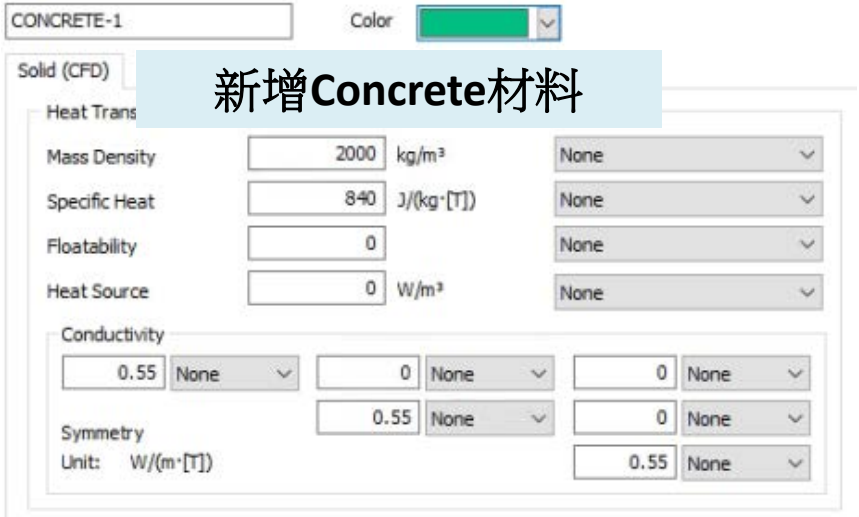
幾何集分類



材料


Matl.
Prop.
Comp. Prop.
Attribute

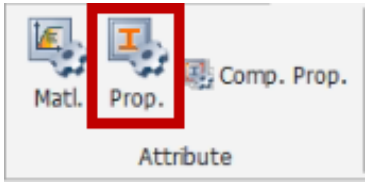

Isotropic
2D Orthotropic
3D Orthotropic
3D Anisotropic
Fluid(CFD)
Solid(CFD)
Rigid

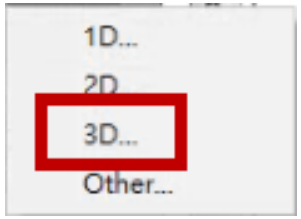

CONCRETE-1
Color
Solid (CFD)
新增Concrete材料
Heat Trans
Mass Density 2000 kg/m³ None
Specific Heat 840 J/(kg·[T]) None
Floatability 0 None
Heat Source 0 W/m³ None
Conductivity
0.55 None 0 None 0 None
0.55 None 0 None
0.55 None
Symmetry
Unit: W/(m·[T])

GLASS-1
Solid (CFD)
新增Glass材料
Heat Transfer
Mass Density 2500 kg/m³ None
Specific Heat 900 J/(kg·[T]) None
Floatability 0 None
Heat Source 0 W/m³ None
Conductivity
1 None 0 None 0 None
1 None 0 None
1 None
Symmetry
Unit: W/(m·[T])

ALUMINIUM-1
Color
Solid (CFD)
新增Aluminum材料
Heat Transfer
Mass Density 2707 kg/m³ None
Specific Heat 896 J/(kg·[T]) None
Floatability 0 None
Heat Source 0 W/m³ None
Conductivity
204 None 0 None 0 None
204 None 0 None
204 None
Symmetry
Unit: W/(m·[T])

屬性





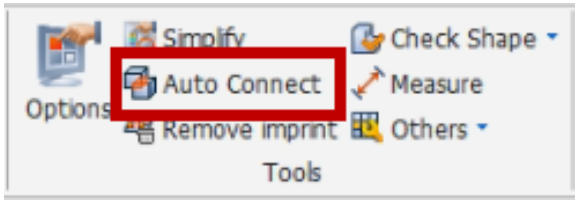
屬性選取Solid

新增Concrete屬性

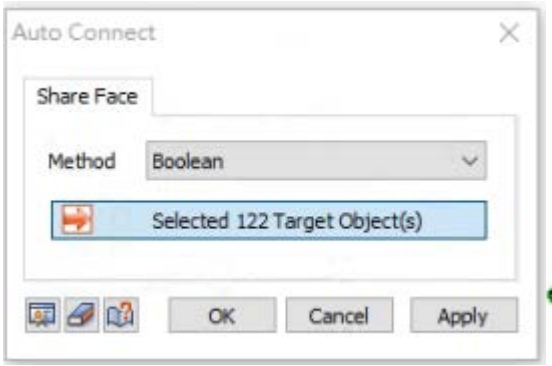
新增Glass屬性

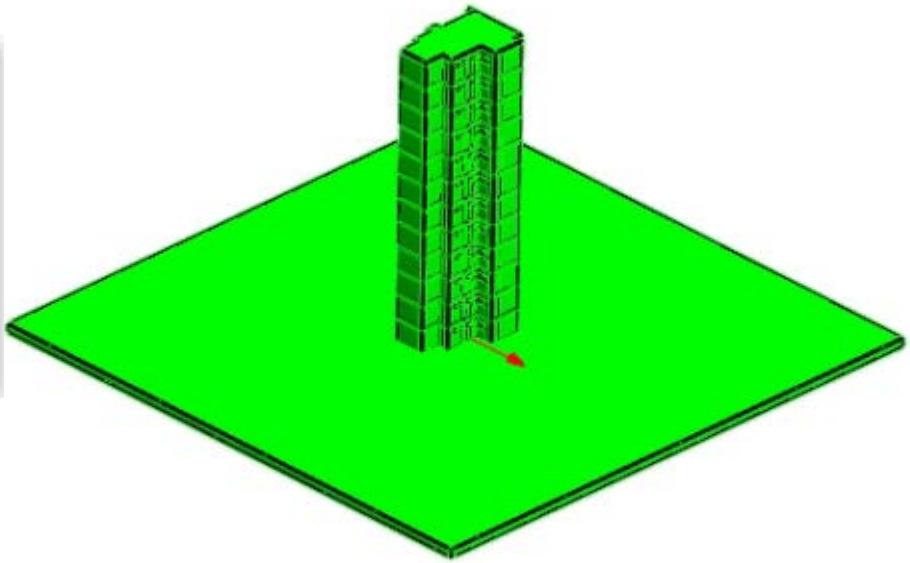
新增Aluminum屬性

相鄰面特徵

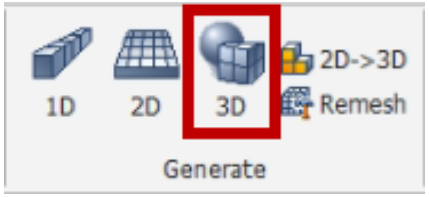


選取所有幾何特徵

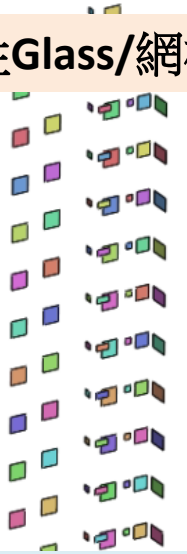




網格-窗



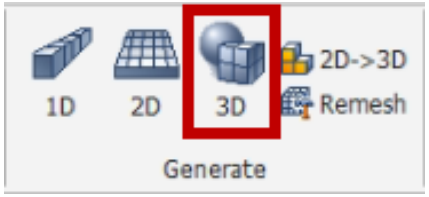
燈具:屬性Glass/網格尺寸0.5



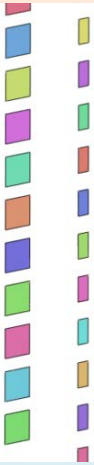
四面體網格/參考相鄰面/共節點/1階元素

註:考慮計算效率，網格劃分使用較大尺寸。

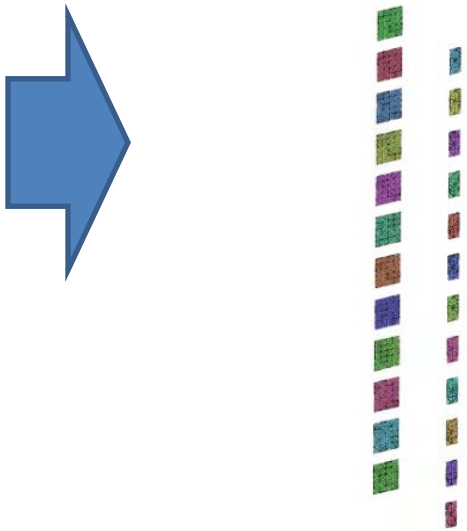
網格-門



燈具:屬性Aluminum/網格尺寸0.5

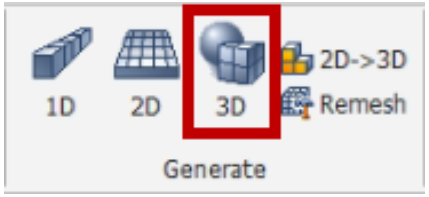


四面體網格/參考相鄰面/共節點/1階元素

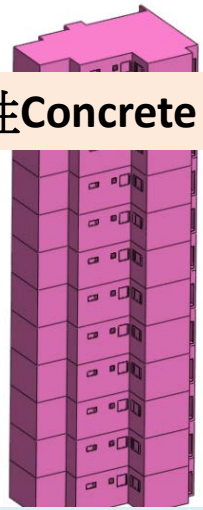


註:考慮計算效率，網格劃分使用較大尺寸。

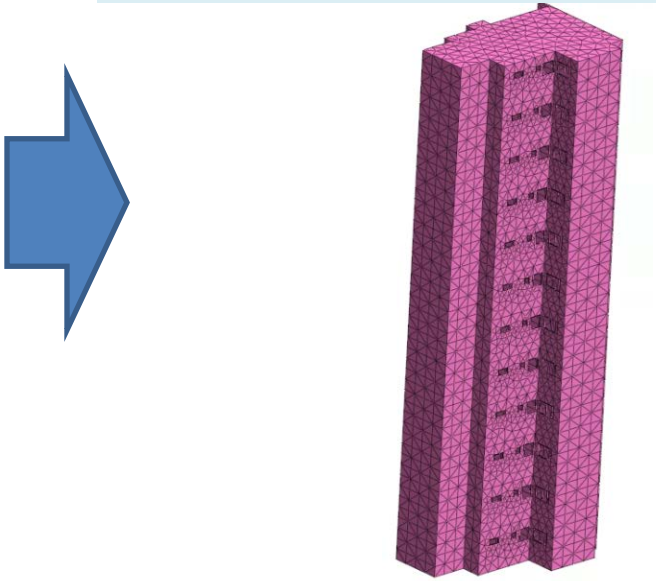
網格-大樓



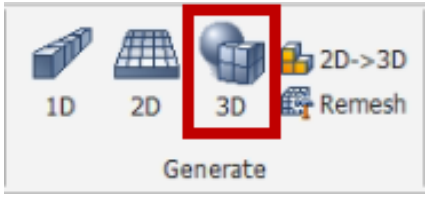
燈具:屬性Concrete /網格尺寸1



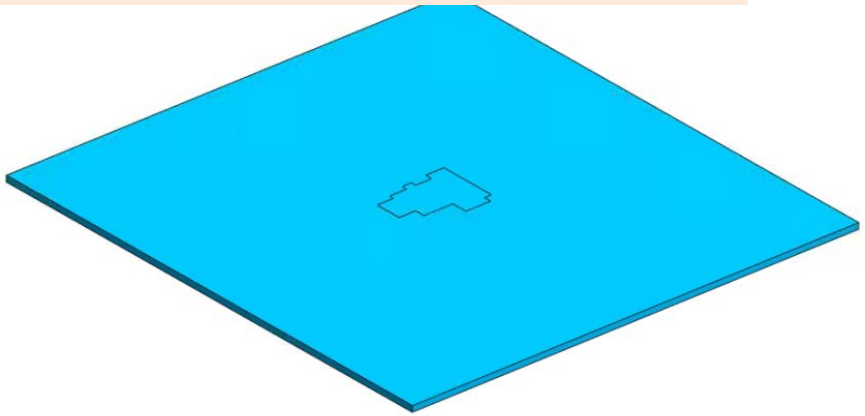
四面體網格/參考相鄰面/共節點/1階元素



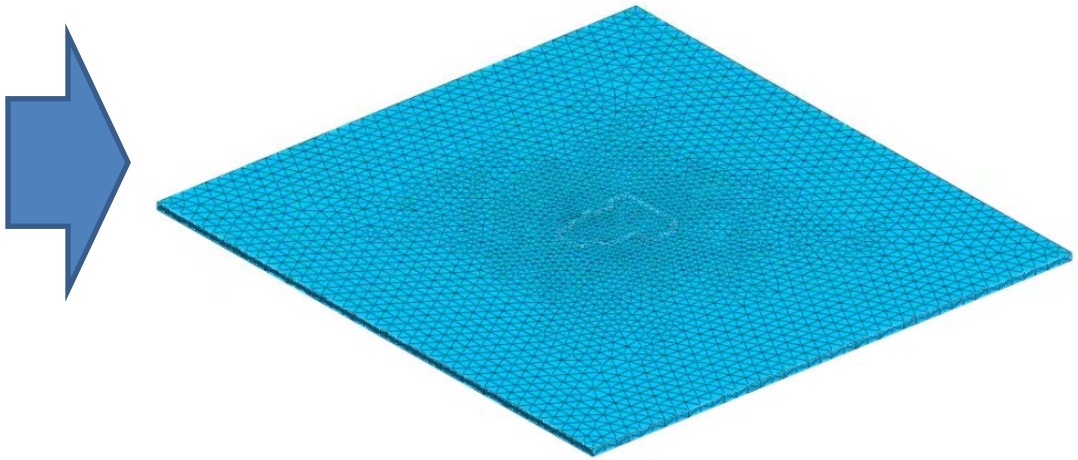
網格-地表



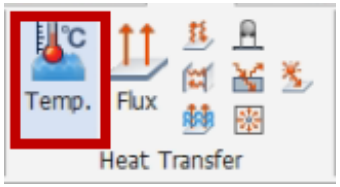
燈具:屬性Concrete /網格尺寸2



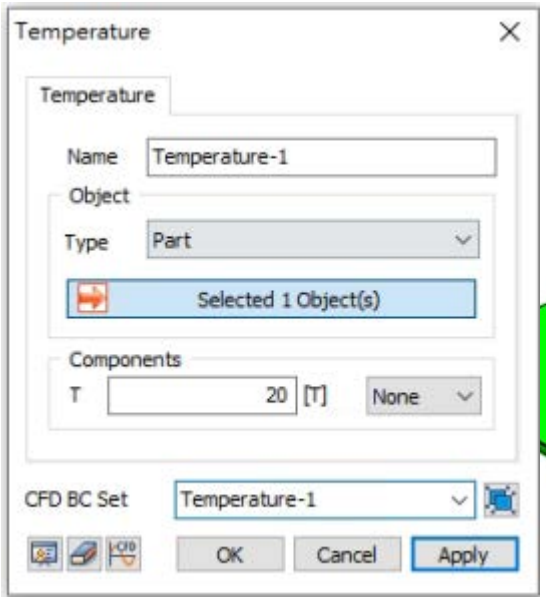
四面體網格/參考相鄰面/共節點/1階元素

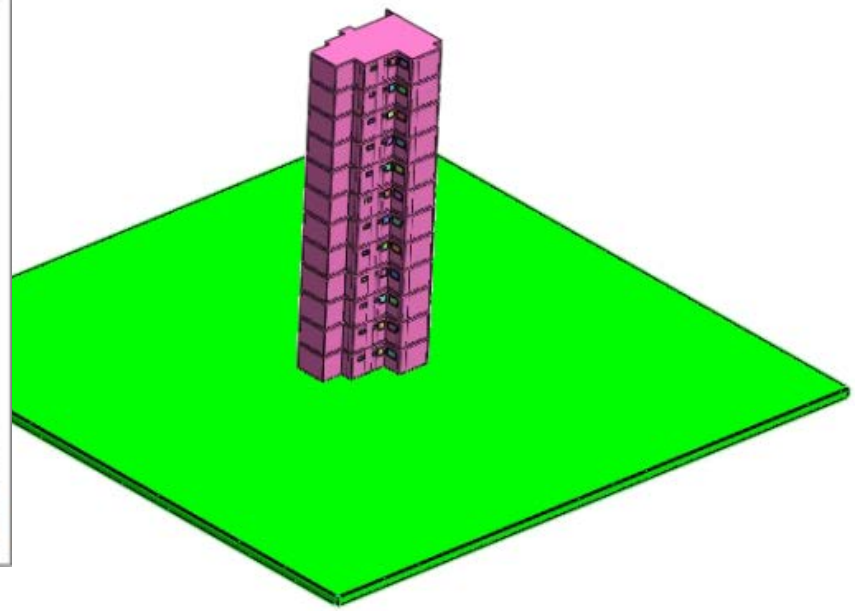


溫度-地表



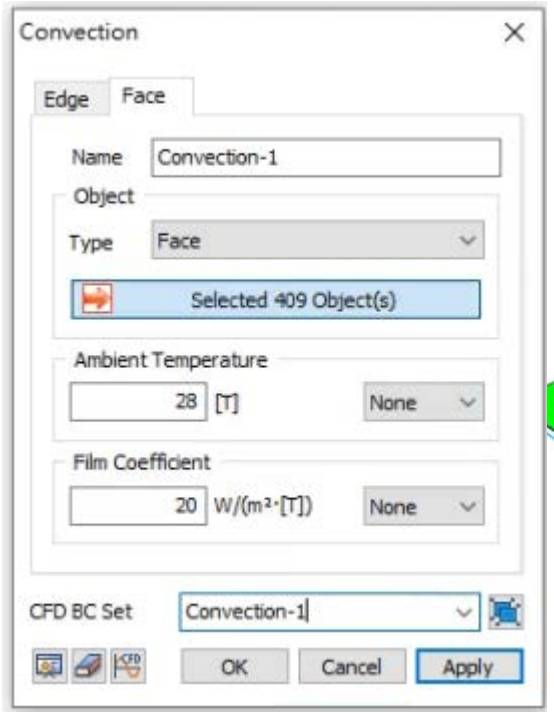
地表溫度維持20 ℃





熱對流

環境溫度:28℃
熱對流係數:20(W/m² ℃)

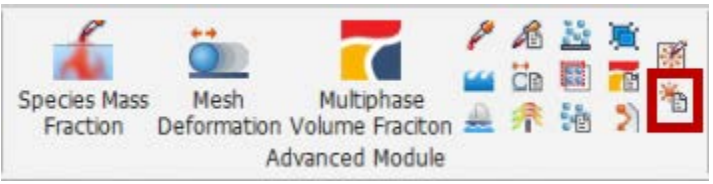


施加在空氣與結構接觸特徵

註1:幾何間的接觸面不用考慮空氣熱對流。
註2:不同邊界&載荷建議使用不同集合名稱。

日照-照射方向

(中午12點)

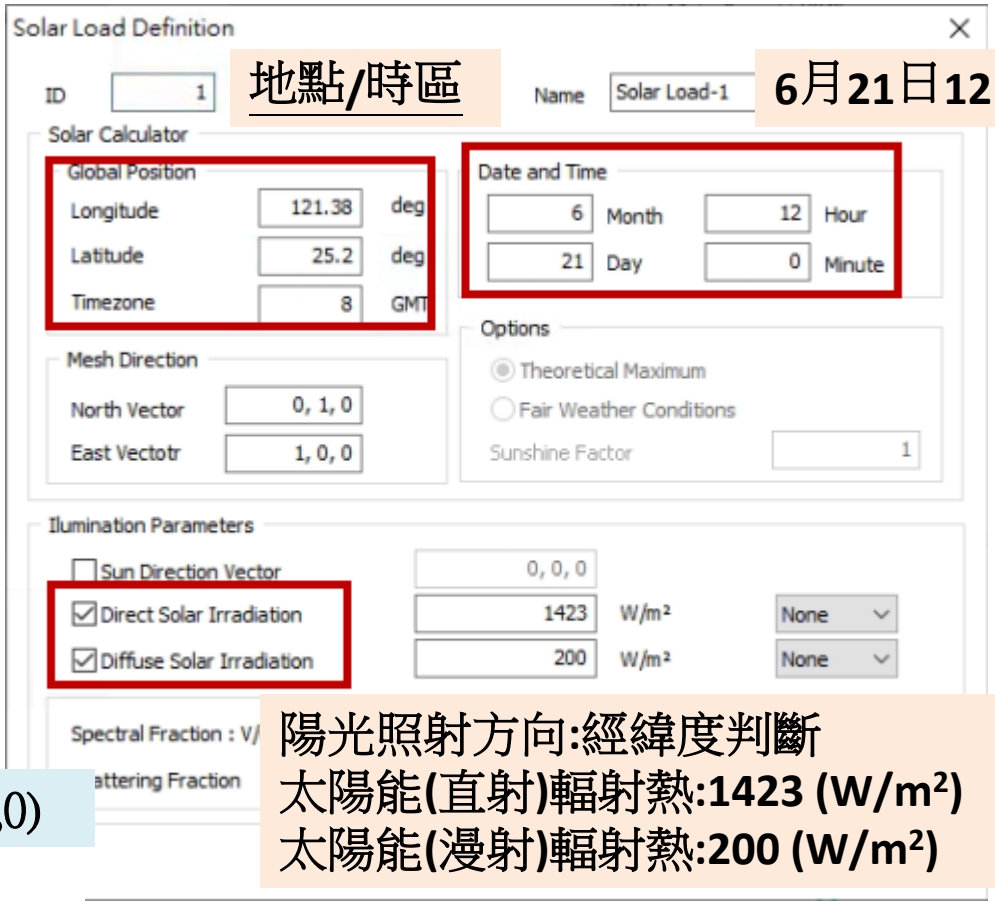


地點
台北121°38'E, 25°2'N

時區
台灣 GMT+8

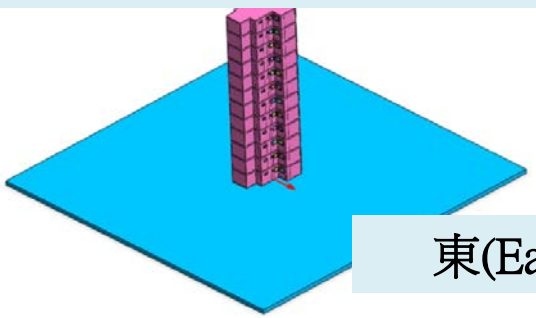
夏至
2023年6月21日 星期三

日光照射時間
Type1.中午12:00



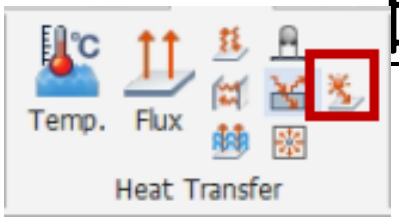
陽光照射方向:經緯度判斷
太陽能(直射)輻射熱:1423 (W/m²)
太陽能(漫射)輻射熱:200 (W/m²)

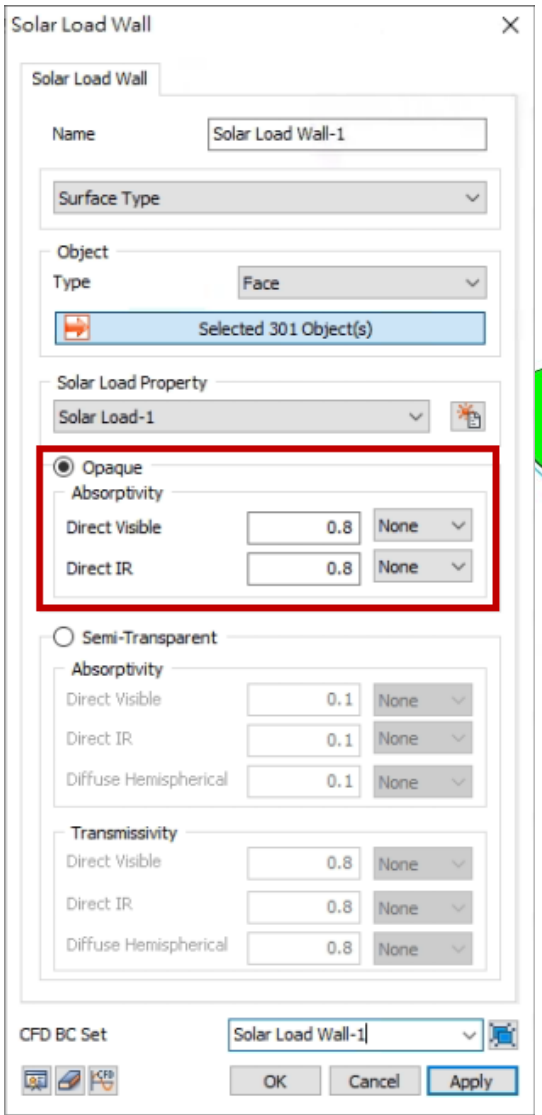
北(North Vector : 0,1,0)



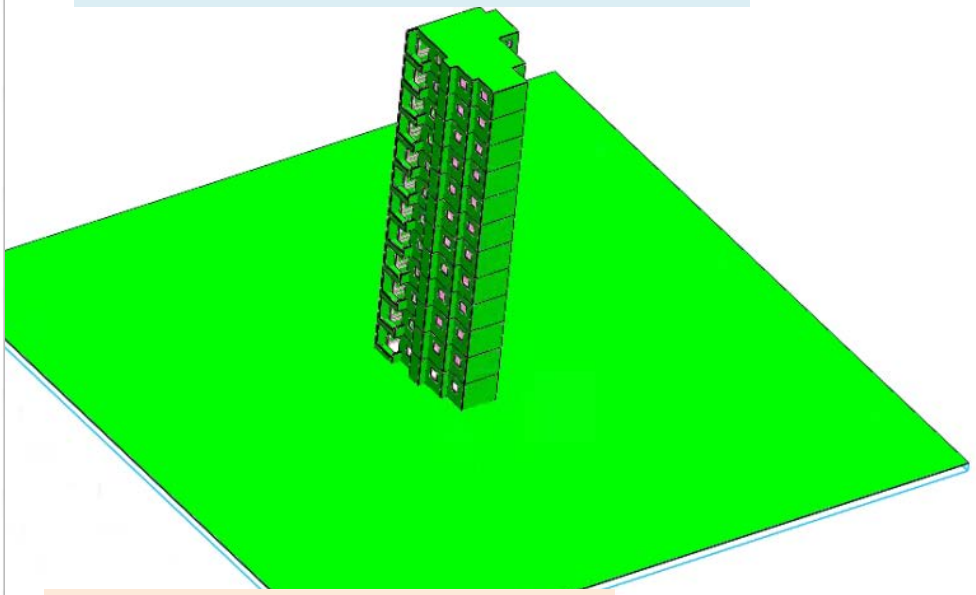
東(East Vector:1,0,0)

日照-照射區域-非透明



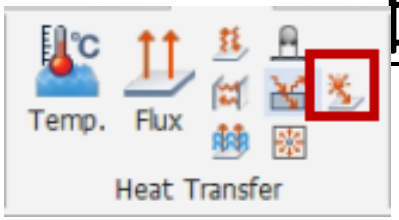


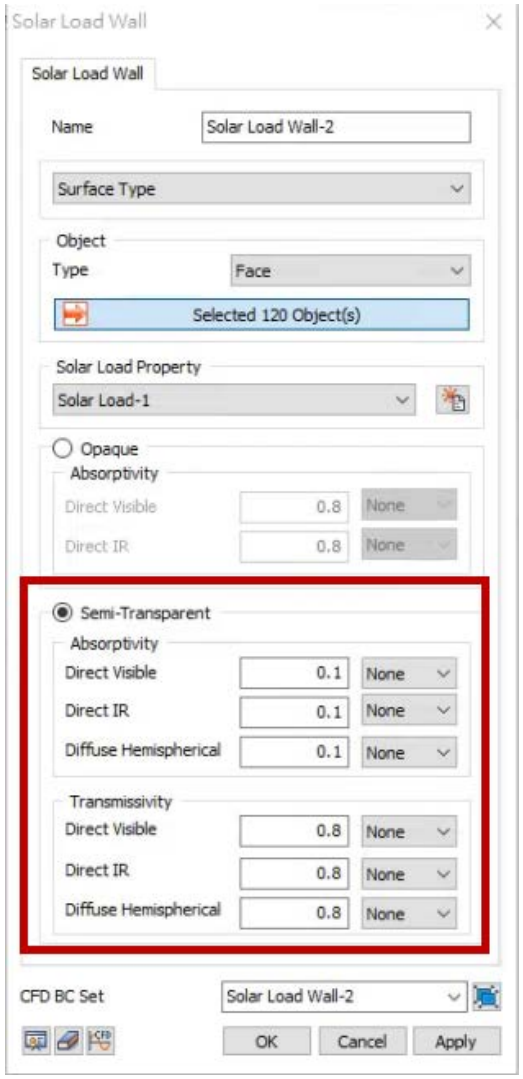
選取建物和地表外表面特徵



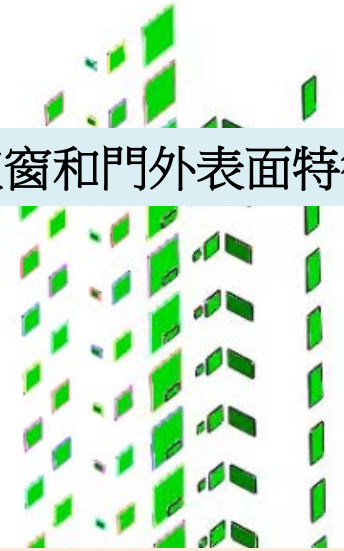
吸收率(Absorptivity) α
直接照射可見光:0.8
直接照射經外線:0.8

日照-照射區域-半透明





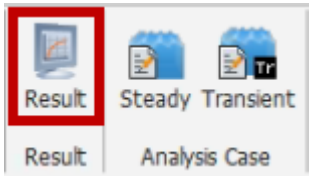
選取窗和門外表面特徵



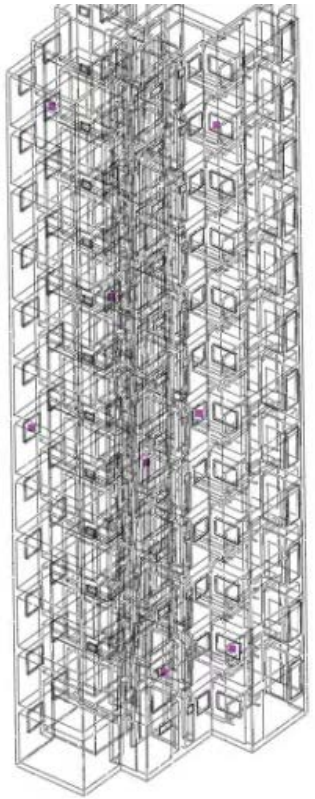
吸收率(Absorptivity) α
直接照射可見光:**0.1**
直接照射經外線:**0.1**
漫射半球形:**0.1**

透射率(Transmissivity) τ
直接照射可見光:**0.1**
直接照射經外線:**0.1**
漫射半球形:**0.1**

觀測點

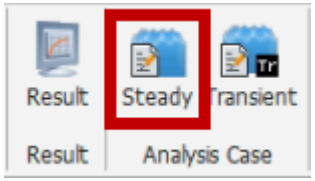


輸出特定節點數據同時能協助判斷收斂穩定

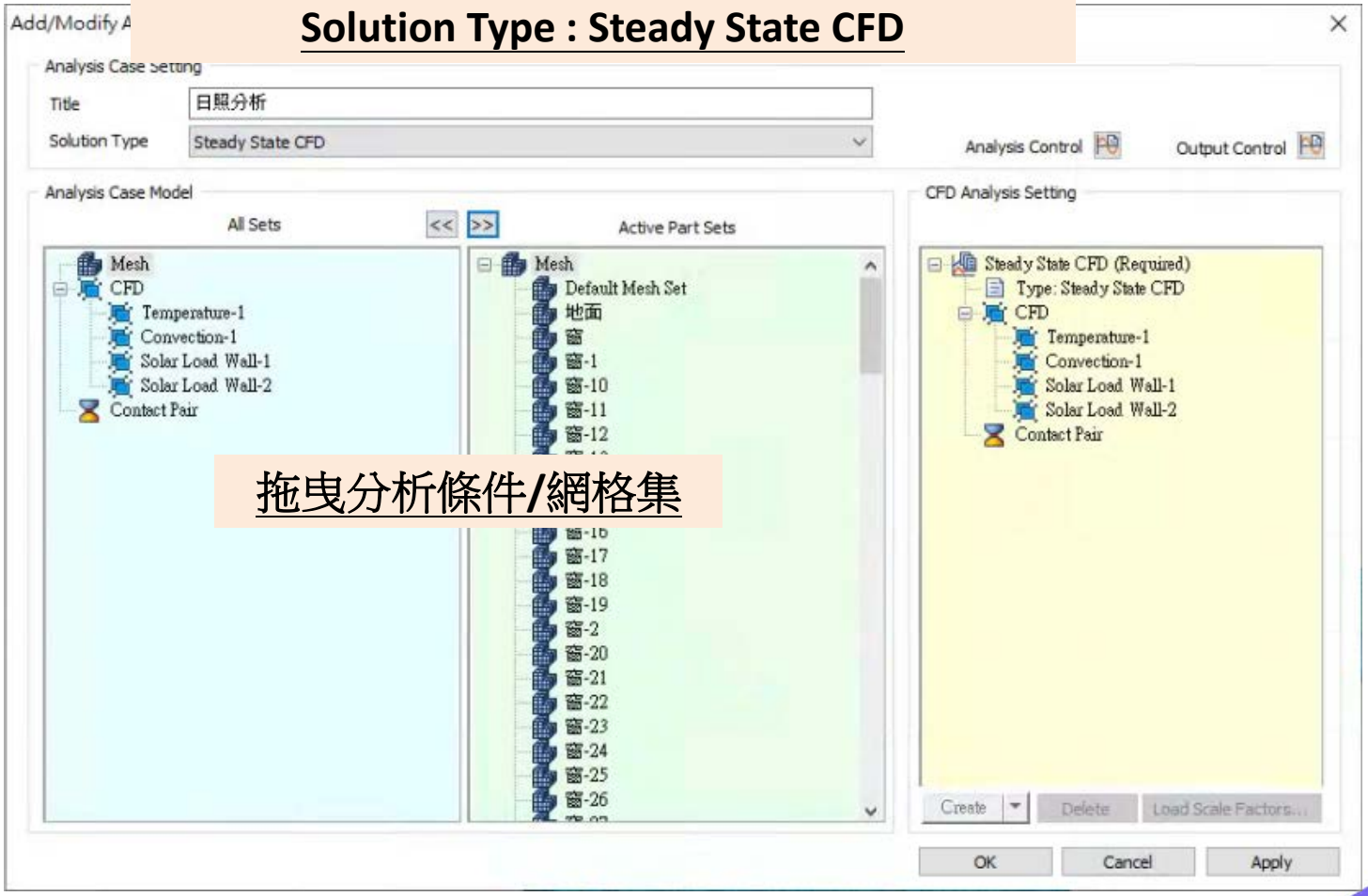


日照分析 -1

(中午12:00)



Solution Type : Steady State CFD



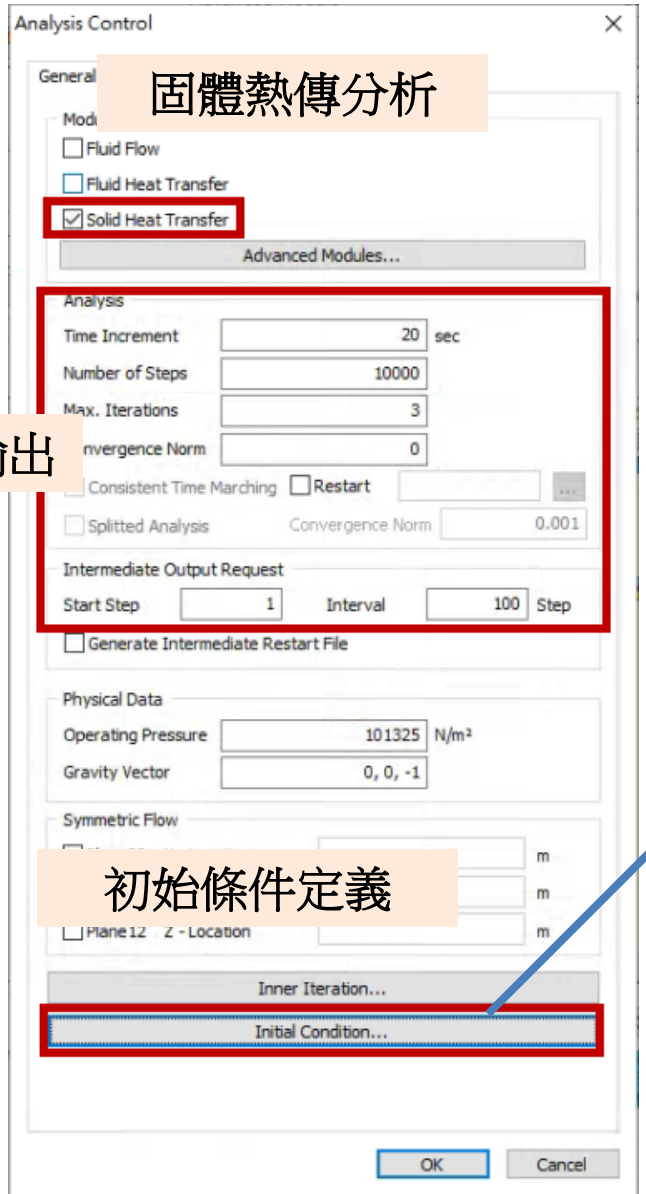
拖曳分析條件/網格集

日照分析 -2

(中午12:00)

Analysis Control | Output Control

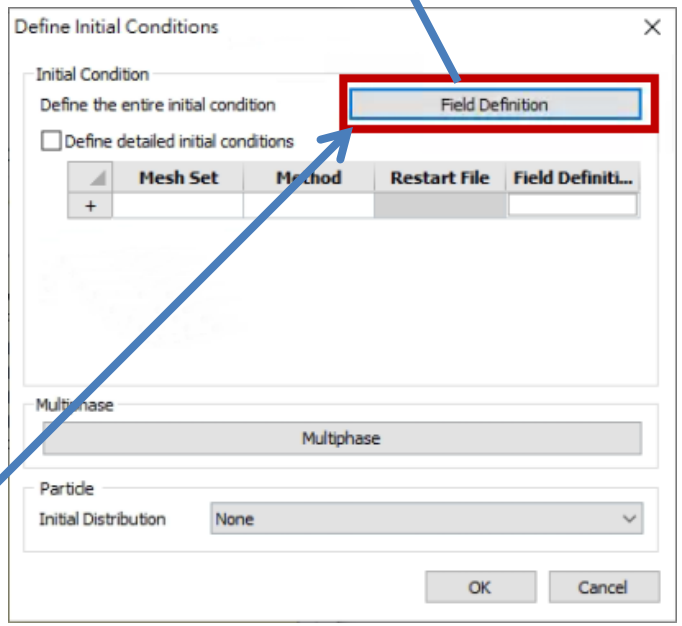
分析工況定義



調整增量和輸出

初始條件定義

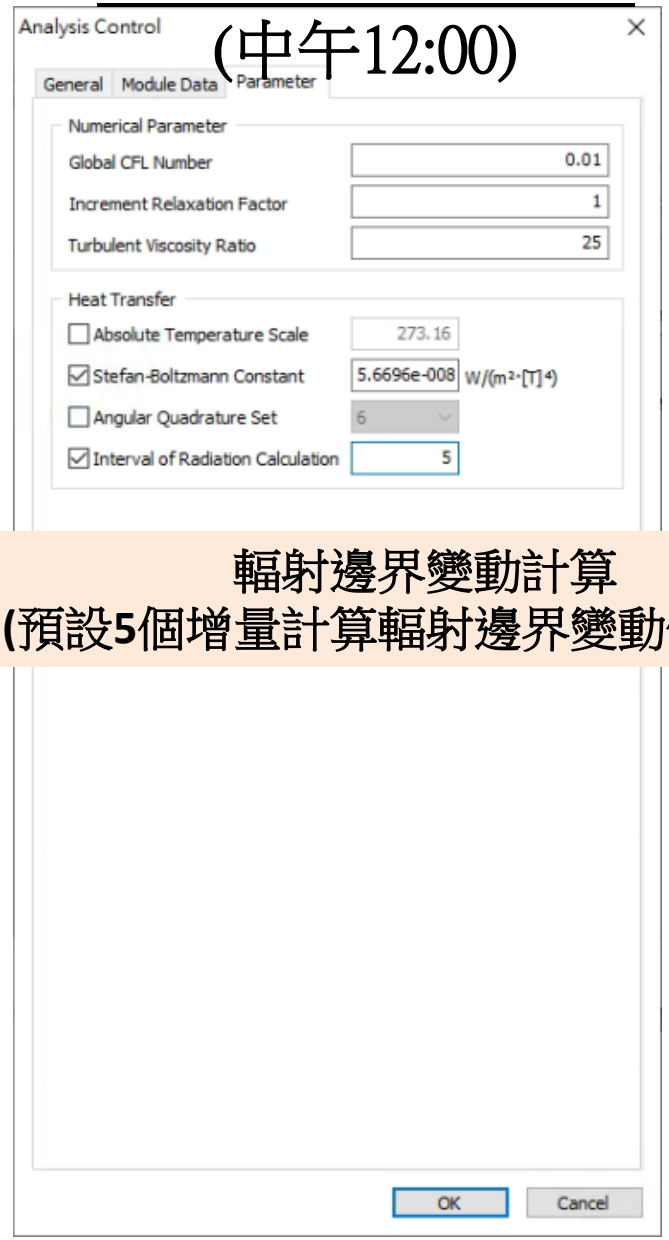
初始溫度25 ℃



日照分析 -3

(中午12:00)

分析工況定義

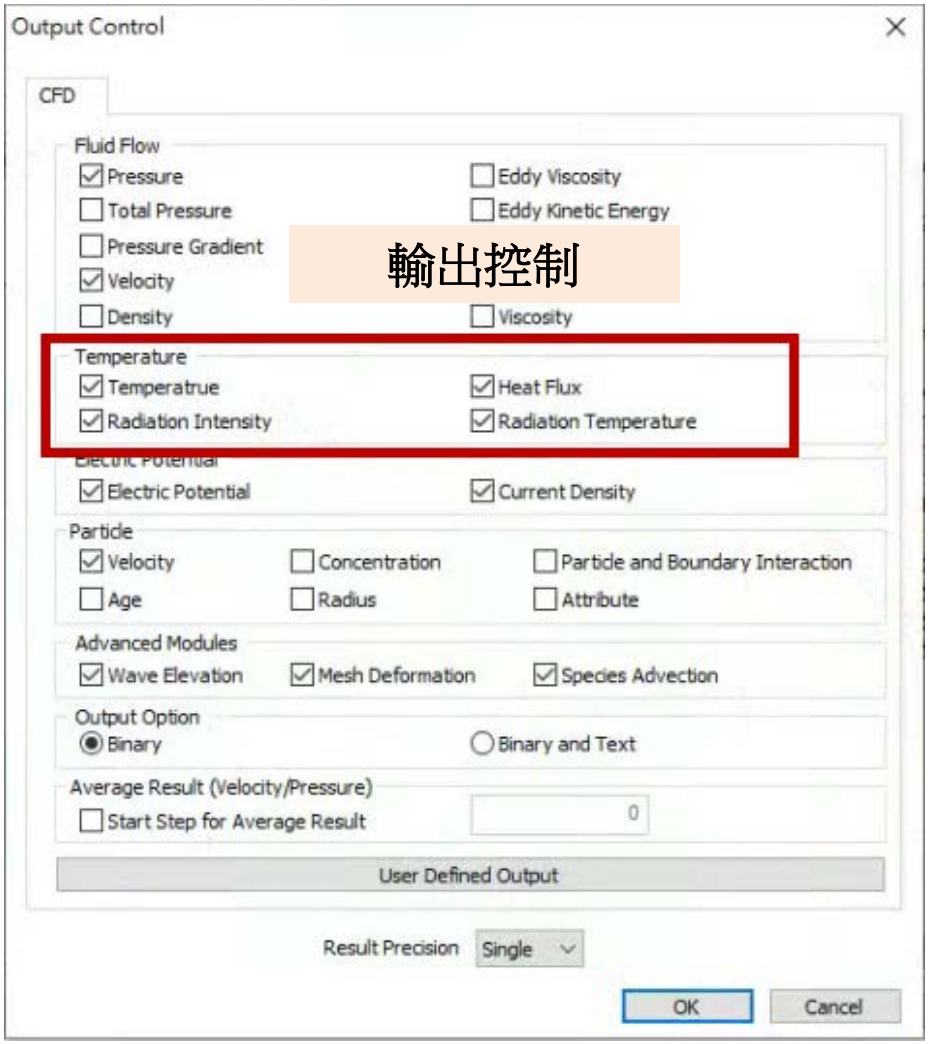


輻射邊界變動計算
(預設5個增量計算輻射邊界變動條件1次)

日照分析 -4

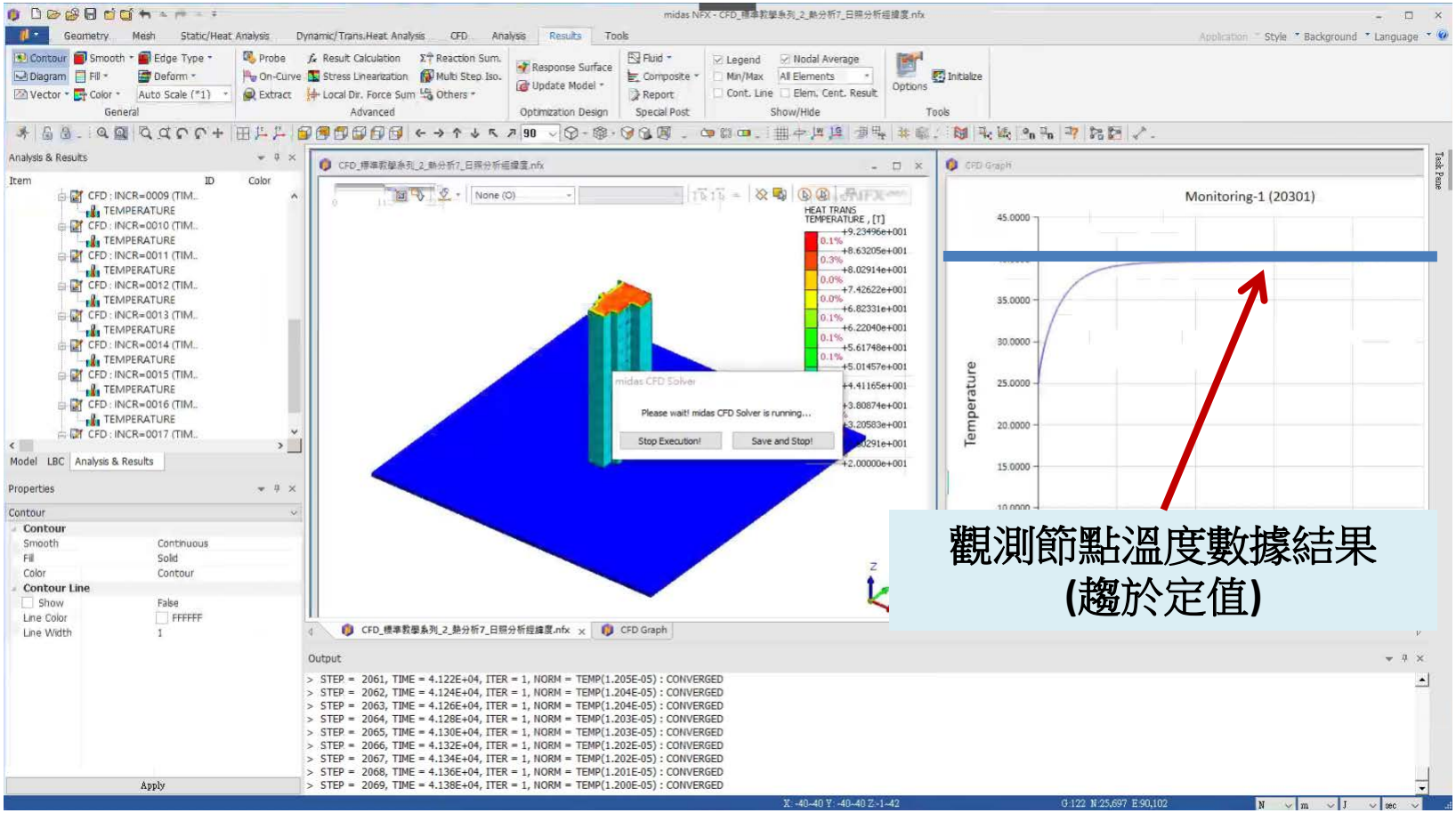
(中午12:00)

Analysis Control | Output Control



執行計算

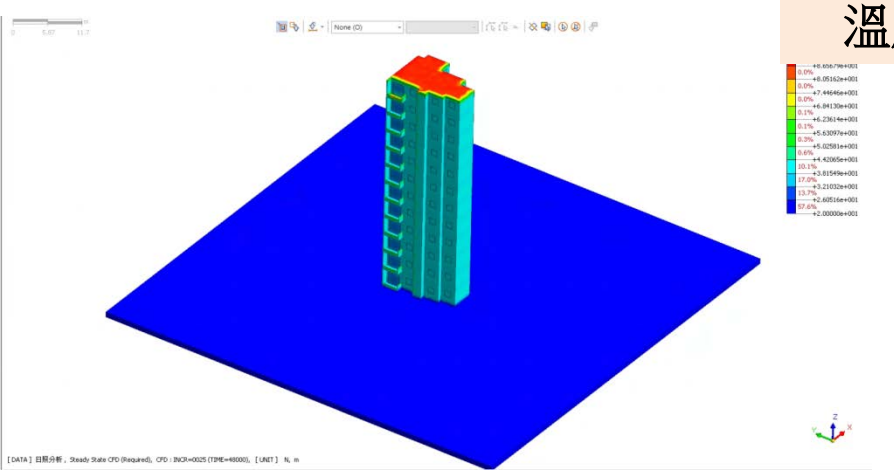
(中午12:00)

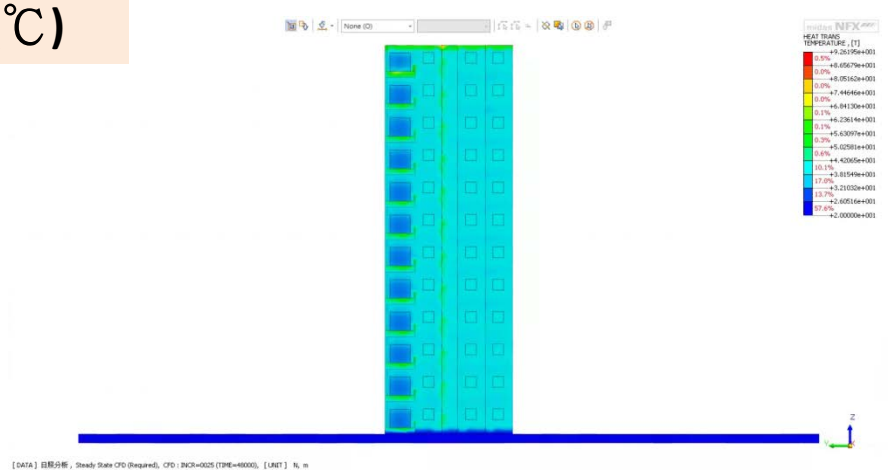

Monitoring-1 (20301)
Temperature
45.0000
35.0000
30.0000
25.0000
20.0000
15.0000
10.0000
HEAT TRANS TEMPERATURE, [T]
+9.23496e+001
+8.63205e+001
+8.02914e+001
+7.42622e+001
+6.82331e+001
+6.22040e+001
+5.61748e+001
+5.01457e+001
+4.41165e+001
+3.80874e+001
+3.20583e+001
+2.60291e+001
+2.00000e+001
midas CFD Solver
Please wait! midas CFD Solver is running...
Stop Execution!
Save and Stop!
觀測節點溫度數據結果
(趨於定值)

分析結果

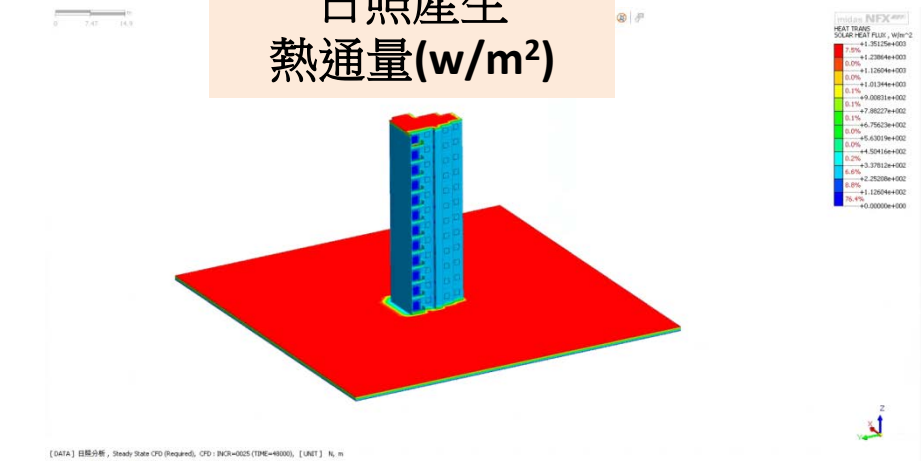
(中午12:00)

溫度(℃)

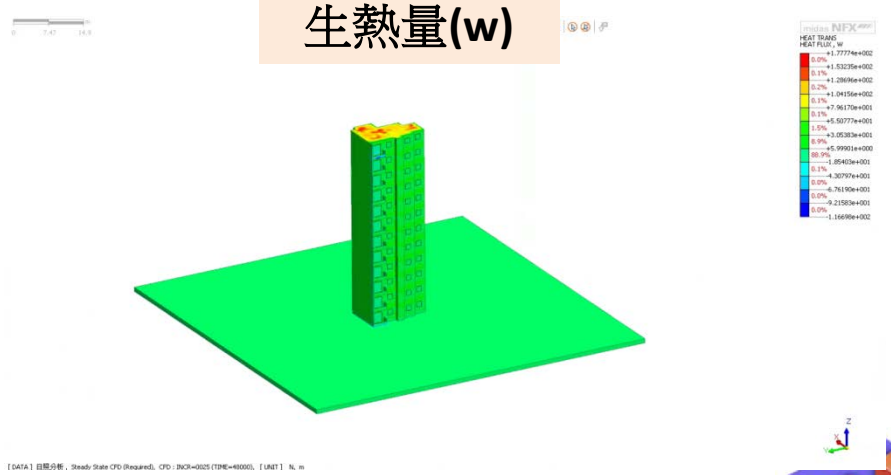




日照產生
熱通量(w/m²)



生熱量(w)



補充:日照-照射方向

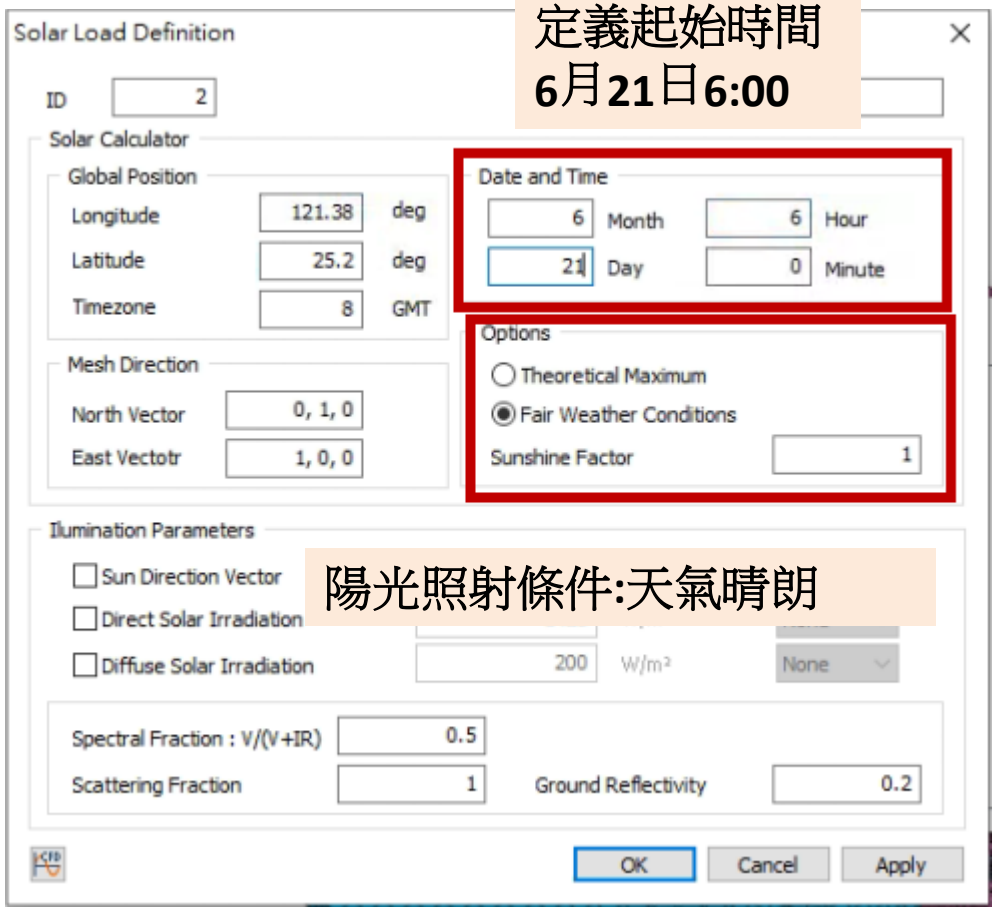
(天氣晴朗/上午6:00~下午6:00)

地點
台北121°38'E, 25°2'N

時區
台灣 GMT+8

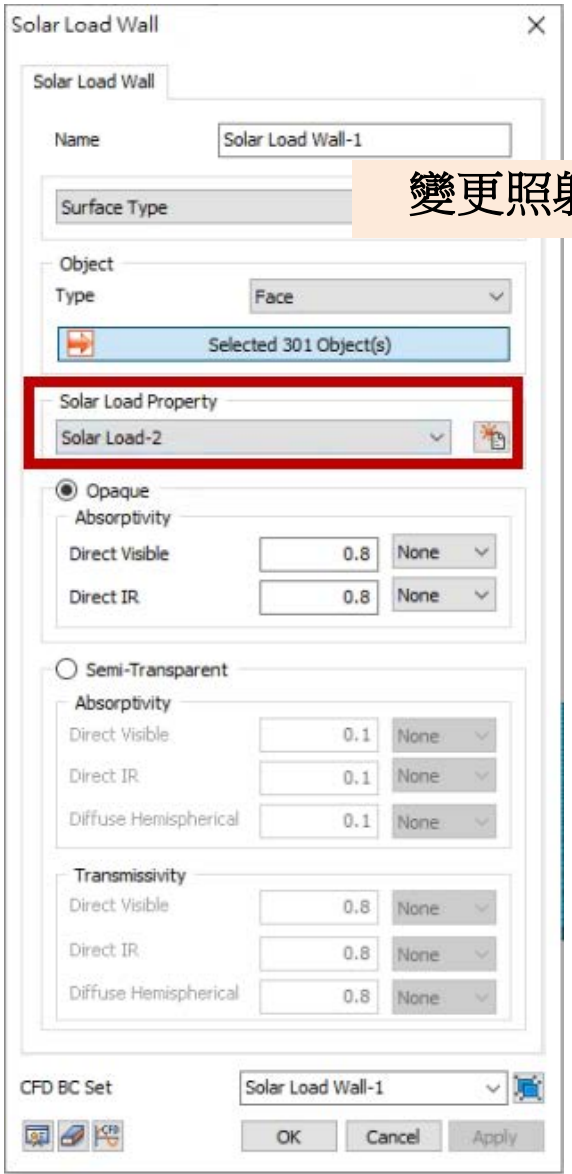
夏至
2023年6月21日 星期三

日光照射時間
天氣晴朗
上午6:00~下午6:00

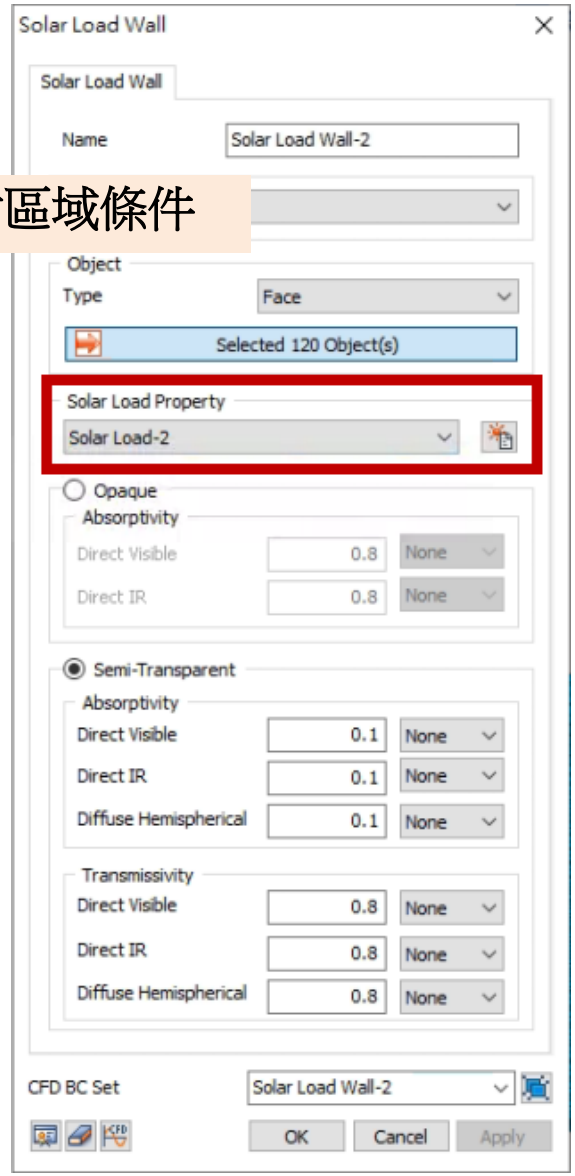


補充:日照-照射區域

(天氣晴朗/上午6:00~下午6:00)

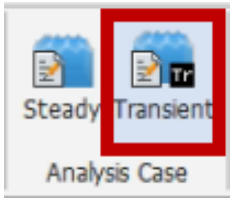


變更照射區域條件



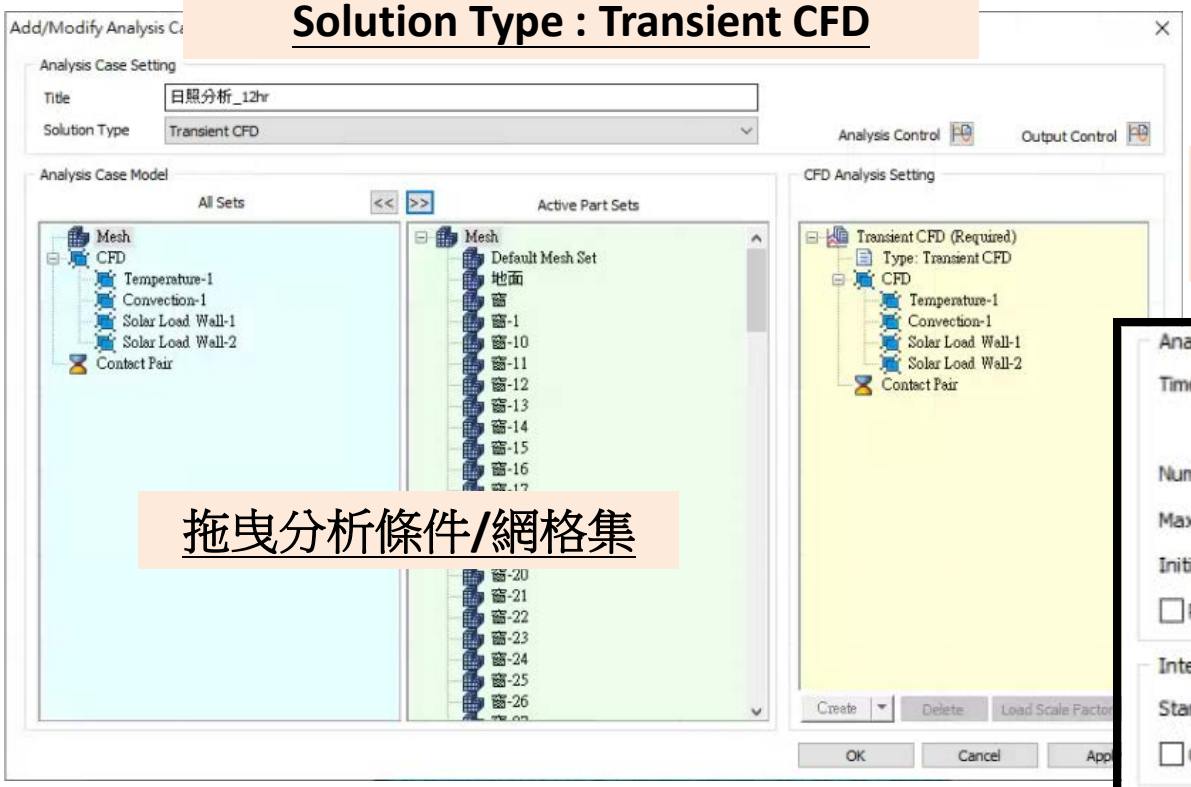
補充:日照分析 -1

(天氣晴朗/上午6:00~下午6:00)



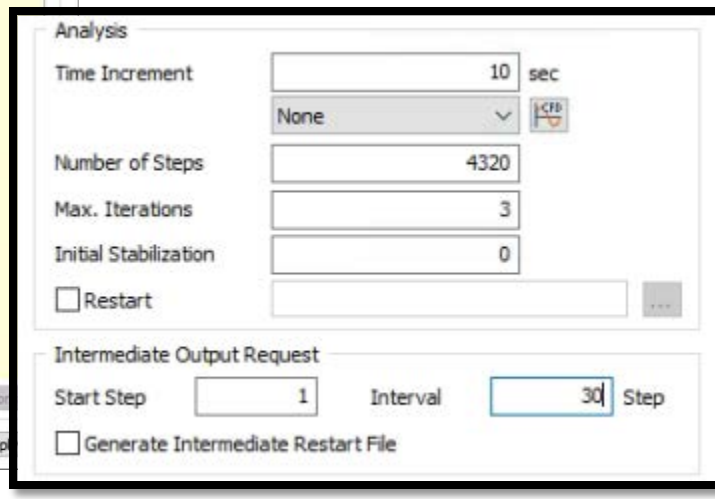
12(hr)=3600 ×12(Sec)
= 43,200(Sec)
每10sec計算1次
共要計算4320次

Solution Type : Transient CFD



拖曳分析條件/網格集

每300sec輸出1次結果
Interval=30step

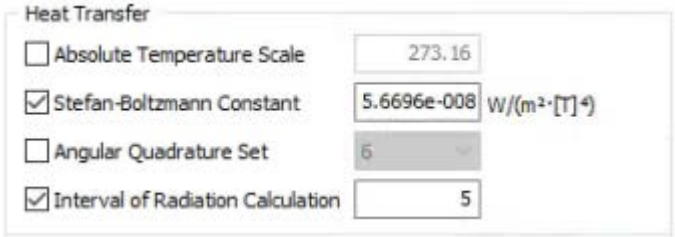


補充:日照分析 -2

(天氣晴朗/上午6:00~下午6:00)

輻射邊界變動計算

(預設5個增量計算輻射邊界變動條件1次)



5個增量50sec(1個增量10sec)

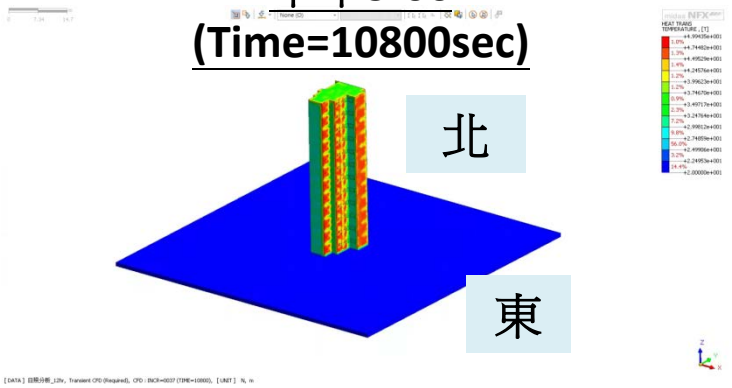
自動變更太陽照射邊界條件1次

```
 SUN DIRECTION VECTOR : 0.917133, 0.353220, 0.184671
 DIRECT NORMAL SOLAR IRRADIATION :  358.531 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (VERTICAL SURFACE)   :   61.582 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (HORIZONTAL SURFACE) :   48.043 [W/m^2]
 GROUND REFRECTED SOLAR IRRADIATION (VERTICAL SURFACE) :   11.425 [W/m^2]
- Solar Load-1
 SUN DIRECTION VECTOR : -0.015144, -0.030737, 0.999413
 DIRECT NORMAL SOLAR IRRADIATION :    0.000 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (VERTICAL SURFACE)   :    0.000 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (HORIZONTAL SURFACE) :    0.000 [W/m^2]
 GROUND REFRECTED SOLAR IRRADIATION (VERTICAL SURFACE) :    0.000 [W/m^2]
STEP =    1, TIME = 1.000E+01, ITER = 1, NORM = TEMP(2.052E-04) : CONVERGED
STEP =    2, TIME = 2.000E+01, ITER = 1, NORM = TEMP(2.014E-04) : CONVERGED
STEP =    3, TIME = 3.000E+01, ITER = 1, NORM = TEMP(1.980E-04) : CONVERGED
STEP =    4, TIME = 4.000E+01, ITER = 1, NORM = TEMP(1.949E-04) : CONVERGED
STEP =    5, TIME = 5.000E+01, ITER = 1, NORM = TEMP(1.920E-04) : CONVERGED
- Solar Load-2
 FAIR WEARTHER CONDITIONS
 SUN DIRECTION VECTOR : 0.917071, 0.351800, 0.187666
 DIRECT NORMAL SOLAR IRRADIATION :  364.938 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (VERTICAL SURFACE)   :   62.653 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (HORIZONTAL SURFACE) :   48.902 [W/m^2]
 GROUND REFRECTED SOLAR IRRADIATION (VERTICAL SURFACE) :   11.739 [W/m^2]
- Solar Load-1
 SUN DIRECTION VECTOR : -0.018479, -0.030711, 0.999357
 DIRECT NORMAL SOLAR IRRADIATION :    0.000 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (VERTICAL SURFACE)   :    0.000 [W/m^2]
 DIFFUSE SOLAR IRRADIATION (HORIZONTAL SURFACE) :    0.000 [W/m^2]
 GROUND REFRECTED SOLAR IRRADIATION (VERTICAL SURFACE) :    0.000 [W/m^2]
STEP =    6, TIME = 6.000E+01, ITER = 1, NORM = TEMP(1.920E-04) : CONVERGED
STEP =    7, TIME = 7.000E+01, ITER = 1, NORM = TEMP(1.894E-04) : CONVERGED
STEP =    8, TIME = 8.000E+01, ITER = 1, NORM = TEMP(1.870E-04) : CONVERGED
STEP =    9, TIME = 9.000E+01, ITER = 1, NORM = TEMP(1.847E-04) : CONVERGED
STEP =   10, TIME = 1.000E+02, ITER = 1, NORM = TEMP(1.826E-04) : CONVERGED
```

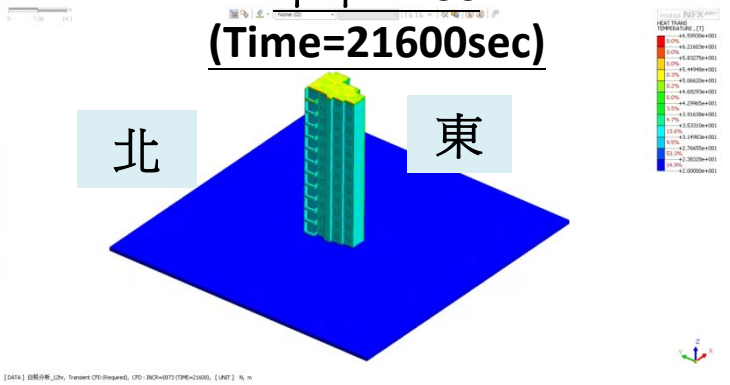
補充:分析結果(溫度(℃))

(天氣晴朗/上午6:00~下午6:00)

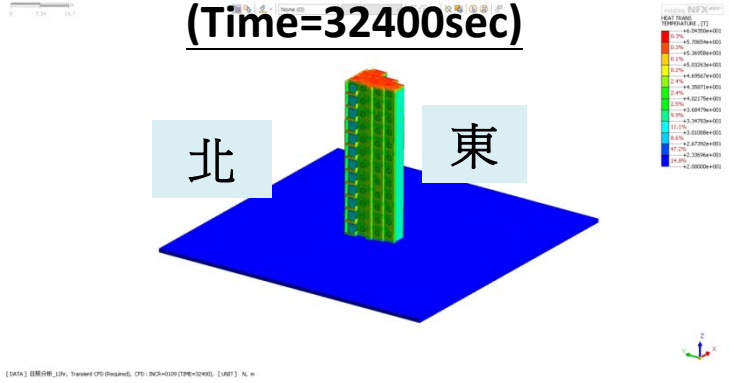
中午9:00
(Time=10800sec)



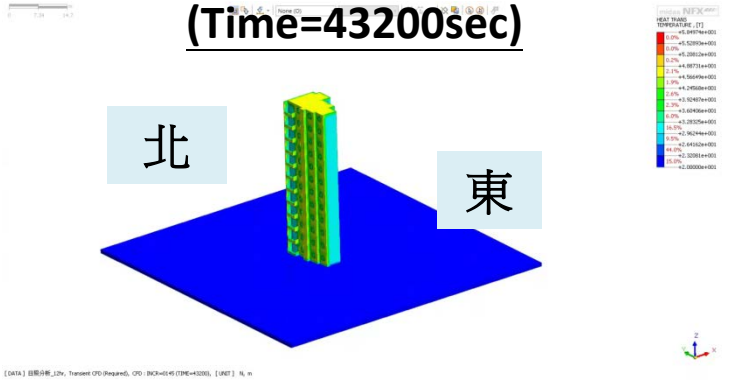
中午12:00
(Time=21600sec)



下午3:00
(Time=32400sec)



下午6:00
(Time=43200sec)



midas NFX-CFD

CFD_標準教學系列

熱對流分析2-共軛熱傳

台灣邁達斯

MIDAS

共軛熱傳(CHT)
(Conjugate heat transfer)

共軛傳熱是透過介質或直接接觸來實現流體與固體間耦合熱交換的技術方法，其核心特徵在於聯立求解溫度場控制方程式實現參數隱式處理。
此方法廣泛應用於電子裝置散熱 、汽車零件熱管理及核電廠密封性能分析等領域。

共軛熱傳(**Conjugate Heat Transfer, CHT**)的**數值計算方法**主要目標是在**固體與流體的交界面**上，**耦合求解熱傳導與對流方程式**，以獲得整個系統的熱行為。這需要同時處理**流體力學（Navier-Stokes）與熱傳導（Fourier）方程式**。

共軛熱傳涉及的主要物理現象：

區域	熱傳方式	控制方程式
流體區	對流 + 傳導	能量方程 + 納維-斯托克斯方程（Navier-Stokes）
固體區	傳導	傳導熱方程（Fourier's Law）
接觸界面	熱通量與溫度連續	$-k_s \nabla T_s = -k_f \nabla T_f$

Reference

https://baike.baidu.com/item/%E5%85%B1%E8%BB%9B%E5%82%B3%E7%86%B1/7080842
https://chatgpt.com/

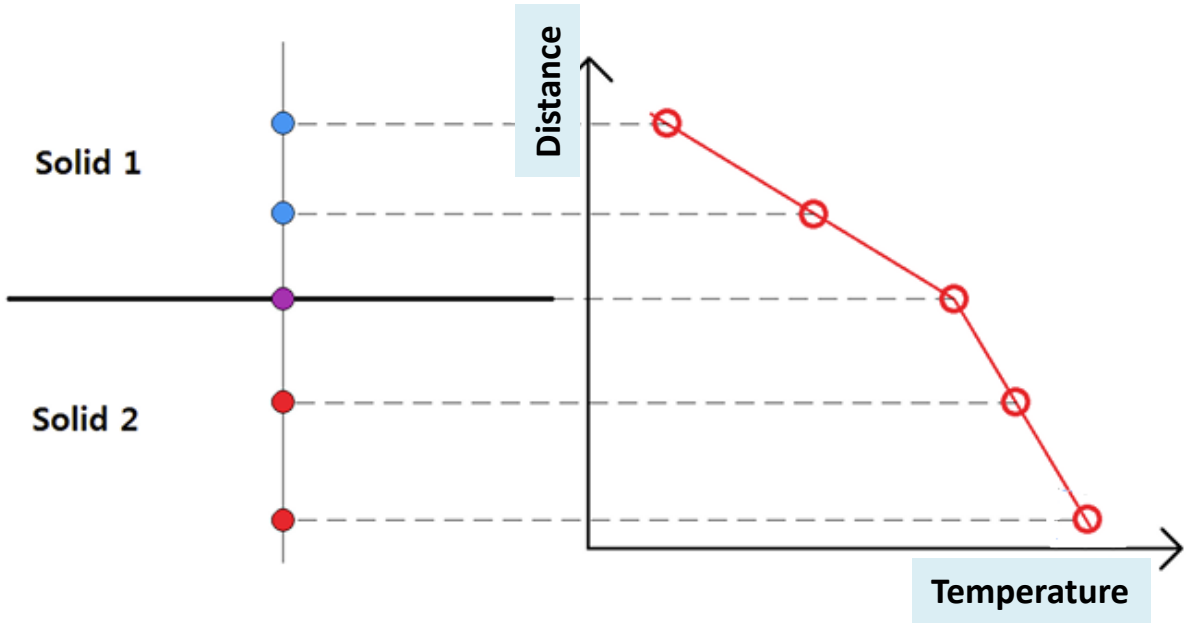
相鄰邊界-Type1.節點相連

Soild1與Solid2 :相鄰邊界採節點相連

當固體材料1與固體材料2接觸時，在邊界面上相對的兩個節點會合併為一個節點以進行熱傳導計算。

此時，合併的節點將使用接觸區域各自的物性參數，與相連節點一起求解熱傳導方程式。由於是一個節點，因此邊界面的溫度被表示為恆定的數值。

此方法主要用於固體之間無熱阻接觸的情況(如焊接、釬焊等)。



Reference

MIDAS NFX CFD TECH NOTE

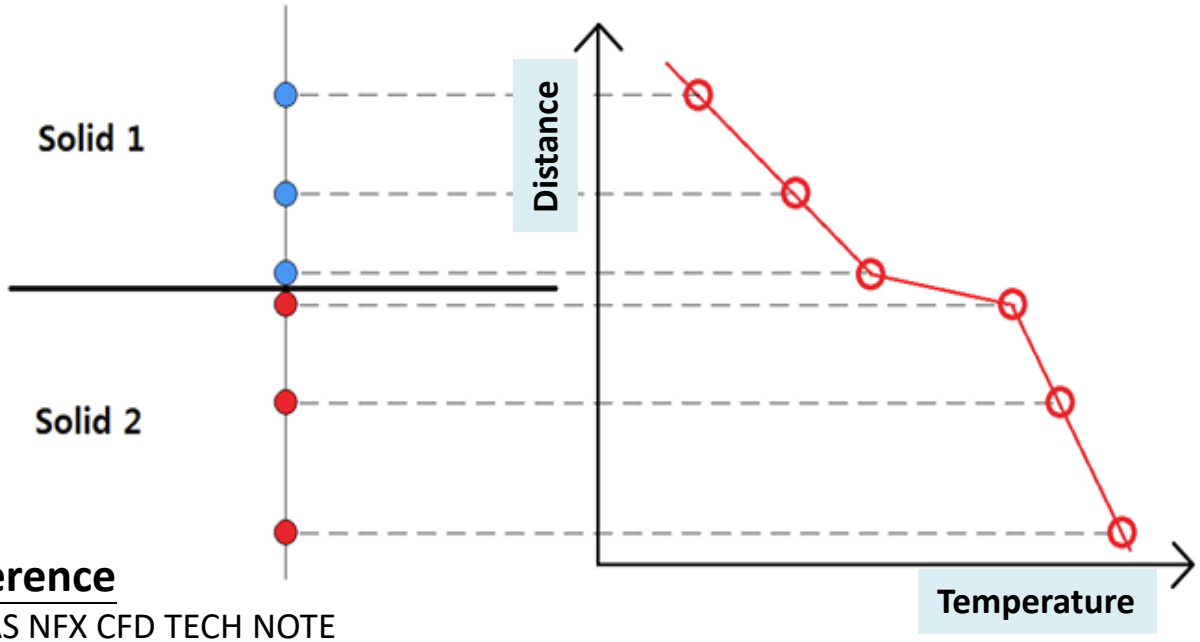
相鄰邊界-Type2.接觸– 熱阻

Soild1與Solid2 :相鄰邊界採接觸定義

當當固體材料1與固體材料2接觸時，保留構成邊界面的各自區域的節點，並賦予接觸條件。

由於在兩個區域之間設有薄的邊界區域，可以分別計算各自區域的溫度，因此可以透過施加恆定的熱阻來實現接觸熱阻。

這種方法主要適用於透過緊固件等方式簡單接觸的固體之間的邊界面。



Reference

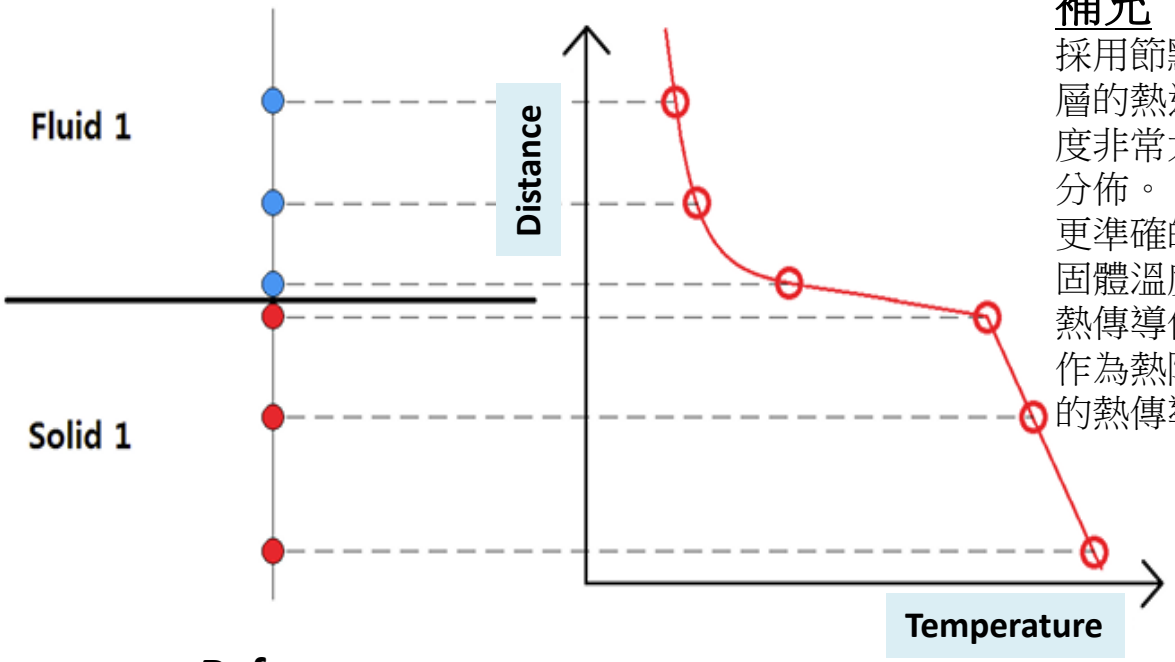
MIDAS NFX CFD TECH NOTE

相鄰邊界-Type3.接觸– 熱邊界層

Fluid1與Solid1:相鄰邊界採接觸定義

附著在壁面上的流體會形成熱邊界層，而該熱邊界層相較於商用計算流體力學(CFD)中所使用的單元尺寸來說非常薄，因此如果不使用非常密集的網格，便難以數值求解溫度分佈。

在這種情況下，可以作為替代使用熱邊界層模型，透過利用壁面處的流動物理量，採用熱壁面函數來計算並施加流體與固體之間的熱通量。



補充

採用節點合併方法，也可以施加考慮熱邊界層的熱通量；但由於緊貼壁面的流體溫度梯度非常大，這可能會扭曲流體區域內的溫度分佈。

更準確的方法是施加接觸條件，將壁面處的固體溫度與流體溫度區分開。使用計算得到熱傳導係數h (heat transfer coefficient)的倒數作為熱阻來施加，可以更合理地表示壁面處的熱傳導與對流耦合行為。

Reference

MIDAS NFX CFD TECH NOTE

接觸熱阻(R_c)
(Thermal Contact Resistance)

接觸熱阻（Thermal Contact Resistance）是指當兩個固體表面接觸時，由於接觸面不完全平整且存在微小空隙，導致熱流通過接觸界面時受到阻礙，從而產生的熱阻。
由於表面的幾何不完美，當兩個固體物體接觸時，實際上只有極少部分（微觀凹凸峰頂）彼此接觸。隨著兩物體間壓力的增加，這些凹凸處會產生一定的變形，從而使實際接觸面積增加。
而在沒有實際物理接觸的區域，熱傳導則主要通過填充其中的氣體、導熱膏(Thermal Grease)以及輻射等方式進行。

熱阻(R_c)
接觸面溫差與熱通量的比值

$$R_c = \frac{\Delta T}{q''}$$

其中：

- ΔT：接觸面兩側溫差 (K)
- q''：通過接觸面的熱通量（W/m²）

接觸熱導率(h_c)
(Thermal Contact Conductance)

接觸熱導率（Thermal Contact Conductance）是接觸熱阻的倒數，用來表示兩個接觸面之間傳遞熱量的能力。它反映了接觸界面導熱性能的好壞，數值越大，熱傳導性能越好，熱阻越小。

數學關係為：

$$h_c = \frac{1}{R_c}$$

其中，

- h_c 是接觸熱導率（W/m²·K），
- R_c 是接觸熱阻（m²·K/W）。

在實際工程和數值模擬中，接觸熱導率用於描述和計算兩個固體表面之間的熱交換效率。

熱邊界層
(Thermal Boundary Layer)

熱邊界層(Thermal boundary layer)

在特定溫度的流體流經另一個溫度的固體表面時所產生的現象。
指的是從固體表面開始，溫度變化達到表面流體溫度與由流體溫度之差的99%的區域。
使用普朗特數描述熱邊界層與速度邊界層的關係。

普朗特數(Prandtl number,Pr)是描述流體中動量擴散與熱擴散相對速率的無量綱數，定義為：

$$Pr = \frac{\nu}{\alpha} = \frac{\text{動量擴散率}}{\text{熱擴散率}}$$

$$Pr = \frac{\mu/\rho}{k/(\rho c_p)} = \frac{c_p \mu}{k}$$

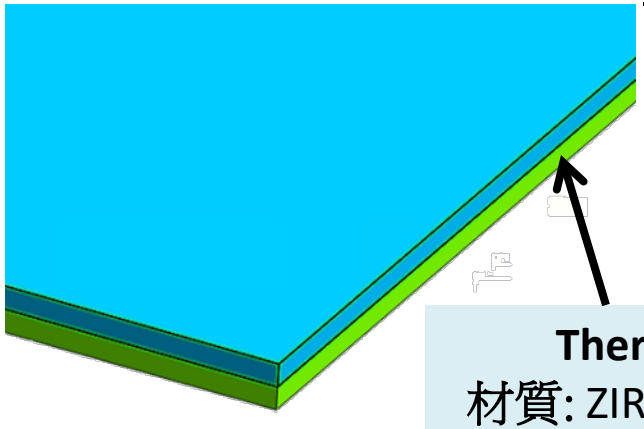
其中：

- μ：動力黏度（Pa·s）
- ρ：密度（kg/m³）
- c_p：定壓比熱（J/kg·K）
- k：熱導率（W/m·K）
- $\nu = \frac{\mu}{\rho}$：運動黏性係數（m²/s）
- $\alpha = \frac{k}{\rho c_p}$：熱擴散率（m²/s）

Reference

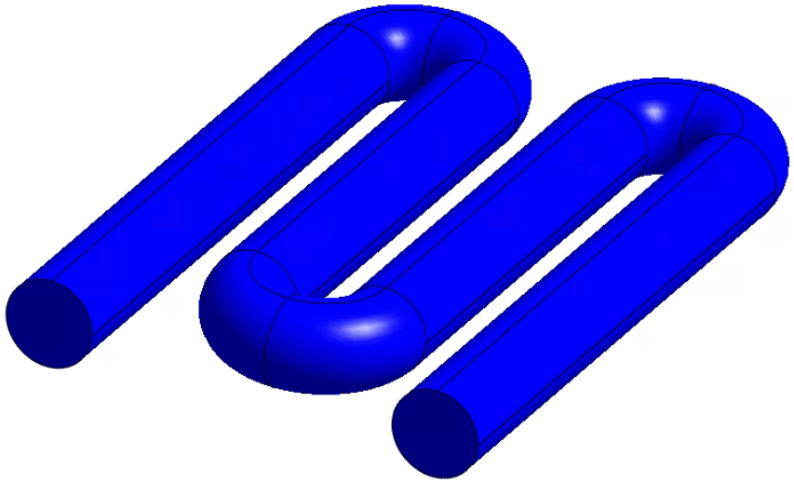
MIDAS NFX CFD TECH NOTE

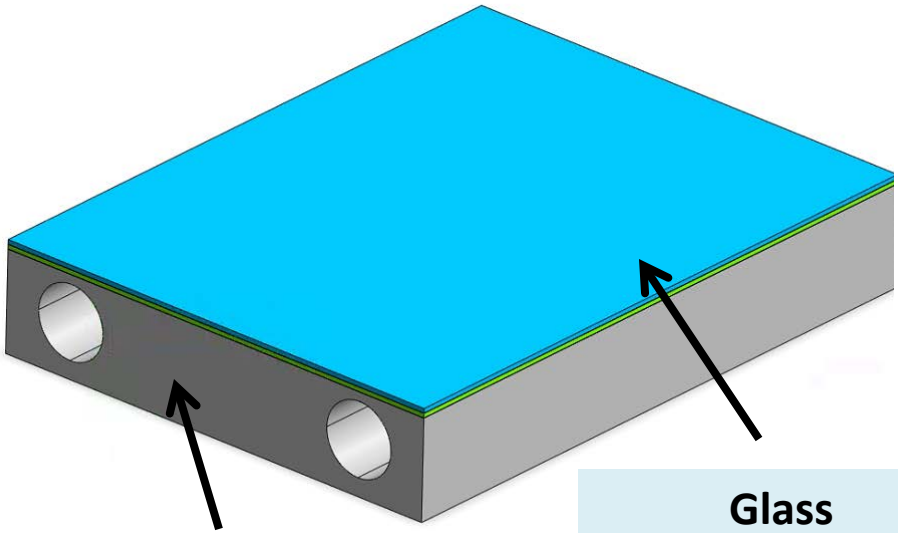
分析說明-1



Thermal Pad
材質: ZIRCONIUM(鋯)

流道
材質:Water



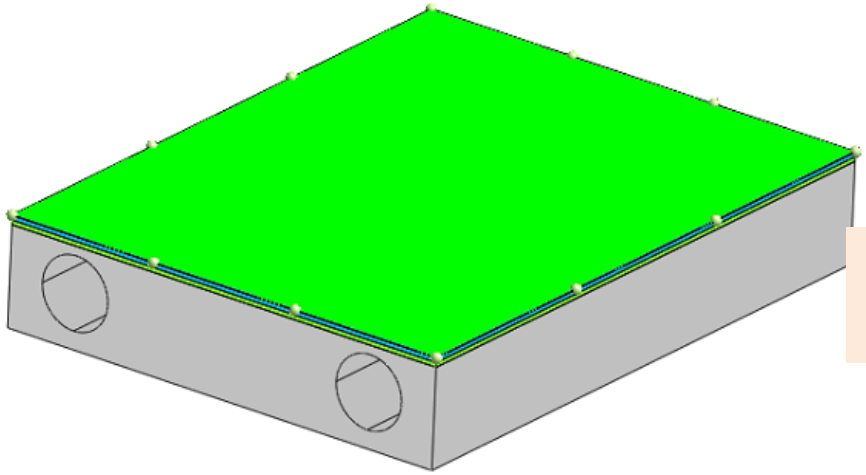


Channel
材質:SUS304

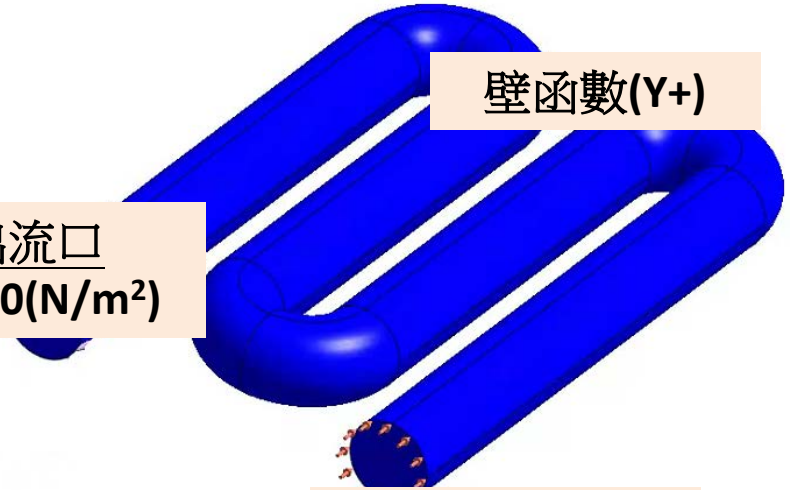
Glass
材質:Glass

分析說明-2

Glass表面
熱源-熱通量(0.005 W/mm^2)



流道
材質:水(Water)



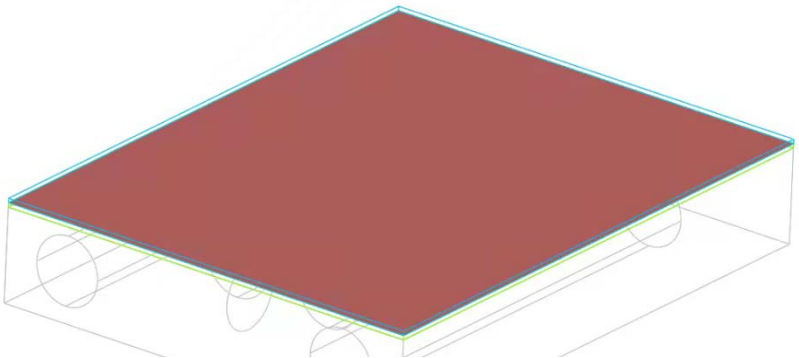
壁函數(Y+)

出流口
壓力0(N/m^2)

入流口
流速200(mm/sec)
溫度25(℃)

環境溫度25 (℃)
流體固體初始溫度:25 (℃)
空氣熱對流係數:5×10^{-6} (W/mm^2 ℃)

分析説明-3

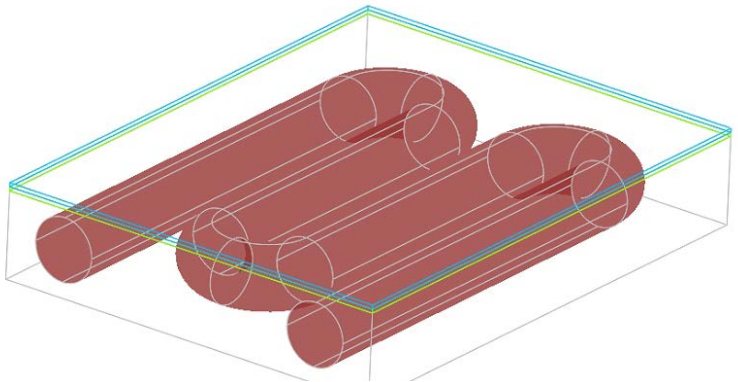


Thermal Resistance

(●) Value 1000 [T]·mm²/W

( ) Thermal Boundary Layer

[Notice] Thermal Boundary Layer can be used only for Fluid-Solid contact type.



Thermal Resistance

( ) Value 1000 [T]·mm²/W

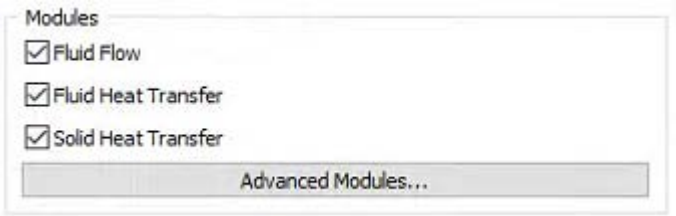
(●) Thermal Boundary Layer

[Notice] Thermal Boundary Layer can be used only for Fluid-Solid contact type.

分析說明-4

熱對流計算
方式一 直接法

流場+熱場同時計算



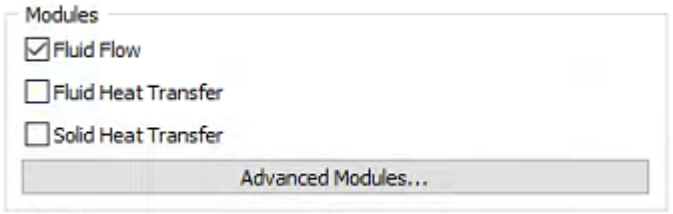
分析結果接近實際情況!!

1.計算所需時間長

2.相對不穩定,對於網格品質要求較高

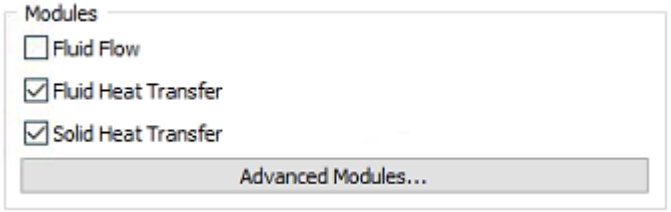
熱對流計算
方式二 間接法

Step1. 流場計算



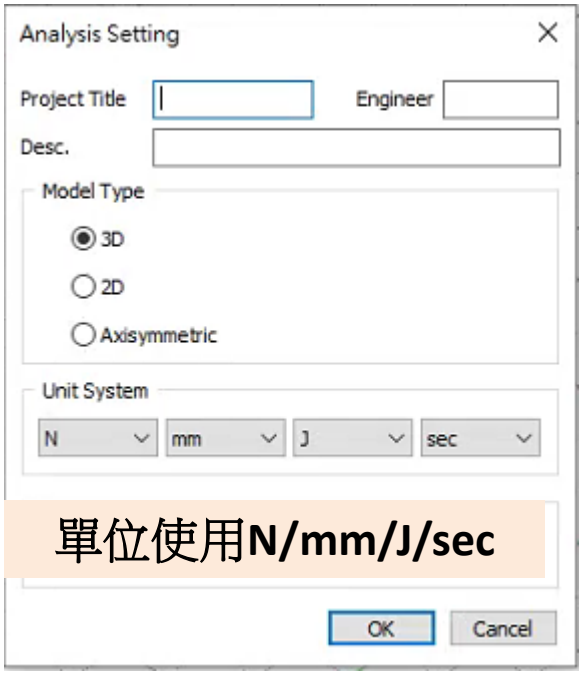
重啓動文件 ***.rst**

Step2.流體/固體熱傳計算

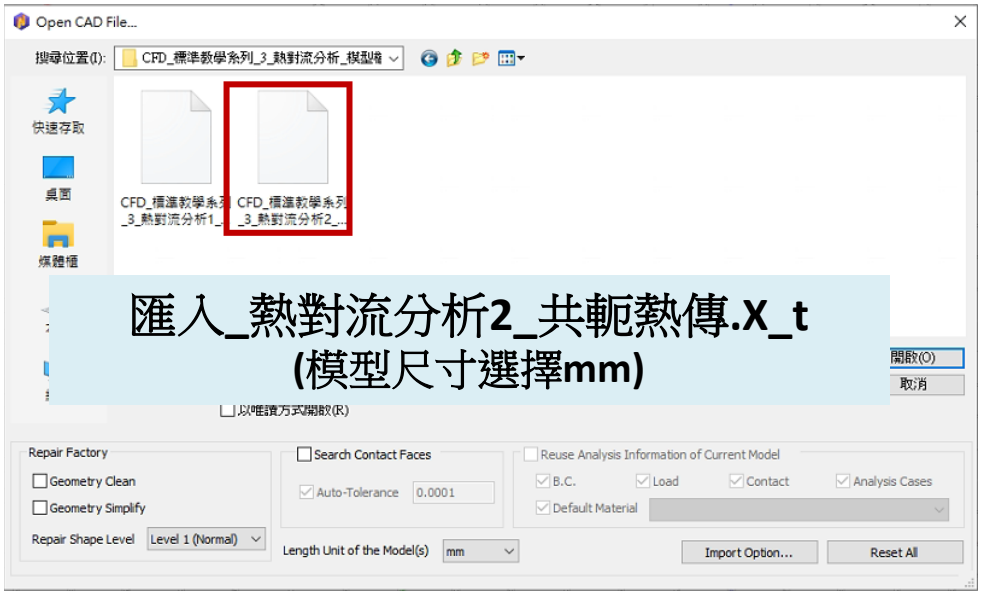


計算效率高!!

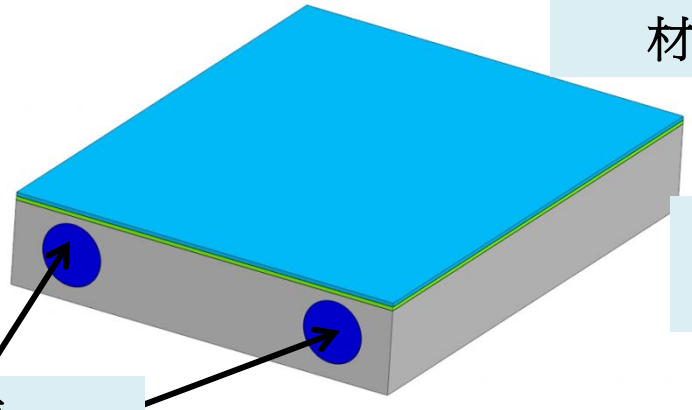
環境 &模型匯入



單位使用N/mm/J/sec



匯入_熱對流分析2_共軛熱傳.X_t
(模型尺寸選擇mm)



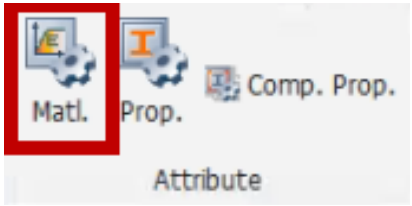
Glass
材質:Glass

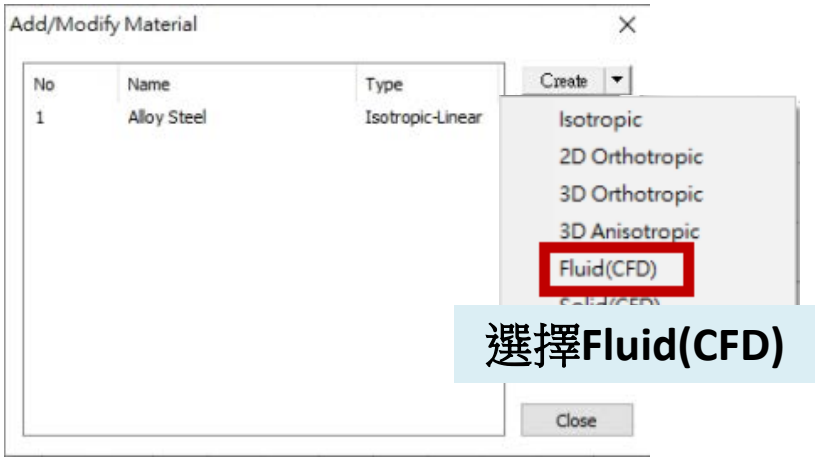
Thermal Pad
材質: ZIRCONIUM

流道
材質:Water

Channel
材質:SUS304

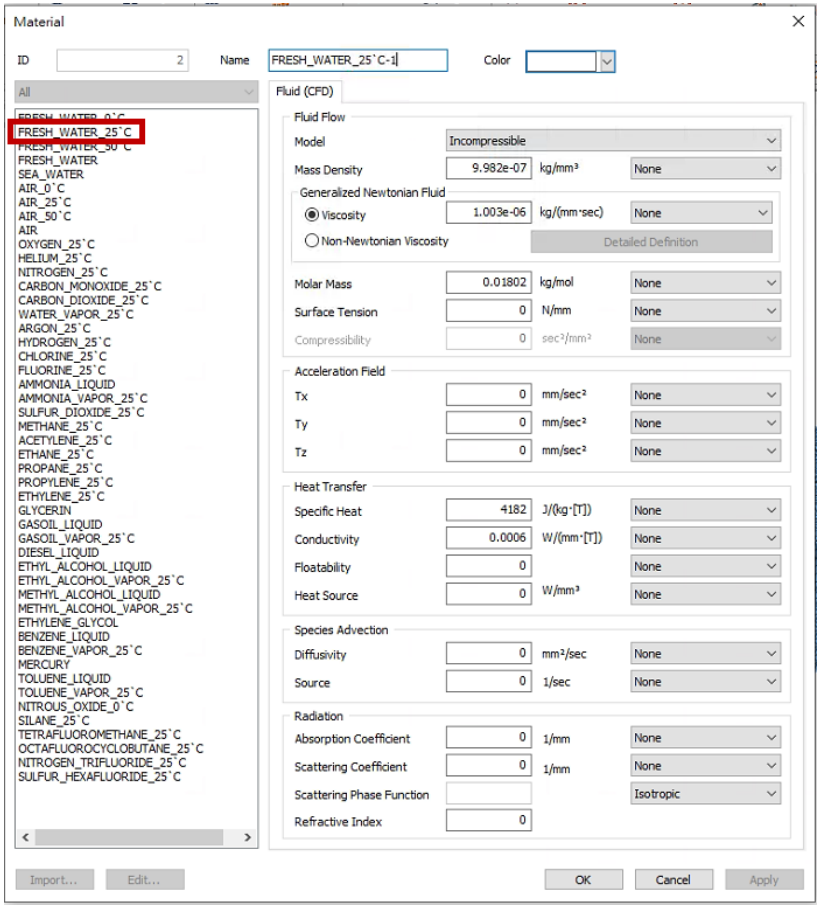
材料-流體(CFD)



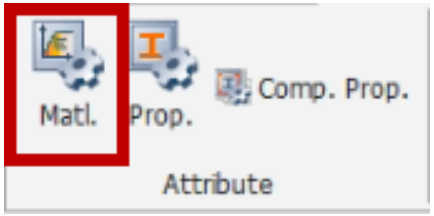


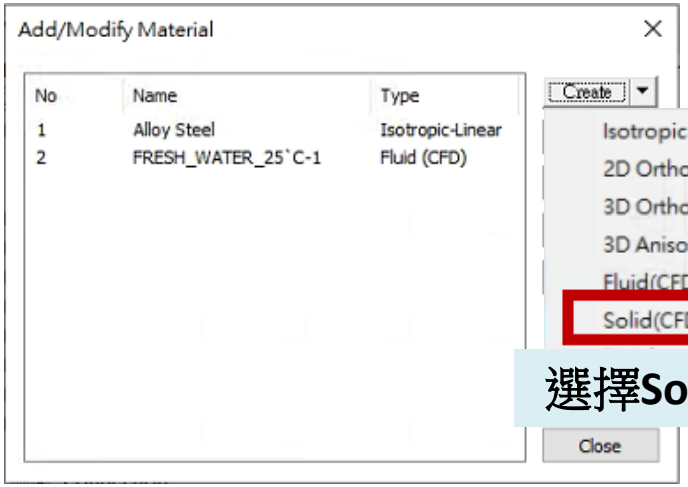
選擇Fluid(CFD)

新增WATER 25 ℃

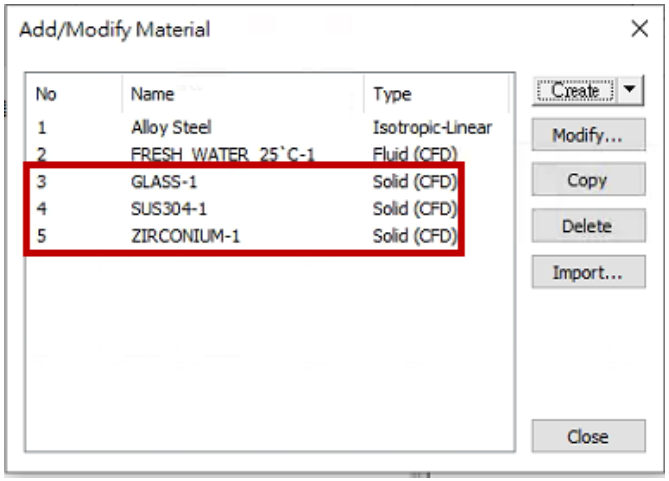


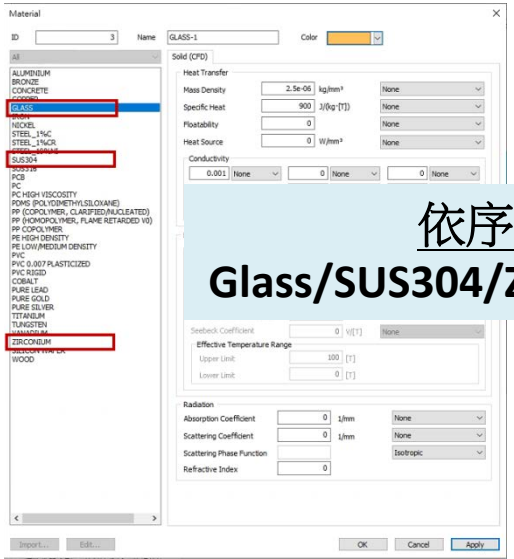
材料-固體(CFD)





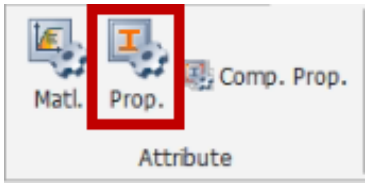
選擇Solid(CFD)



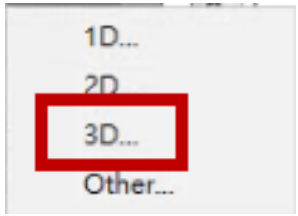


依序新增
Glass/SUS304/ZIRCONIUM(鋯)

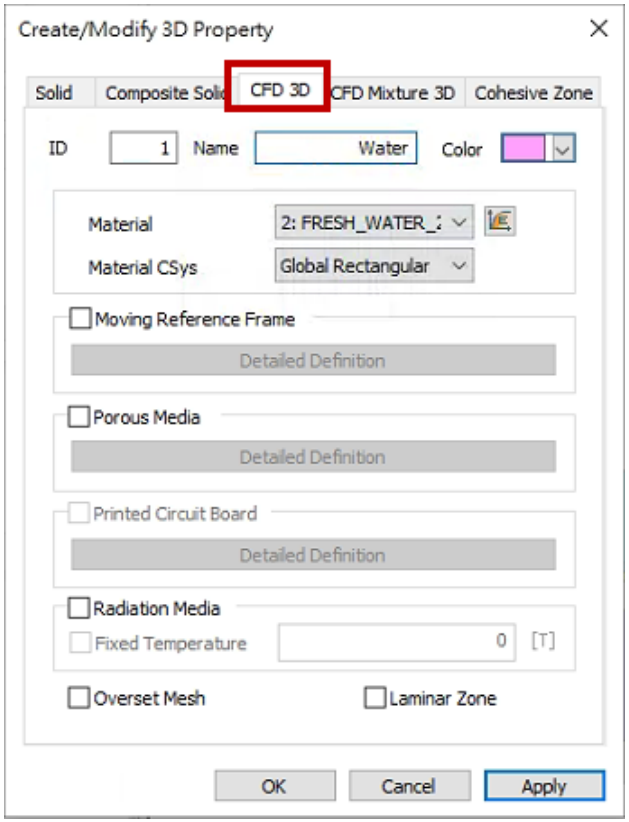
屬性

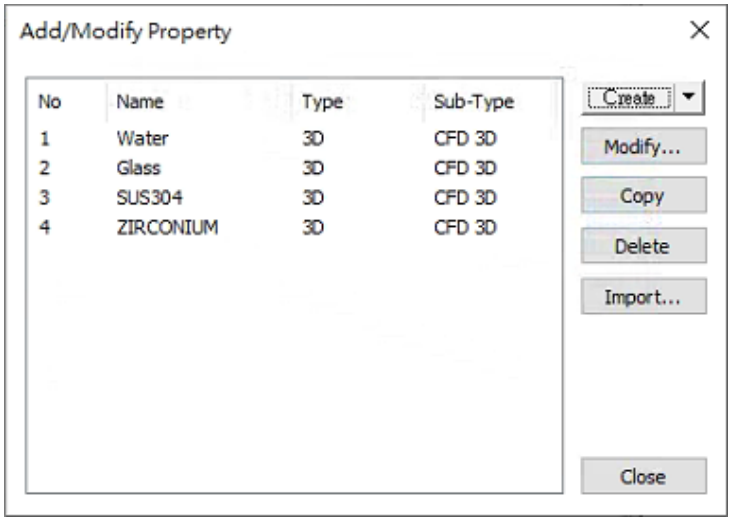


依序新增CFD 3D屬性
Water/Glass/SUS304/ZIRCONIUM(鋯)

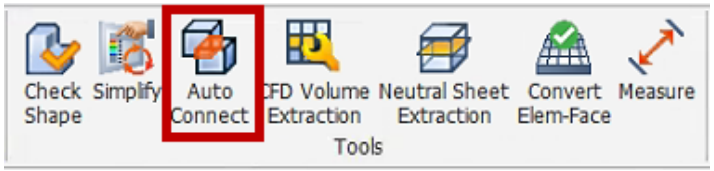


屬性選取Solid

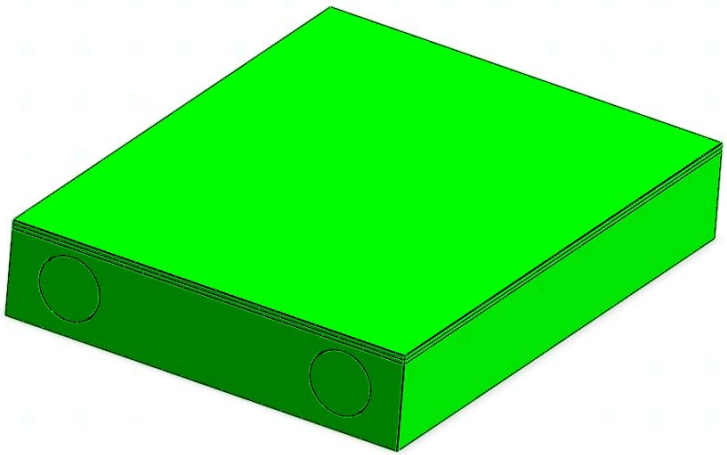


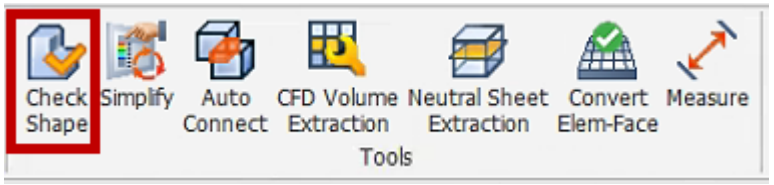


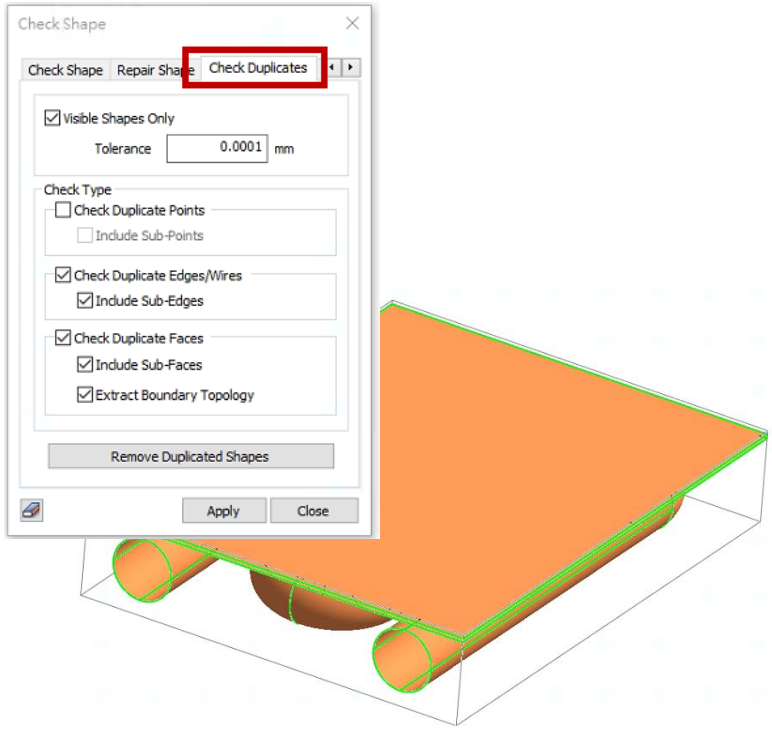
相鄰面特徵建立&確認



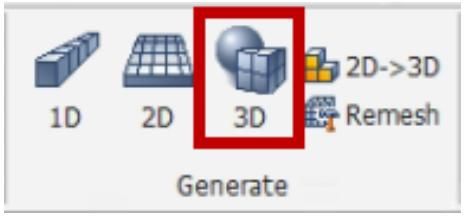
選取所有幾何特徵



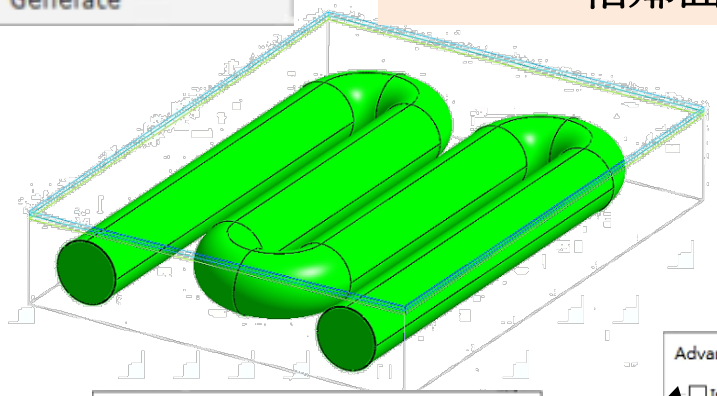


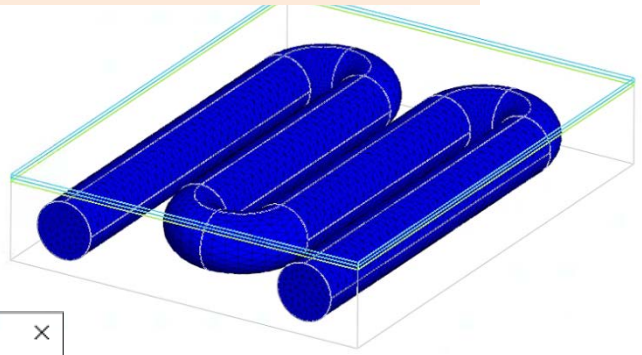


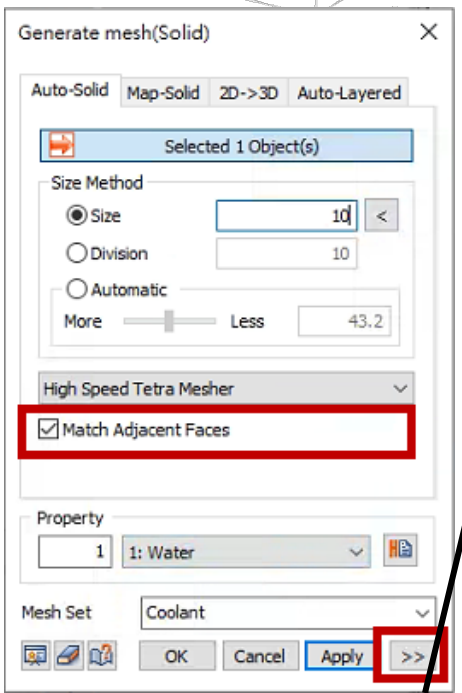
3D網格-流體區域

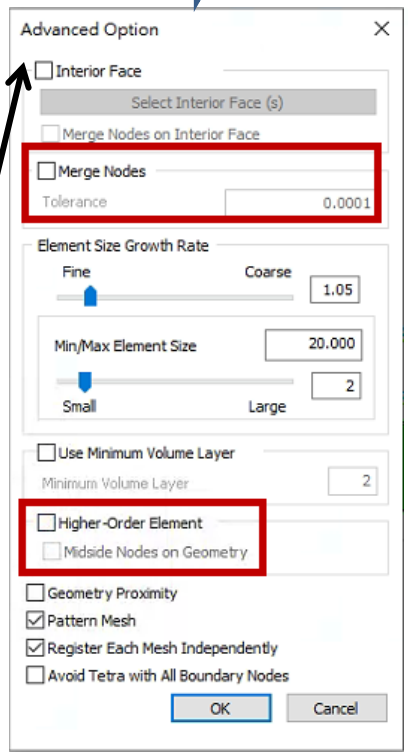


屬性:Water
Tetra Mesher(四面體網格)/網格尺寸10(mm)
相鄰面特徵/1階元素/節點不相連

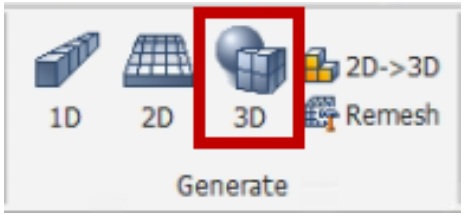




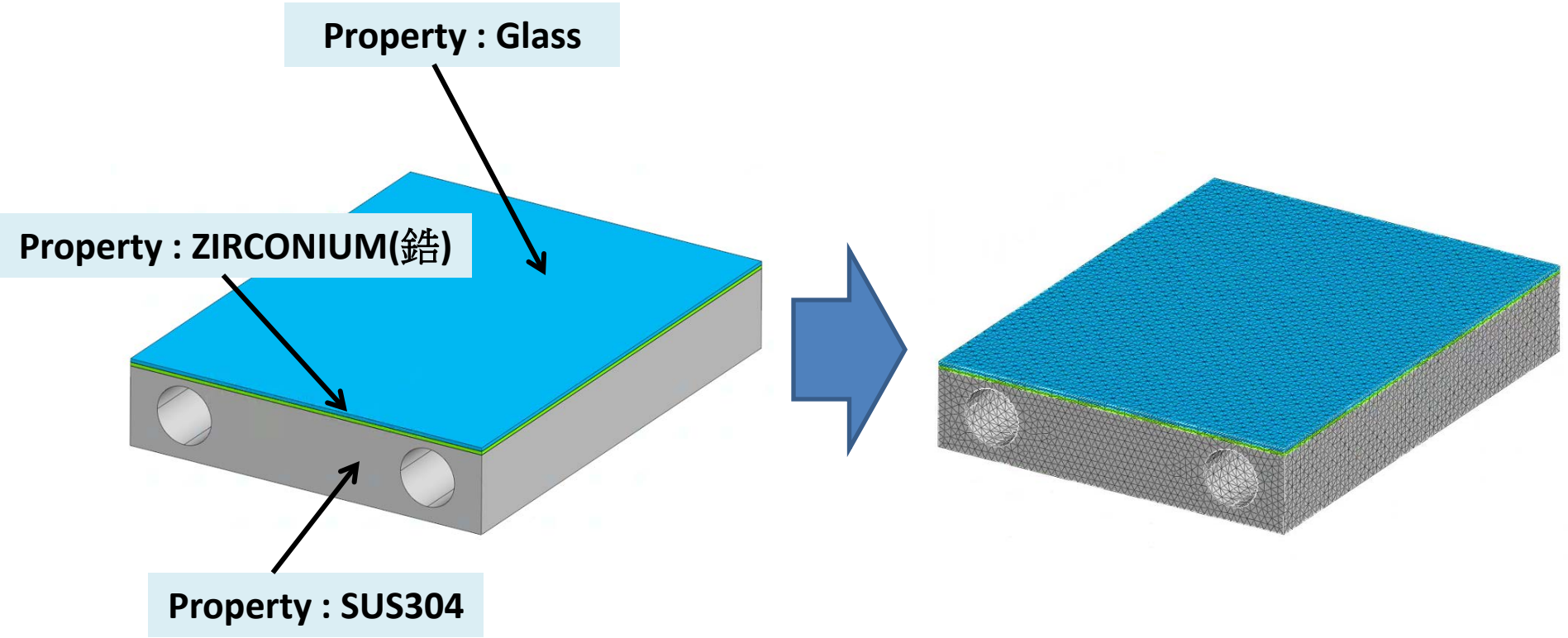




3D網格-固體區域



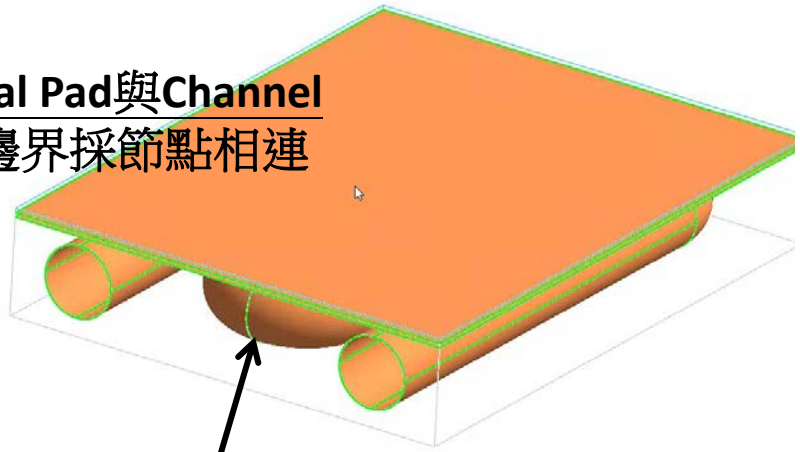
Tetra Mesher(四面體網格)/網格尺寸10(mm)
相鄰面特徵/1階元素/節點不相連



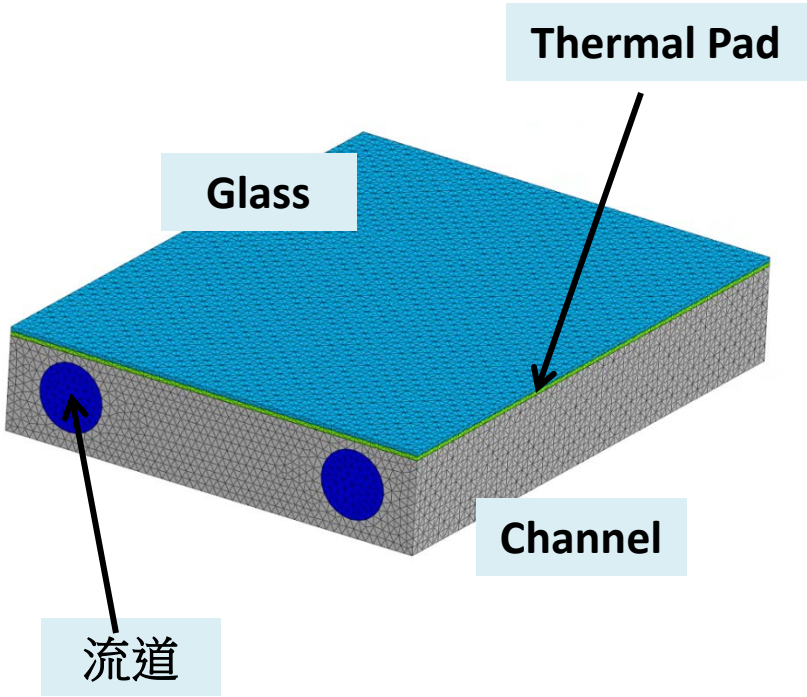
連接方式說明

Glass與Thermal Pad
相鄰邊界採接觸定義

Thermal Pad與Channel
相鄰邊界採節點相連

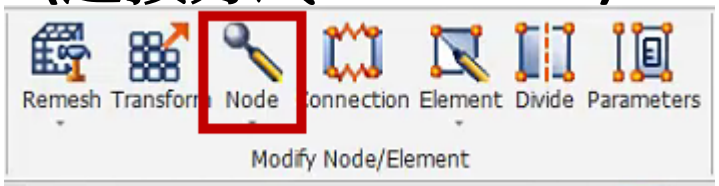


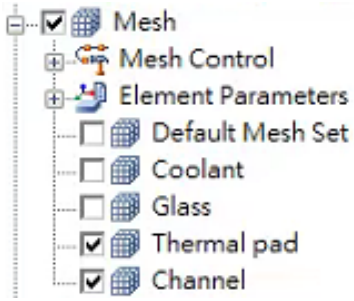
流道與Channel
相鄰邊界採接觸定義

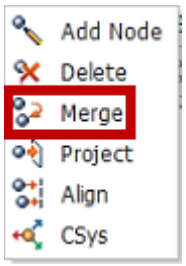


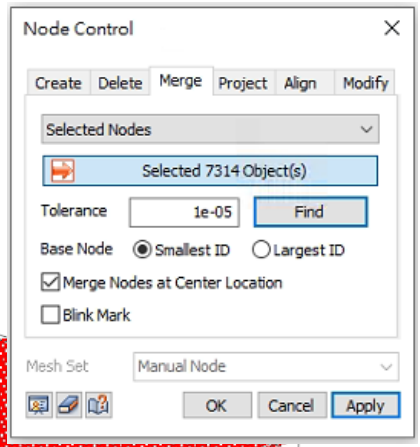
合併節點

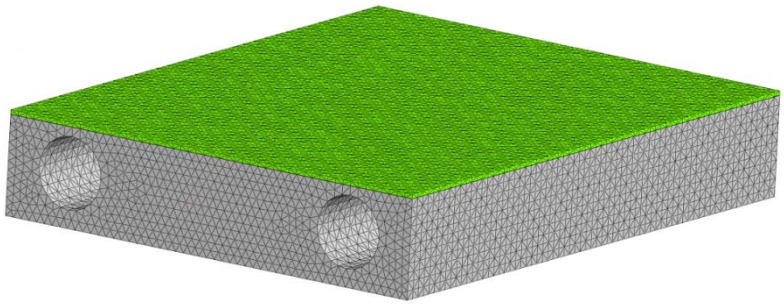
(連接方式Solid-Solid)

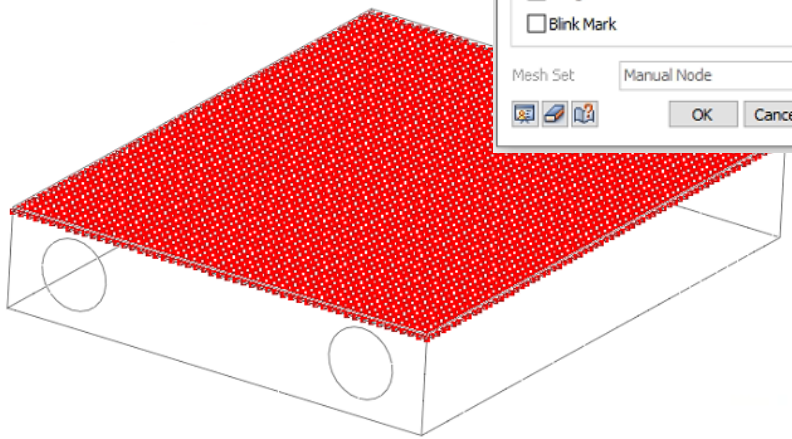








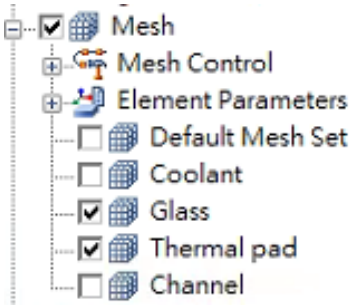


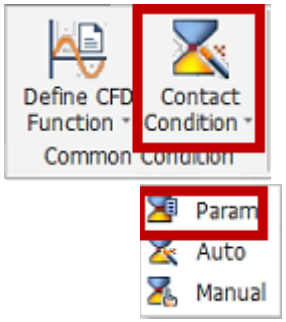


只顯示Thermal Pad和Channel網格集

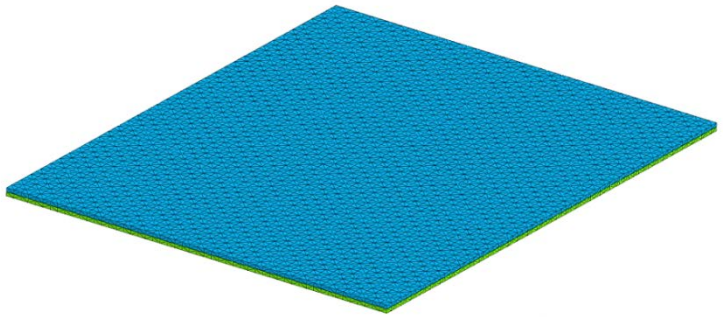
CFD接觸定義-1

(連接方式Solid-Solid)

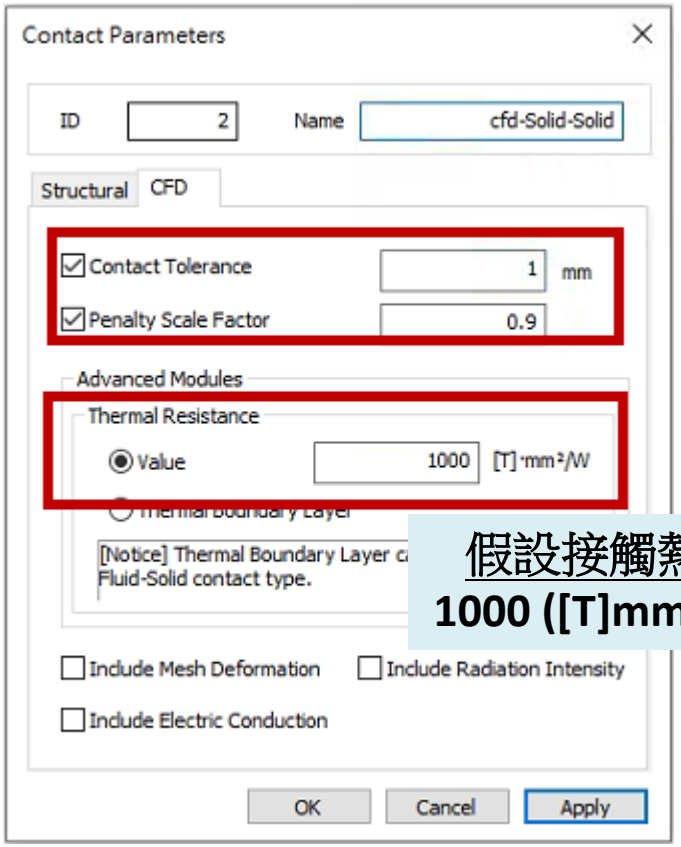




接觸間隙和懲罰函數
=>分析數值計算過程穩定



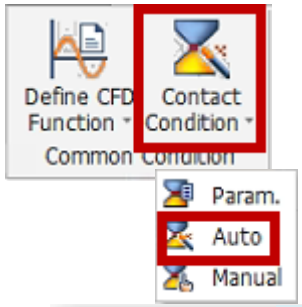
只顯示Glass和Thermal Pad網格集



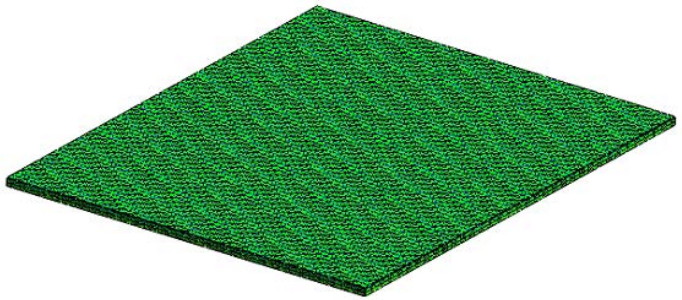
假設接觸熱阻
1000 ([T]mm²/W)

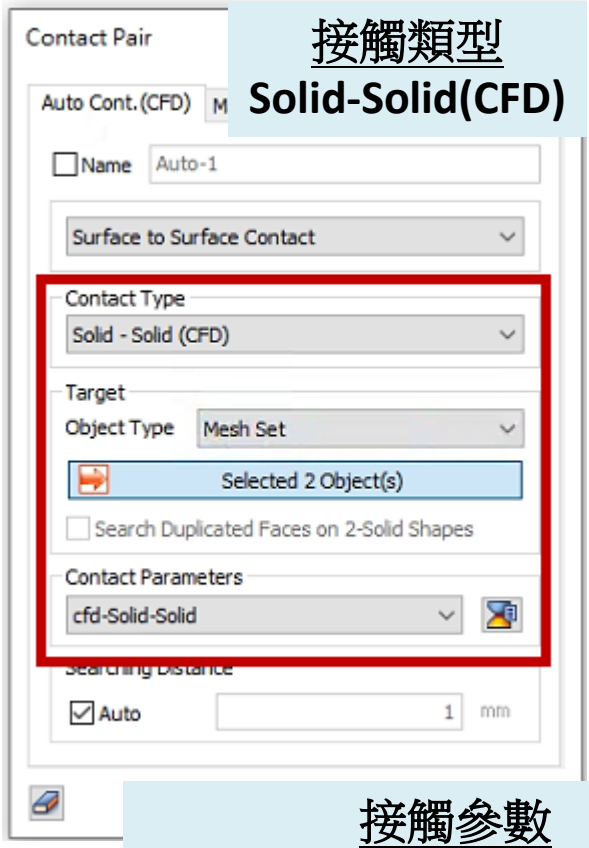
CFD接觸定義-2

(連接方式Solid-Solid)



選擇Glass和Thermal Pad網格集

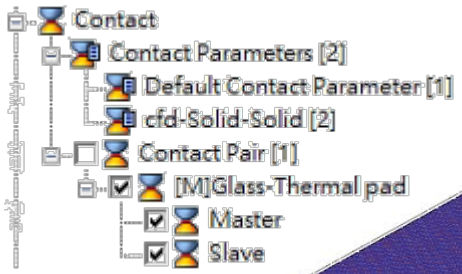


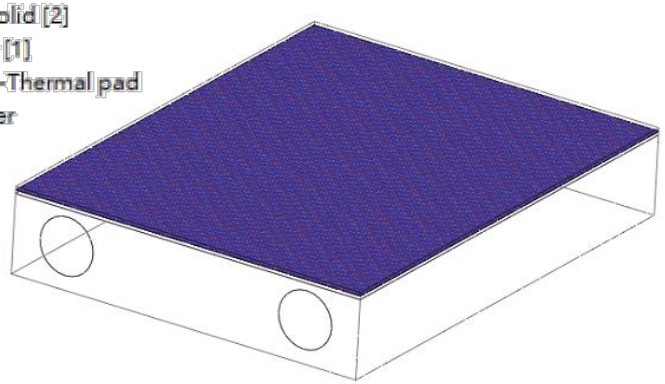


接觸類型
Solid-Solid(CFD)

接觸參數
指定CFD-Solid-Solid(上頁操作)

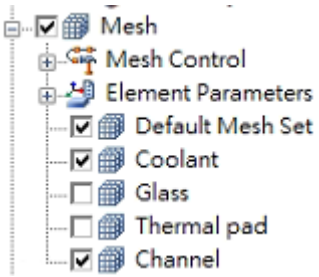
接觸對檢視

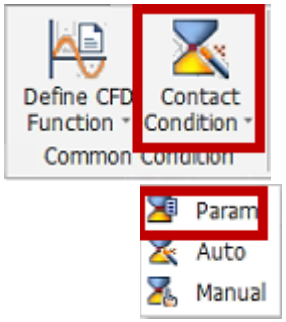




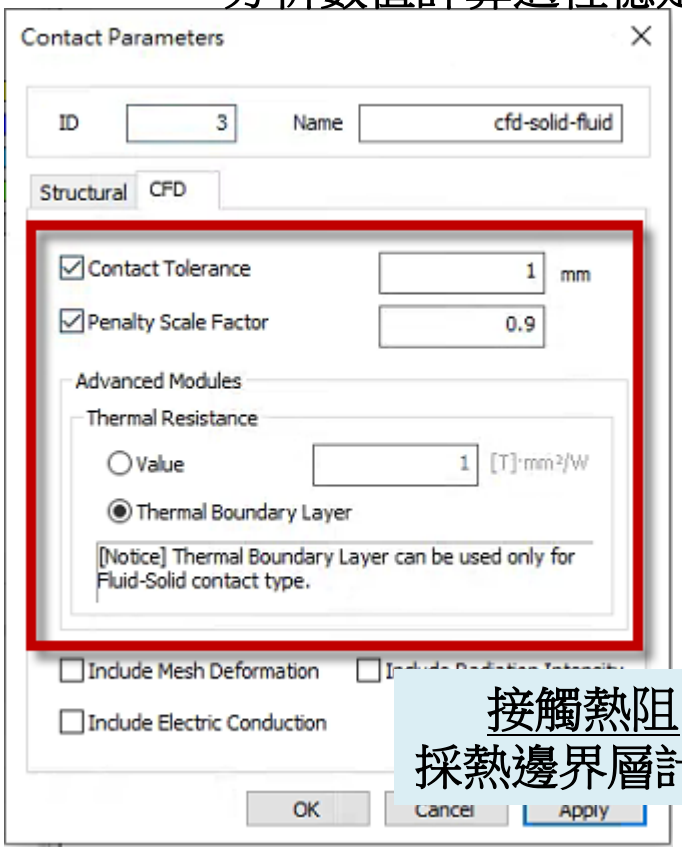
CFD接觸定義-3

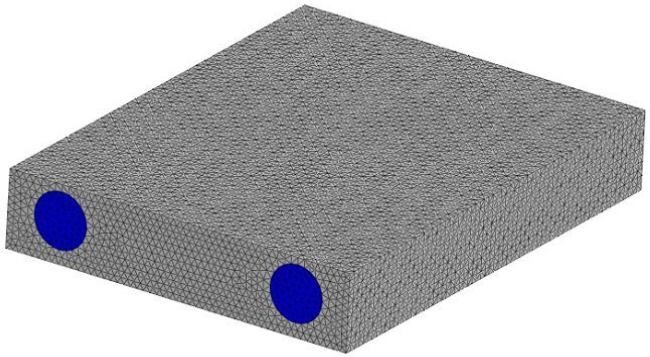
(連接方式Solid-Fluid)





接觸間隙和懲罰函數
=>分析數值計算過程穩定





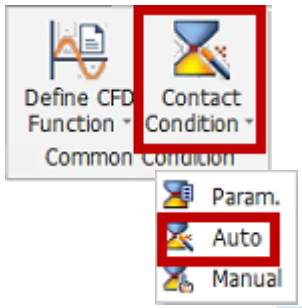
只顯示Coolant和Channel網格集

接觸熱阻
採熱邊界層計算

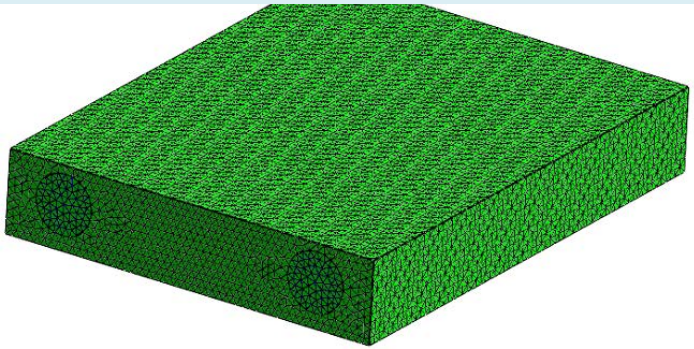
midas NFX-CFD

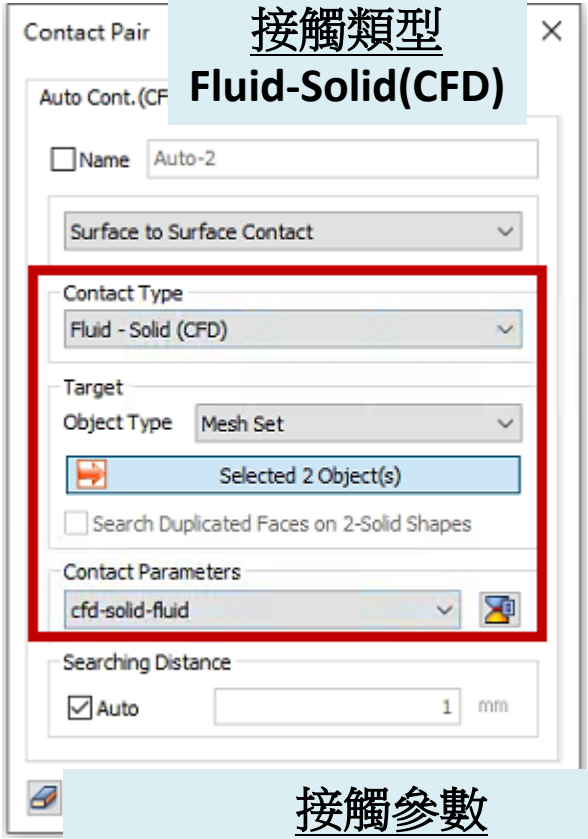
CFD接觸定義-4

(連接方式Solid-Fluid)

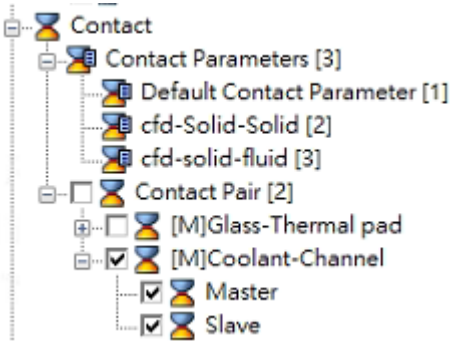


選擇Coolant和Channel網格集

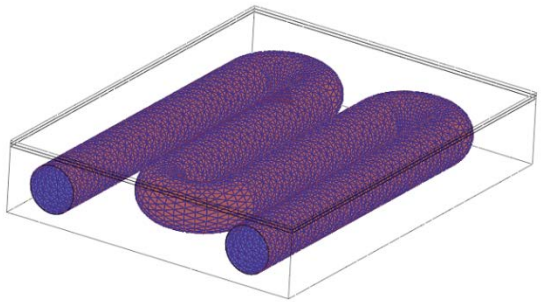




接觸類型
Fluid-Solid(CFD)

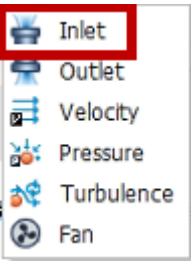


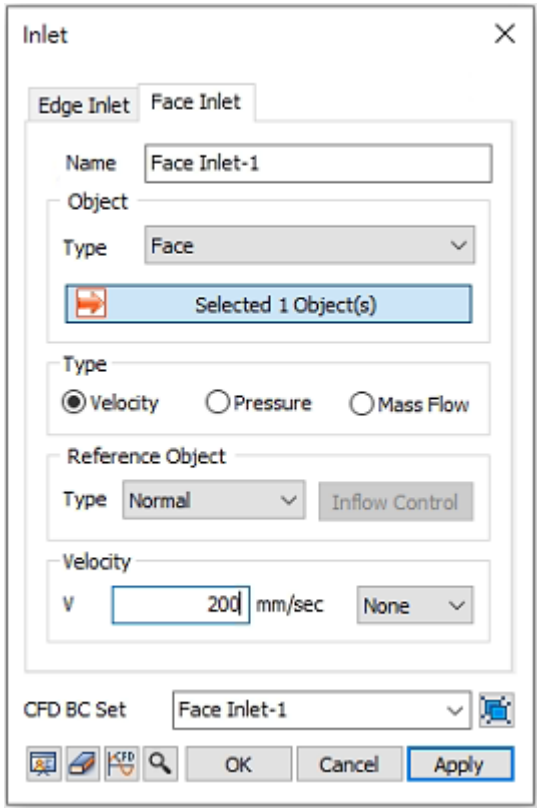
接觸對檢視



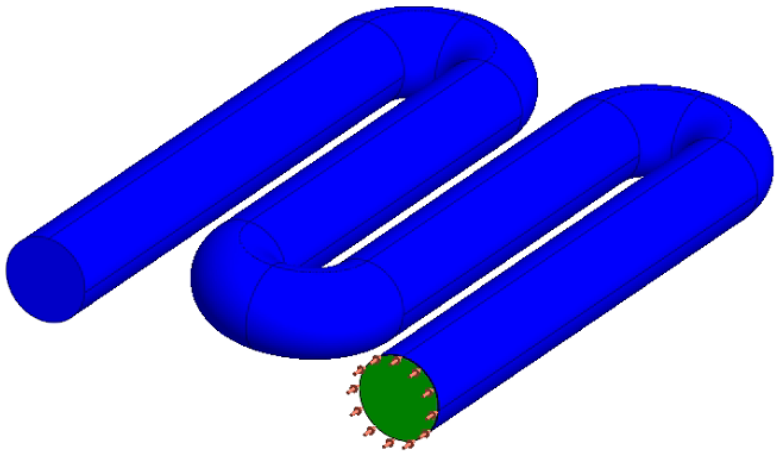
接觸參數
指定CFD-solid-fluid(上頁操作)

入流

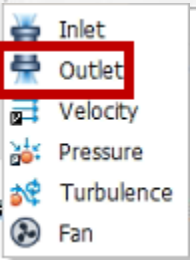


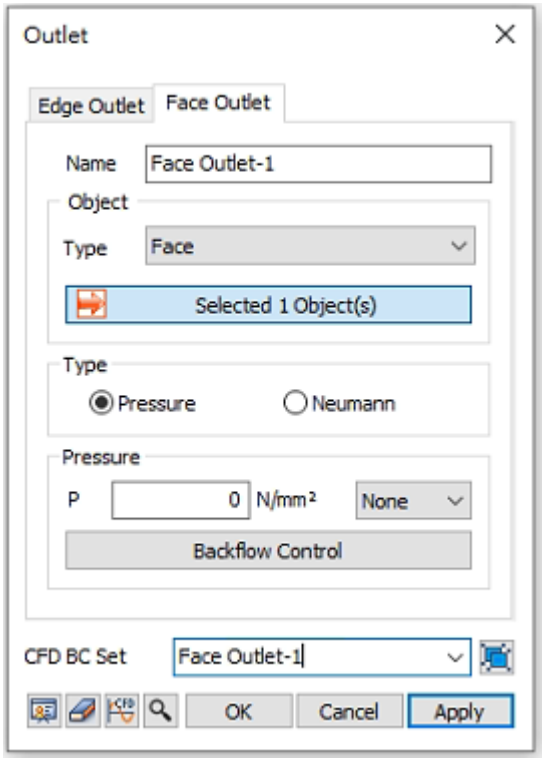


입류口=200(mm/sec)

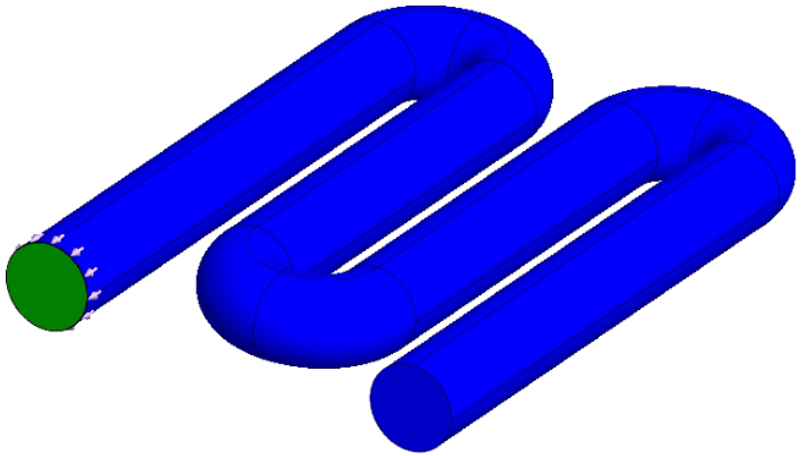


出流



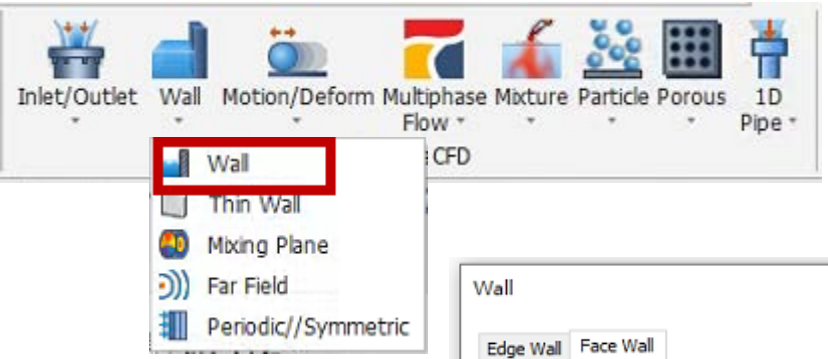


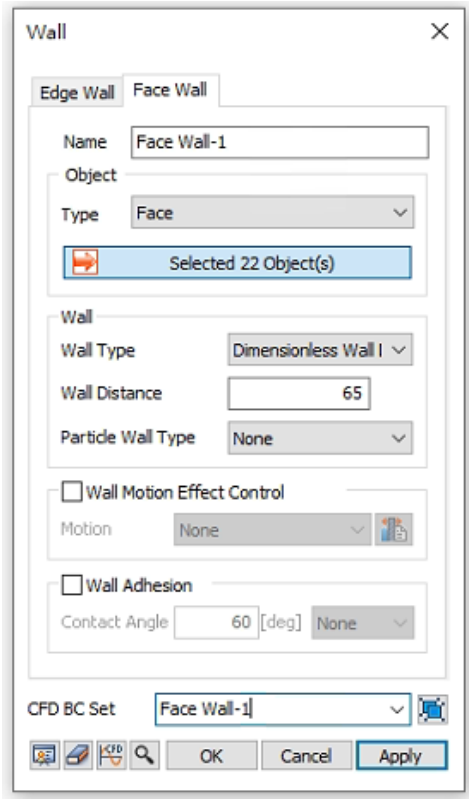
壓力0(N/m²)



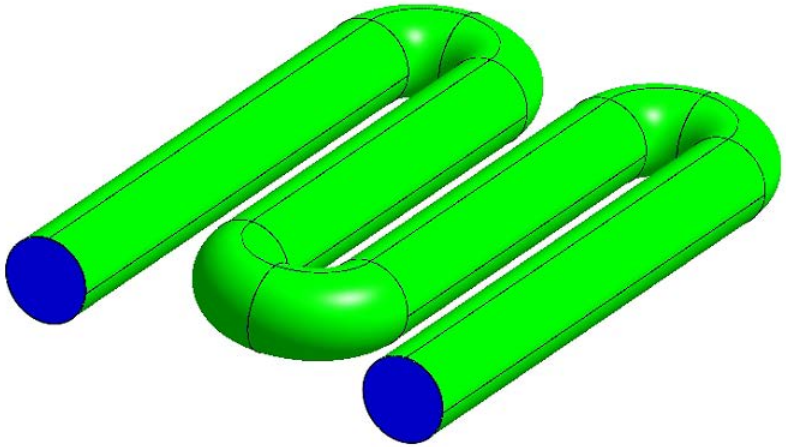
註:不同邊界&載荷建議使用不同集合名稱。

壁函數
(Dimensionless Wall Applied)





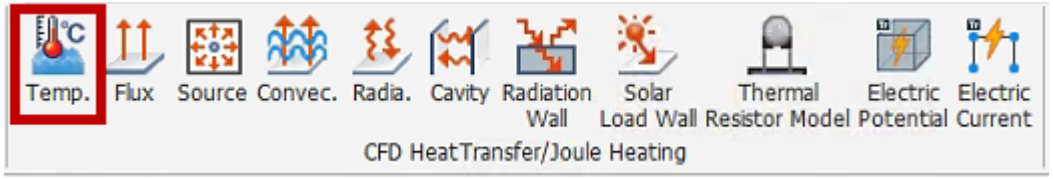
選取有流道區域特徵
(不包含入出流口)

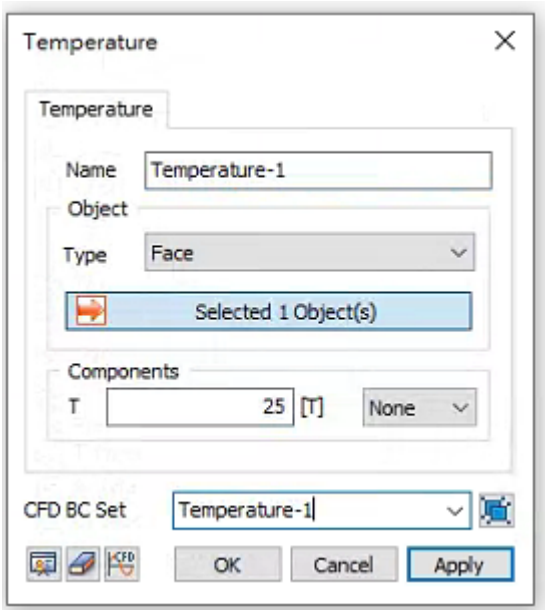


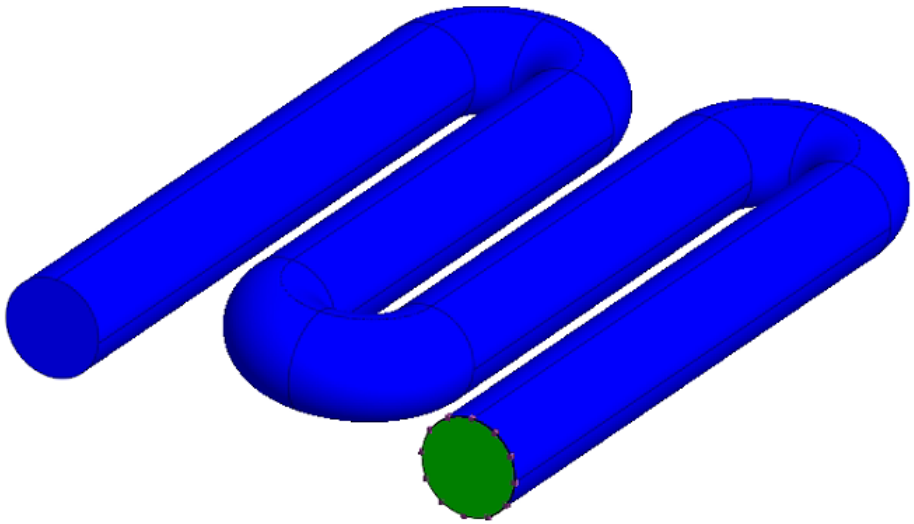
壁函數(Dimensionless Wall Applied)
Y+=65

註:壁函數施加在流體特徵與固體接觸區域。

入流溫度

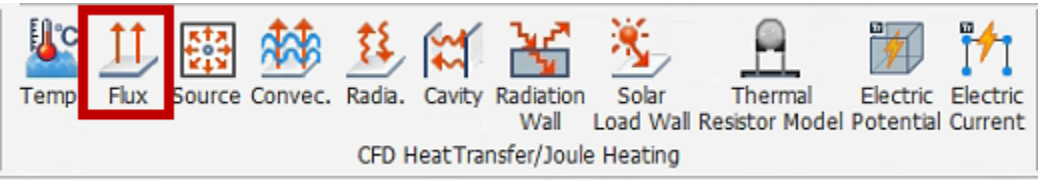


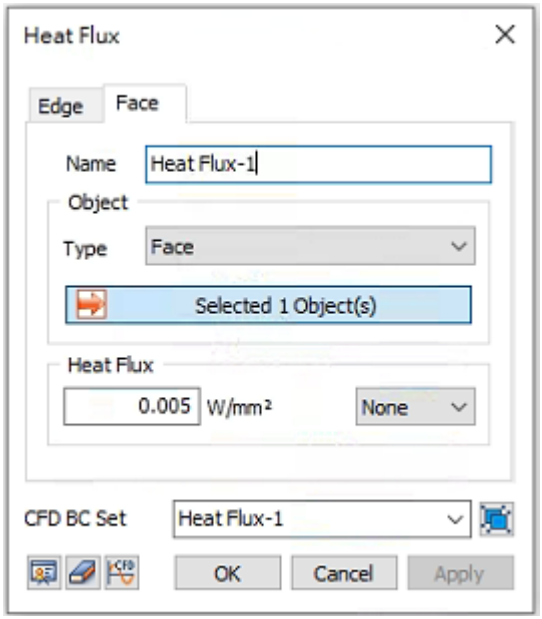




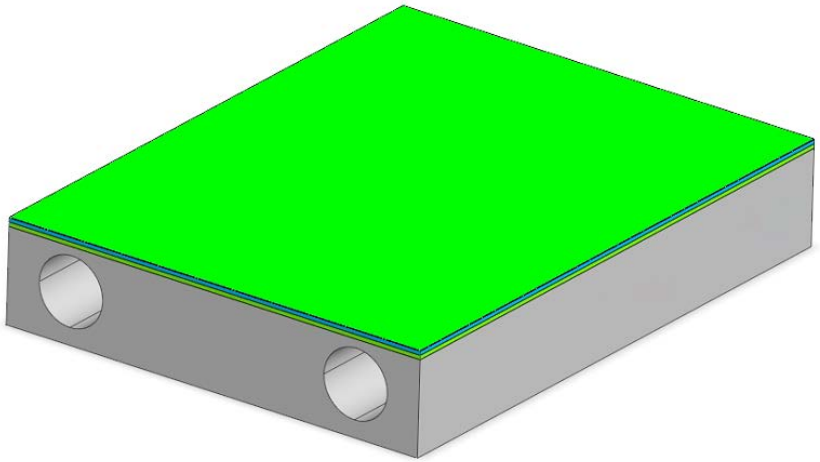
입流口水溫度(25 ℃)

熱通量

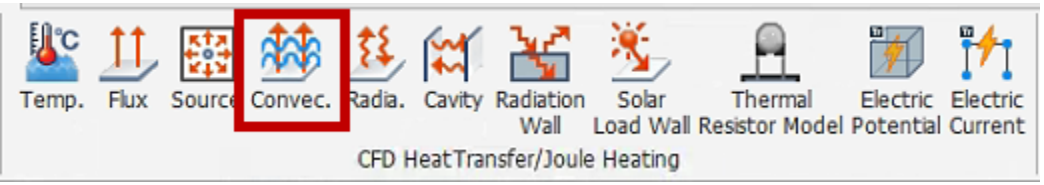


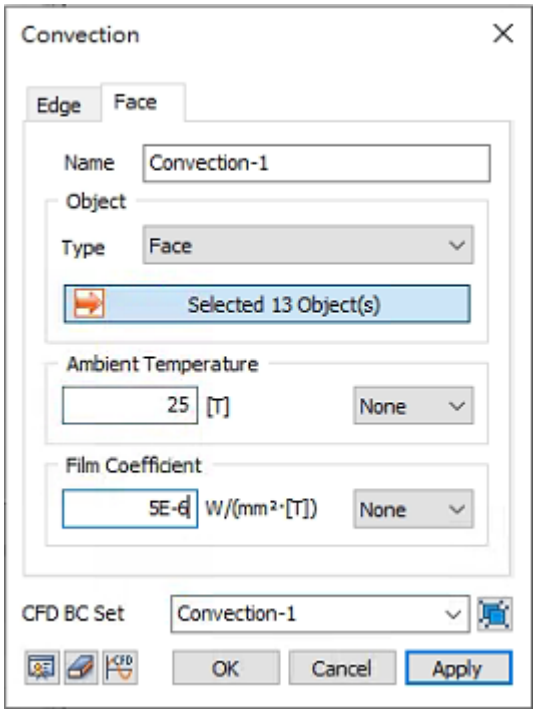


Glass上表面(0.005W/mm^2)



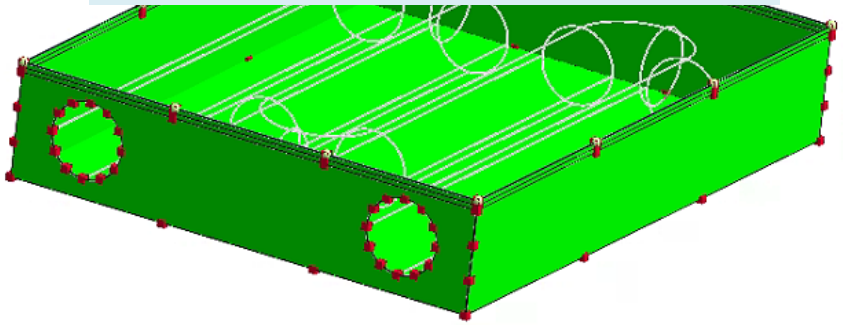
熱對流





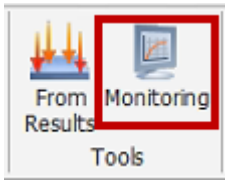
環境溫度:25
熱對流係數:5×10^{-6} (W/mm^2 ℃)

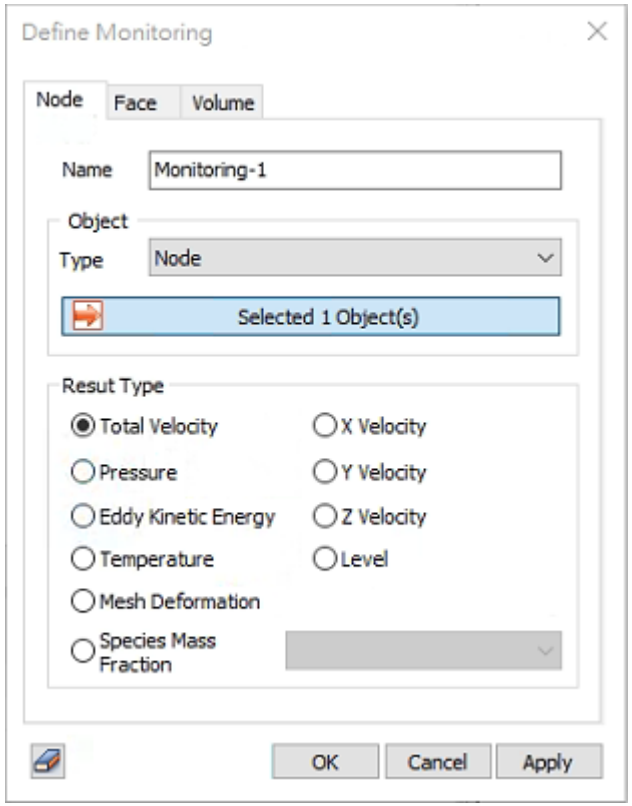
施加在空氣與結構接觸特徵
(不包含熱通量施加區域)



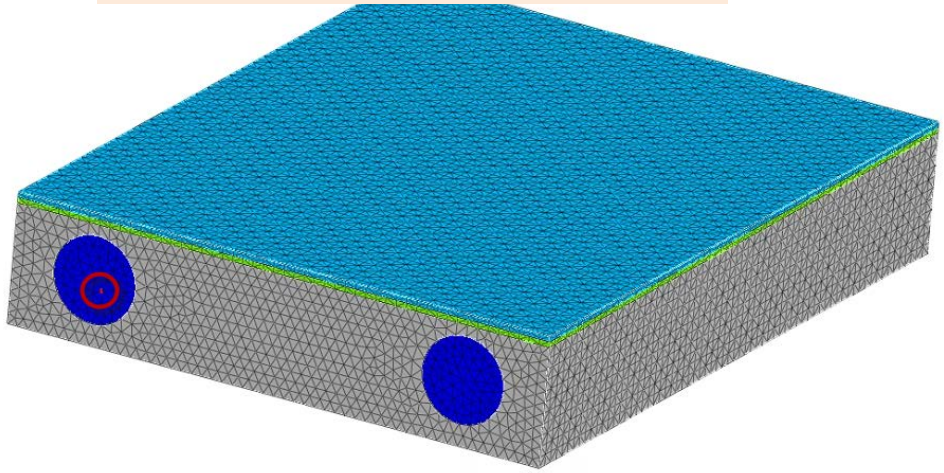
一般空氣熱對流係數
1.自然對流: 3×10^{-6} ~ 12×10^{-6} (W/mm^2 ℃)
2.強制對流: 10×10^{-6} ~ 100×10^{-6} (W/mm^2 ℃)

觀測點-流速



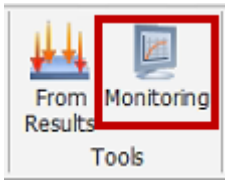


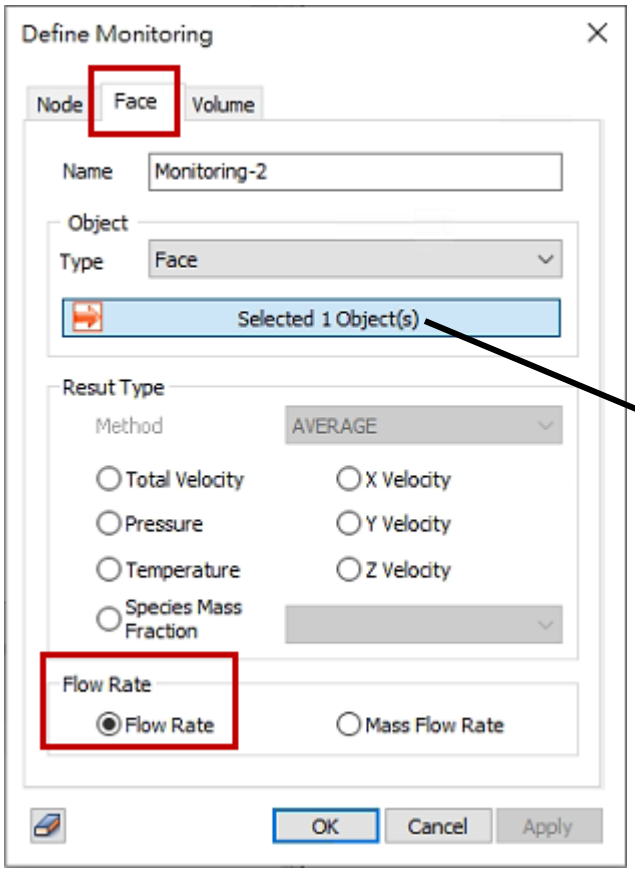
選取出流口節點觀測流速



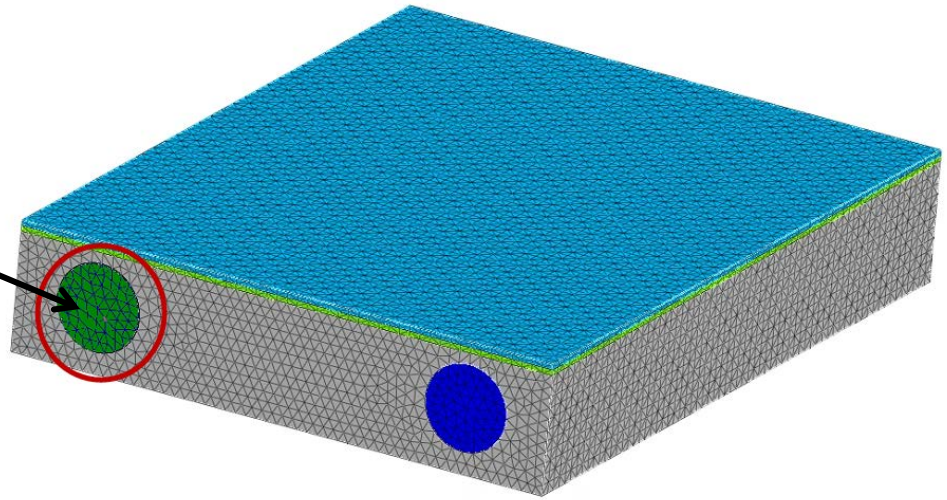
註:輸出特定節點數據同時能協助判斷收斂穩定

觀測面-流量



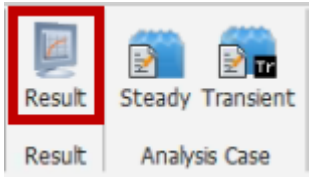


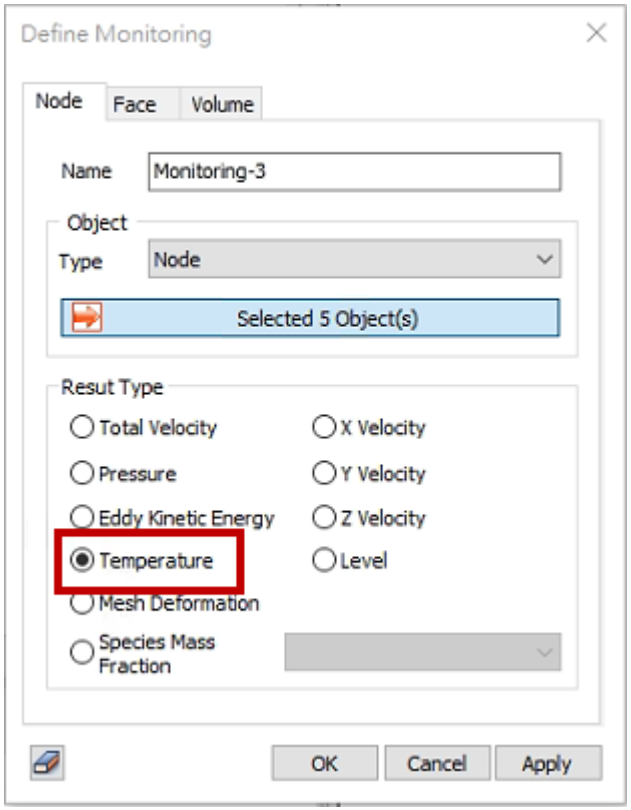
選取出流口特徵面觀測流量



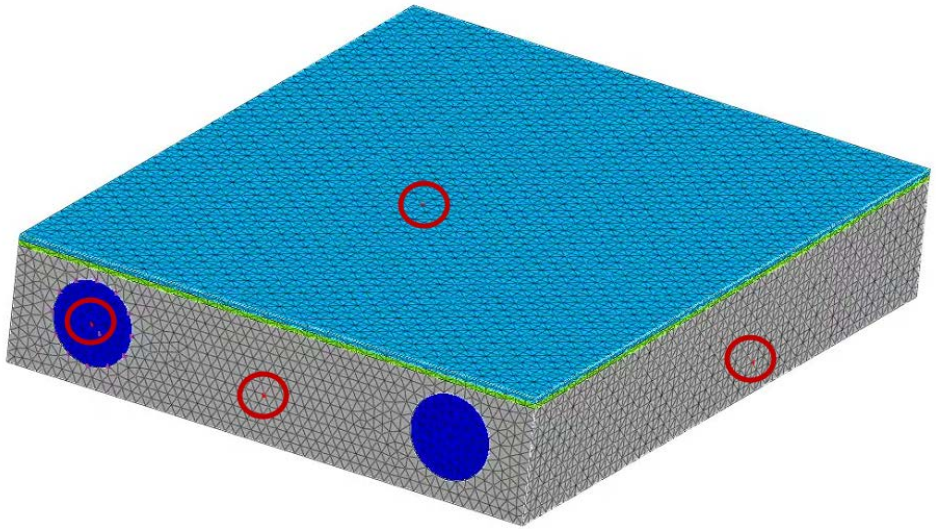
註:輸出出流口流量,同時能協助判斷收斂穩定

觀測點-溫度





選取各部區域節點觀測溫度



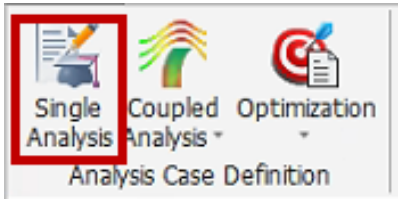
註:輸出特定節點數據同時能協助判斷收斂穩定

共軛熱傳&熱對流

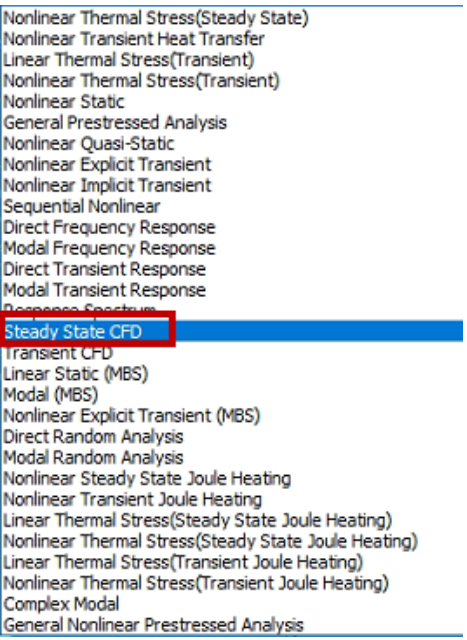
(直接法)

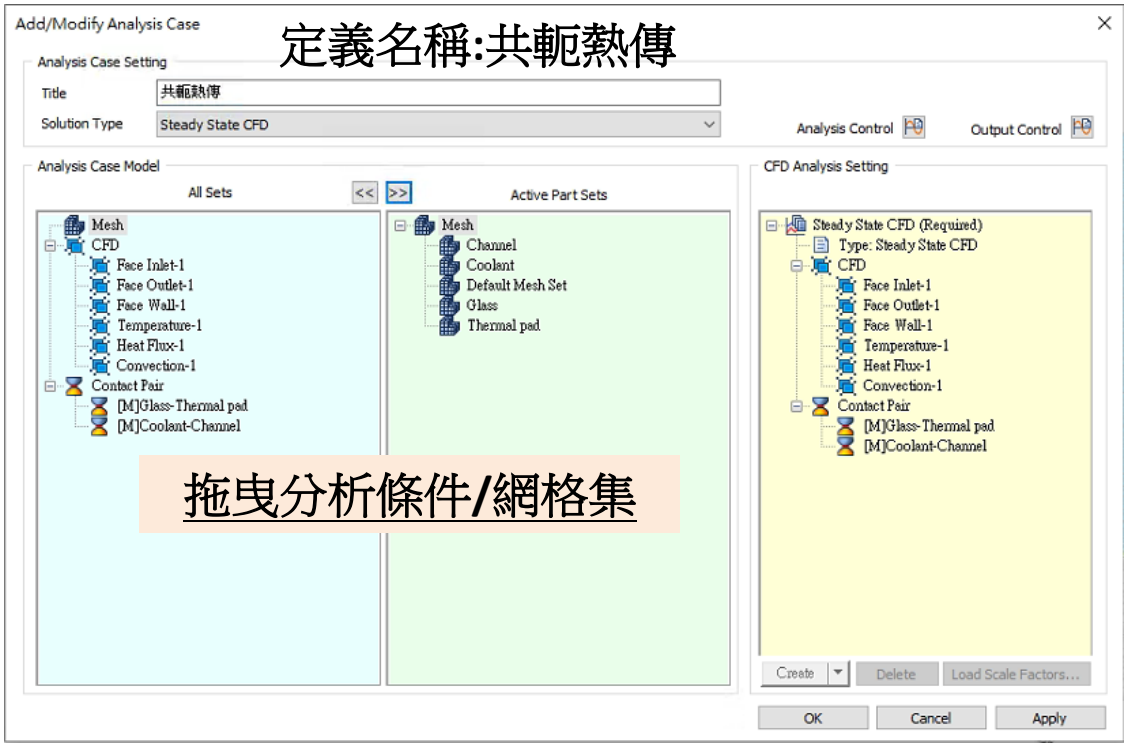
midas NFX-CFD

共軛熱傳&熱對流-1



Solution Type : Steady State CFD





MIDAS

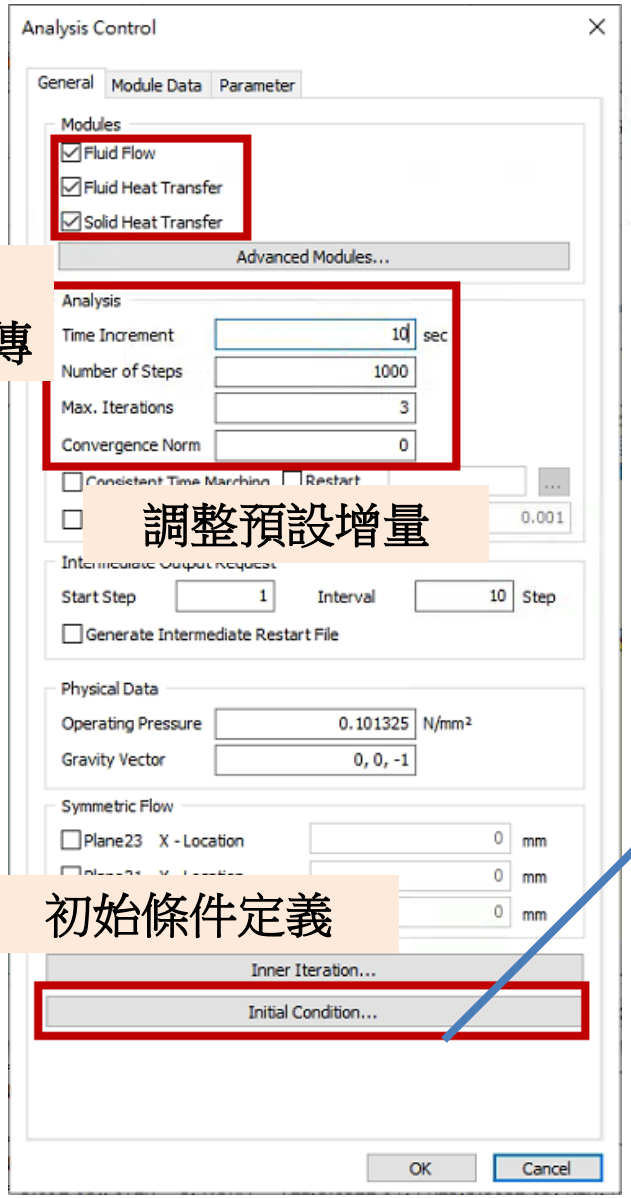
midas NFX-CFD

共軛熱傳&熱對流-2

Analysis Control | Output Control

分析工況定義

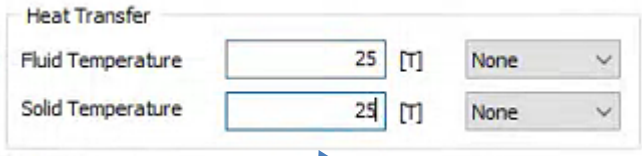
分析模組勾選
流體流動/流體熱傳/固體熱傳

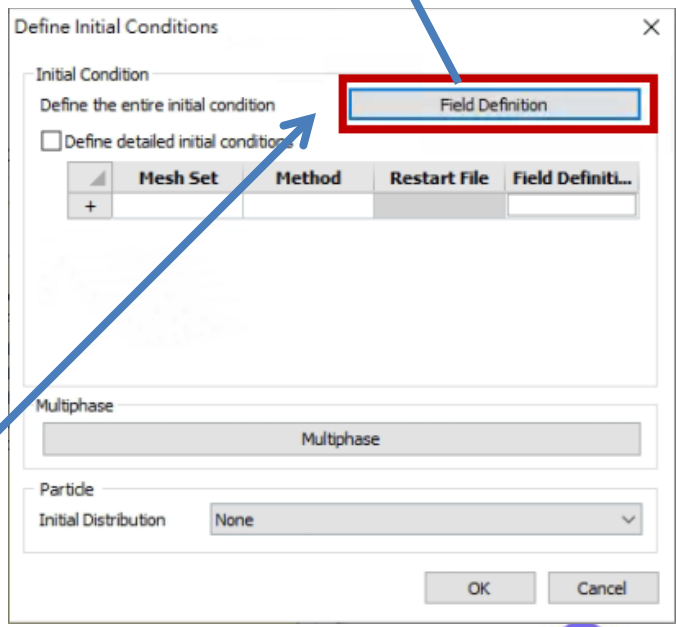


調整預設增量

初始條件定義

初始溫度25 ℃

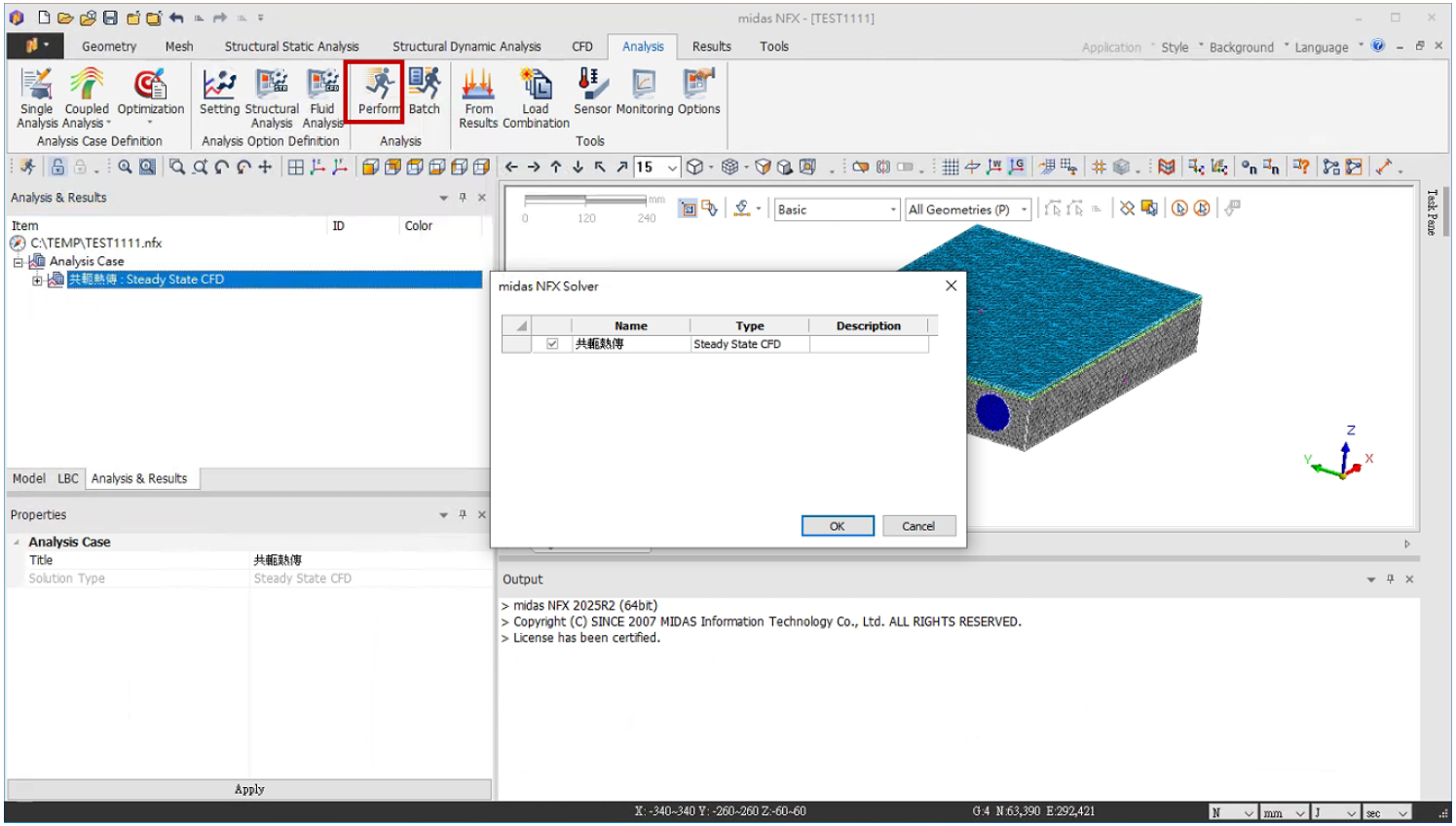




MIDAS

執行計算-1

(共軛熱傳&熱對流)

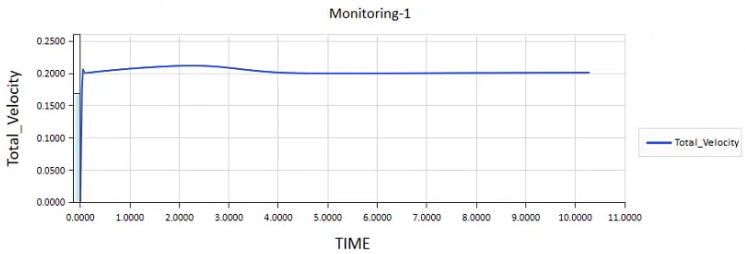


執行計算-2

(共軛熱傳&熱對流)

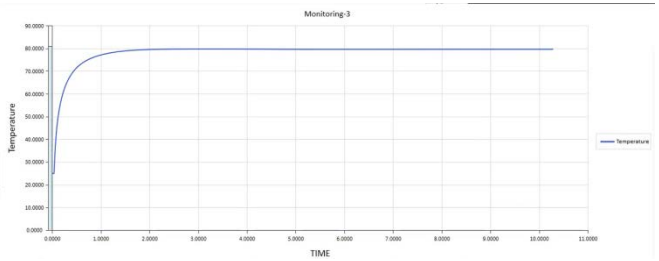
觀測點判斷是否終止計算

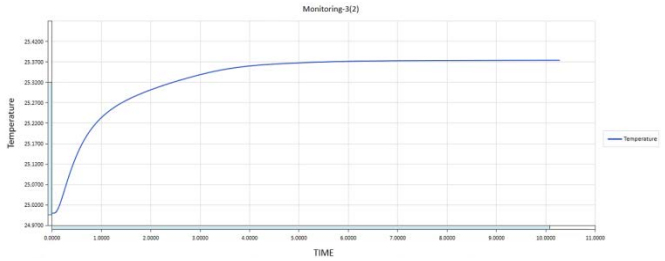
觀測節點-流速 (趨於定值)

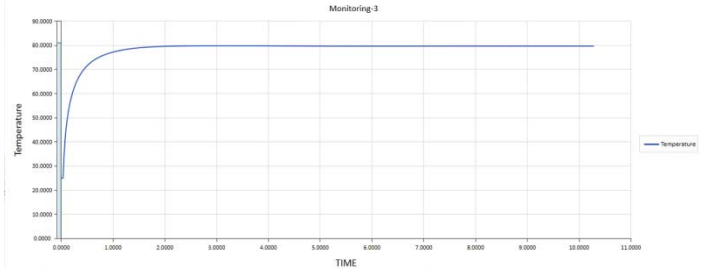


觀測面-出流口流量 (趨於定值)

觀測節點-溫度 (趨於定值)



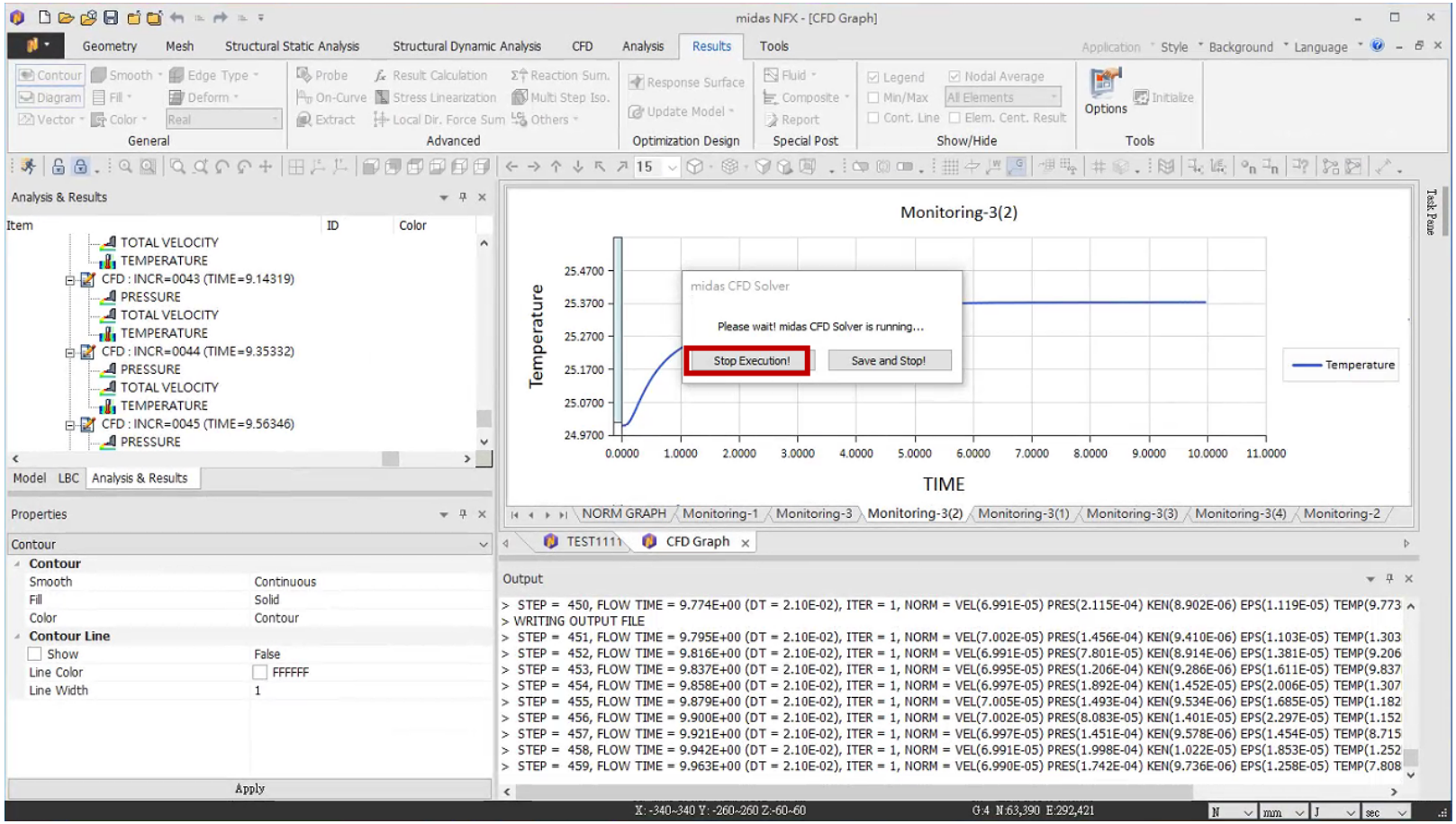




註:流量負值代表流出/正值代表流入

執行計算-2

(共軛熱傳&熱對流)



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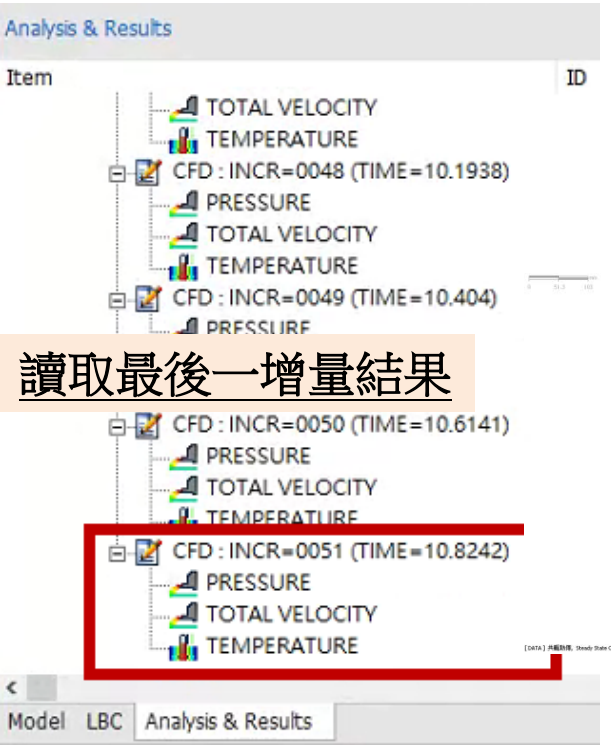
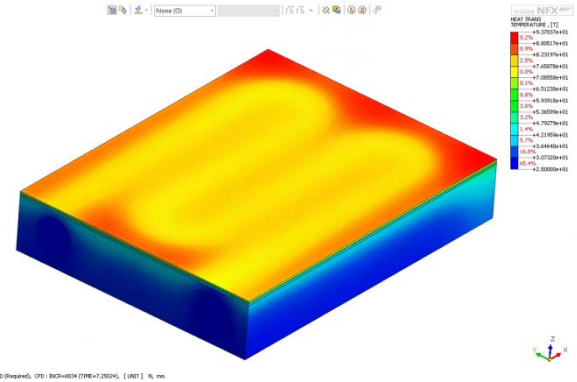
分析結果-1

(共軛熱傳&熱對流)

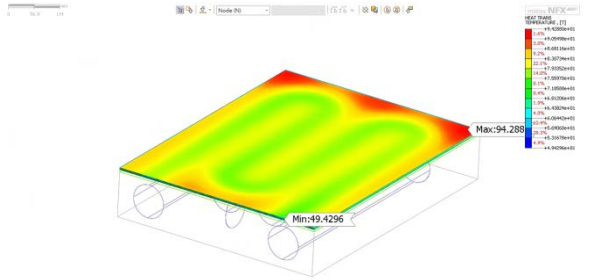


讀取最後一增量結果

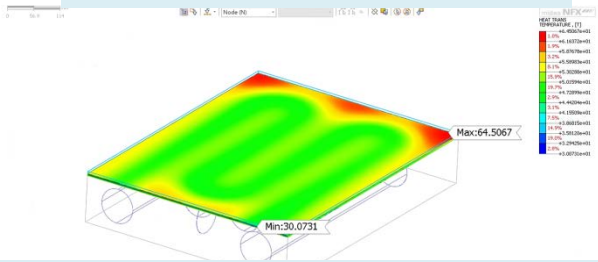
溫度(℃)



各部件溫度(℃)

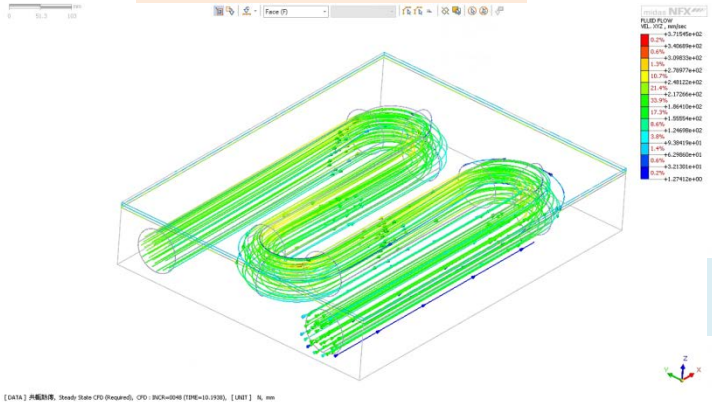


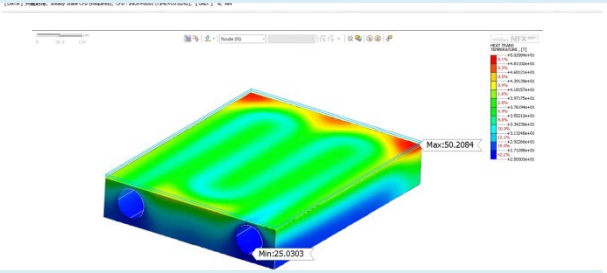
Glass最高溫(94.288℃)



Thermal Pad最高溫(64.5067 ℃)

流速(mm/sec)

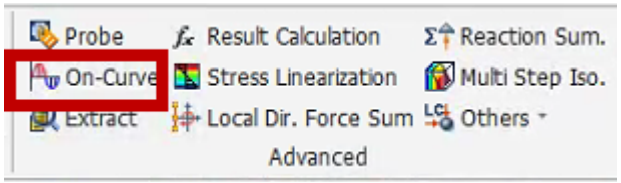




Channel最高溫(50.2084 ℃)

MIDAS

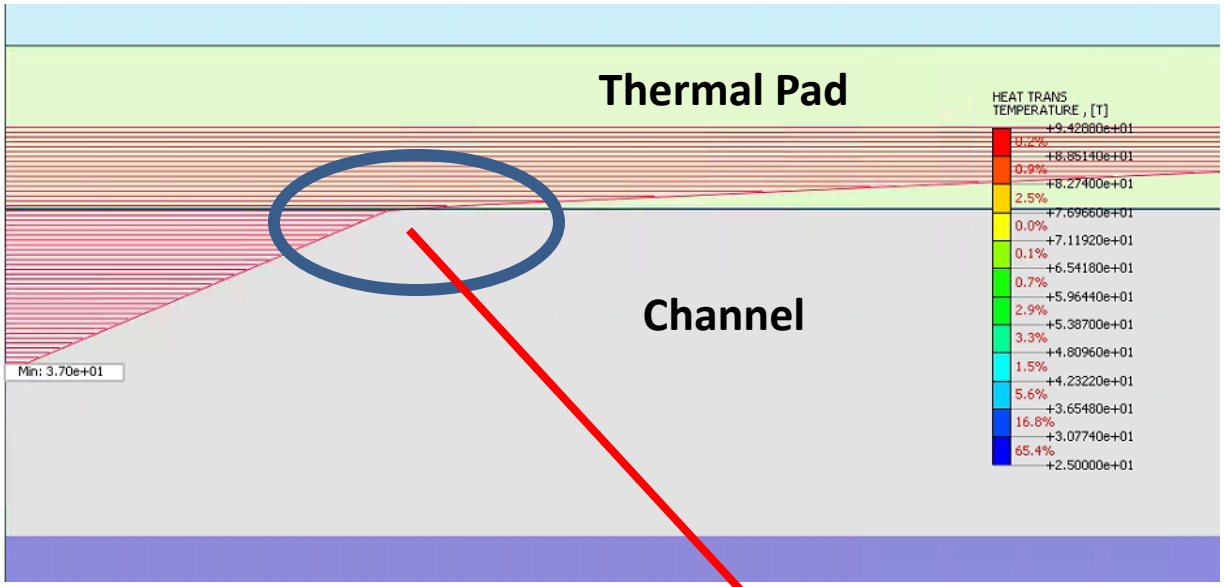
midas NFX-CFD

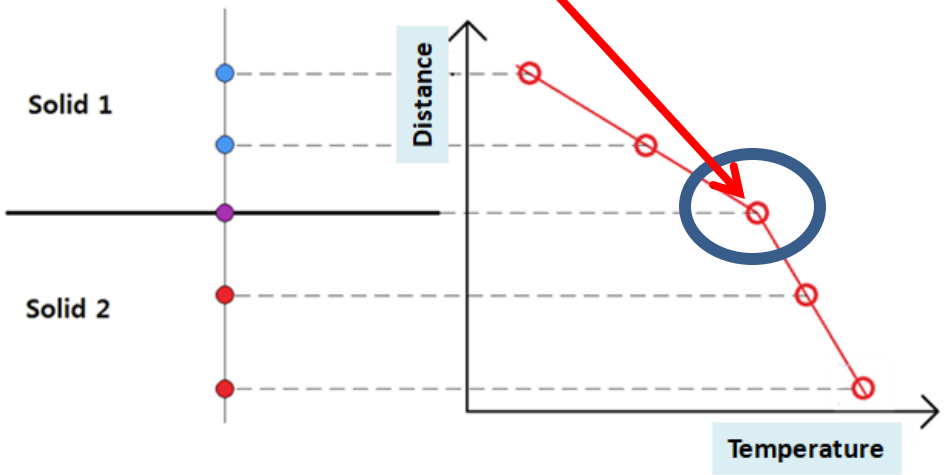


分析結果-2

(共軛熱傳&熱對流)

Soild1與Solid2 :相鄰邊界採節點相連

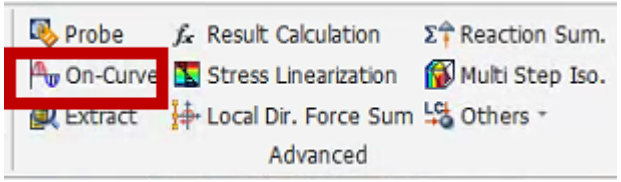




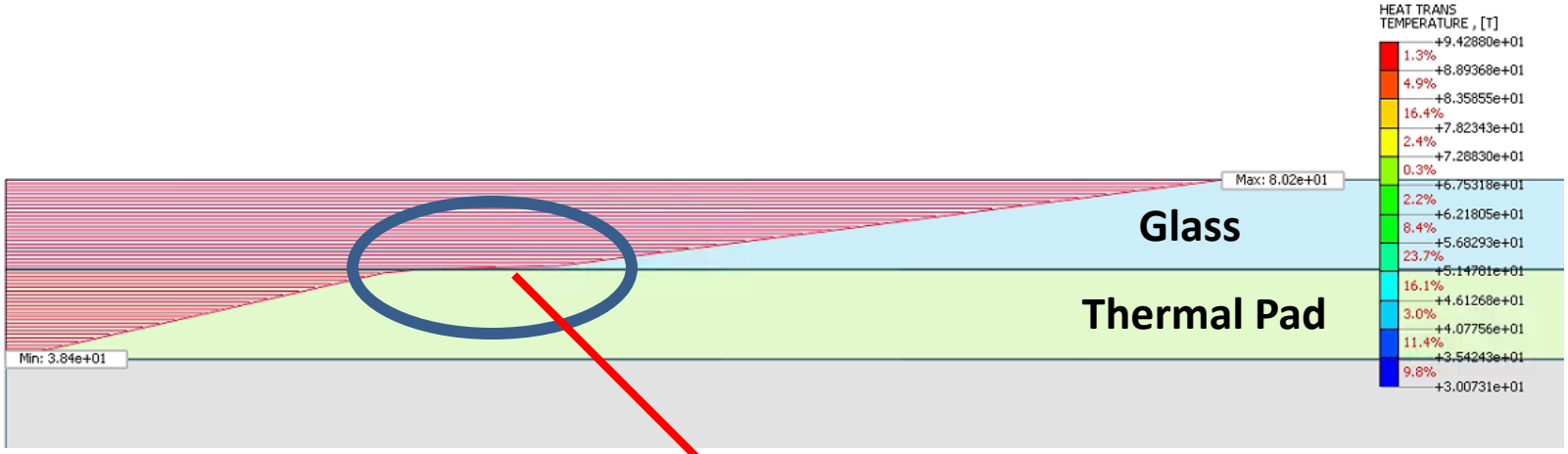
midas NFX-CFD

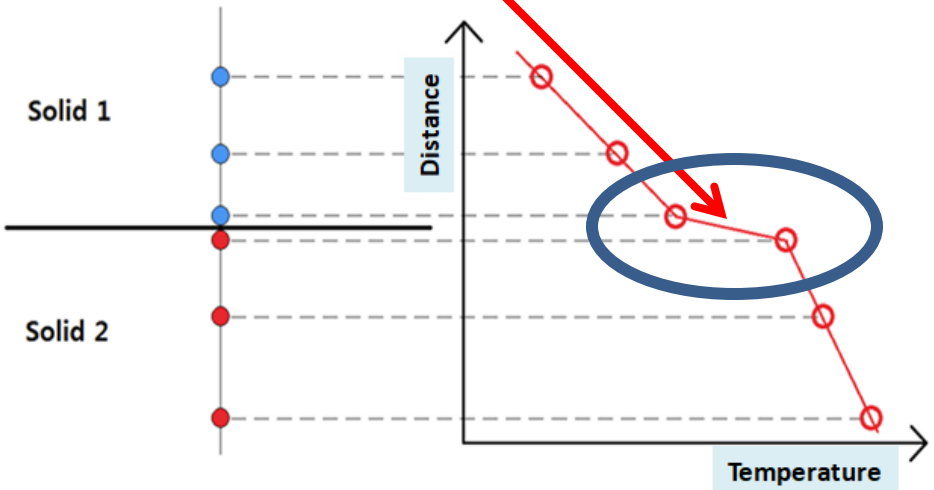
分析結果-3

(共軛熱傳&熱對流)

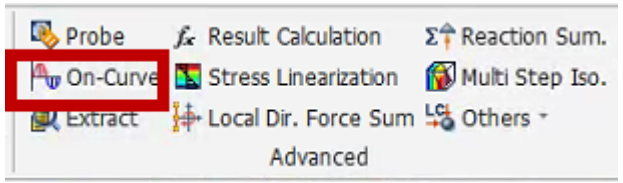


Soild1與Solid2 :相鄰邊界採接觸定義(熱阻)





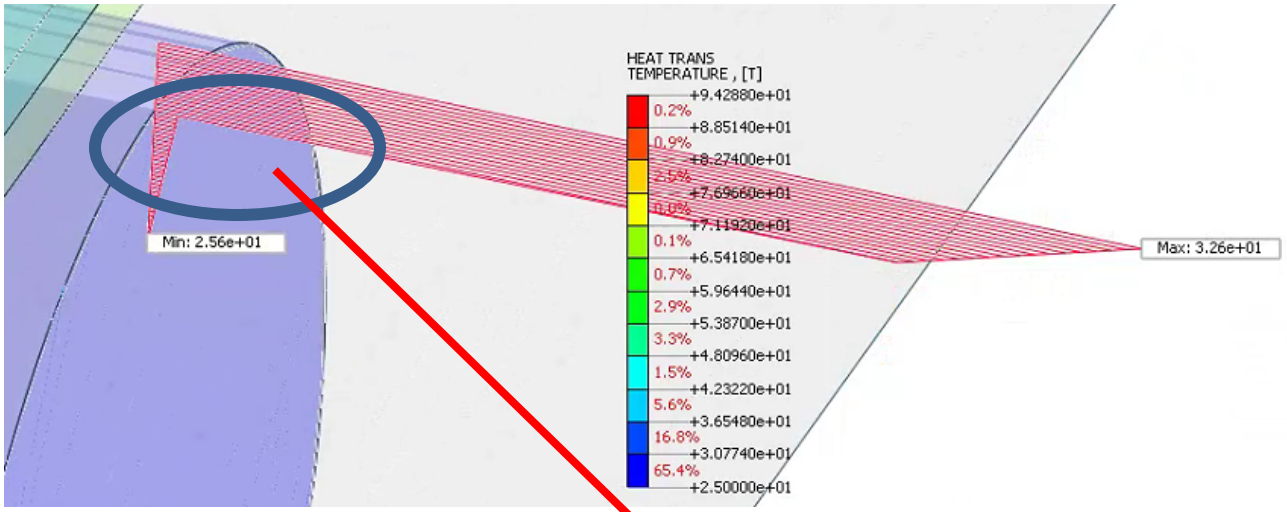
midas NFX-CFD

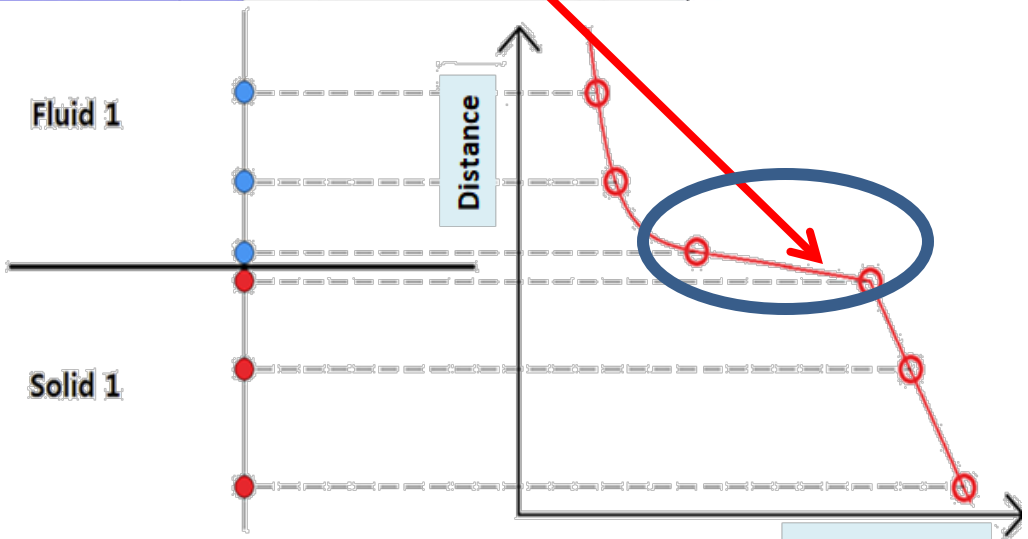


分析結果-4

(共軛熱傳&熱對流)

Fluid1與Solid1:相鄰邊界採接觸定義(熱邊界層)





midas NFX-CFD

CFD_標準教學系列

熱對流分析3-電子系統強制熱對流分析

台灣邁達斯

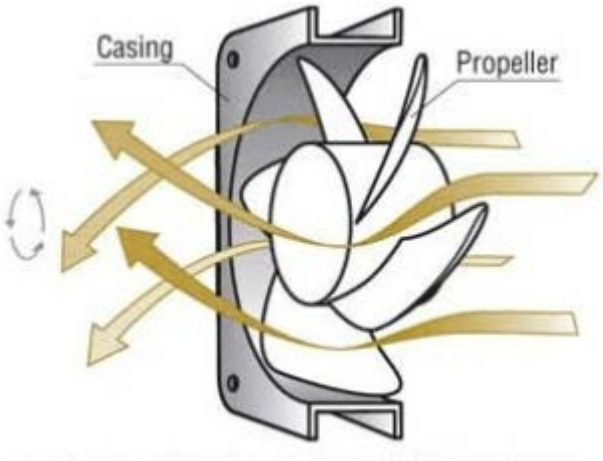
MIDAS

風扇

常見的風扇大致可分成兩類，一類為軸流風扇，另一類則是離心風扇。這兩種風扇差別在於進氣方向與排氣方向不同。

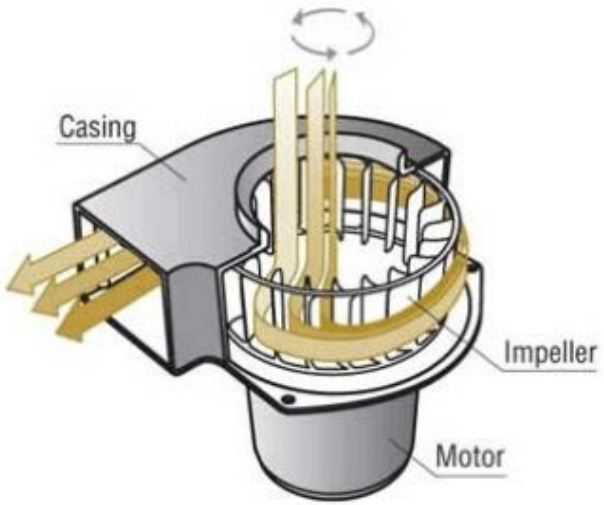
軸流式

軸流風扇的進氣方向與出氣方向皆平行於風扇旋轉軸。
通常軸流風扇有著高流量與低靜壓的特性，這意味軸流風扇雖然在低阻抗環境下能產生較高流量，但在高阻抗環境卻無法帶來風。



離心式

離心風扇雖然進氣方向與風扇旋轉軸平行，但沿著風扇切線方向排氣。
離心風扇具有低流量與高靜壓的特性，在低阻抗環境下雖流量較低，但由於風扇本身能產生較高靜壓，抵抗環境阻抗能力較佳，高阻抗環境下依然仍有風量。



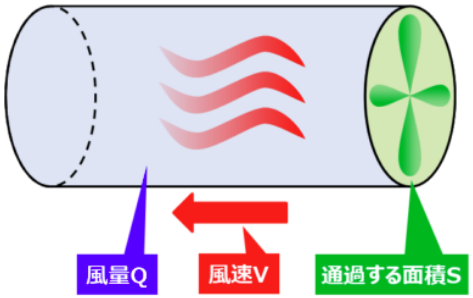
Reference

https://www.techchickensoup.com/technology/fan-curve-intro/

風量
(Air Volume/Air Flow)

風量

平面速度一定時，扇葉葉輪外徑越大，通風面積越大，風量則越大。
風量越大，冷空氣吸熱量則越大，
空氣流動轉移時能帶走更多的熱量，
散熱效果越明顯。



$$Q = S\,V$$

風量 [m^3/s] ／ 通過する面積 [m^2] ／ 風速 [m/s]

常用風量單位

CFS:(ft^3/sec)
CFM :(ft^3/min)
CMS:(m^3/sec)
CMM:(m^3/min)
CMH :(m^3/h)
L/s:(L/sec)
L/min:(L/min)

風量單位對照表

單位	CFS	CFM	CMS	CMM	CMH	L/s	L/min
CFS	1	60	0.0283	1.698	101.9	28.3	1690
CFM	0.167	1	0.00047	0.0283	1.698	0.472	28.3
CMS	35.3	2118	1	60	3600	1000	60000
CMM	0.588	35.35	0.0167	1	60	16.7	1000
CMH	0.00981	0.588	0.000277	0.0167	1	0.277	16.7
L/s	0.0353	2.118	0.001	0.06	3.6	1	60
L/min	0.000588	60	0.0000167	0.001	0.06	0.0167	1

Reference

https://detail-infomation.com/air-volume-and-wind-speed/

風扇風量計算
(Fan air volume calculation)

風量(Q)計算公式取決於已知數據，一般有兩種情況：

1.已知風速與截面積

$$Q = V \times A$$

Q：風量
V：風速（m/s）
A：風道截面積（m^2）

2.已知馬達與風扇性能曲線

- 從風扇廠商的性能曲線圖讀取在特定靜壓下的風量數值。
- 常用於工業排風扇、HVAC 系統。

補充:RPM和風速換算

$$v = \frac{\pi \times D \times \mathrm{RPM}}{60}$$

V：速度（m/s）
D：直徑（m）
RPM：每分鐘轉數
1 分鐘 = 60 秒

體積發熱率

(Heat Generation/ Volumetric Heat Generation Rate)

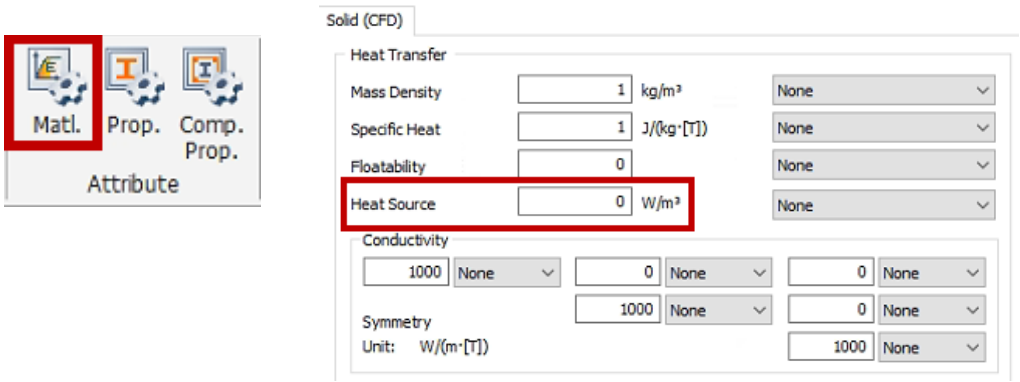
體積發熱率 (Heat Generation)

用符號 q‴表示，單位是 **W/m³**，是指每立方公尺的材料或空間內，每秒產生的熱功率(瓦)。

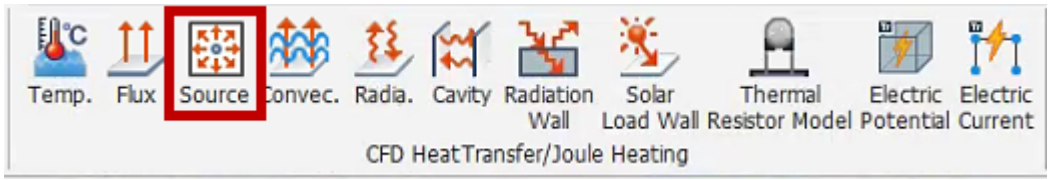
$$Q_{\text{total}} = q''' \times V$$

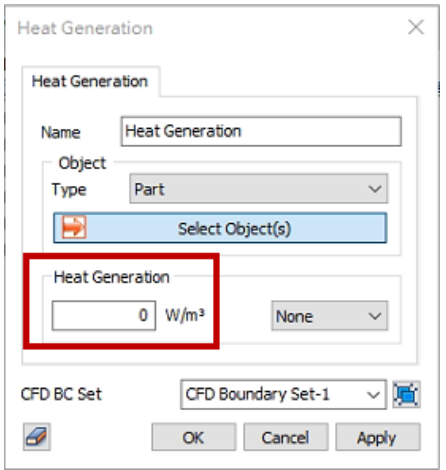
Q_{total}：總發熱量(W)
q‴：體積發熱率(W/m³)
V：體積(m³)

NFX CFD定義方式1

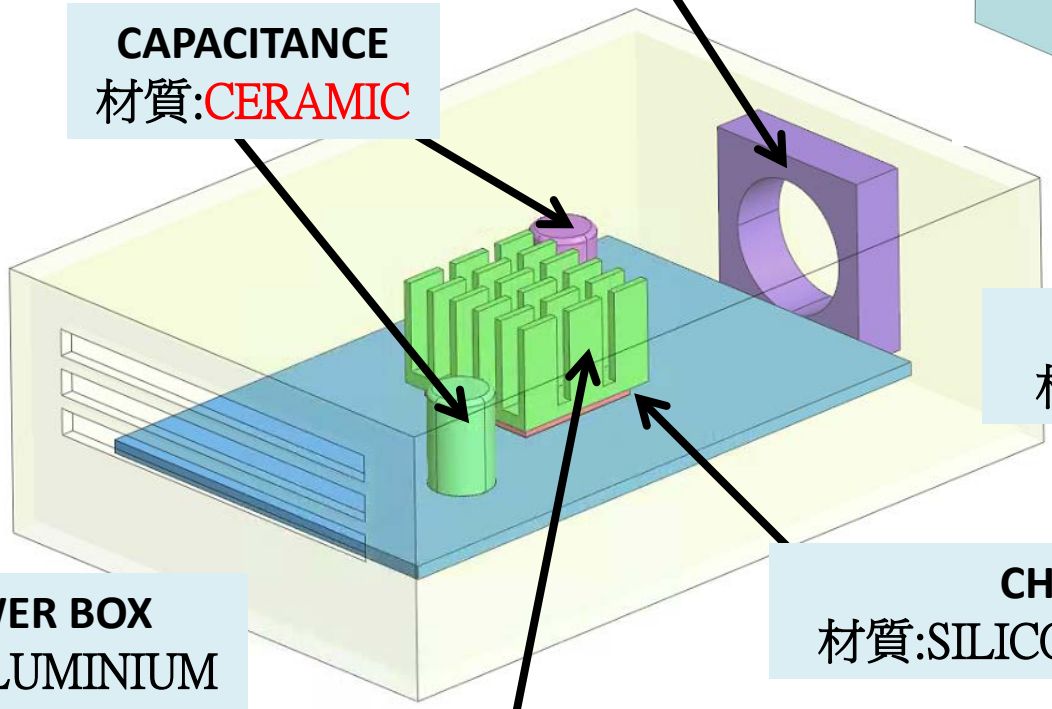


NFX CFD定義方式2





分析說明-1
(材料)



內流域
材質:AIR 25℃

FAN HOUSE
材質: PC

CAPACITANCE
材質:CERAMIC

BOARD
材質: PCB

POWER BOX
材質:ALUMINIUM

CHIP
材質:SILICON WAFER

Heat SINK
材質:ALUMINIUM

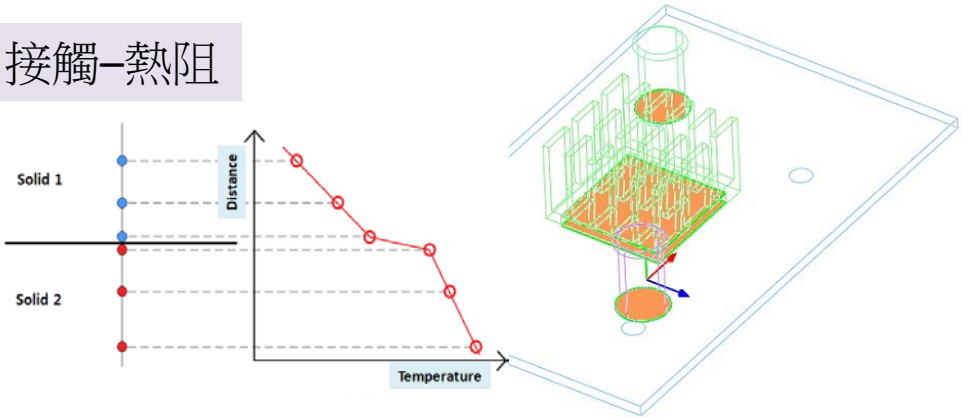
註: 自行定義ceramic材料參數,其餘材料直接使用材料庫參數。

分析說明-2
(連接方式)

Board/Heat Sink/Chip/Capacitance

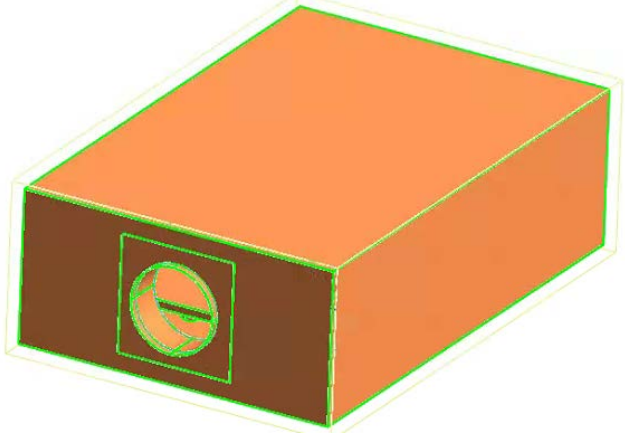
相鄰特徵採接觸定義

接觸–熱阻



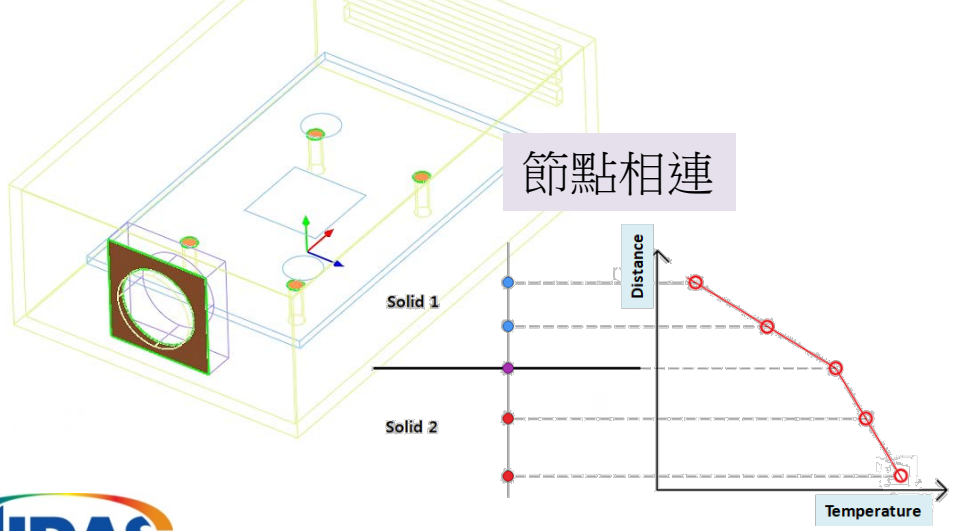
內流域

相鄰特徵採接觸定義

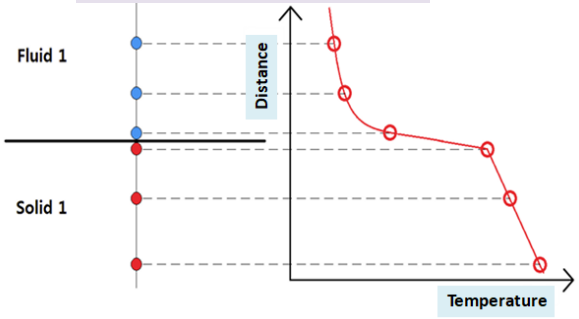


Power Box/Fan House/Board

相鄰特徵採節點相連



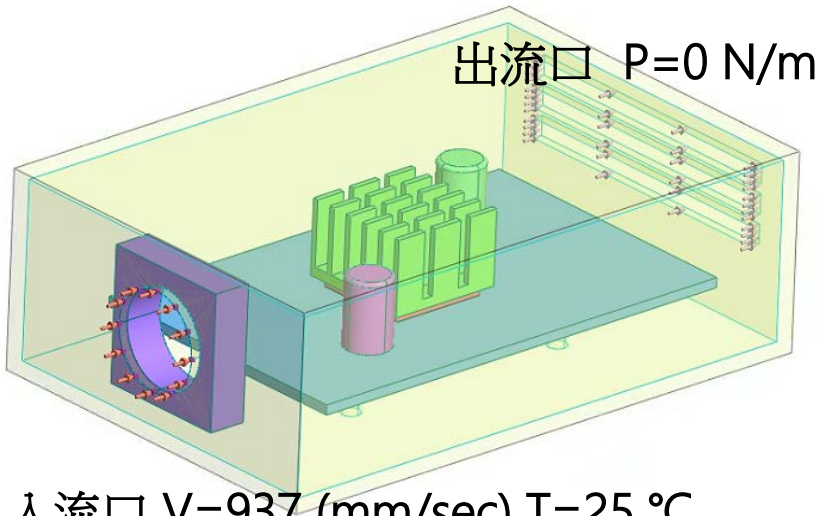
接觸–熱邊界層



分析說明-3

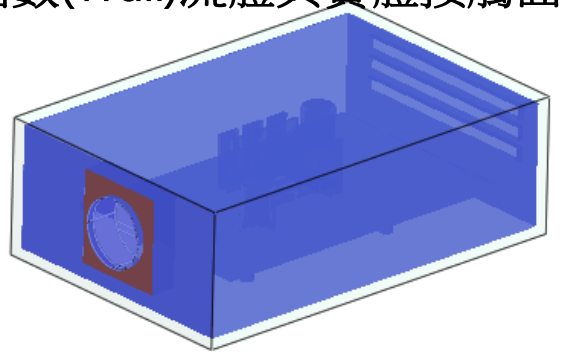
環境溫度:25
熱對流係數:5×10^{-6} (W/mm^2 ℃)

出流口 P=0 N/mm2



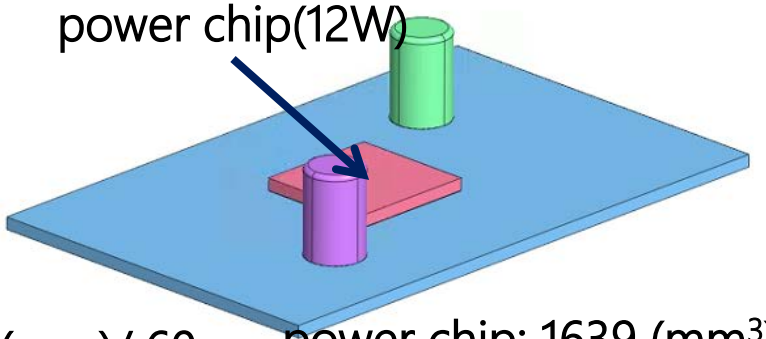
入流口 V=937 (mm/sec) T=25 ℃

壁函數(Wall)流體與實體接觸面



體積發熱率=0.007322 (w/mm^3)

power chip(12W)



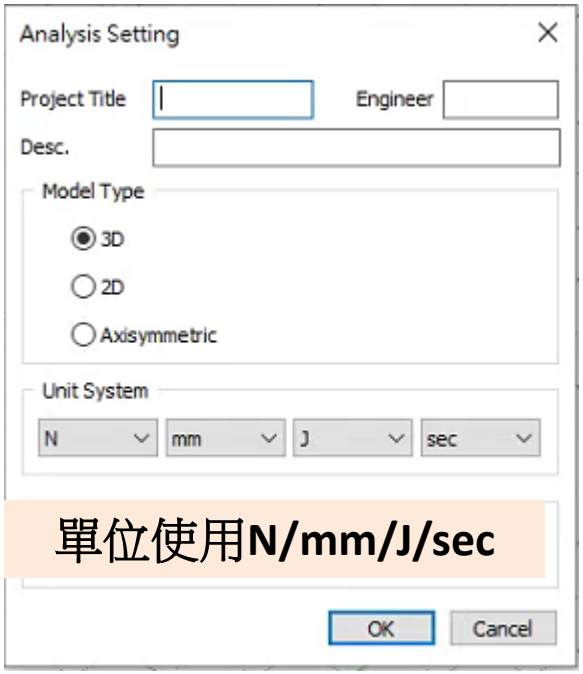
power chip: 1639 (mm^3)

註: 風扇轉速 1000 RPM
風扇直徑25.4mm)
風扇效率 **η = 70%**

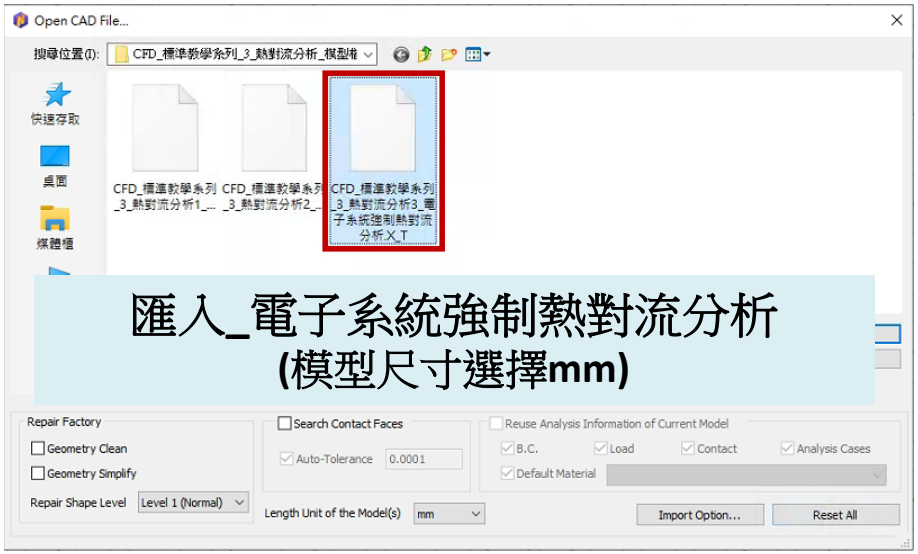
風扇風速計算

風速(m/s) = η× π×D×轉速/60
= 70%×3.1415×0.0254(m)×1000(rpm)/ 60
= 70% × 1.33(m/s)
= 70% × 1330(mm/s)
= 931 mm/s

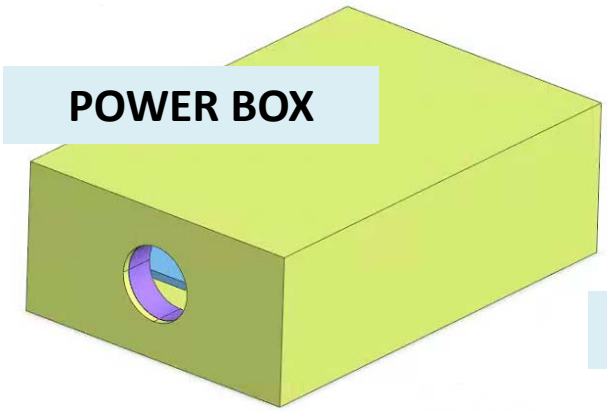
環境 &模型匯入

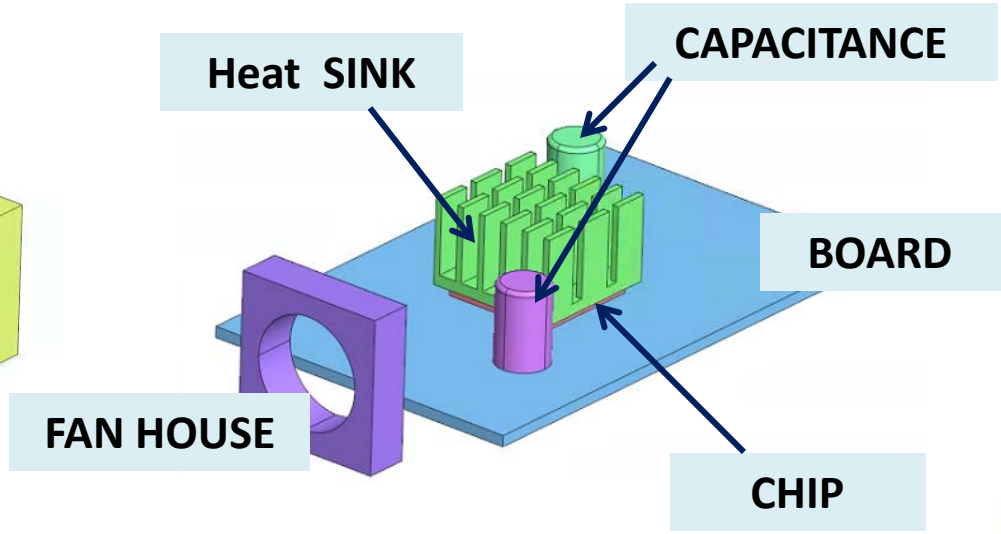


單位使用N/mm/J/sec



匯入_電子系統強制熱對流分析
(模型尺寸選擇mm)

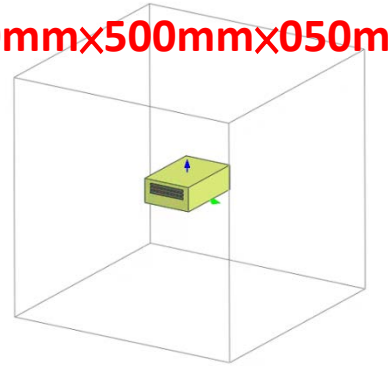


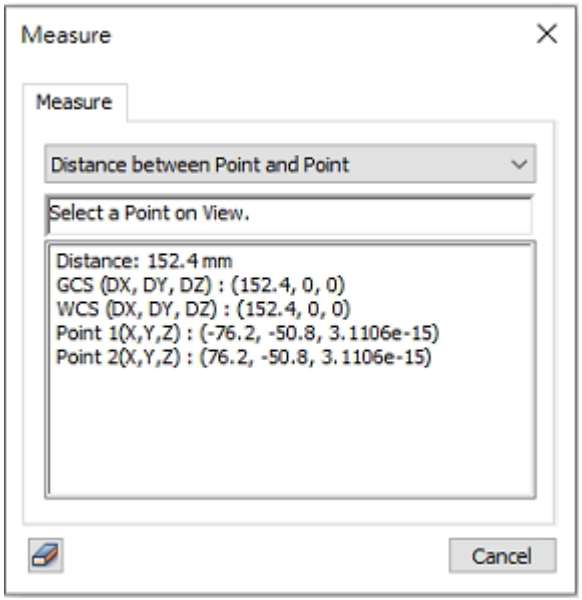


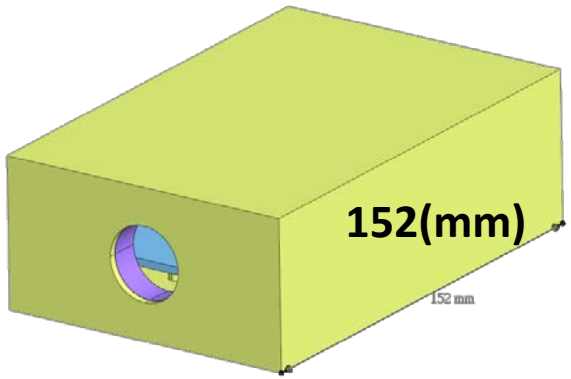
模型尺寸量測

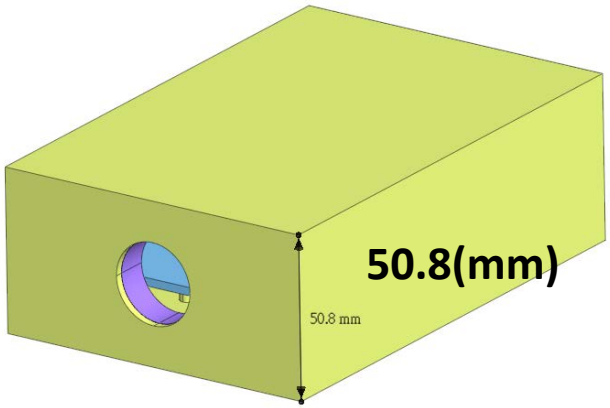
估算建立流場區域空間

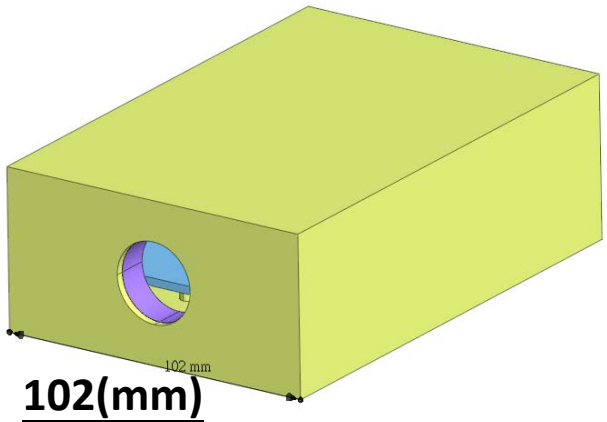
500mm×500mm×050mm





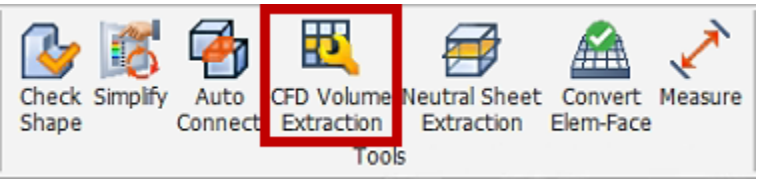




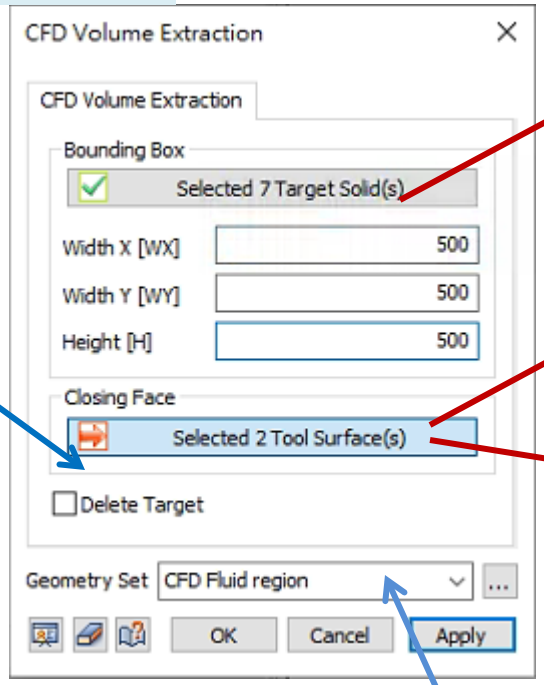


102(mm)

流域模型建立

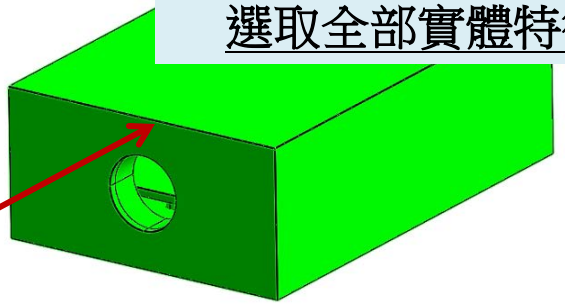


流場區域空間
500mm×500mm×500mm

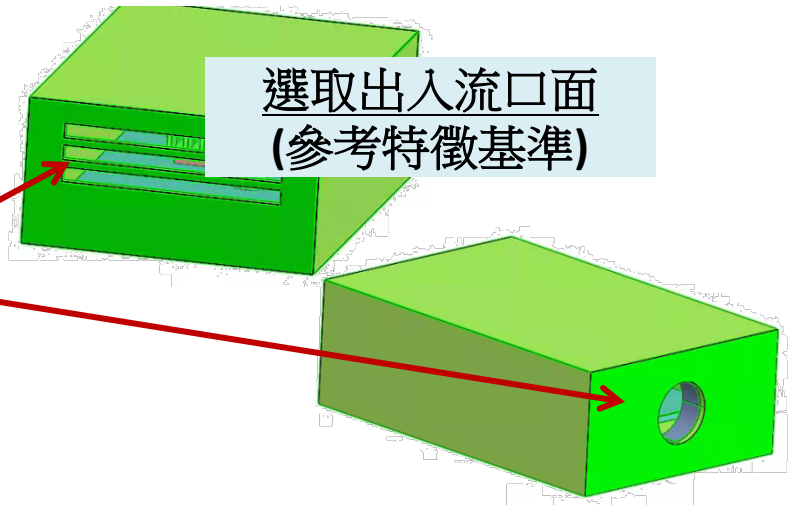


原有幾何保留

流域內之特徵
選取全部實體特徵

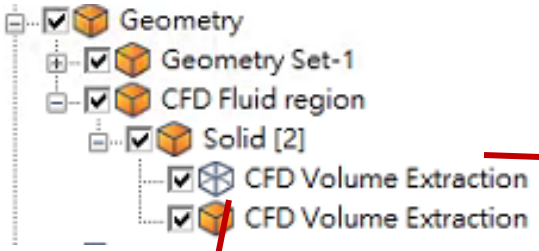


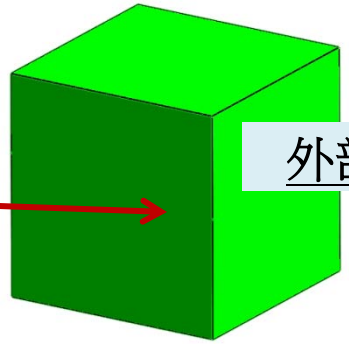
選取出入流口面
(參考特徵基準)



生成模型放置流域模型幾何集

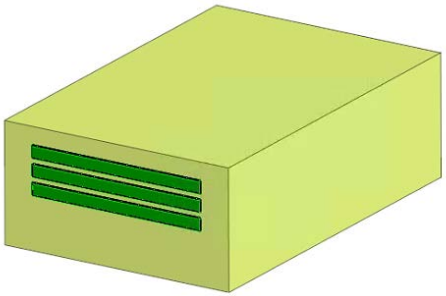
幾何刪除





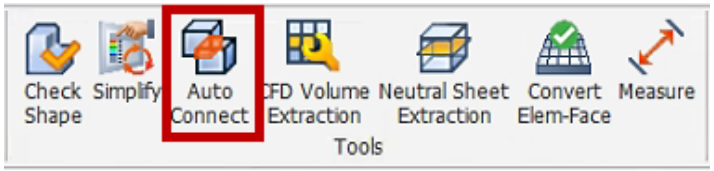
外部流場區域=>刪除

內流場區域=>保留

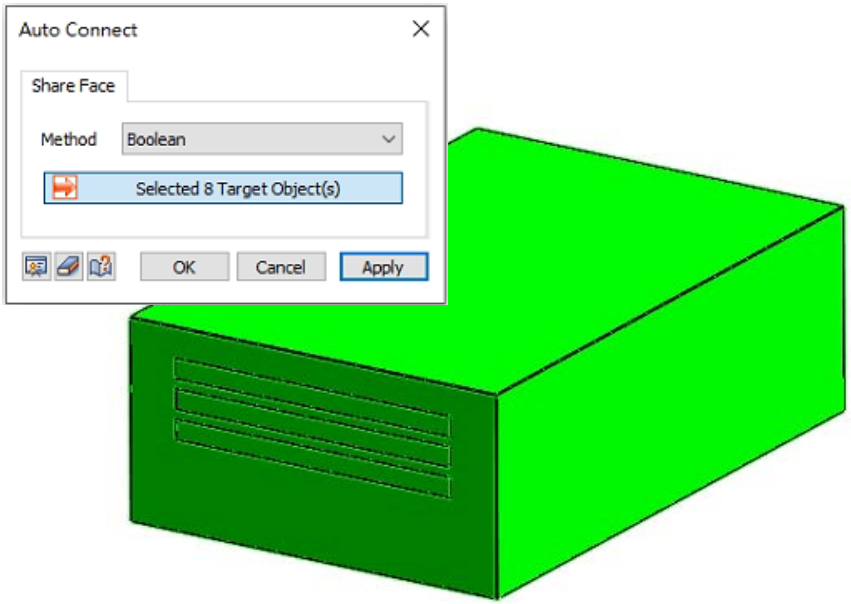


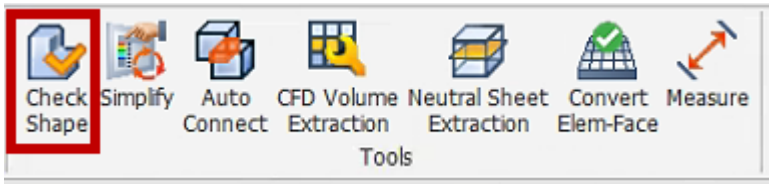
手動變更流域幾何顏色顯示
(預設灰色)

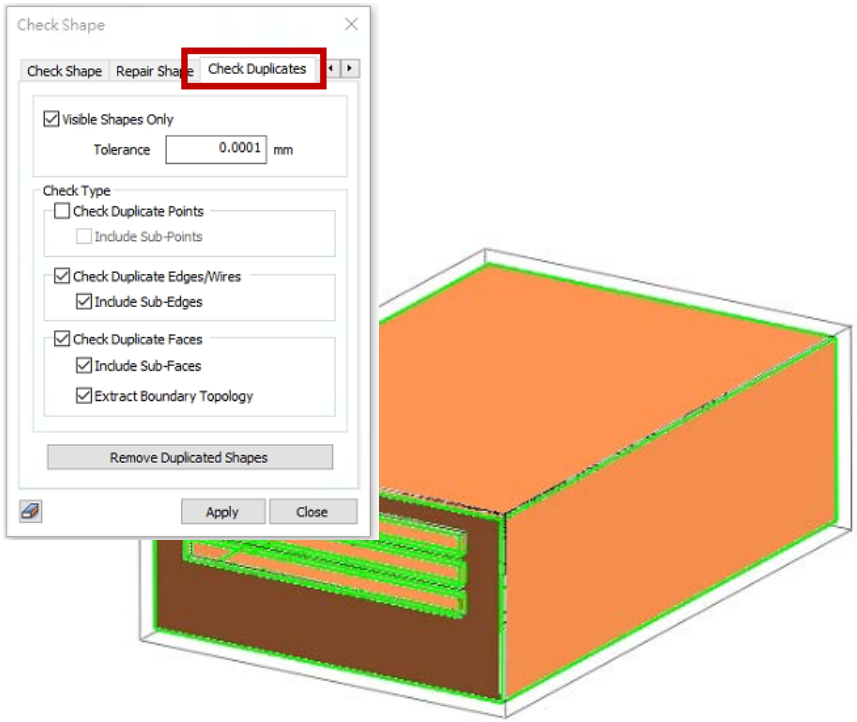
相鄰面特徵建立&確認



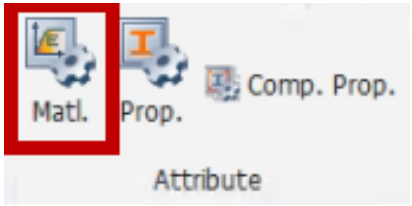
相鄰面特徵建立
(選取所有幾何特徵)

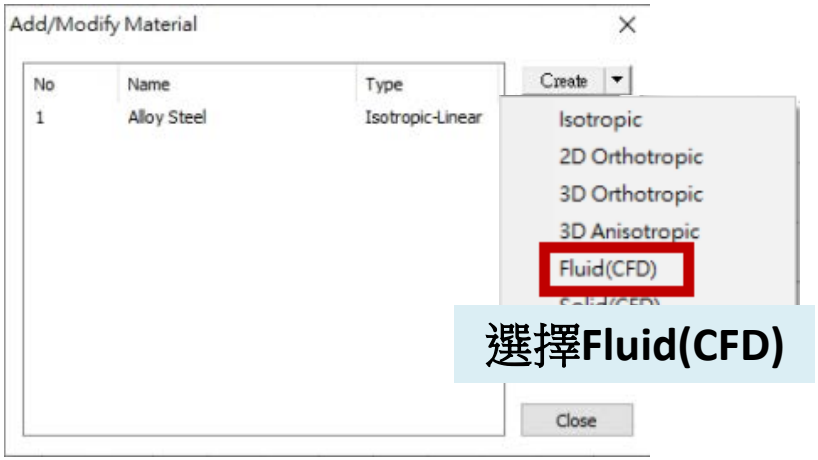






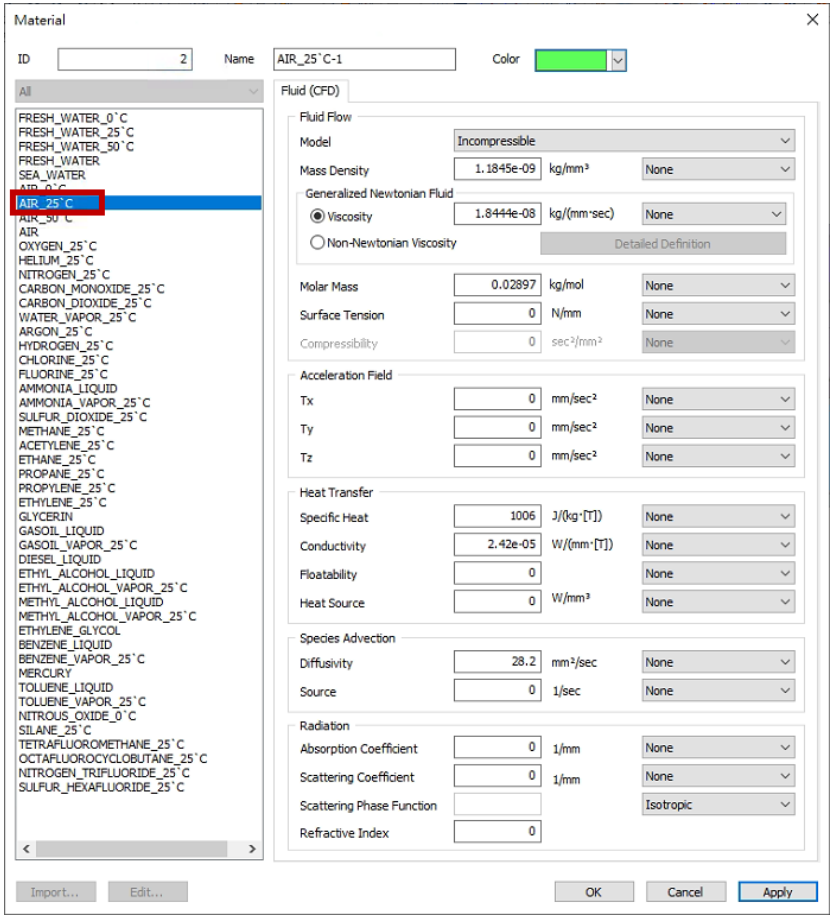
材料-流體(CFD)





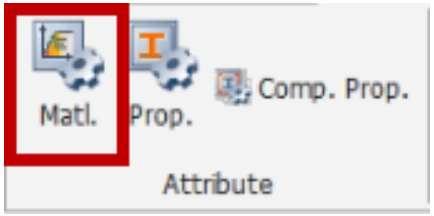
選擇Fluid(CFD)

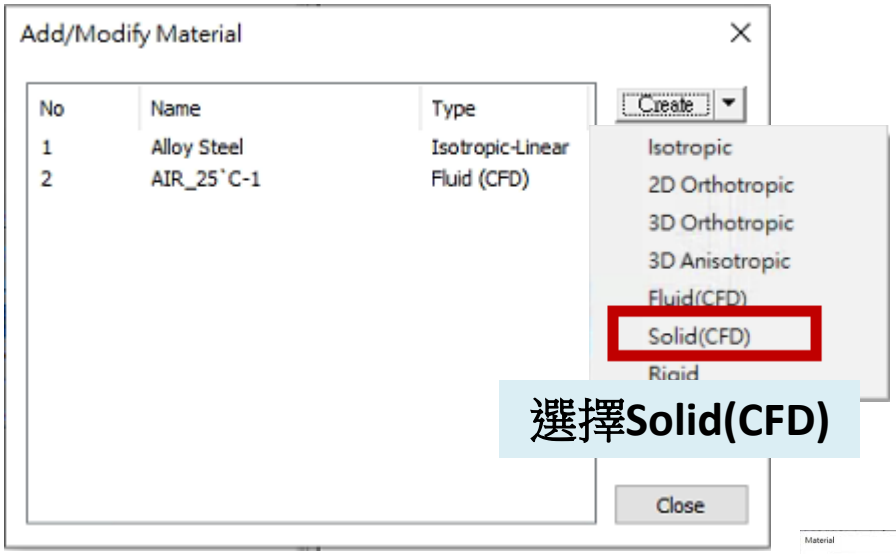
新增AIR 25 ℃



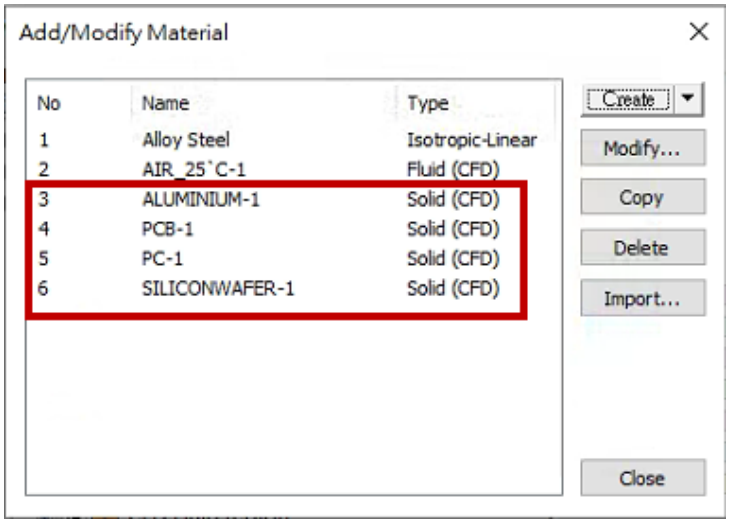
midas NFX-CFD

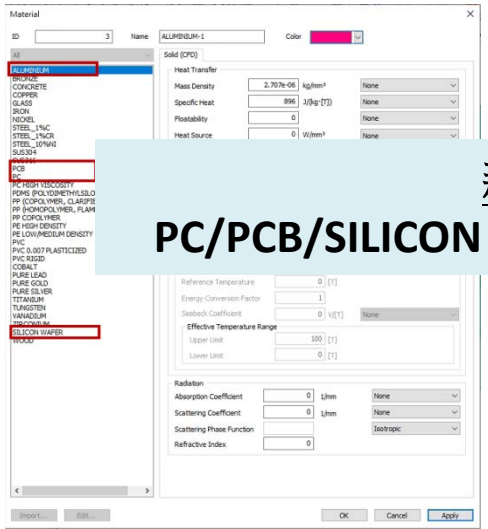
材料-固體(CFD)-1





選擇Solid(CFD)





新增

PC/PCB/SILICON WAFER/ALUMINIUM

MIDAS

材料-固體(CFD)-2

PC 材質通常指 **聚碳酸酯**（Polycarbonate），是一種常用的工程塑膠。
它的比熱容會因配方、添加劑、溫度而有些差異，但一般在室溫（約 20~25 °C）下的數值大致為：

聚碳酸酯（PC）的比熱容

- 約 **1.17 ~ 1.30 kJ/(kg·K)**
- 換算成 J/(g·K) 為 **1.17 ~ 1.30 J/(g·K)**

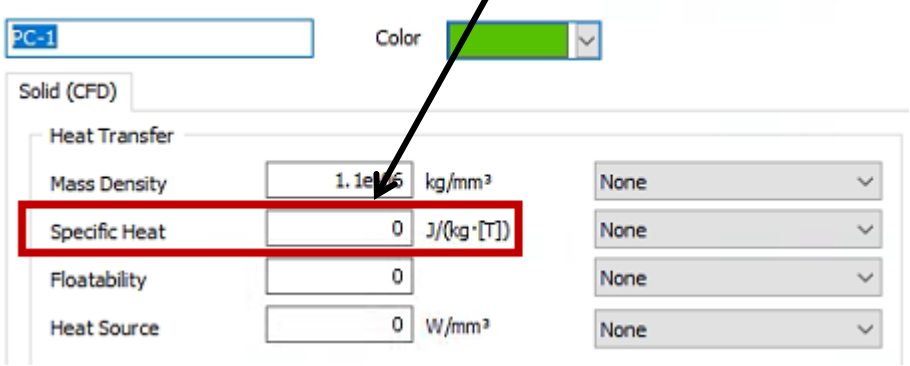
📌 參考值：

- 1.20 kJ/(kg·K) 在 20 °C 常被作為工程計算的平均值
- 若溫度升高，比熱會略微上升

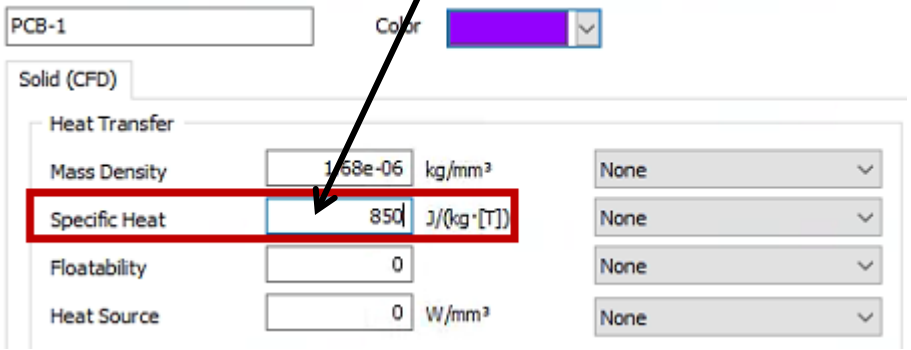
PCB 的比熱要看它的**基板材質**與**玻璃纖維比例**。
常見 PCB（例如 FR-4 材質）是 **玻璃纖維 + 環氧樹脂** 的複合材料，比熱會介於兩者之間：

材質	比熱 (kJ/(kg·K))	備註
環氧樹脂	~1.0–1.3	隨溫度變化而升高
玻璃纖維	~0.8–0.9	穩定度高
FR-4（常見 PCB 板材）	**~0.85–1.0**	在 20–25 °C 測得

PC比熱
自訂1200(J/kg-[T])

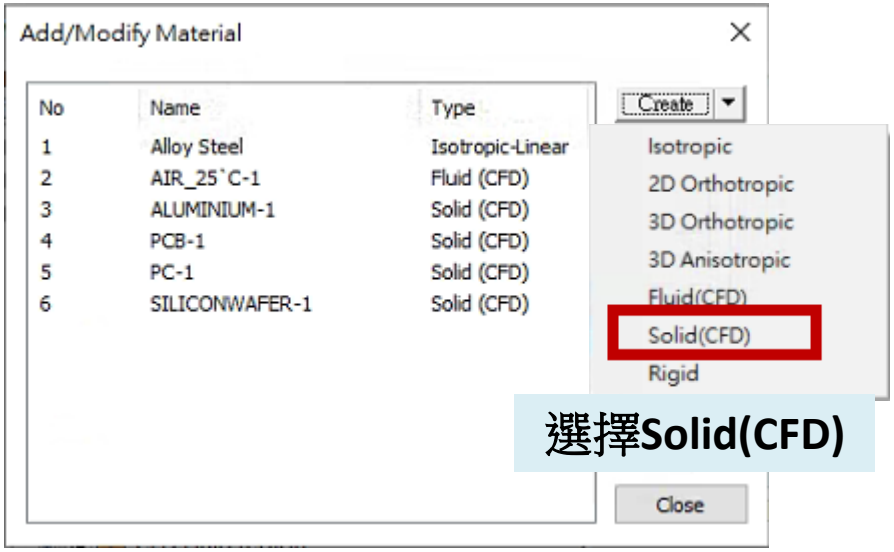


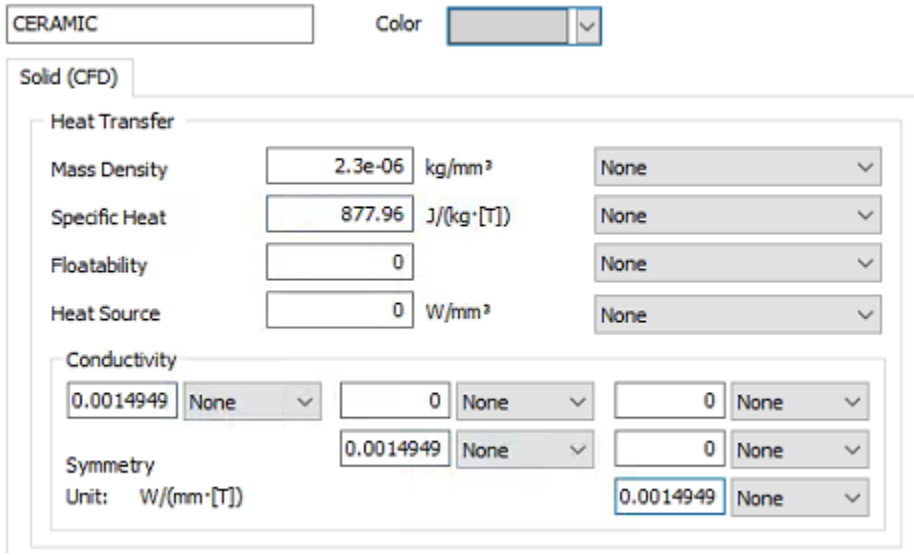
PCB比熱
自訂850(J/kg-[T])



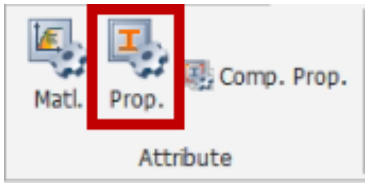
手動新增材料-固體(CFD)

	密度 kg/mm^3	比熱 J/(Kg*[T])	熱傳導率 W/(mm*[T])
CERAMIC陶瓷	2.3e-06	877.96	0.0014949



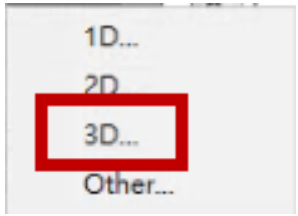


屬性

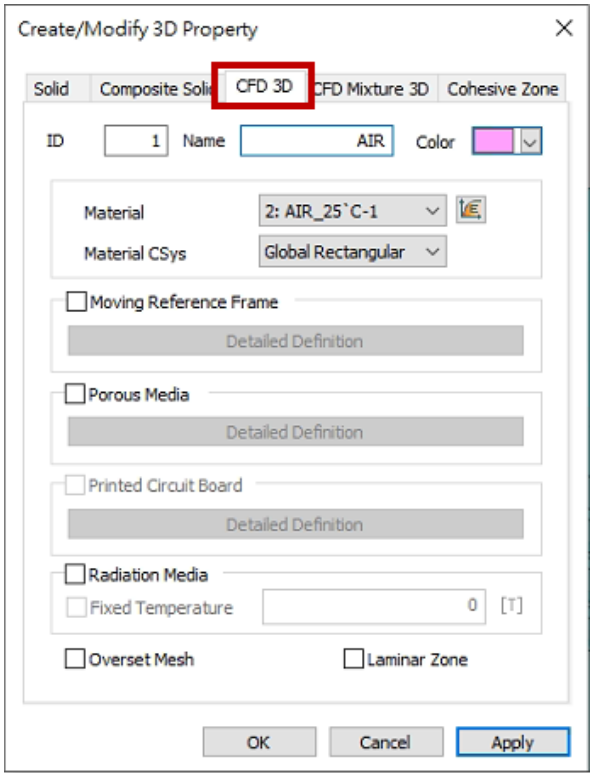


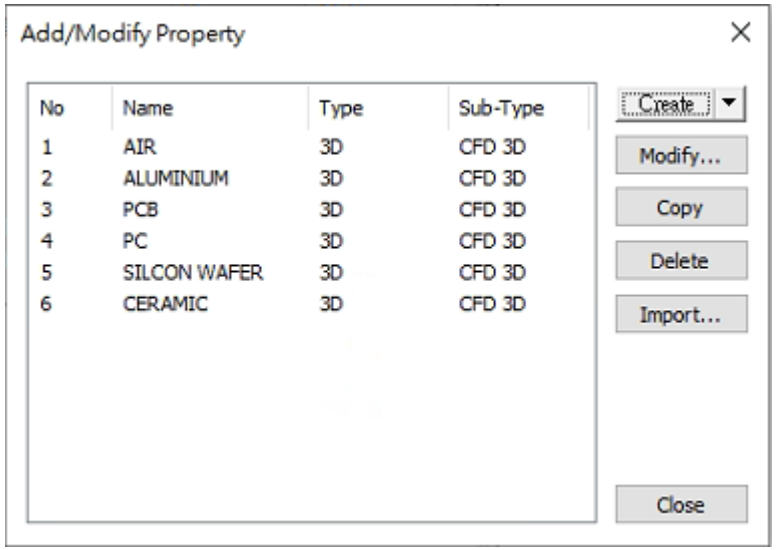
依序新增CFD 3D屬性

AIR/PC/PCB/SILICON WAFER/ALUMINIUM/CERAMIC

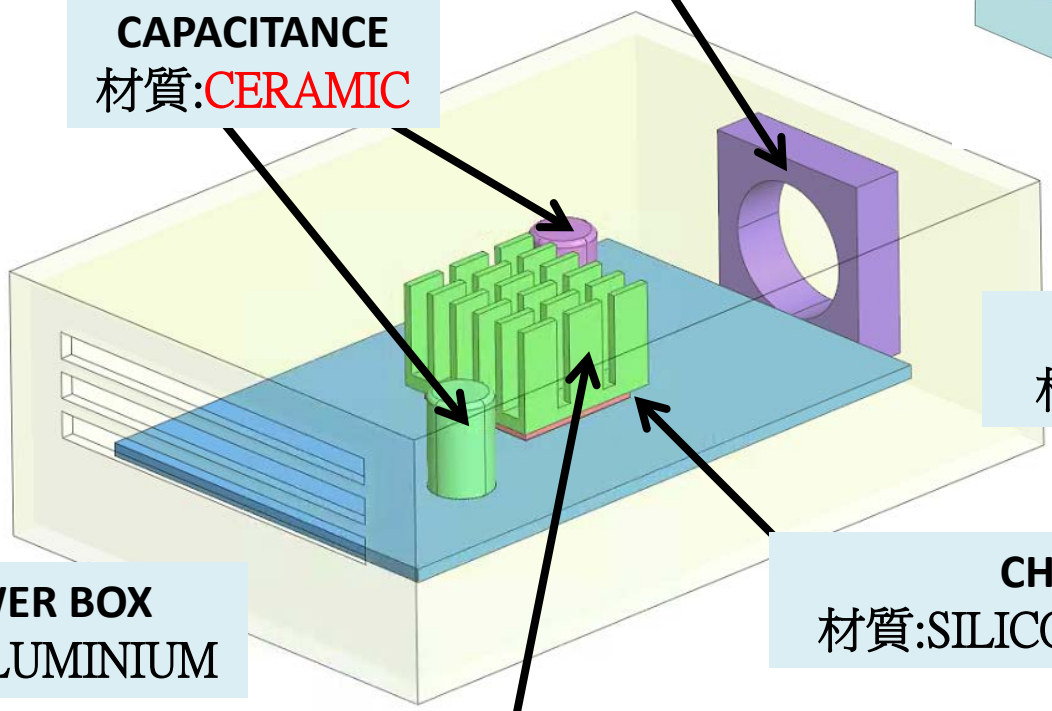


屬性選取Solid





材料



內流域
材質:AIR 25℃

FAN HOUSE
材質: PC

CAPACITANCE
材質:CERAMIC

BOARD
材質: PCB

CHIP
材質:SILICON WAFER

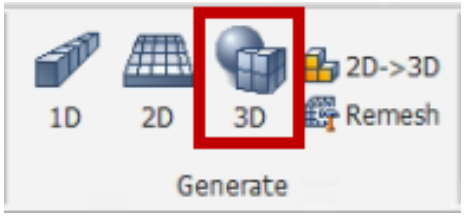
POWER BOX
材質:ALUMINIUM

Heat SINK
材質:ALUMINIUM

註: 自行定義ceramic材料參數,其餘材料直接使用材料庫參數。

3D網格-固體區域-1

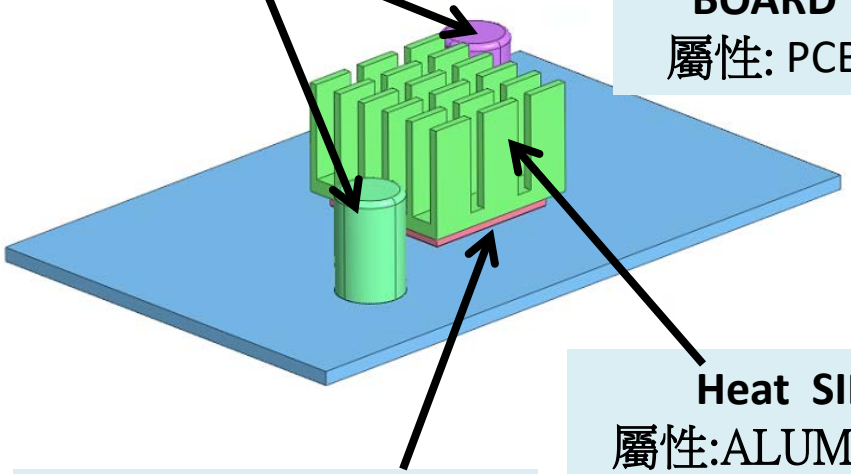
(接觸熱阻區域)

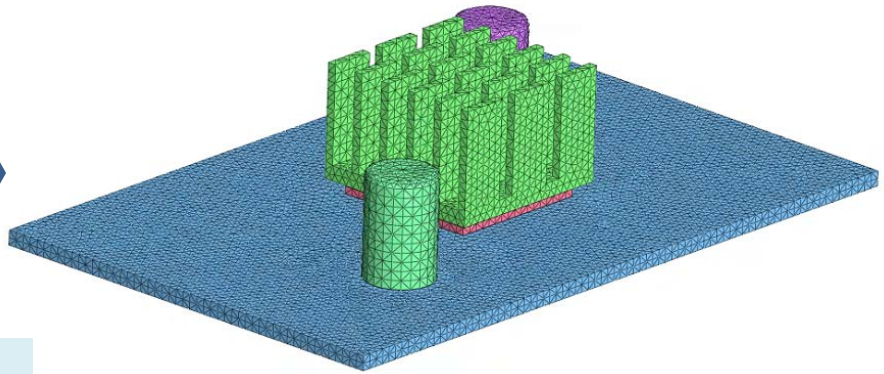


Tetra Mesher(四面體網格)/網格尺寸1.5(mm)
相鄰面特徵/1階元素/節點不相連

CAPACITANCE
屬性:CERAMIC

BOARD
屬性: PCB



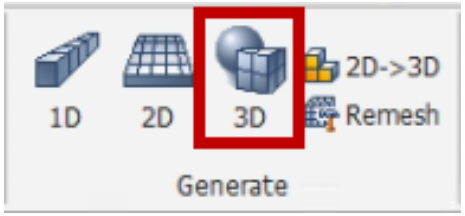


Heat SINK
屬性:ALUMINIUM

CHIP
屬性:SILICON WAFER

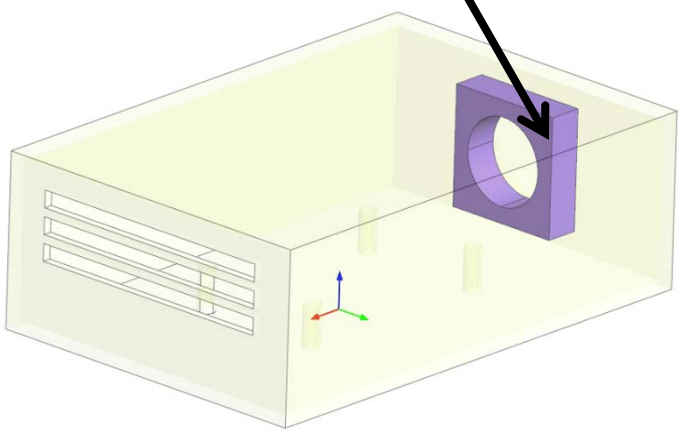
3D網格-固體區域-2

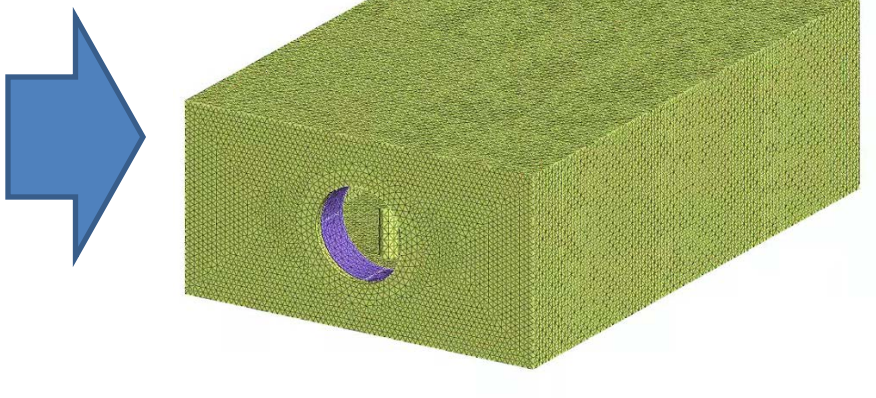
(忽略接觸熱阻區域)



Tetra Mesher(四面體網格)/網格尺寸1.5(mm)
相鄰面特徵/1階元素/節點相連

FAN HOUSE
屬性: PC

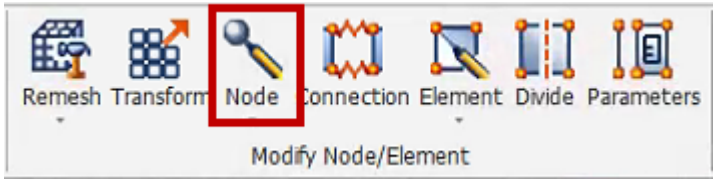


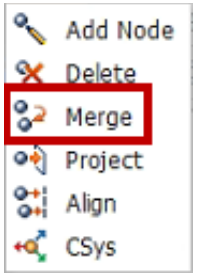


POWER BOX
屬性:ALUMINIUM

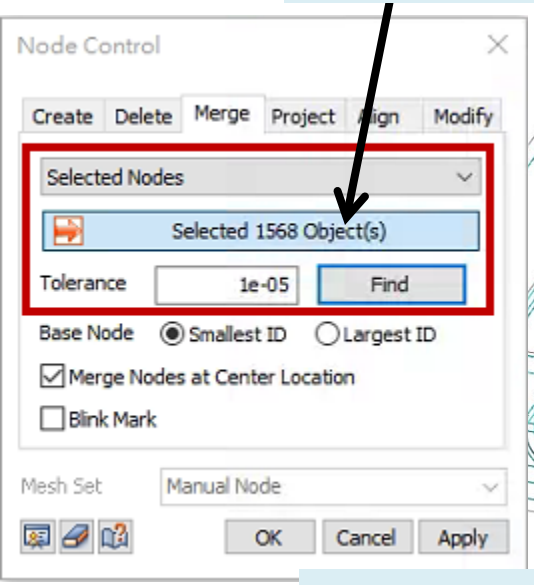
元素&節點相連接檢視

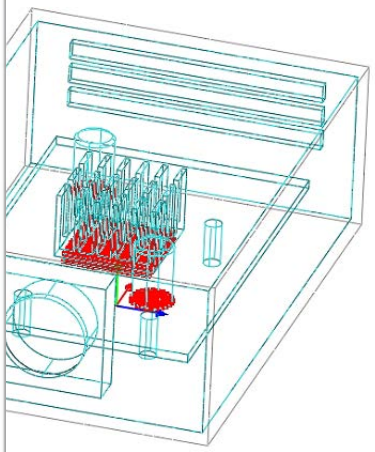
方法一





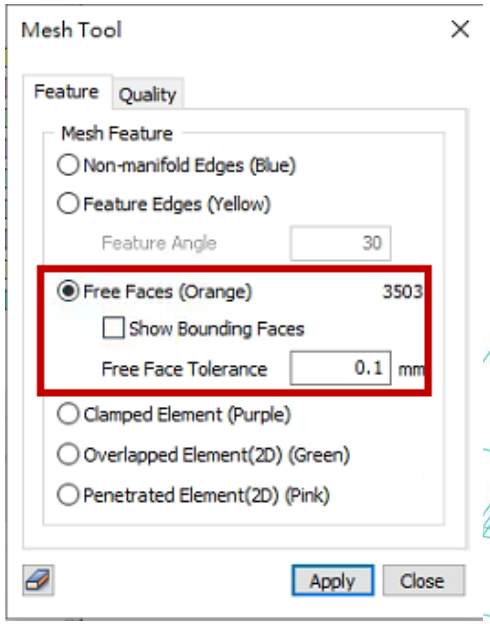
框選要檢視元素

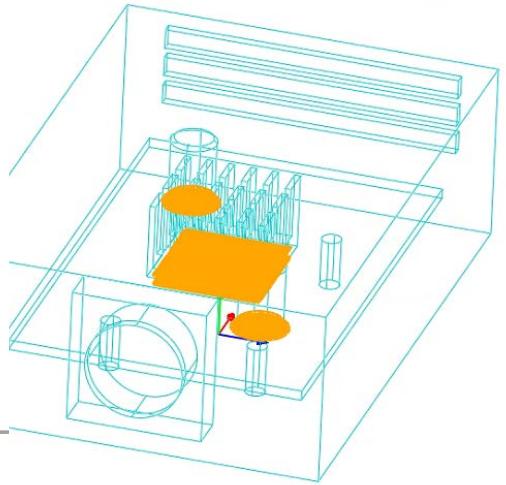




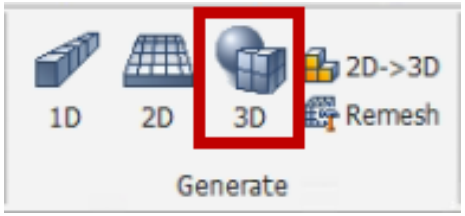
不要執行
(執行後會強制合併節點)

方法二



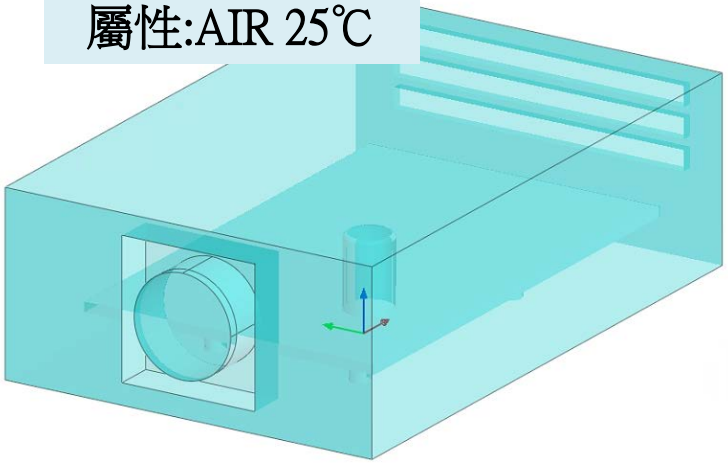


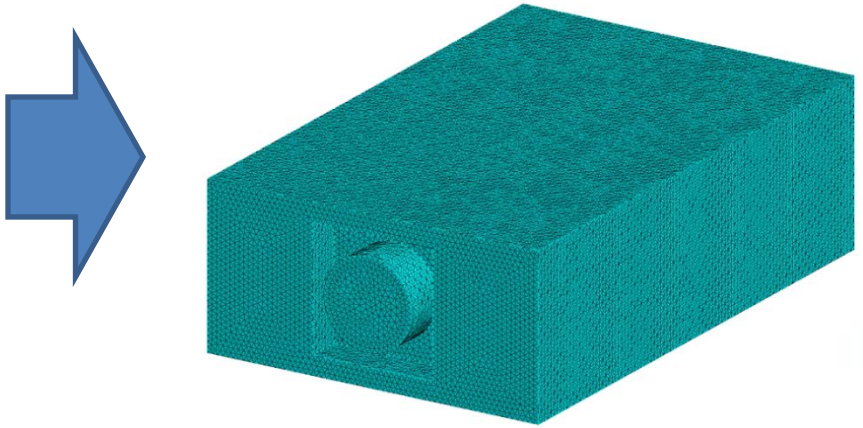
3D網格-流體區域



屬性:Water
Tetra Mesher(四面體網格)/網格尺寸2.5(mm)
相鄰面特徵/1階元素/節點不相連

內流域
屬性:AIR 25℃



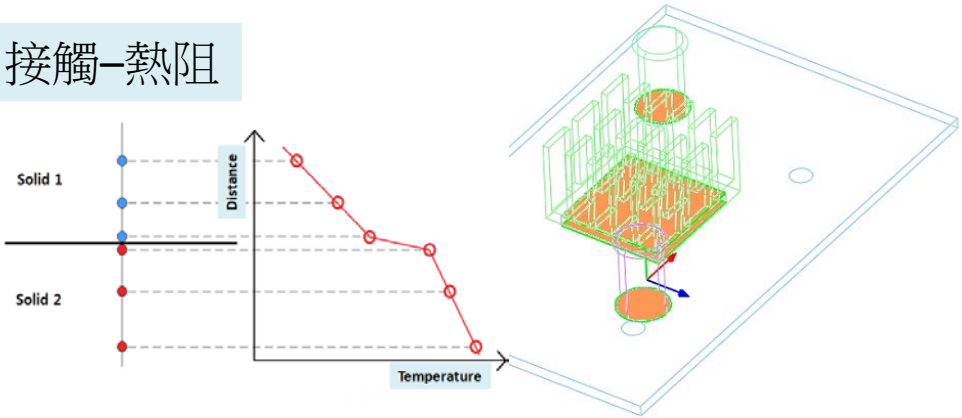


連接方式

Board/Heat Sink/Chip/Capacitance

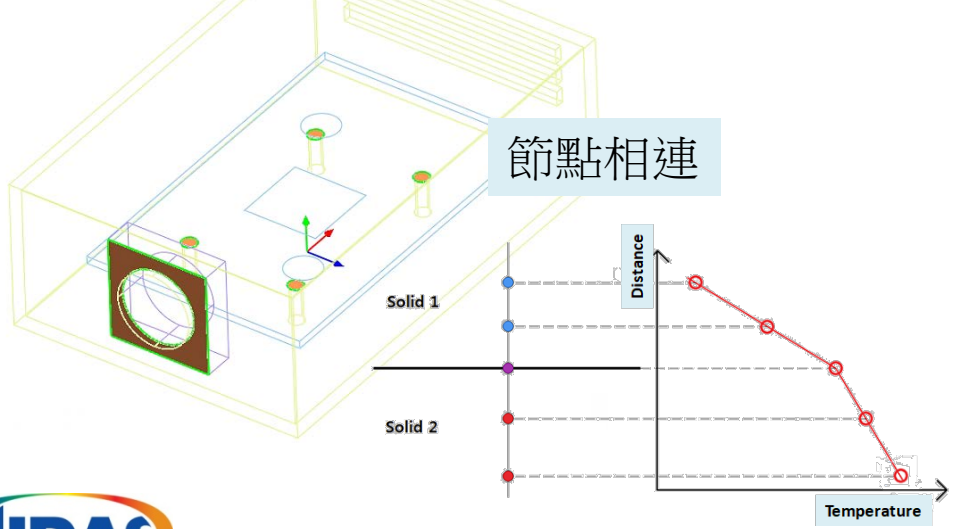
相鄰特徵採接觸定義

接觸–熱阻



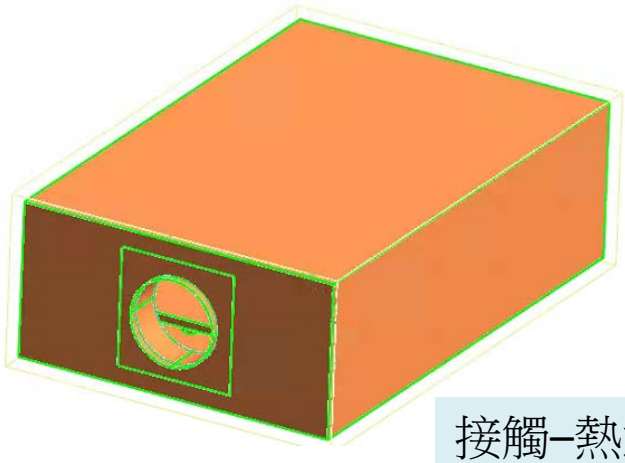
Power Box/Fan House/Board

相鄰特徵採節點相連

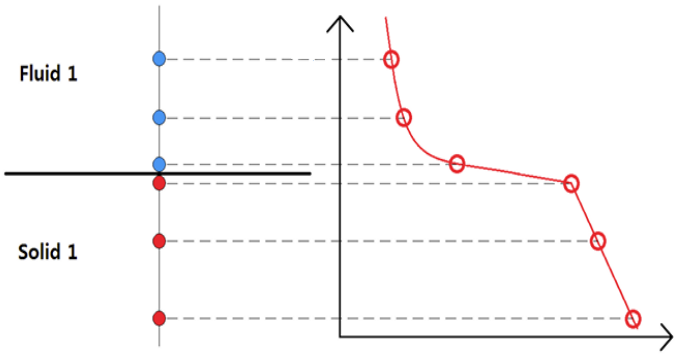


內流域

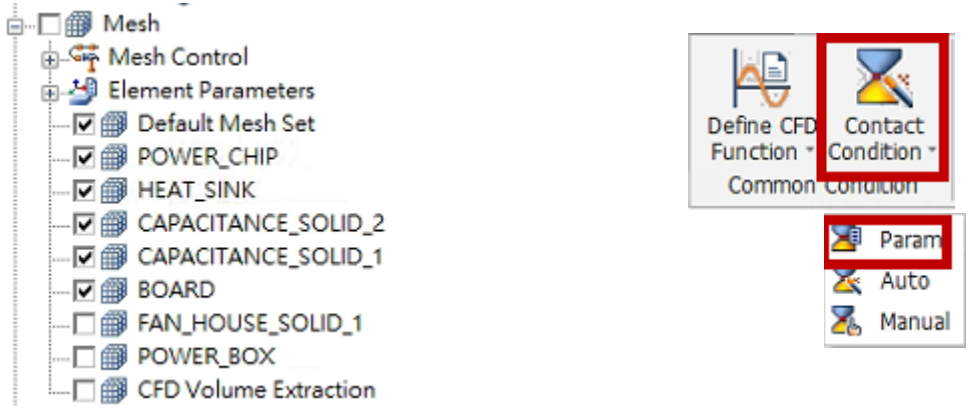
相鄰特徵採接觸定義

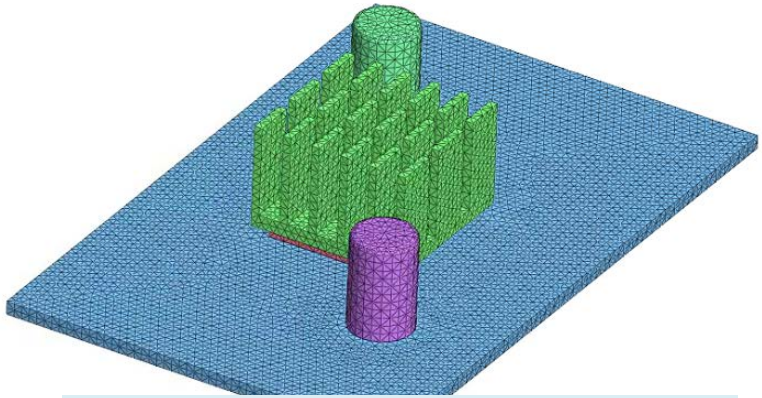


接觸–熱邊界層



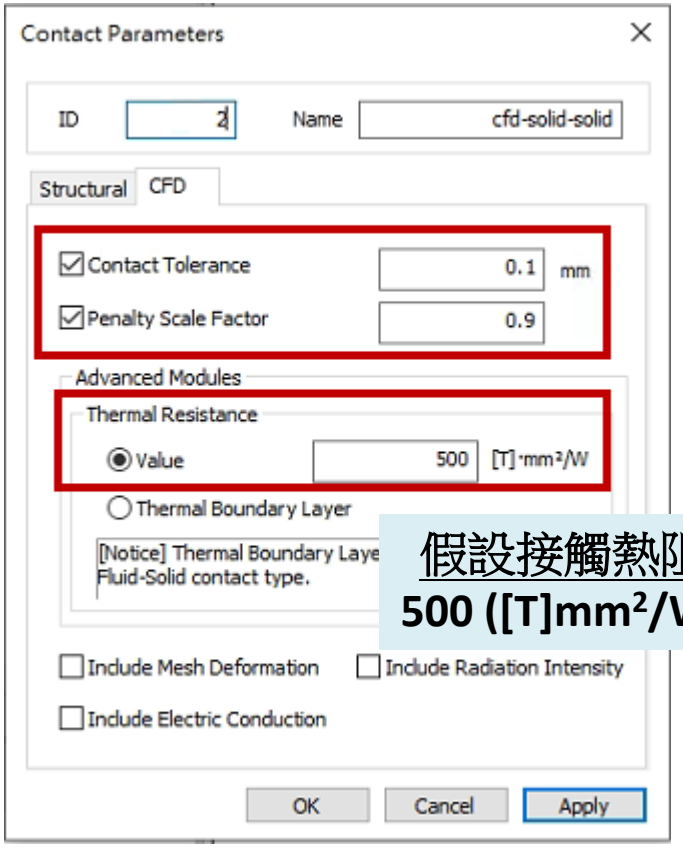
Solid-Solid接觸定義-1





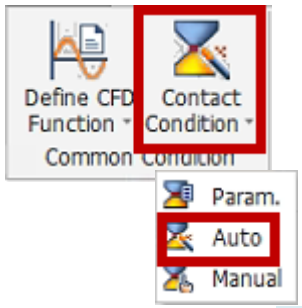
顯示Board/Heat Sink/Chip/Capacitance網格集

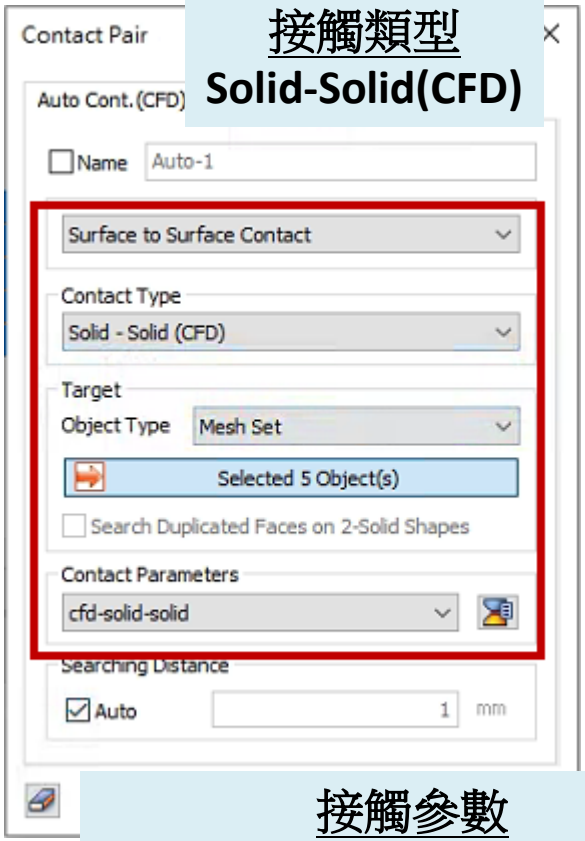
接觸間隙和懲罰函數
=>分析數值計算過程穩定



假設接觸熱阻
500 ([T]mm²/W)

Solid-Solid接觸定義-2

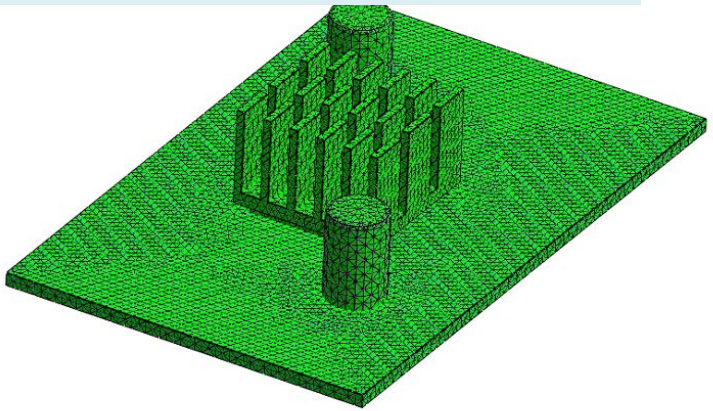


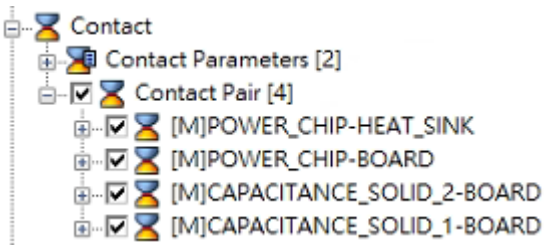


接觸類型
Solid-Solid(CFD)

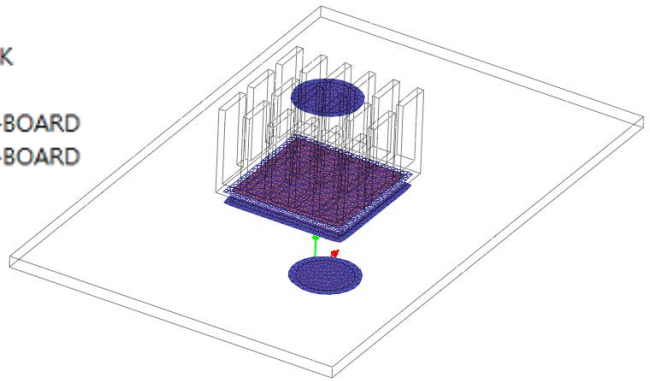
接觸參數
指定CFD-Solid-Solid(上頁操作)

選擇Board/Heat Sink/Chip/Capacitance網格集

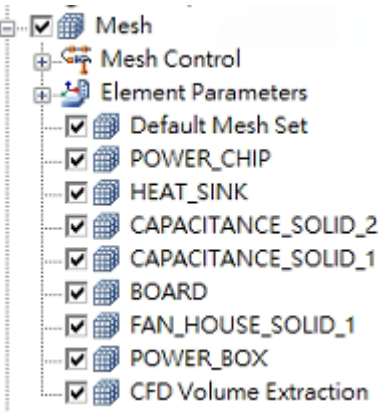


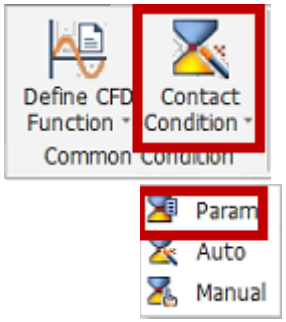


接觸對檢視

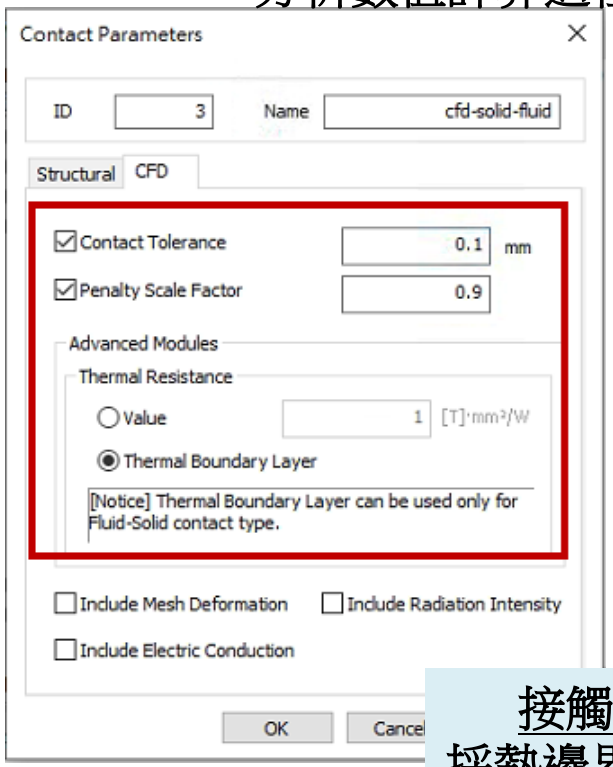


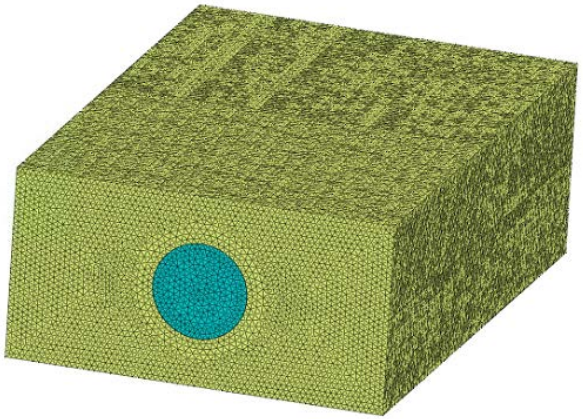
Fluid-Solid接觸定義-1





接觸間隙和懲罰函數
=>分析數值計算過程穩定

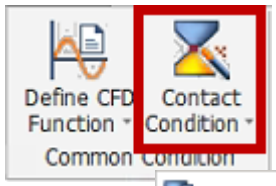




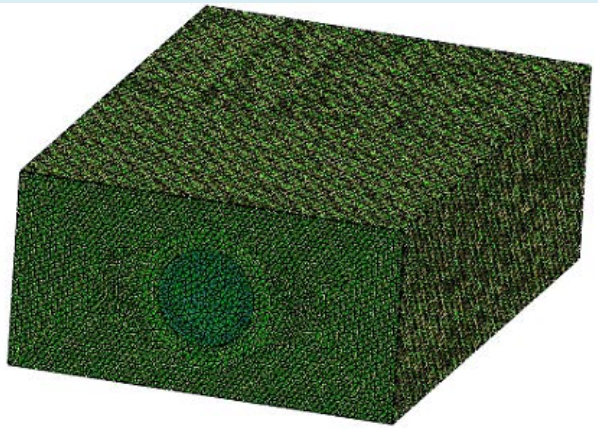
顯示所有網格集

接觸熱阻
採熱邊界層計算

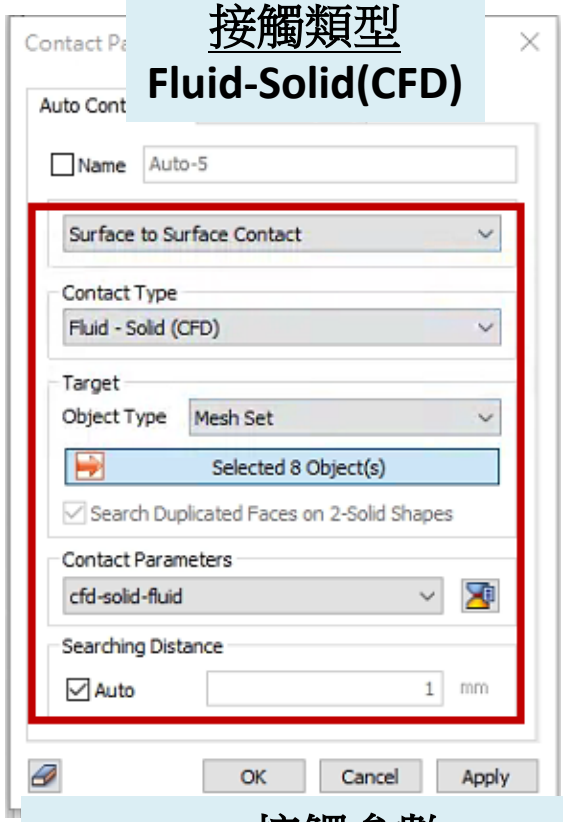
Fluid-Solid接觸定義-2

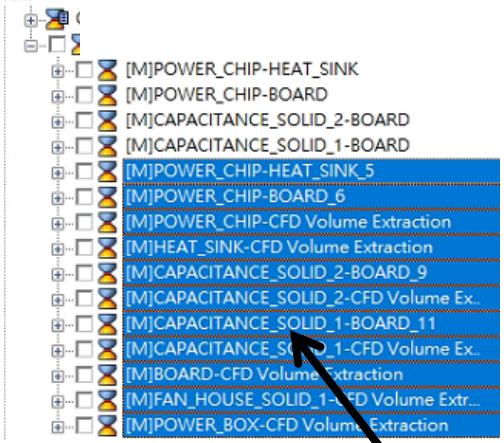


選擇所有網格集

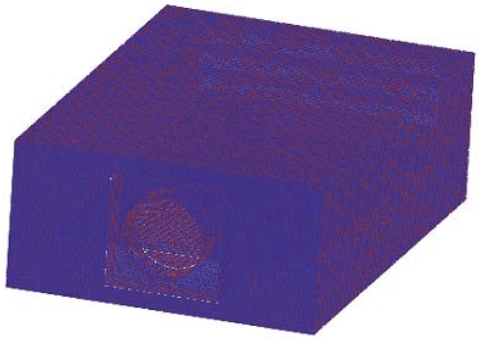


接觸類型
Fluid-Solid(CFD)





接觸對檢視

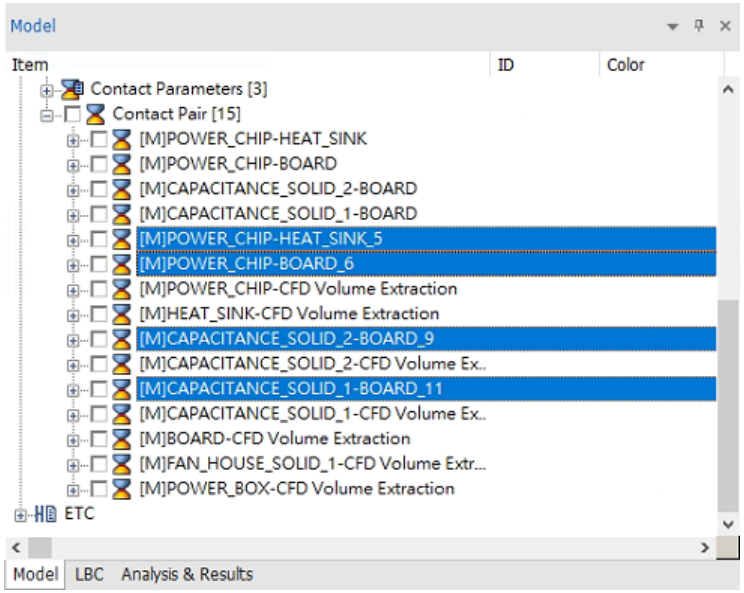


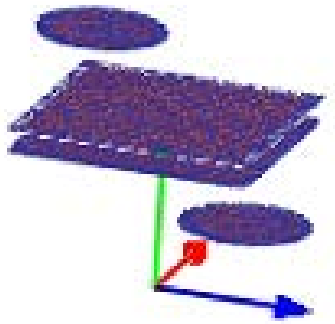
接觸參數
指定CFD-solid-fluid(上頁操作)

包含了固體網格集

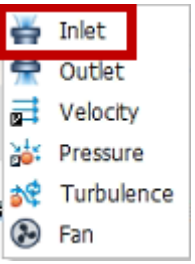
Fluid-Solid接觸定義-3

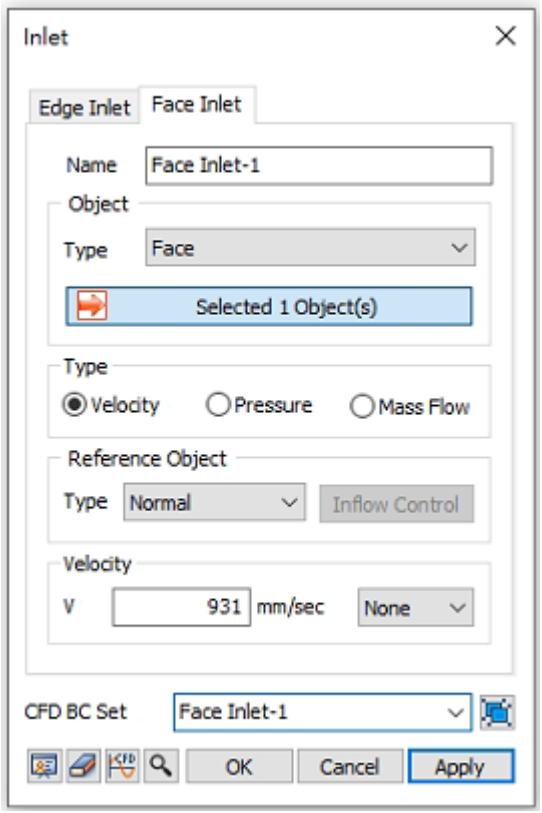
選取無流域網格集接觸對
鍵盤Delete鍵



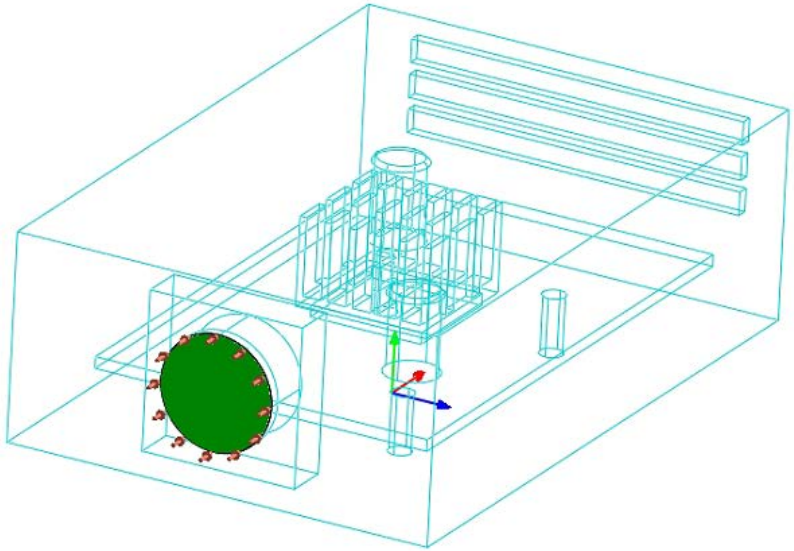


入流

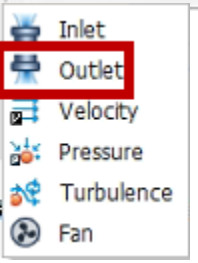


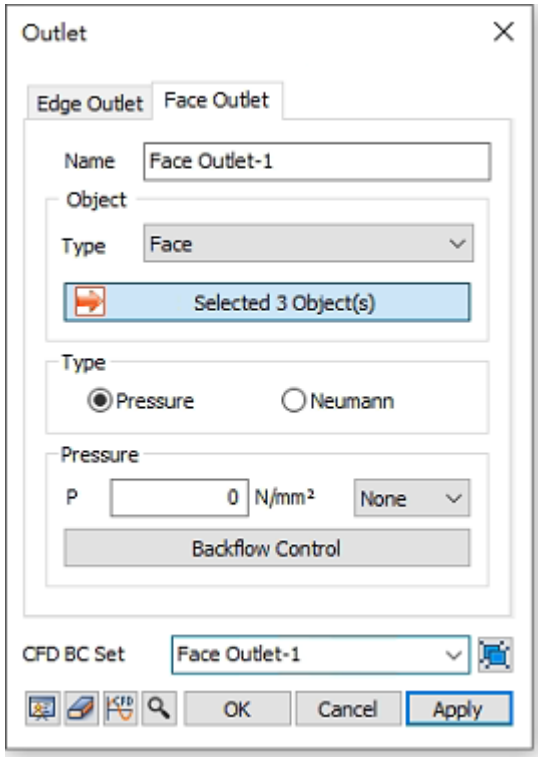


입流口=931 (mm/sec)

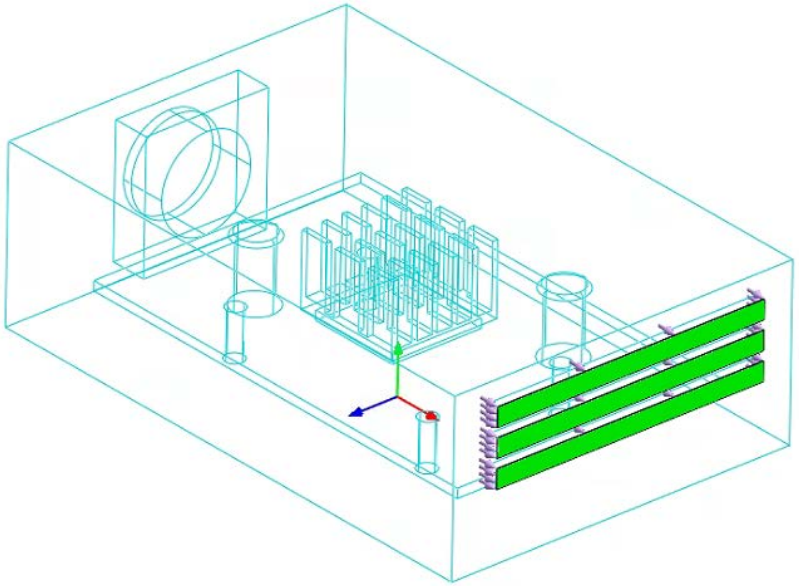


出流



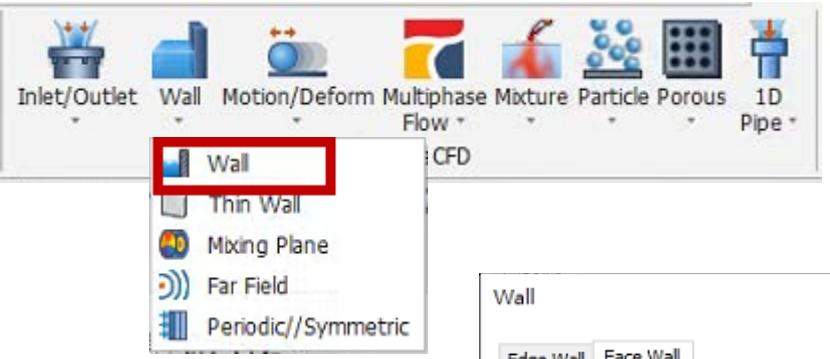


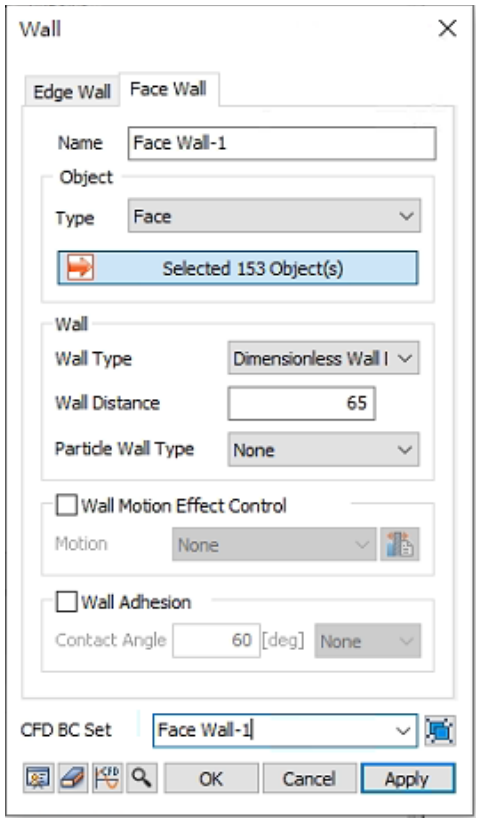
壓力0(N/m²)



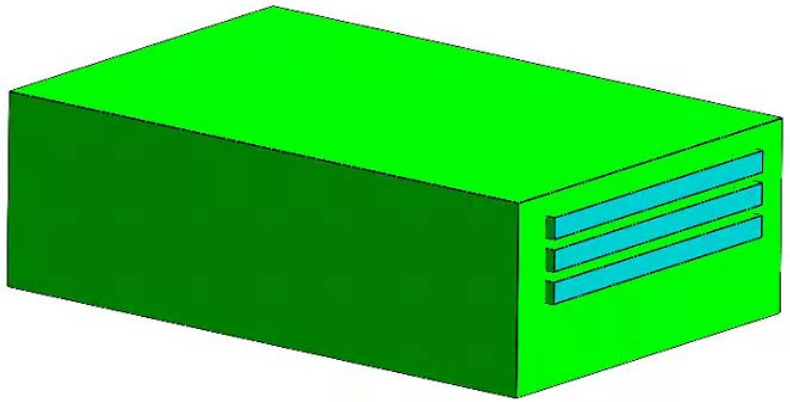
註:不同邊界&載荷建議使用不同集合名稱。

壁函數
(Dimensionless Wall Applied)





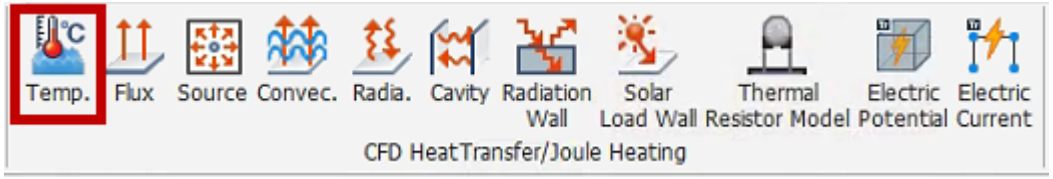
選取有流道區域特徵
(不包含入出流口)

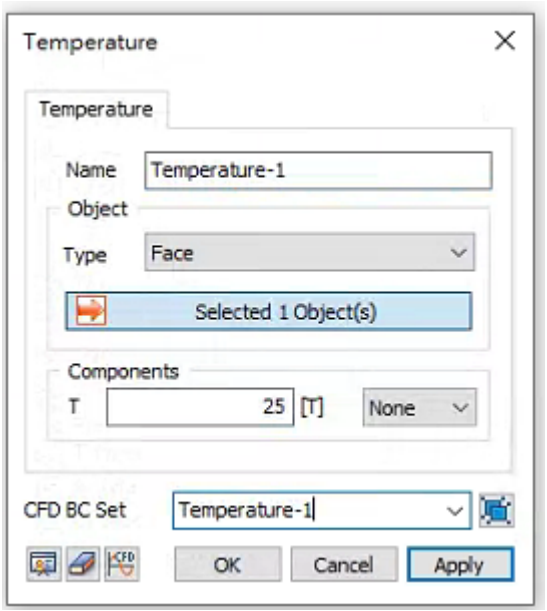


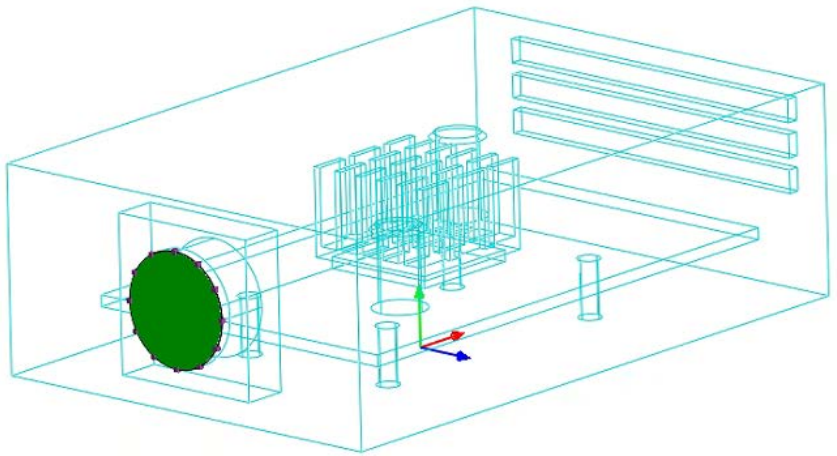
壁函數(Dimensionless Wall Applied)
Y+=65

註:壁函數施加在流體特徵與固體接觸區域。

入流溫度

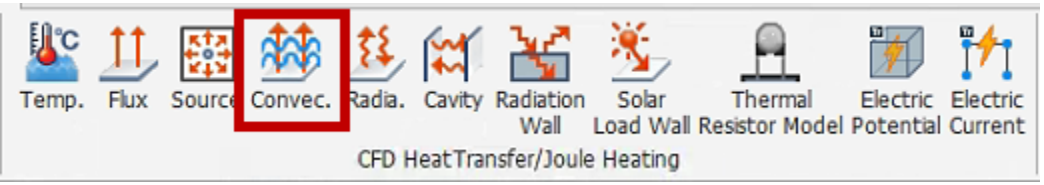


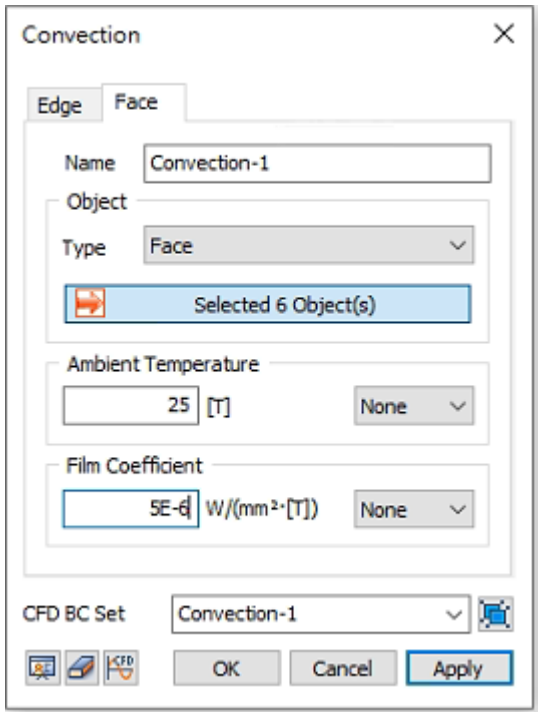




입流口溫度(25 ℃)

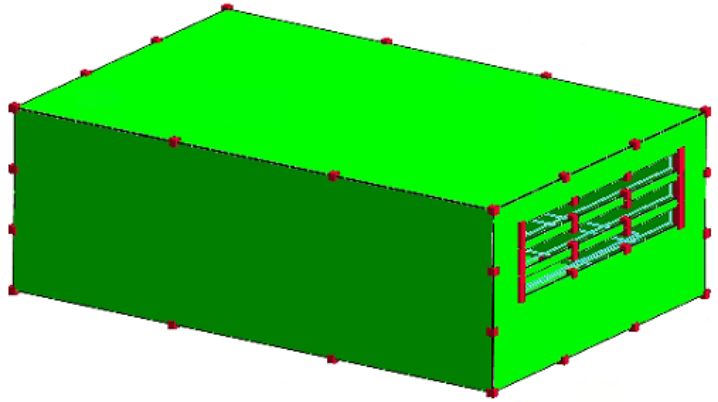
熱對流





環境溫度:25

熱對流係數:5×10^{-6} (W/mm^2 ℃)



施加在外部空氣與實體接觸特徵

一般空氣熱對流係數

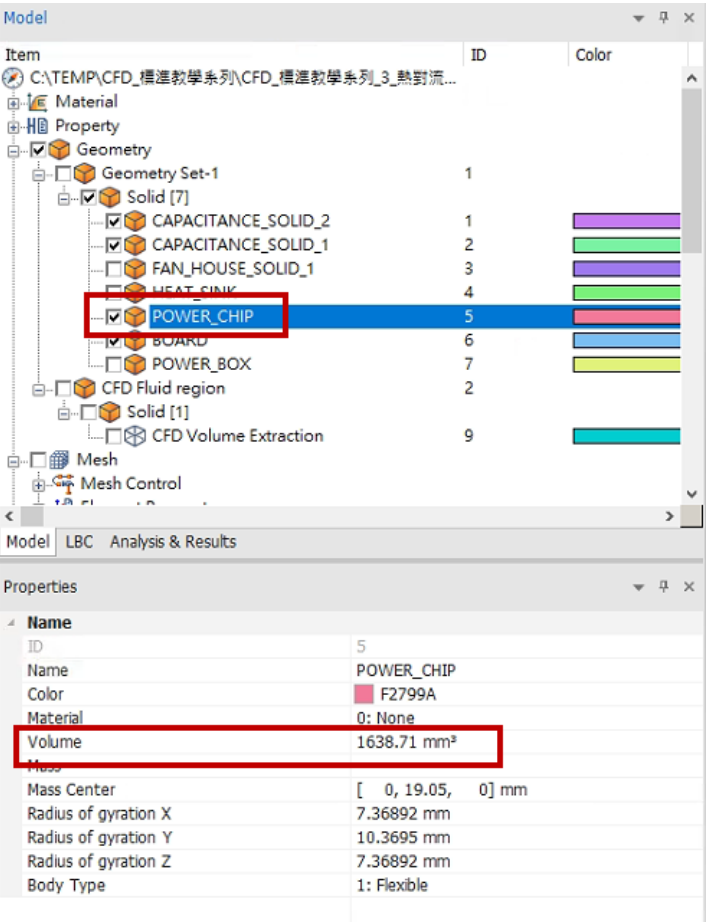
1.自然對流: 3×10^{-6} ~12×10^{-6} (W/mm^2 ℃)

2.強制對流: 10×10^{-6} ~100×10^{-6} (W/mm^2 ℃)

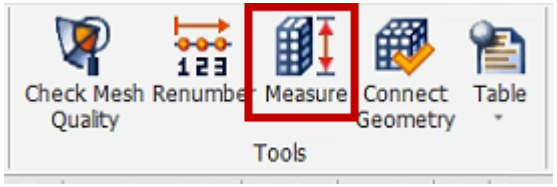
midas NFX-CFD

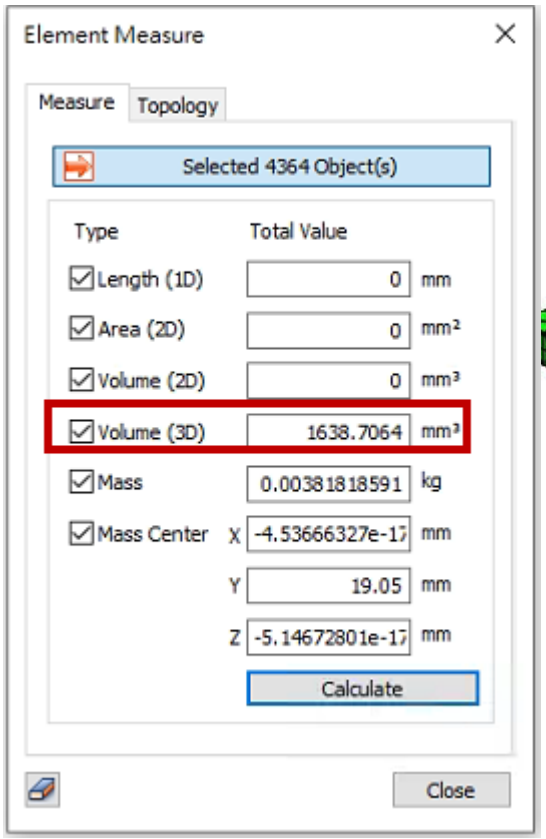
體積量測

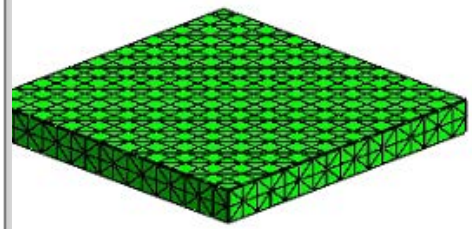
方法一(幾何體積特徵量測)



方法二(網格體積量測)

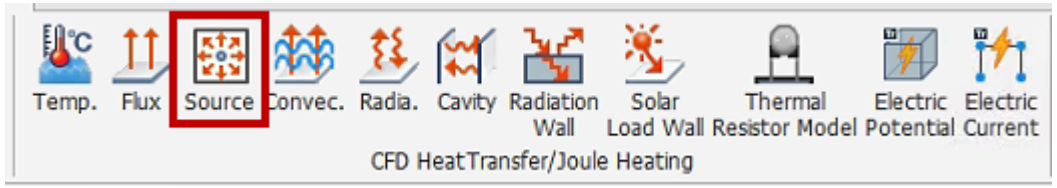


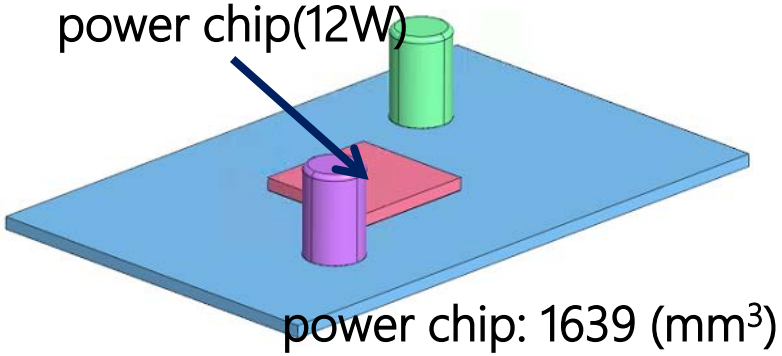


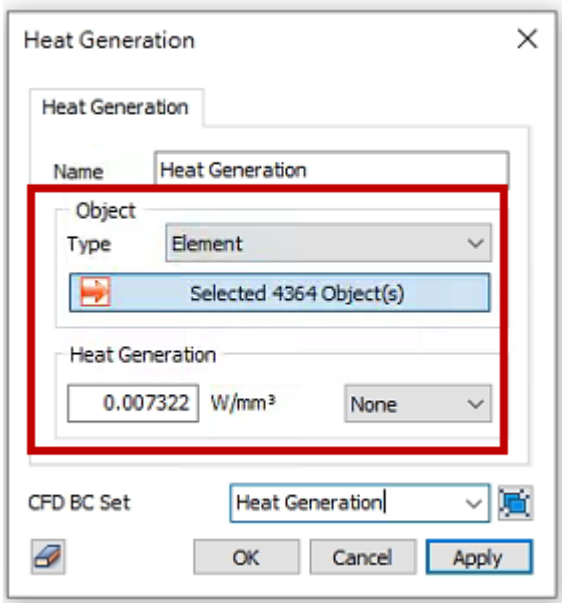


MIDAS

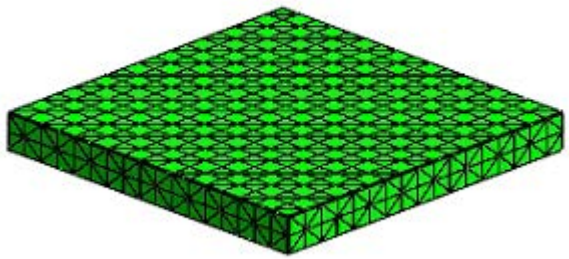
體積發熱率





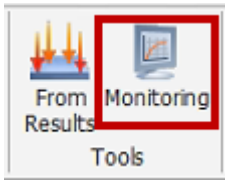


體積發熱率=0.007322 (w/mm³)

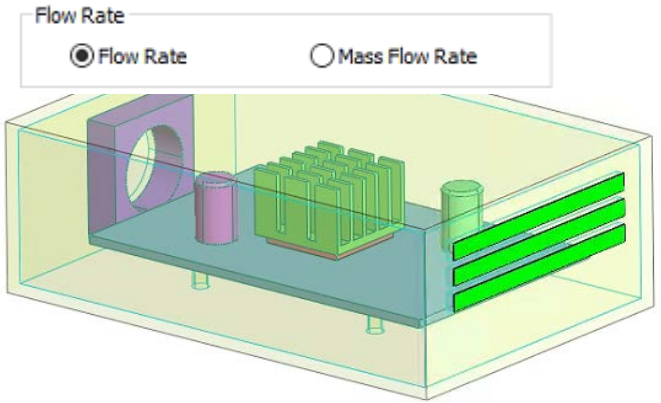


midas NFX-CFD

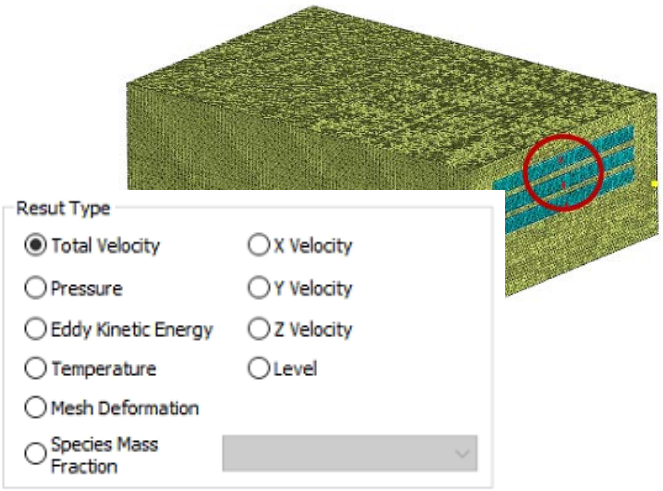
觀測點-流速/流量/溫度



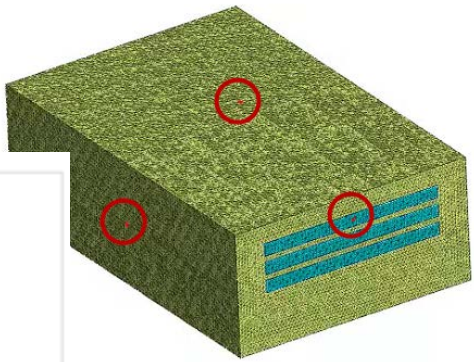
選取出流口特徵面觀測流量

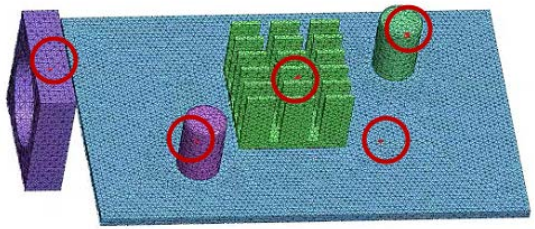


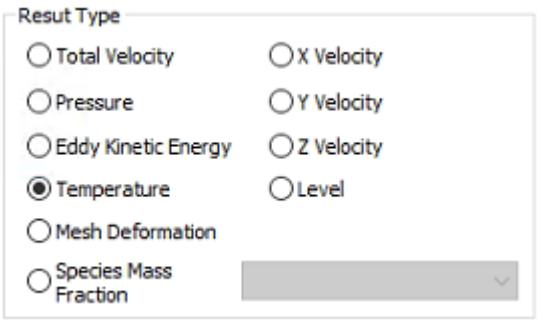
選取出流口節點觀測流速



選取各部區域節點觀測溫度







MIDAS

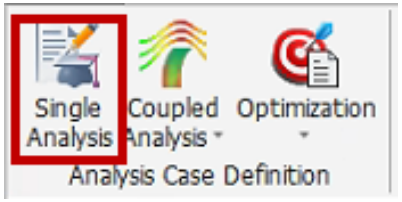
註:輸出特定節點數據同時能協助判斷收斂穩定

共軛熱傳&熱對流

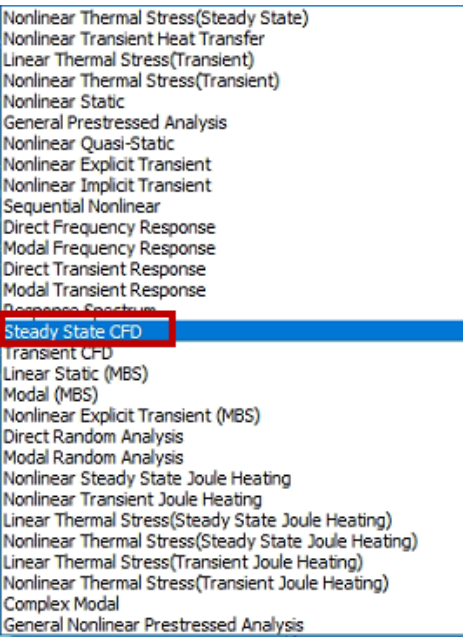
(直接法)

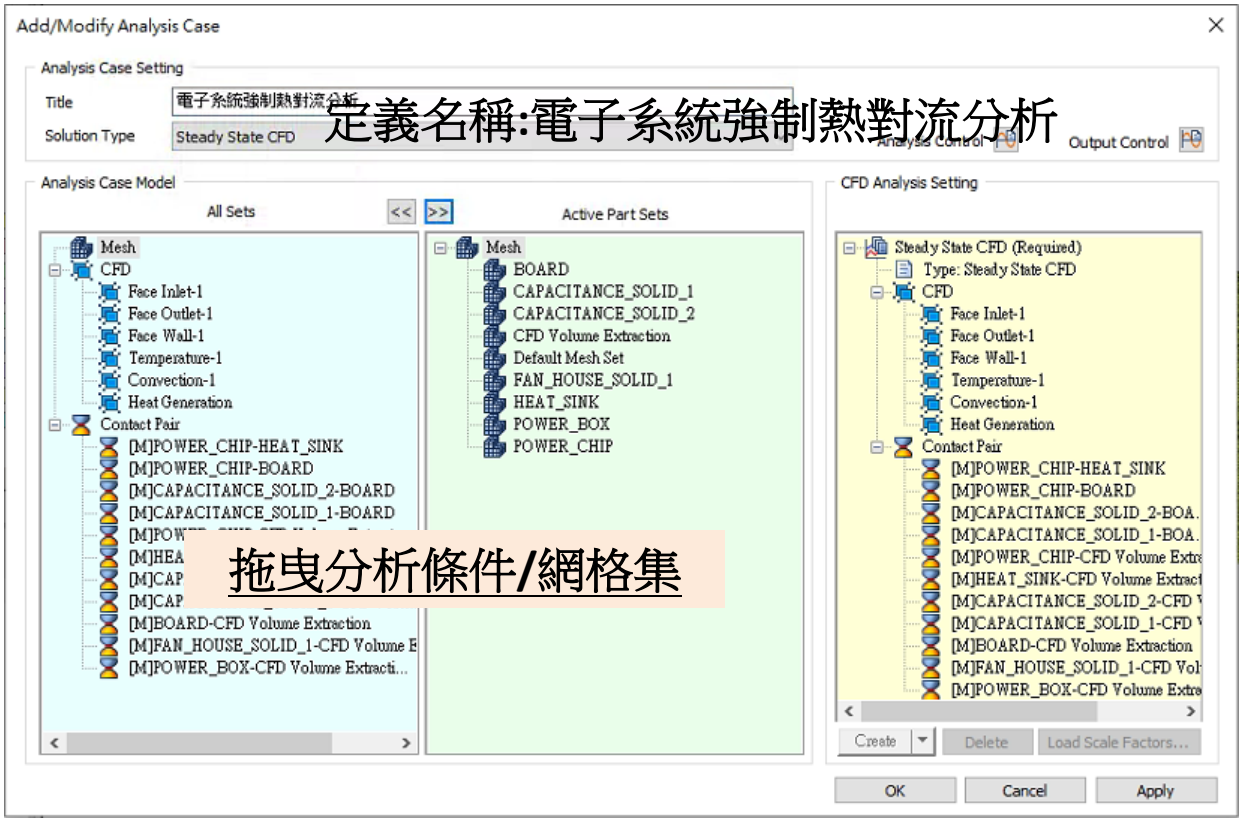
midas NFX-CFD

共軛熱傳&熱對流-1



Solution Type : Steady State CFD





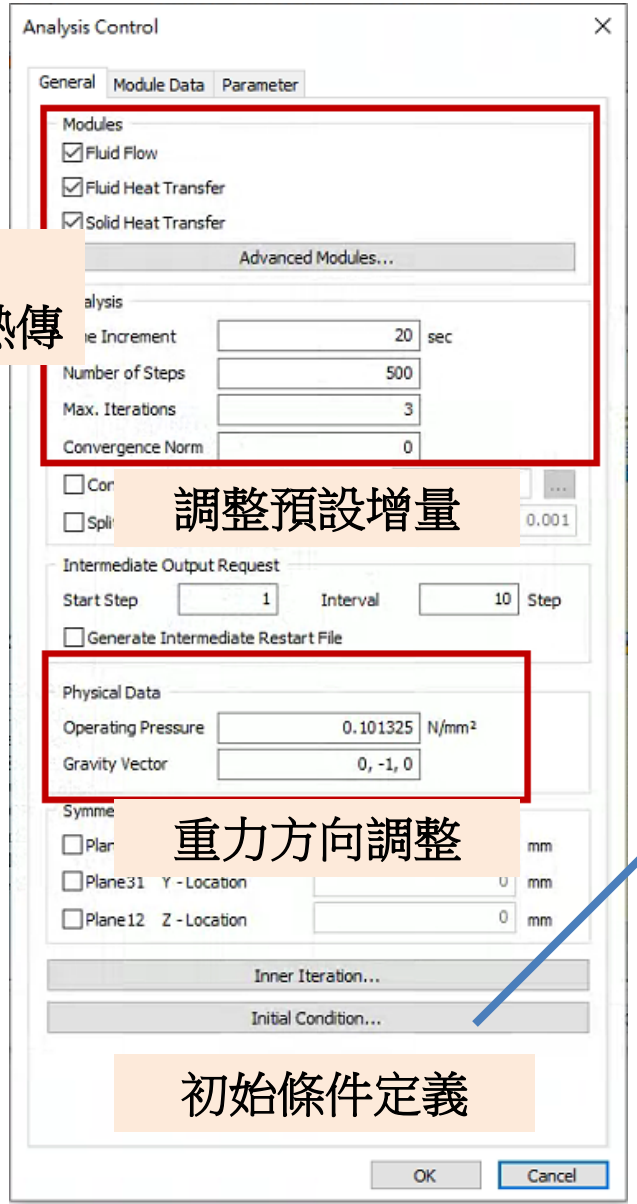
定義名稱:電子系統強制熱對流分析

拖曳分析條件/網格集

共軛熱傳&熱對流-2

分析工況定義

分析模組勾選
流體流動/流體熱傳/固體熱傳

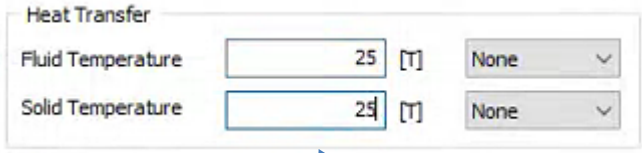


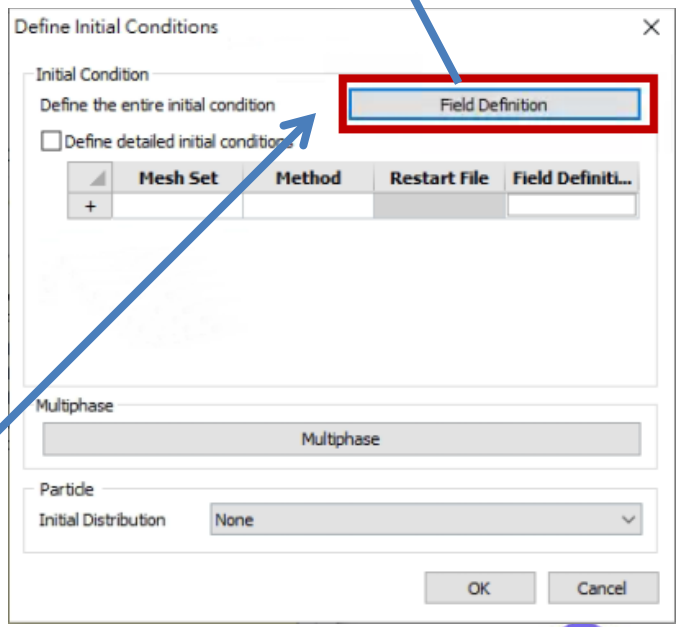
調整預設增量

重力方向調整

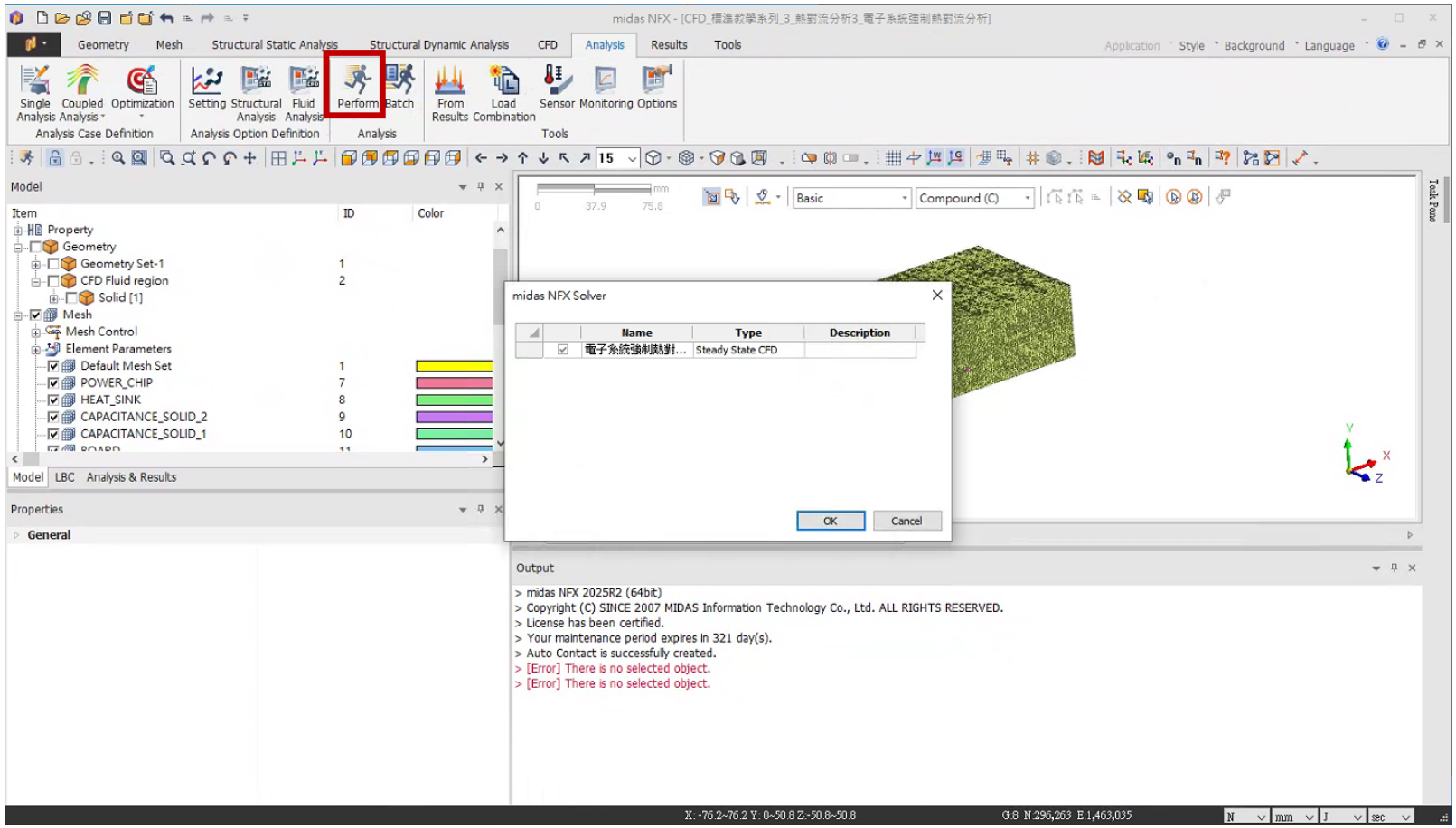
初始條件定義

初始溫度25 ℃





執行計算-1

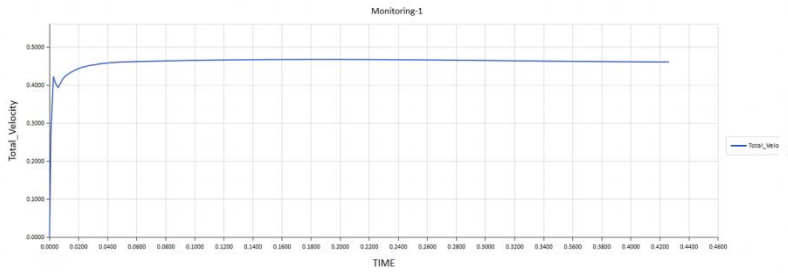

midas NFX - [CFD_標準教學系列_3_熱對流分析3_電子系統強制熱對流分析]
Geometry
Mesh
Structural Static Analysis
Structural Dynamic Analysis
CFD
Analysis
Results
Tools
Single Analysis
Coupled Analysis
Optimization
Setting
Structural Analysis
Fluid Analysis
Perform
Batch
From Results
Load Combination
Sensor
Monitoring
Options
Analysis Case Definition
Analysis Option Definition
Analysis
Tools
Model
Item
ID
Color
Property
Geometry
Geometry Set-1
CFD Fluid region
Solid [1]
Mesh
Mesh Control
Element Parameters
Default Mesh Set
POWER_CHIP
HEAT_SINK
CAPACITANCE_SOLID_2
CAPACITANCE_SOLID_1
Model
LBC
Analysis & Results
Properties
General
Basic
Compound (C)
midas NFX Solver
Name
Type
Description
電子系統強制熱對...
Steady State CFD
OK
Cancel
Output
> midas NFX 2025R2 (64bit)
> Copyright (C) SINCE 2007 MIDAS Information Technology Co., Ltd. ALL RIGHTS RESERVED.
> License has been certified.
> Your maintenance period expires in 321 day(s).
> Auto Contact is successfully created.
> [Error] There is no selected object.
> [Error] There is no selected object.

執行計算-2

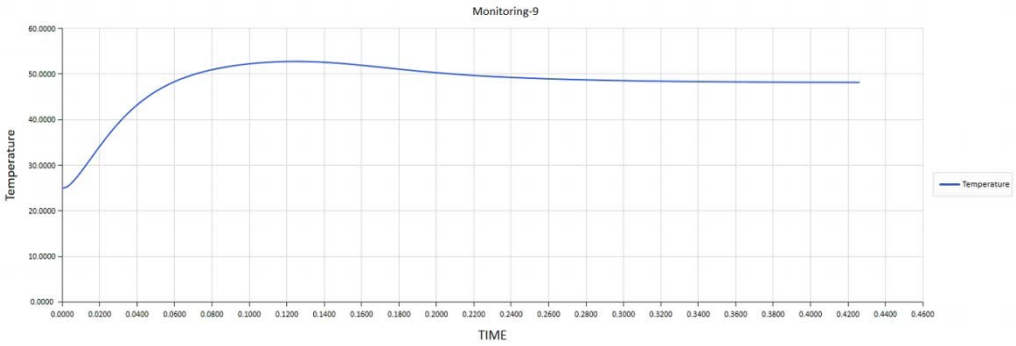
(共軛熱傳&熱對流)

觀測點判斷是否終止計算

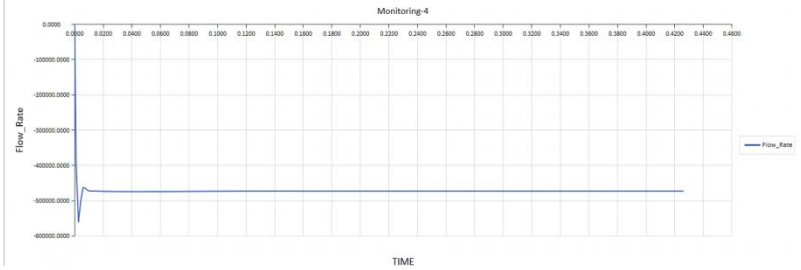
觀測節點-流速
(趨於定值)

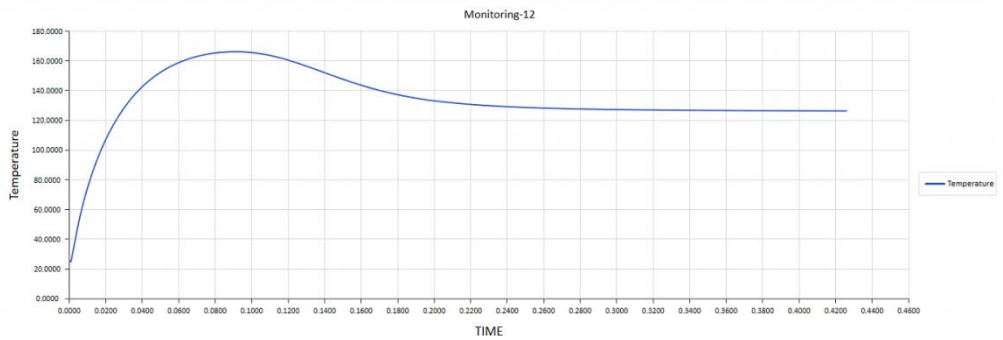


觀測節點-溫度
(趨於定值)



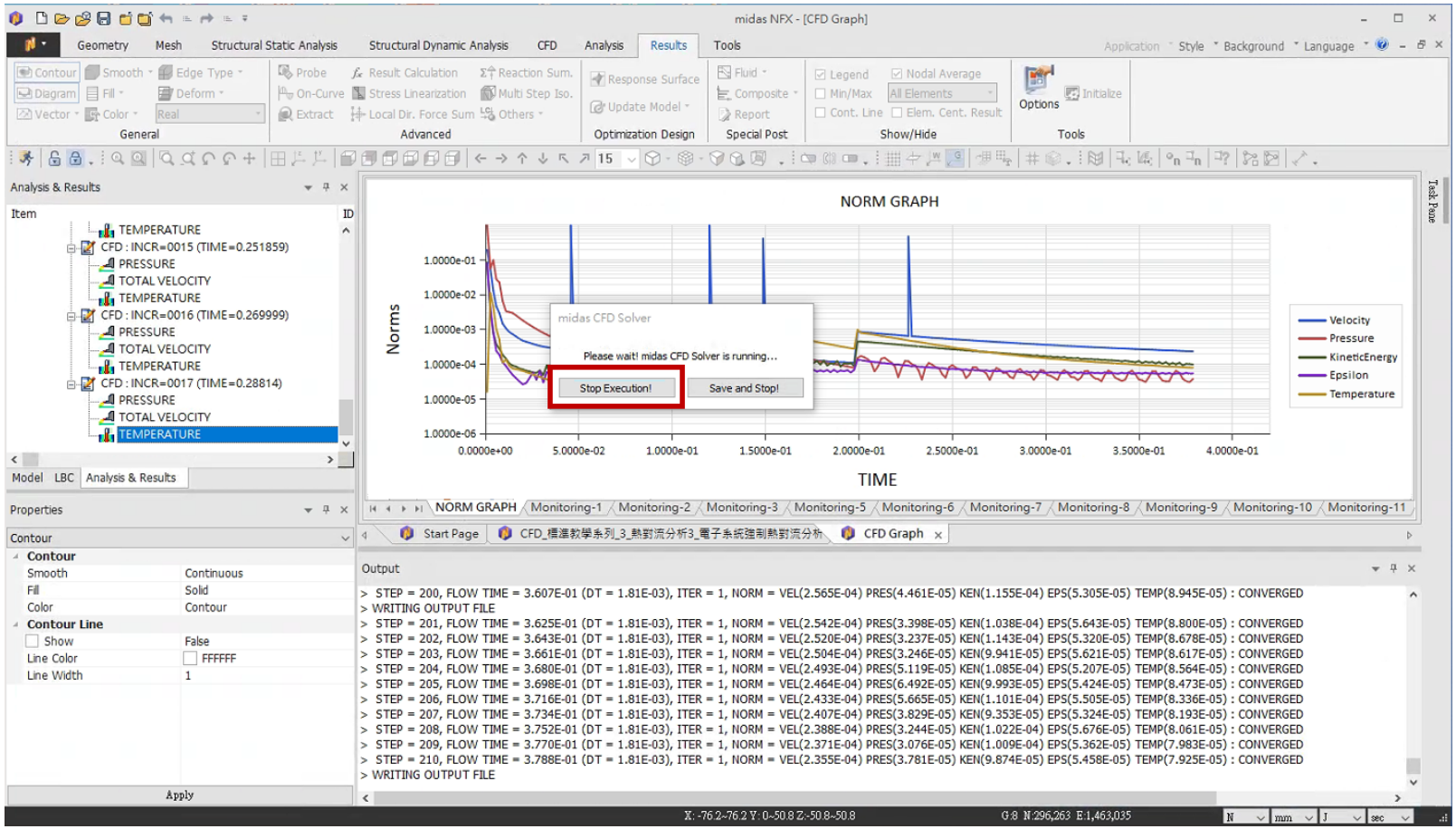
觀測面-出流口流量
(趨於定值)



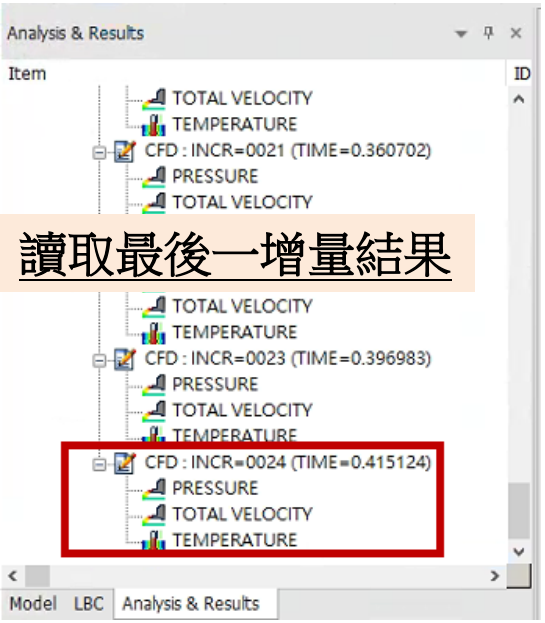


註:流量負值代表流出/正值代表流入

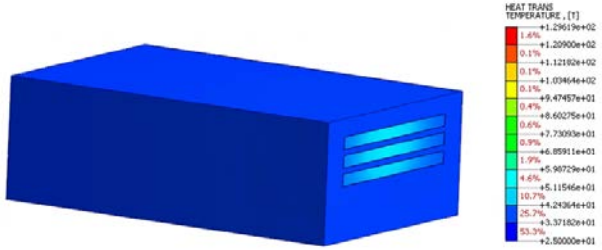
執行計算-3


midas NFX - [CFD Graph]
Geometry
Mesh
Structural Static Analysis
Structural Dynamic Analysis
CFD
Analysis
Results
Tools
Analysis & Results
Item
TEMPERATURE
CFD : INCR=0015 (TIME=0.251859)
PRESSURE
TOTAL VELOCITY
TEMPERATURE
CFD : INCR=0016 (TIME=0.269999)
PRESSURE
TOTAL VELOCITY
TEMPERATURE
CFD : INCR=0017 (TIME=0.28814)
PRESSURE
TOTAL VELOCITY
TEMPERATURE
Properties
Contour
Smooth
Continuous
Fill
Solid
Color
Contour
Contour Line
Show
False
Line Color
FFFFFF
Line Width
1
Apply
NORM GRAPH
Norms
TIME
midas CFD Solver
Please wait! midas CFD Solver is running...
Stop Execution!
Save and Stop!
Velocity
Pressure
KineticEnergy
Epsilon
Temperature
Monitoring-1
Monitoring-2
Monitoring-3
Monitoring-5
Monitoring-6
Monitoring-7
Monitoring-8
Monitoring-9
Monitoring-10
Monitoring-11
Start Page
CFD Graph
Output
> STEP = 200, FLOW TIME = 3.607E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.565E-04) PRES(4.461E-05) KEN(1.155E-04) EPS(5.305E-05) TEMP(8.945E-05) : CONVERGED
> WRITING OUTPUT FILE
> STEP = 201, FLOW TIME = 3.625E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.542E-04) PRES(3.398E-05) KEN(1.038E-04) EPS(5.643E-05) TEMP(8.800E-05) : CONVERGED
> STEP = 202, FLOW TIME = 3.643E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.520E-04) PRES(3.237E-05) KEN(1.143E-04) EPS(5.320E-05) TEMP(8.678E-05) : CONVERGED
> STEP = 203, FLOW TIME = 3.661E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.504E-04) PRES(3.246E-05) KEN(9.941E-05) EPS(5.621E-05) TEMP(8.617E-05) : CONVERGED
> STEP = 204, FLOW TIME = 3.680E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.493E-04) PRES(5.119E-05) KEN(1.085E-04) EPS(5.207E-05) TEMP(8.564E-05) : CONVERGED
> STEP = 205, FLOW TIME = 3.698E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.464E-04) PRES(6.492E-05) KEN(9.993E-05) EPS(5.424E-05) TEMP(8.473E-05) : CONVERGED
> STEP = 206, FLOW TIME = 3.716E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.433E-04) PRES(5.665E-05) KEN(1.101E-04) EPS(5.505E-05) TEMP(8.336E-05) : CONVERGED
> STEP = 207, FLOW TIME = 3.734E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.407E-04) PRES(3.829E-05) KEN(9.353E-05) EPS(5.324E-05) TEMP(8.193E-05) : CONVERGED
> STEP = 208, FLOW TIME = 3.752E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.388E-04) PRES(3.244E-05) KEN(1.022E-04) EPS(5.676E-05) TEMP(8.061E-05) : CONVERGED
> STEP = 209, FLOW TIME = 3.770E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.371E-04) PRES(3.076E-05) KEN(1.009E-04) EPS(5.362E-05) TEMP(7.983E-05) : CONVERGED
> STEP = 210, FLOW TIME = 3.788E-01 (DT = 1.81E-03), ITER = 1, NORM = VEL(2.355E-04) PRES(3.781E-05) KEN(9.874E-05) EPS(5.458E-05) TEMP(7.925E-05) : CONVERGED
> WRITING OUTPUT FILE

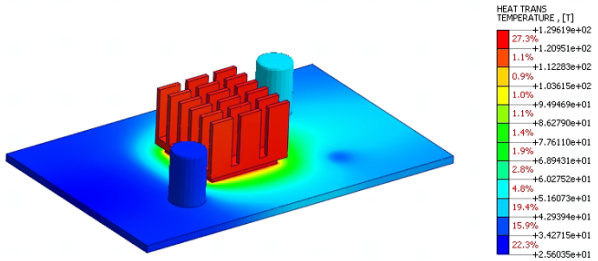
分析結果

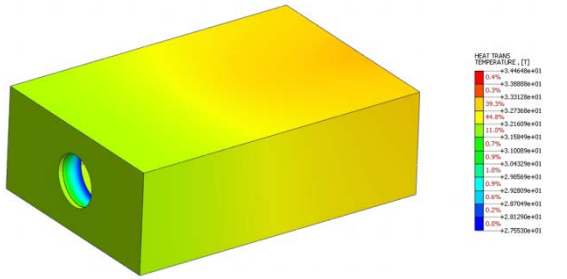


溫度(℃)

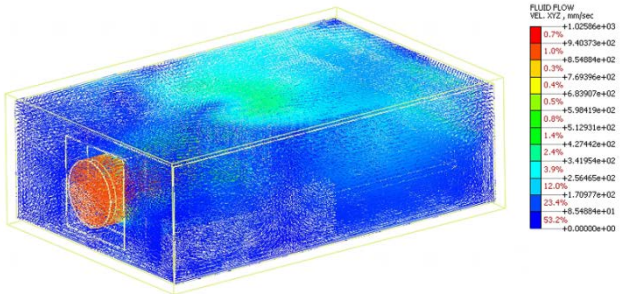


各部件溫度(℃)





流速(mm/sec)



midas NFX-CFD

CFD_標準教學系列

熱對流分析5-PCB和熱阻分析

台灣邁達斯

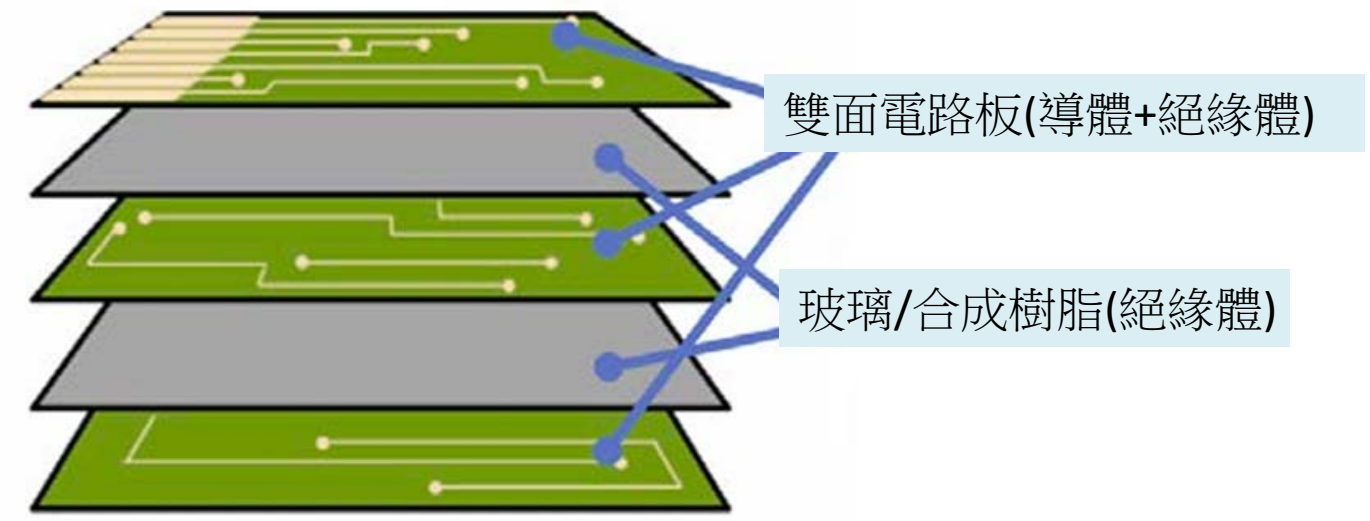
MIDAS

印刷電路板-1
(Printed Circuit Board)

印刷電路板(PCB)

傳統的電路板，採用印刷蝕刻阻劑的工法，做出電路的線路及圖紙，因此稱為印刷電路板或印刷線路板。

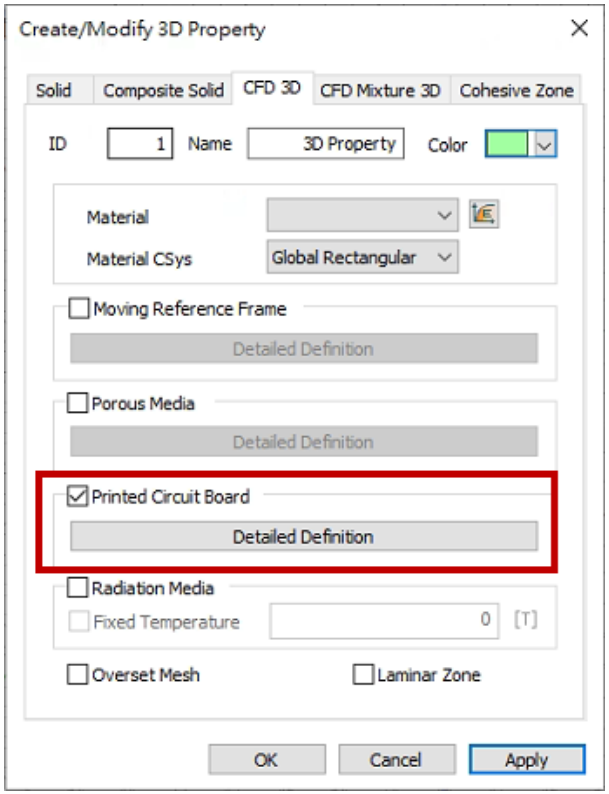
積體電路的快速發展及廣泛應用，使電子設備的體積越來越小，電路佈線密度和難度越來越大，這就要求印刷板要不斷更新。目前印製板的品種已從單面板發展到雙面板、多層板和撓性板；結構和質量也已發展到超高密度、微型化和高可靠性程度；新的設計方法、設計用品和製板材料、制板過程不斷湧現。

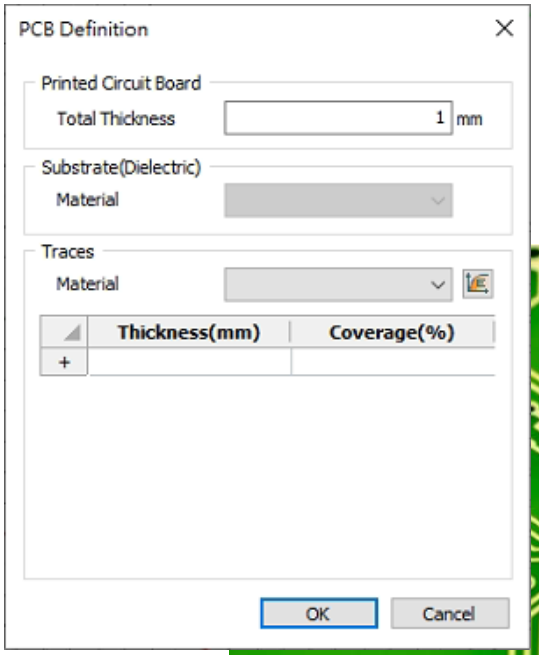


印刷電路板-2
(Printed Circuit Board)

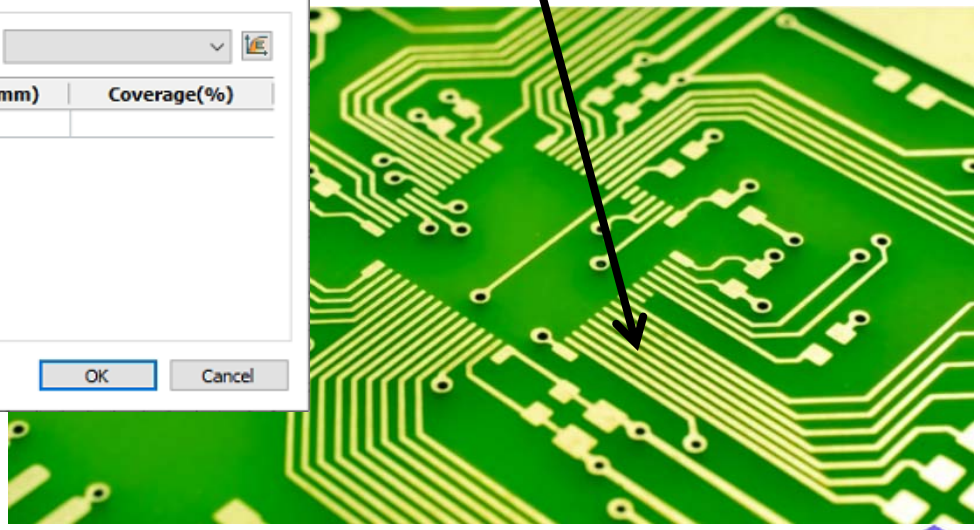
印刷電路板層壓結構在平面方向上表現出高導熱性，而在厚度(垂直)方向上則表現出低導熱性。

NFX CFD 提供了印刷電路板特性定義，透過輸入電路所用材料、各層厚度及導體含量比，自動計算各方向的平均熱導率。





PCB Traces(PCB 走線/銅箔線路)



Substrate(基板)

印刷電路板-3
(Printed Circuit Board)

多層電路板(PCB)或複合材料板的等效導熱係數(thermal conductivity)計算公式

公式 1.平面方向的等效導熱係數

$$k_{\text{inplane}} = \frac{\sum k_i t_i}{\sum t_i}$$

- $k_{inplane}$：PCB板平面方向(in-plane)的等效導熱係數
- k_i：第 i 層的導熱係數
- t_i：第 i 層的厚度

公式 2.厚度(垂直)方向的等效導熱係數

$$k_{\text{normal}} = \frac{\sum t_i}{\sum (t_i / k_i)}$$

- k_{normal}：PCB板垂直方向(normal)的等效導熱係數
- k_i：第 i 層的導熱係數
- t_i：第 i 層的厚度

公式 3.單層導熱係數 k_i

銅箔(Cu)層 $k_i = f_i k_{\text{cu}}$ 其中 f_i 是銅的填充比例，k_{cu}是銅的導熱係數。

FR4(PCB 基板材料)層 $k_i = k_{\text{FR4}}$ 直接取 FR4 材料的導熱係數。

熱阻
(Thermal Resistor)

熱阻 (Thermal Resistance, θ)是一個和熱有關的性質，是指在有溫度差的情形下，物體抵抗傳熱的能力。熱導率越好的物體，熱阻通常會比較低。

單位：K/W 或 ˚C/W

$$\theta = \frac{\Delta T}{P}$$ 其中 ΔT是溫差，P 是熱功率(W)

串聯熱阻公式

$$R_{th,total} = R_{th1} + R_{th2} + R_{th3} + \cdots$$

◆ **舉例**

假設一個晶片要把熱傳到環境：

- **接面 → 封裝殼體**：$R_{jc} = 1.5\ \mathrm{K/W}$
- **封裝殼體 → 散熱器**：$R_{cs} = 0.5\ \mathrm{K/W}$
- **散熱器 → 環境**：$R_{sa} = 3.0\ \mathrm{K/W}$

則總熱阻：

$$R_{ja} = R_{jc} + R_{cs} + R_{sa} = 1.5 + 0.5 + 3.0 = 5.0\ \mathrm{K/W}$$

如果功率 $Q = 2\ \mathrm{W}$，環境溫度 $T_a = 30^\circ C$，
接面溫度：

$$T_j = T_a + Q \cdot R_{ja} = 30 + 2 \times 5 = 40^\circ C$$

並聯熱阻公式

$$\frac{1}{R_{th,total}} = \frac{1}{R_{th1}} + \frac{1}{R_{th2}} + \frac{1}{R_{th3}} + \cdots$$

◆ **舉例**

一個 IC 同時透過 PCB 與散熱器散熱：

- **結點 → PCB**：$R_{jb} = 15\ \mathrm{K/W}$
- **結點 → 散熱器**：$R_{jc} = 5\ \mathrm{K/W}$

則總熱阻：

$$\frac{1}{R_{total}} = \frac{1}{15} + \frac{1}{5} = \frac{1+3}{15} = \frac{4}{15}$$

$$R_{total} = 3.75\ \mathrm{K/W}$$

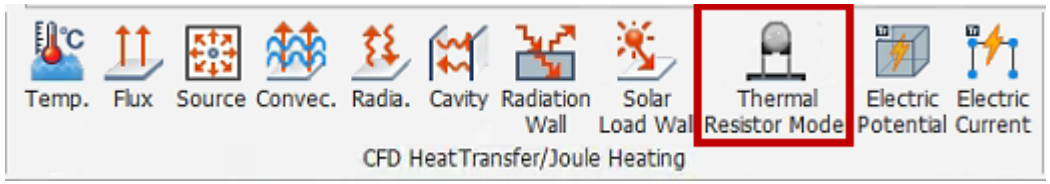
若功率 $Q = 2\ \mathrm{W}$，環境溫度 $T_a = 30^\circ C$，
接面溫度：

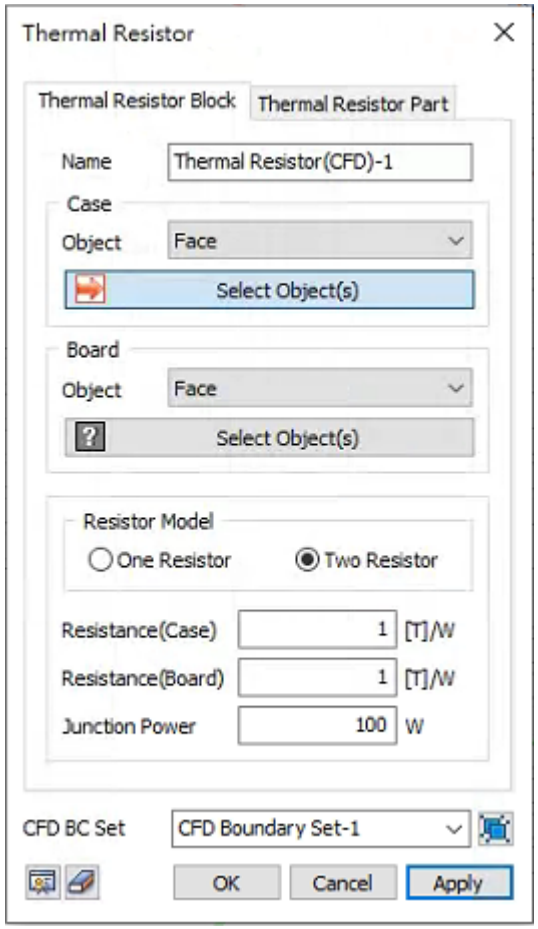
$$T_j = T_a + Q \cdot R_{total} = 30 + 2 \times 3.75 = 37.5^\circ C$$

Reference

https://chatgpt.com/

熱阻模型
(Thermal Resistor Model)





CFD的熱分析中，熱阻模型 (Thermal Resistance Model) 是一種常見的簡化方法，用於描述半導體封裝或電子元件的熱傳導行為，而無需在 CFD 軟體中建立非常複雜的三維幾何與材料細節

<u>常見熱阻分析方式</u>

緊湊熱模型 (Compact Thermal Model, CTM)
1.單熱阻模型 (1-Resistor Model, θja)
2.雙熱阻模型 (2-Resistor Model, θjb 與 θjc)
3.Delphi 模型 (Delphi Model)

詳細模型(Detailed Model)
4. 分佈式熱模型 (Detailed FEM/CFD Model)

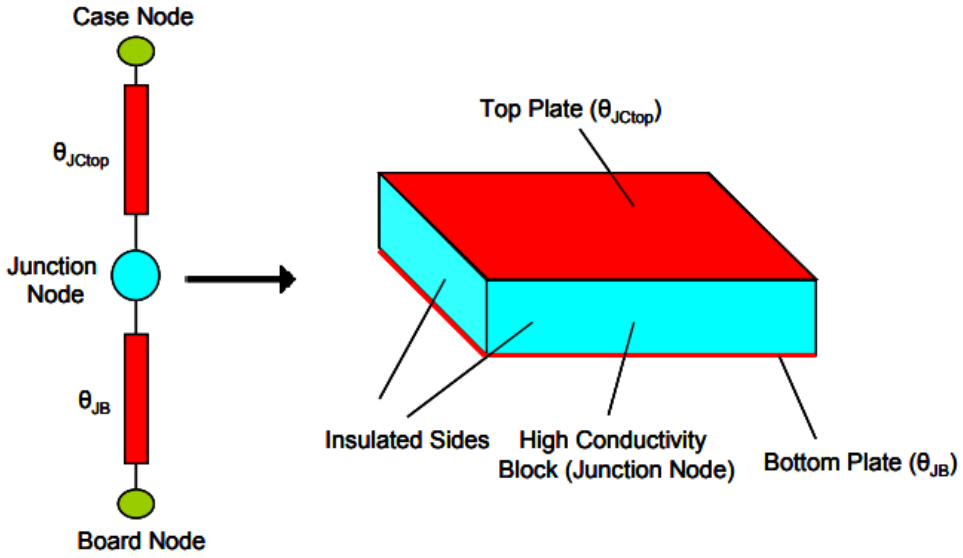
雙熱阻模型
(2- Resistor Model)

雙熱阻模型會根據輸入的熱阻值來反映熱特性，因此在半導體封裝部分不需要額外的有限元素結構。只需要定義 半導體封裝與電路板接觸的底面 以及 半導體封裝的上表面 即可。如果存在發熱情況，可以在 接面位置 輸入熱源

2- Resistor Model ，假設熱主要經過 兩條路徑

節點 → 電路板 (Junction-to-Board, θ_b)
節點→ 封裝外殼/頂部 (Junction-to-Case, θ_c)

Junction Node作為熱源(輸入功率 P),兩個熱θ_c,θ_b從結點並聯分流。



$$\frac{1}{\theta_{ja,eff}} = \frac{1}{\theta_{jc}+\theta_{ca}} + \frac{1}{\theta_{jb}+\theta_{ba}}$$

其中,
$\theta_{ja,eff}$:總等效熱阻
θ_{jc}:節點 → Top Plate
θ_{ca}:Top Plate→ 環境

θ_{jb}:節點 → Bottom Plate
θ_{bc}: Bottom Plate → 環境

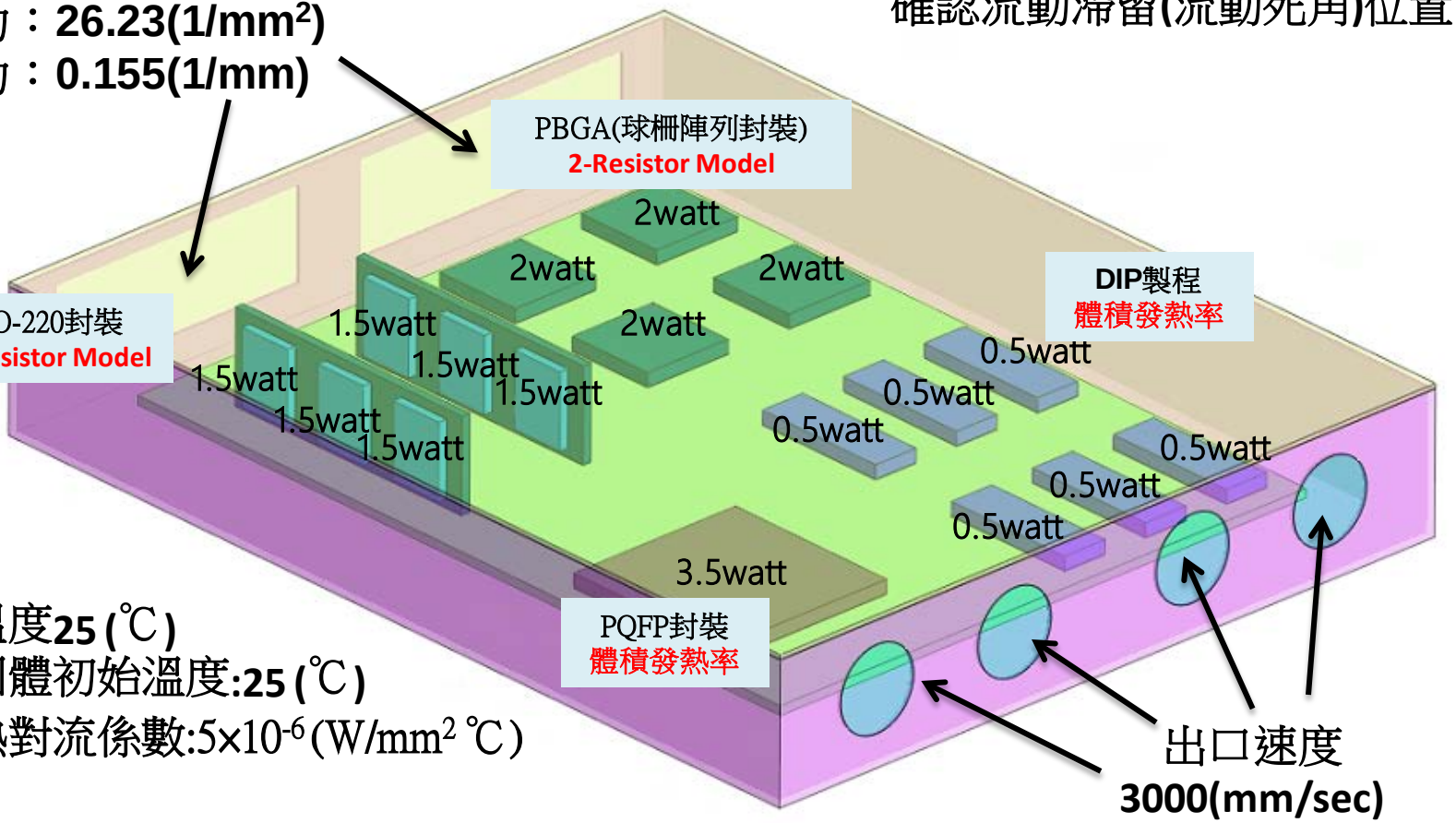
Reference

YANKI ASLAN , “Thermal-Aware Synthesis of 5G Base Station Antenna Arrays: An Overview and a Sparsity-Based Approach”

分析說明-1

分析目標如下：
確認封裝(Package)的溫度分佈
了解電子設備內部流動特性
確認流動滯留(流動死角)位置

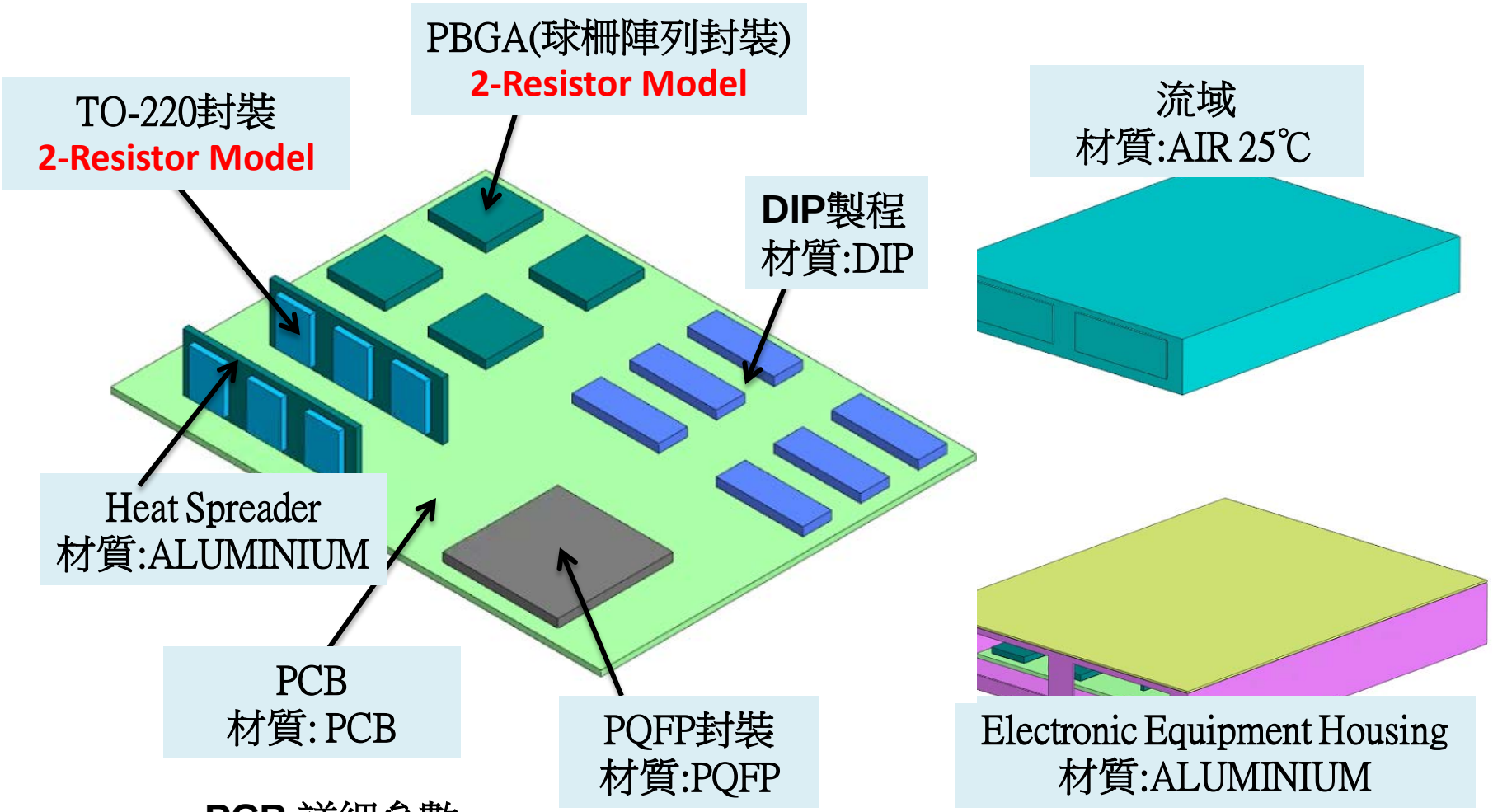
入口多孔過濾器
厚度：**5 mm**
黏性阻力：**26.23(1/mm²)**
慣性阻力：**0.155(1/mm)**



環境溫度**25** (℃)
流體固體初始溫度:**25** (℃)
空氣熱對流係數:5×10^{-6} (W/mm² ℃)

分析說明-2

(材料)



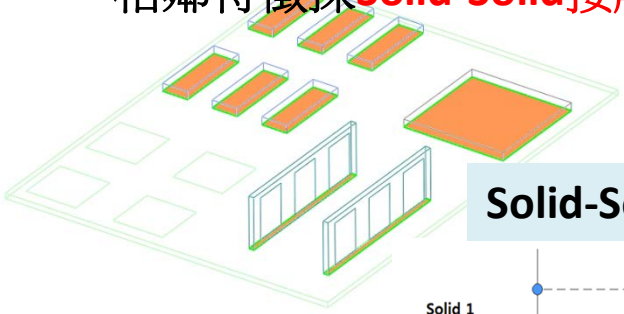
PCB 詳細參數

- 總厚度：2 mm
- 基板構成： PCB
- 電路層數與厚度：3 層/厚0.0341mm /COPPER/覆蓋範圍30%

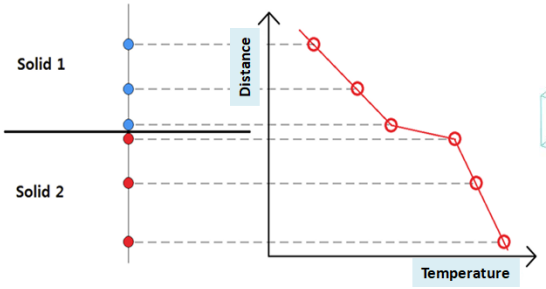
分析說明-3
(連接方式)

PCB/HeatSpreader/DIP

相鄰特徵採**Solid-Solid接觸定義**

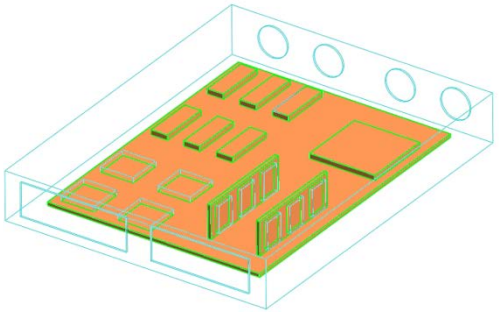


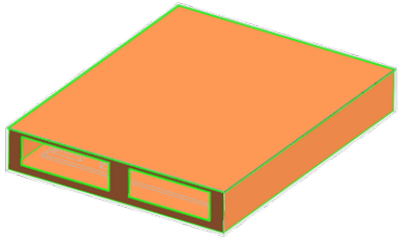
Solid-Solid接觸–熱阻



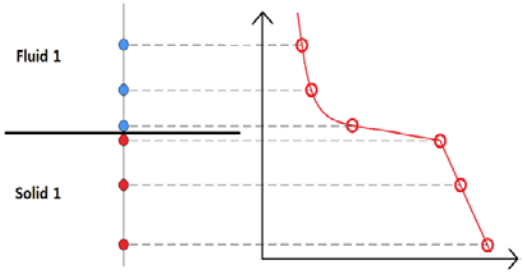
流域

相鄰特徵採**Fluid-Solid接觸定義**



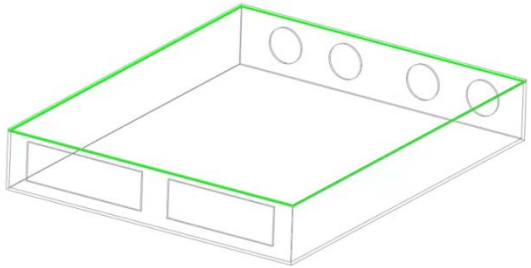


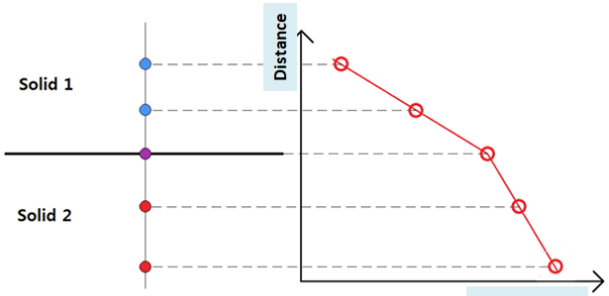
Fluid-Solid接觸–熱邊界層



BOX Top/Box Bottom

Soild1與Solid2 :相鄰邊界採節點相連





分析說明-4

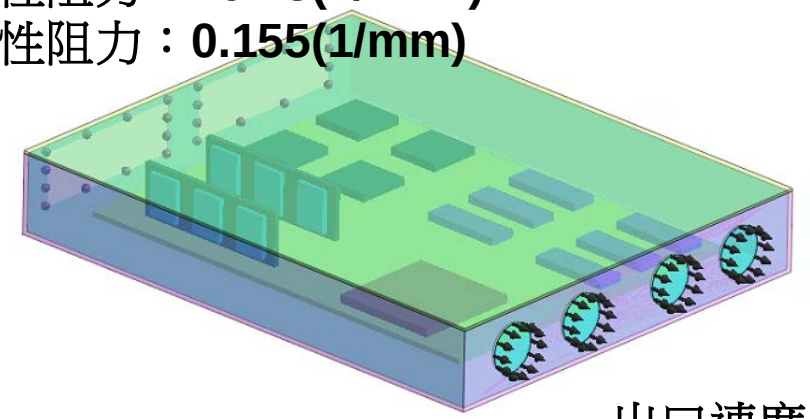
(邊界條件)

入口多孔過濾器

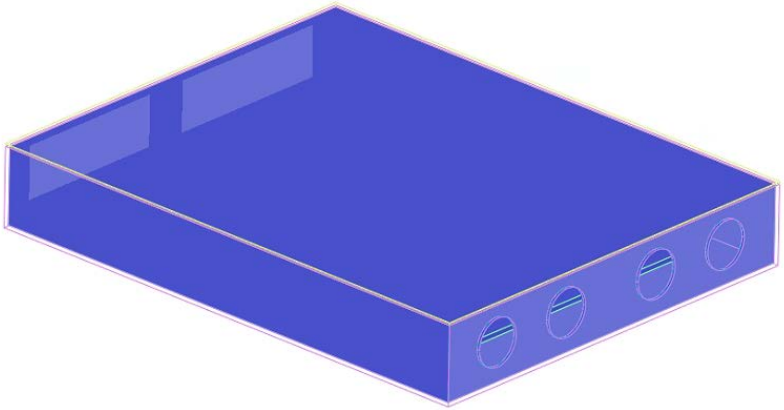
厚度：**5 mm**

黏性阻力：**26.23(1/mm²)**

慣性阻力：**0.155(1/mm)**



壁函數(Wall)流體與實體接觸面



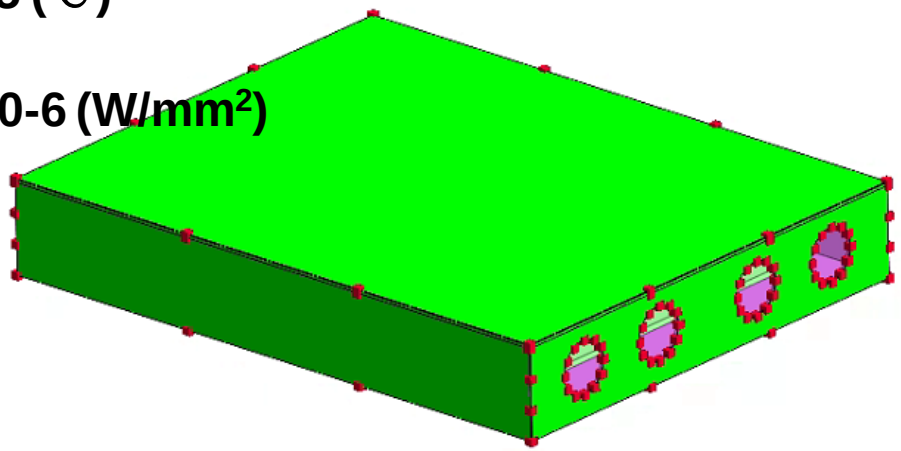
出口速度

3000(mm/sec)

流體固體初始溫度:**25 (℃)**

環境溫度**25 (℃)**

空氣熱對流係數:**5x10-6 (W/mm²)**



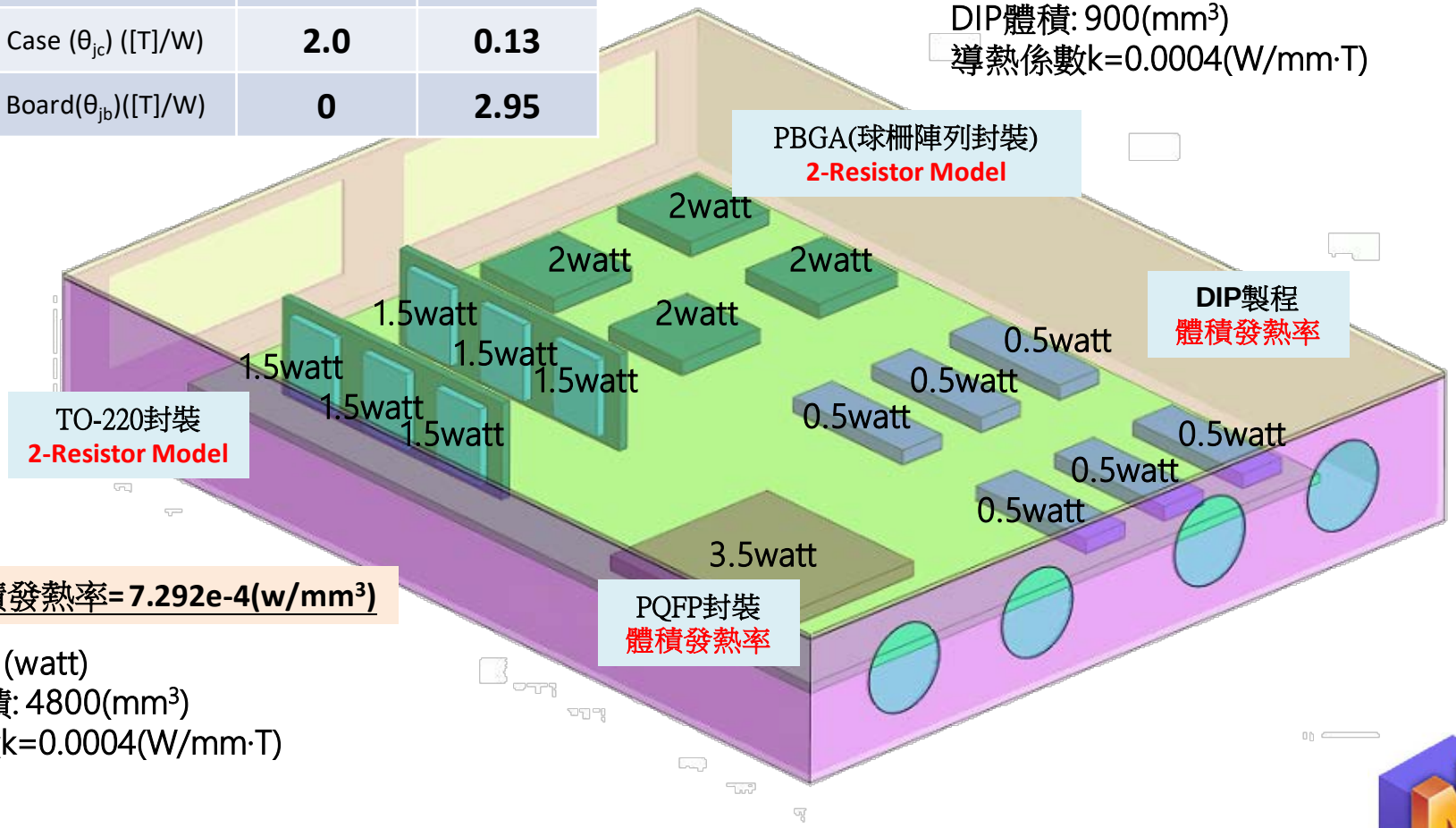
分析說明-5

(熱阻和體積發熱率)

	TO-220	PBGA
Junction Power (W)	**1.5**	**2.0**
Resistance Case (θ_{jc}) ([T]/W)	**2.0**	**0.13**
Resistance Board(θ_{jb})([T]/W)	**0**	**2.95**

DIP體積發熱率= 5.556e-4(w/mm³)

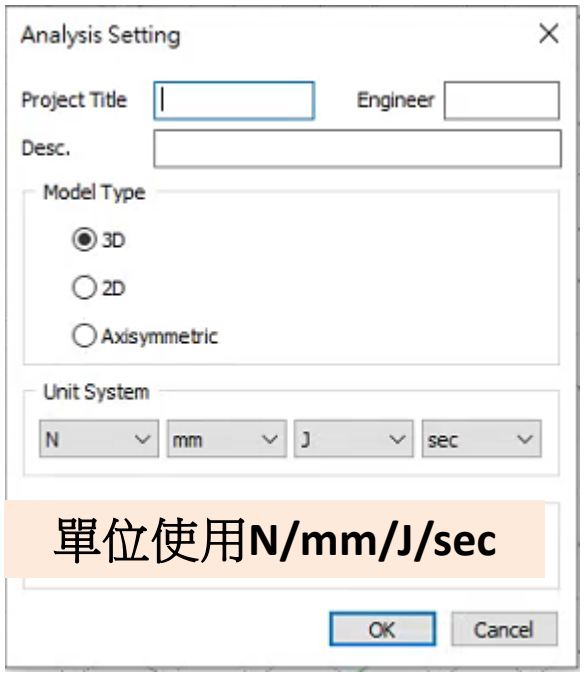
DIP:0.5 (watt)
DIP體積: 900(mm³)
導熱係數k=0.0004(W/mm·T)



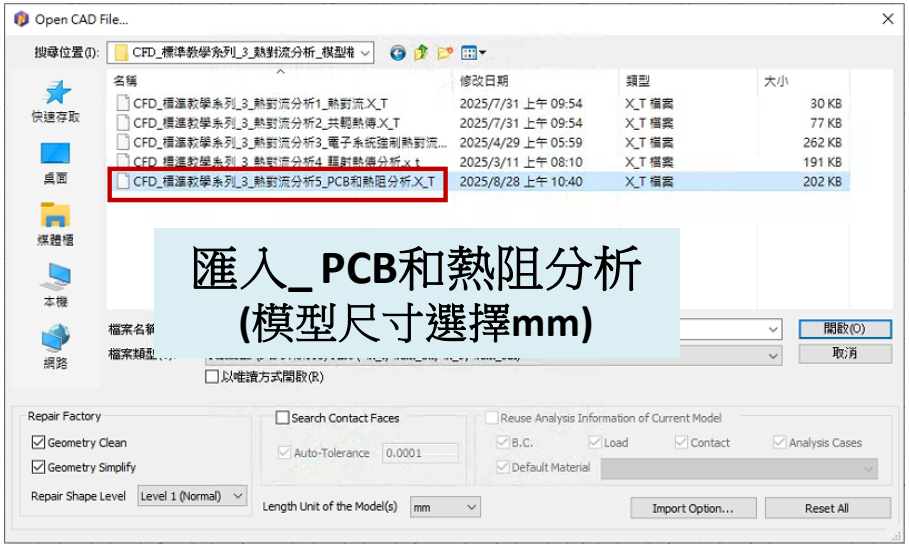
PQFP體積發熱率= 7.292e-4(w/mm³)

PQFP:3.5 (watt)
PQFT體積: 4800(mm³)
導熱係數k=0.0004(W/mm·T)

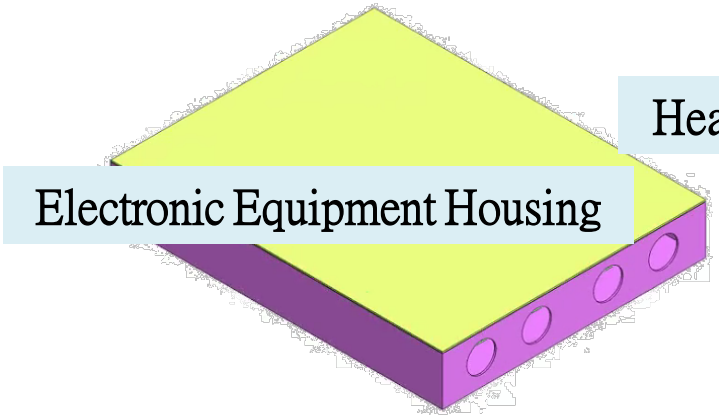
環境 &模型匯入



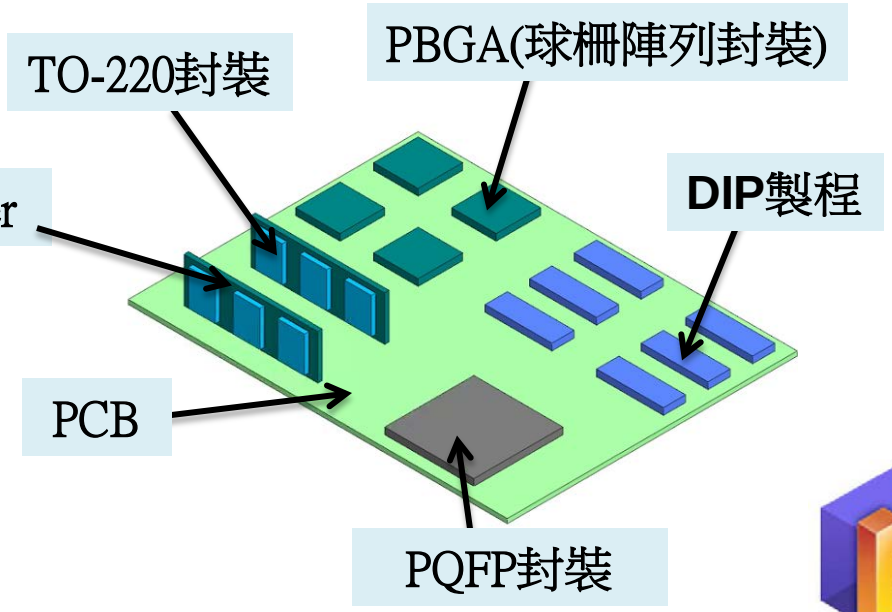
單位使用N/mm/J/sec



匯入_PCB和熱阻分析
(模型尺寸選擇mm)



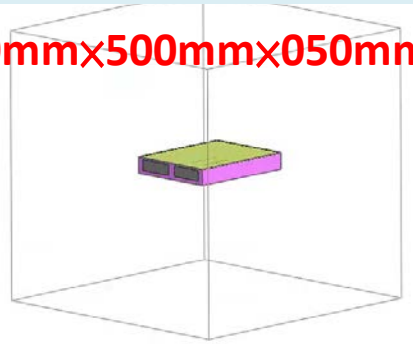
Heat Spreader

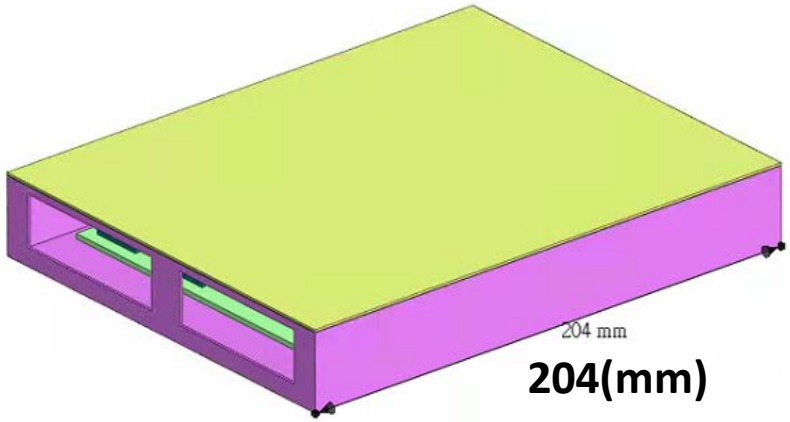


模型尺寸量測

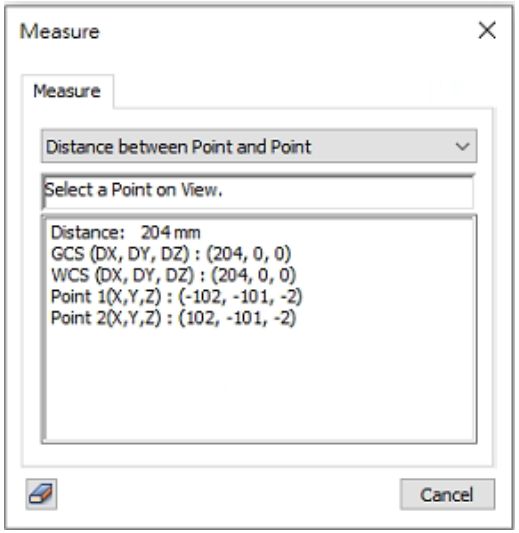
估算建立流場區域空間

500mm×500mm×050mm

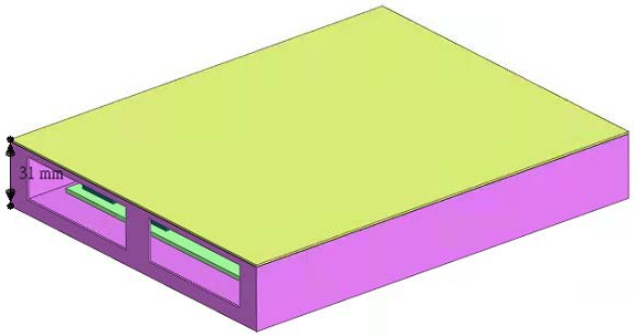


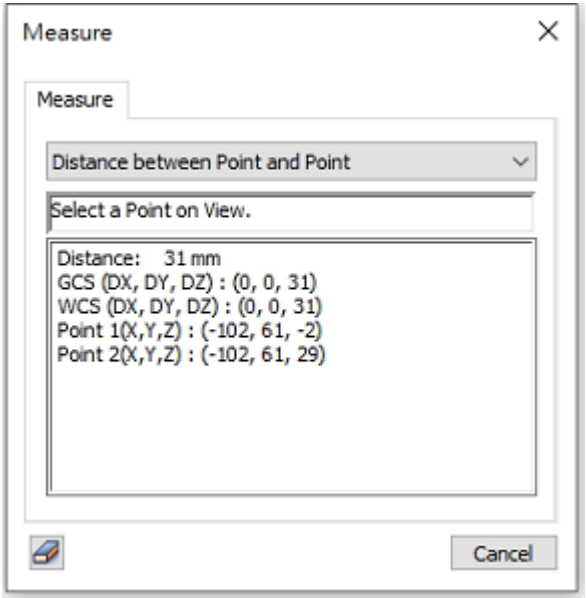


204(mm)

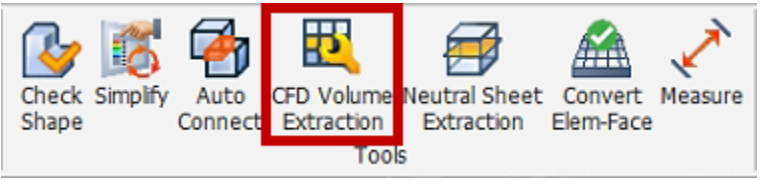


31(mm)



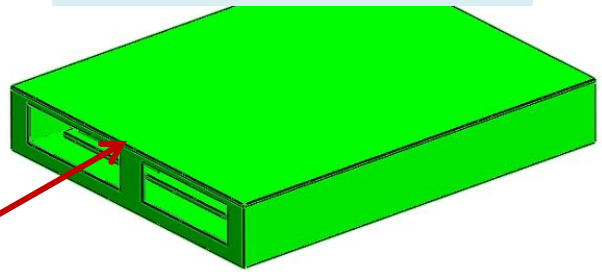


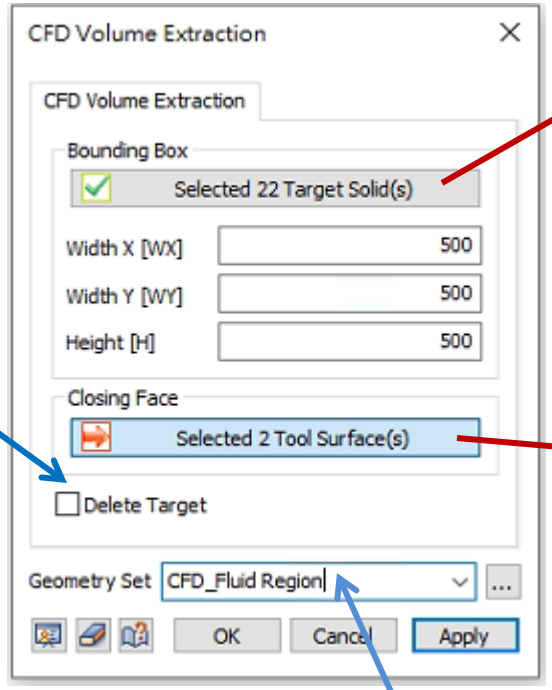
流域模型建立



流場區域空間
500mm×500mm×500mm

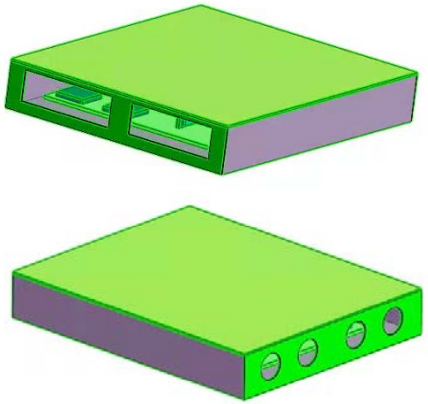
選取全部實體特徵





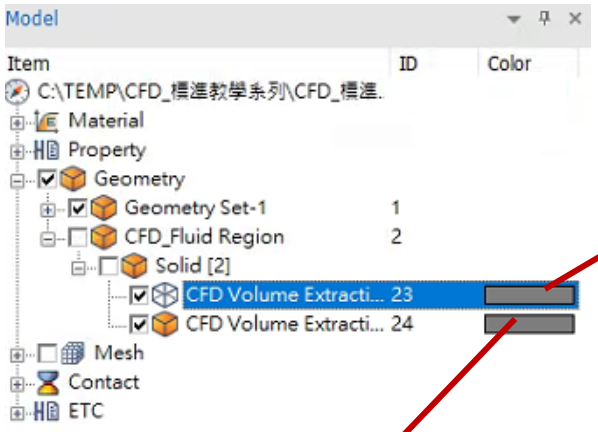
原有幾何保留

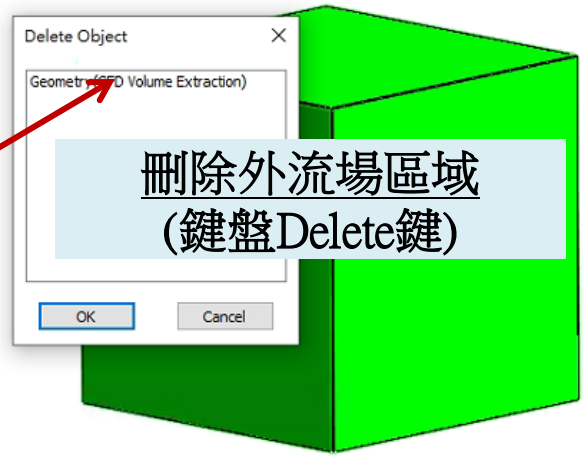
選擇2側出入流口作為參考特徵基準



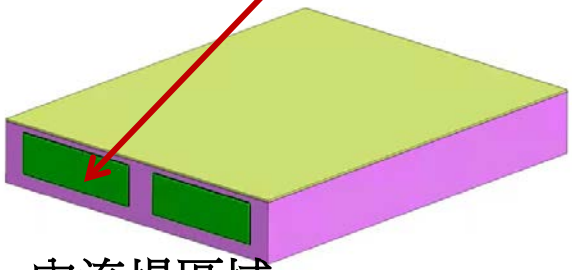
生成模型放置流域模型幾何集

幾何刪除和顏色指定



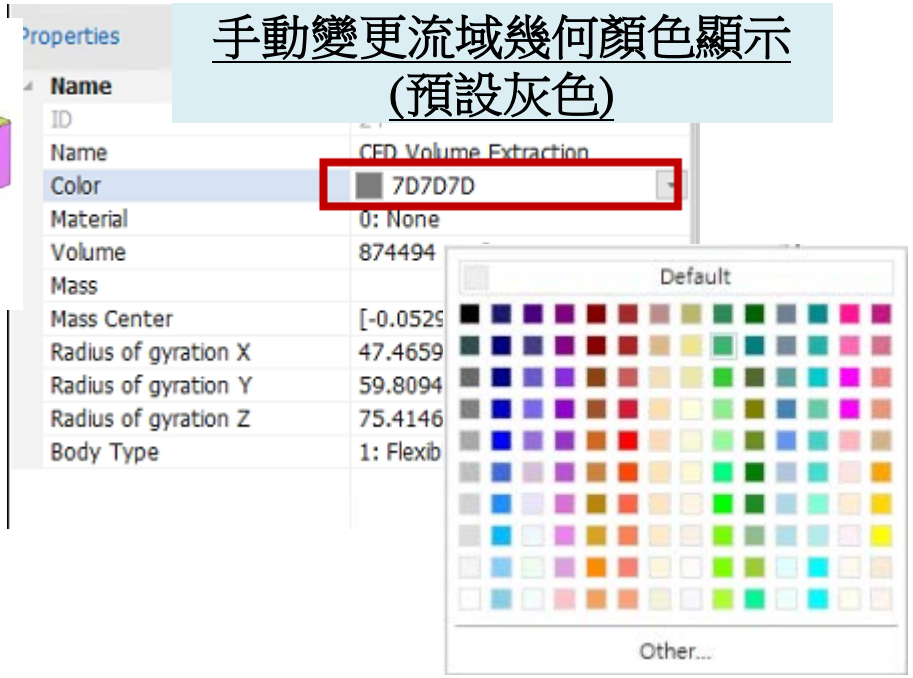


刪除外流場區域
(鍵盤Delete鍵)

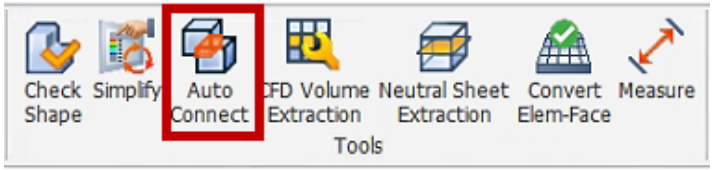


內流場區域

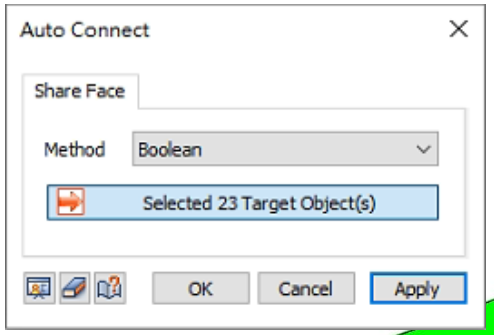
手動變更流域幾何顏色顯示
(預設灰色)

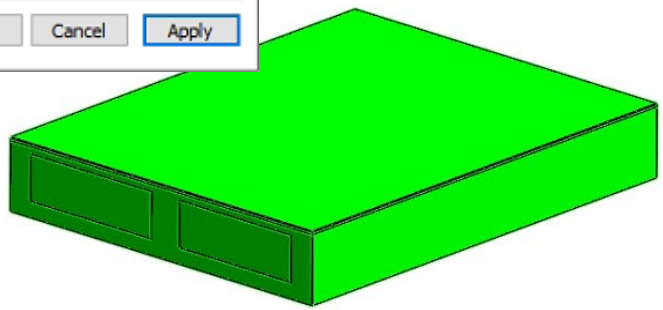


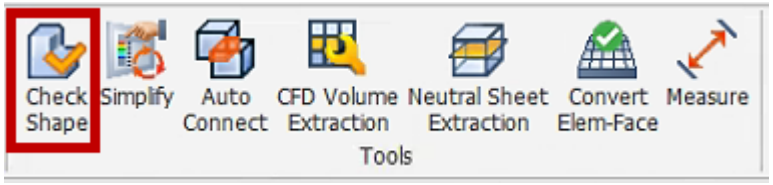
相鄰面特徵建立&確認

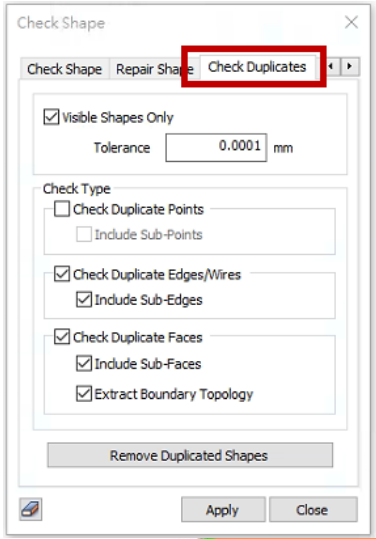


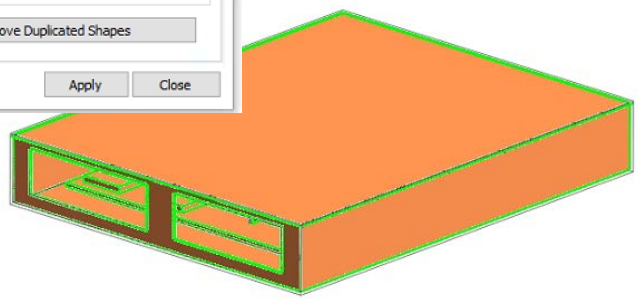
相鄰面特徵建立
(選取所有幾何特徵)



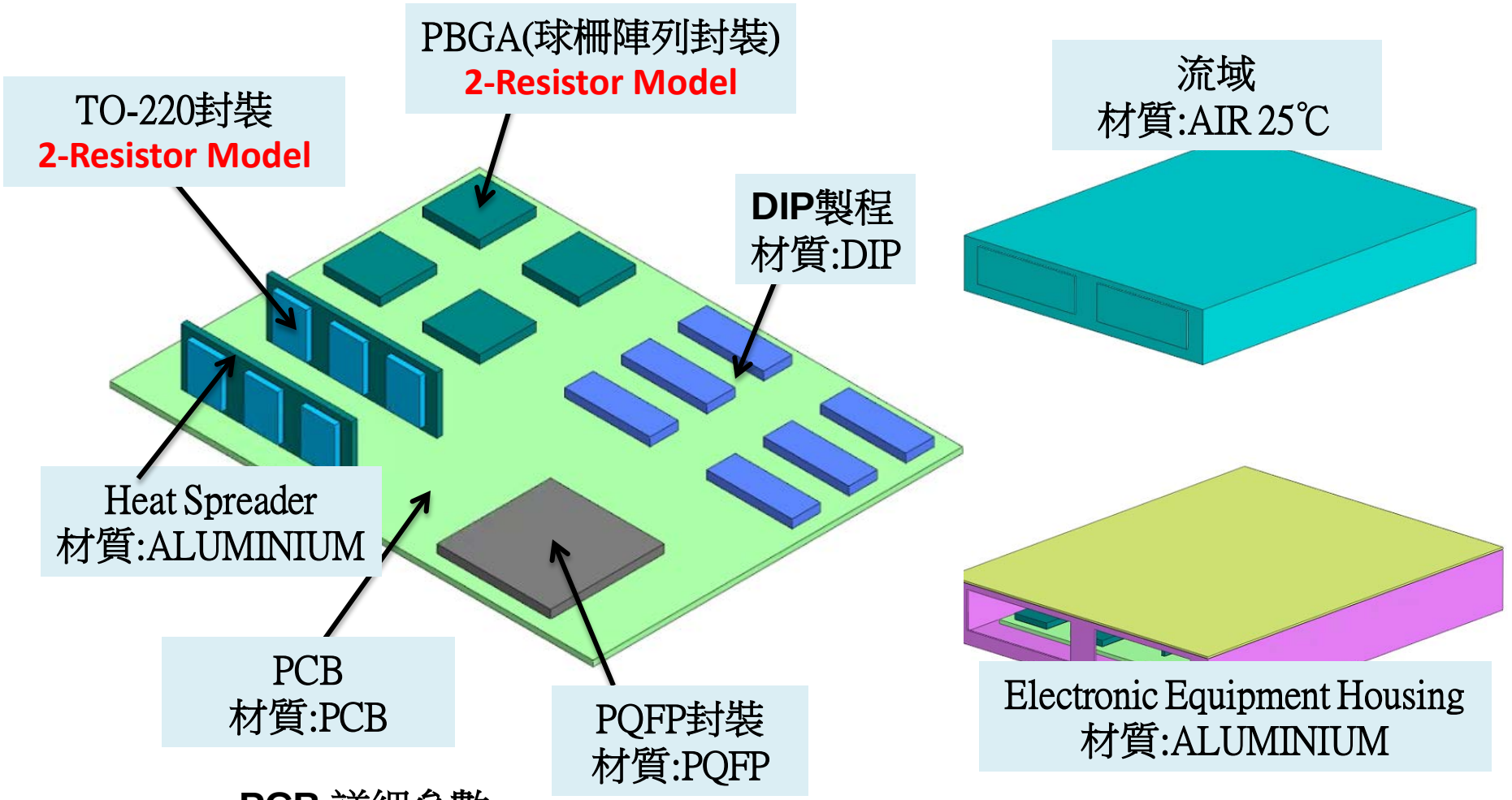








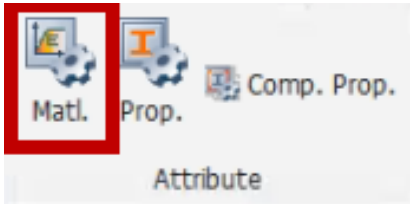
材料分布說明



PCB 詳細參數

- 總厚度：2 mm
- 基板構成： PCB
- 電路層數與厚度：3 層/厚0.0341mm /COPPER/覆蓋範圍30%

材料-流體(CFD)

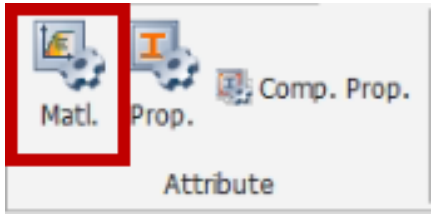


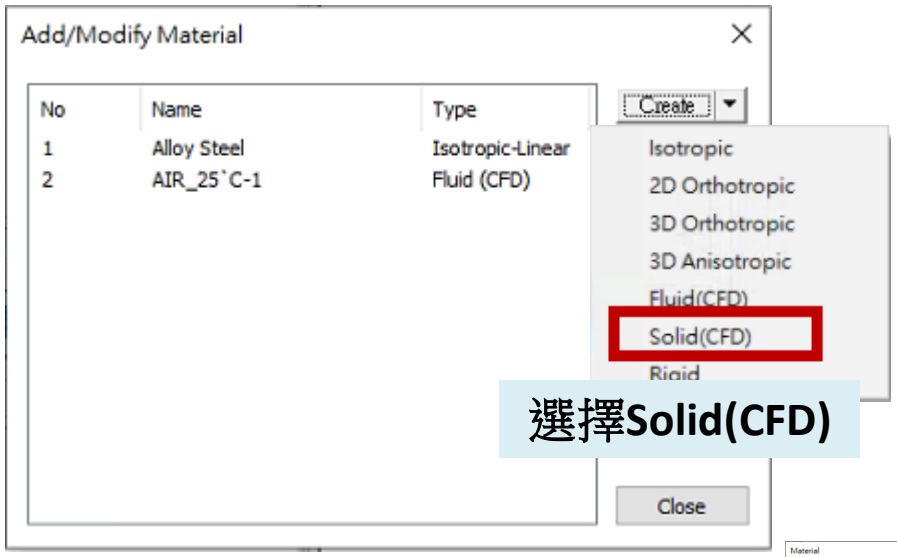
選擇Fluid(CFD)

新增AIR 25 ℃

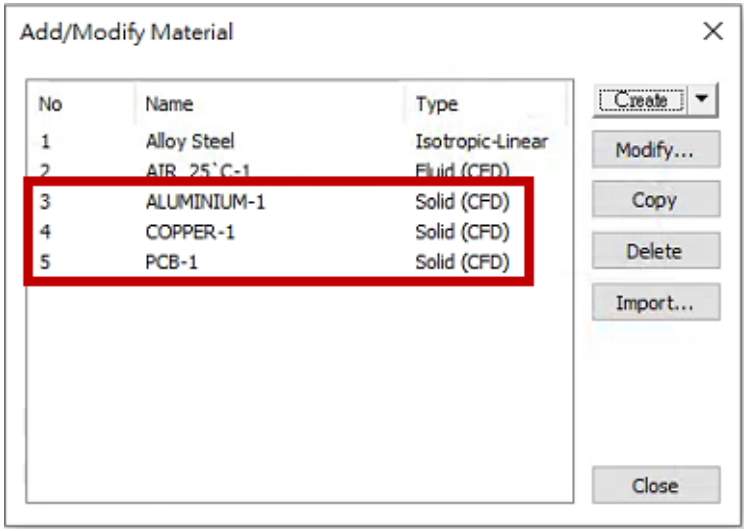
流體類型
Incompressible(不可壓縮流)

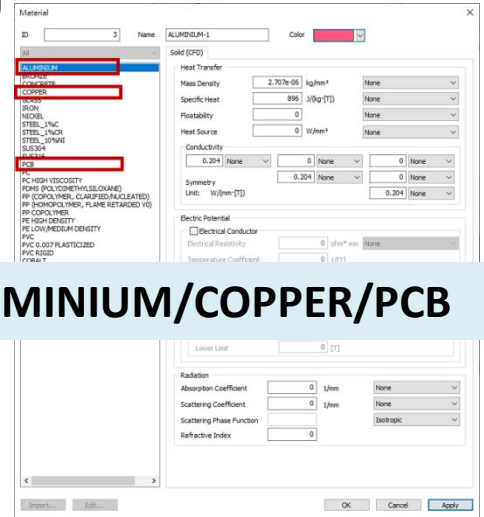
材料-固體(CFD)-自動





選擇Solid(CFD)





ALUMINIUM/COPPER/PCB

PCB材料自訂比熱
1300 (J/kg.T)

材料-固體(CFD)-手動

PQFP

Heat Transfer

Mass Density	2e-06	kg/mm³	None
Specific Heat	120	J/(kg·[T])	None
Floatability	0		None
Heat Source	0	W/mm³	None

Conductivity

0.0004	None	0	None	0	None
		0.0004	None	0	None
				0.0004	None

Symmetry

Unit: W/(mm·[T])

DIP

Heat Transfer

Mass Density	2e-06	kg/mm³	None
Specific Heat	120	J/(kg·[T])	None
Floatability	0		None
Heat Source		W/mm³	None

Conductivity

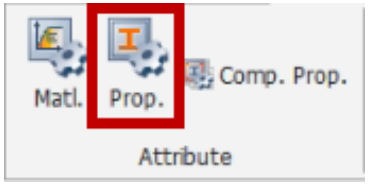
0.0004	None	0	None	0	None
		0.0004	None	0	None
				0.0004	None

Symmetry

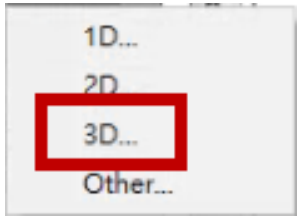
Unit: W/(mm·[T])

註: PQFP &DIP 皆採假設參數。

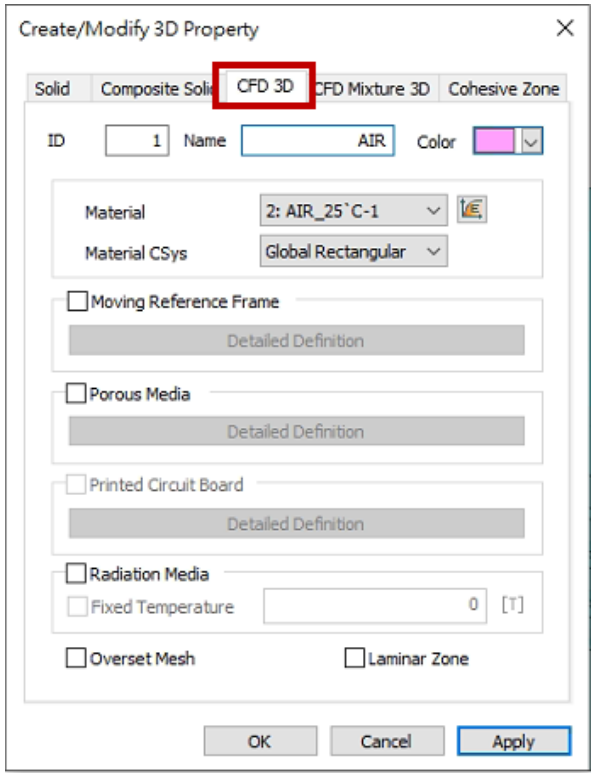
屬性-標準

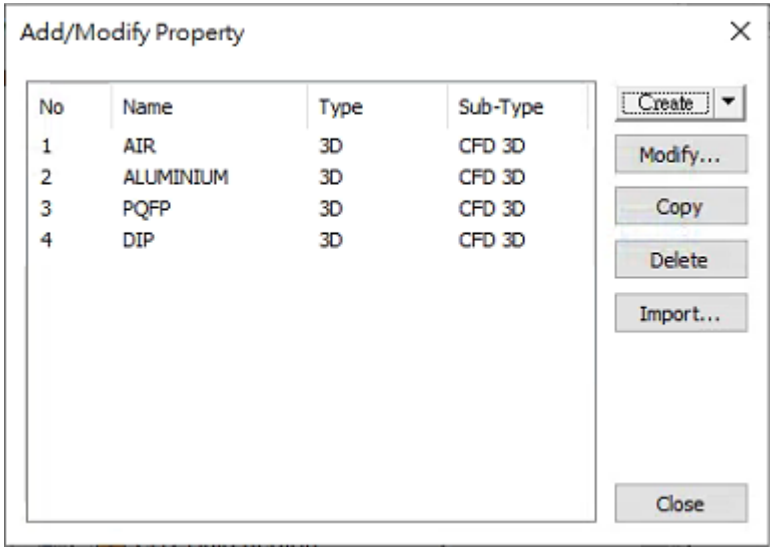


依序新增CFD 3D屬性
AIR/ALUMINIUM/PQFP/DIP

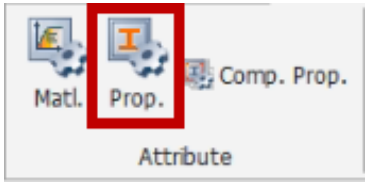


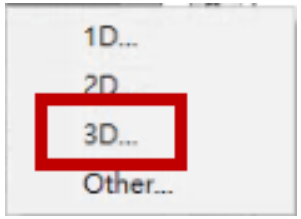
屬性選取Solid





屬性-PCB





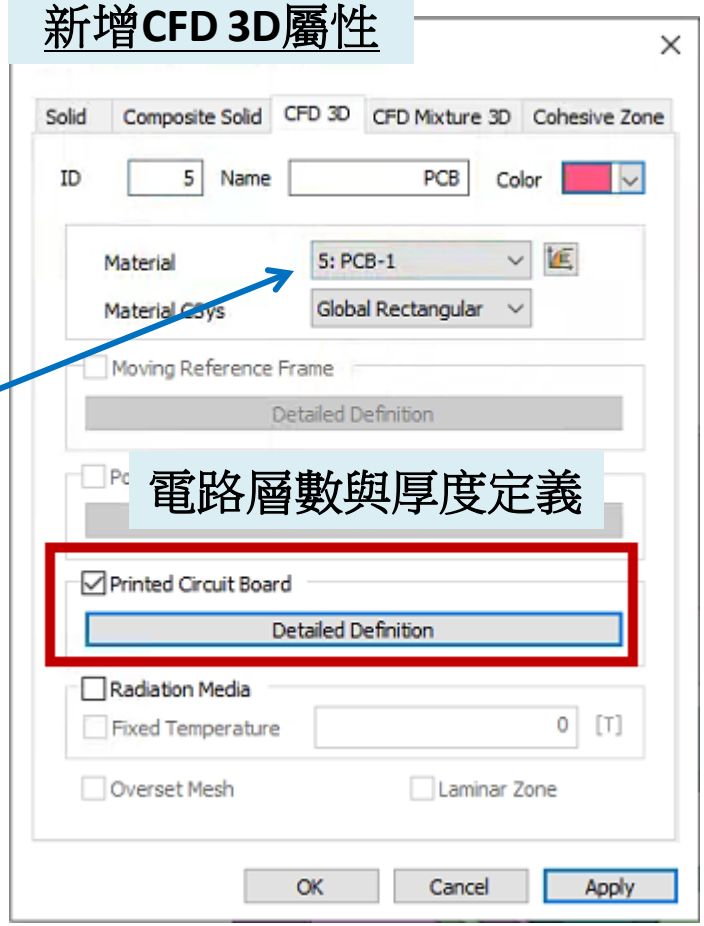
屬性選取Solid

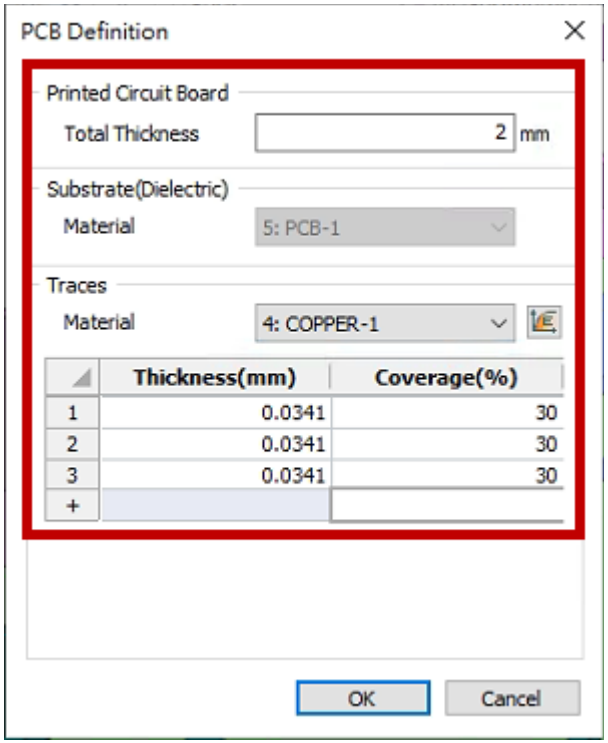
基板構成： PCB

PCB 詳細參數

- 總厚度：2 mm
- 基板構成： PCB
- 電路層數與厚度：3 層/厚0.0341mm /COPPER/覆蓋範圍30%

新增CFD 3D屬性

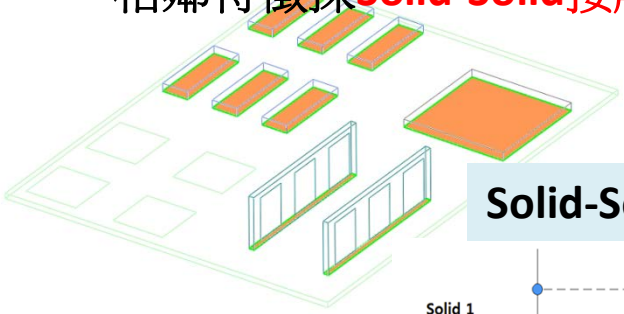




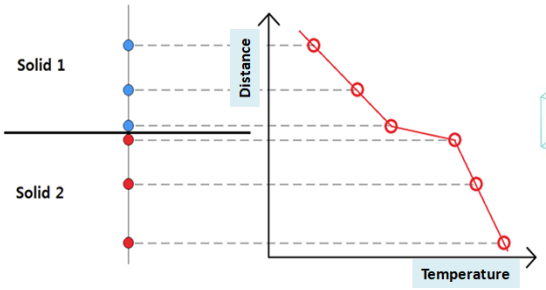
連接方式說明

PCB/HeatSpreader/DIP

相鄰特徵採**Solid-Solid接觸定義**

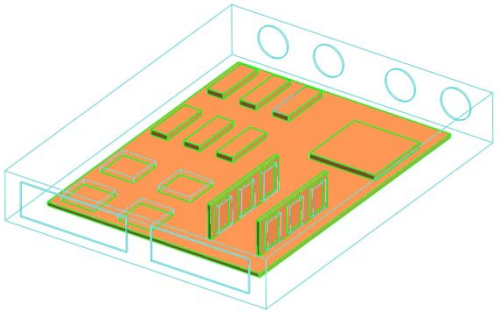


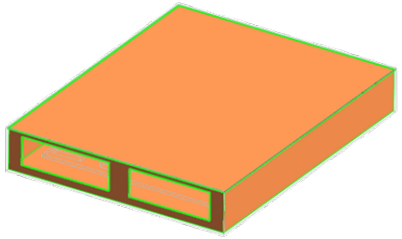
Solid-Solid接觸–熱阻



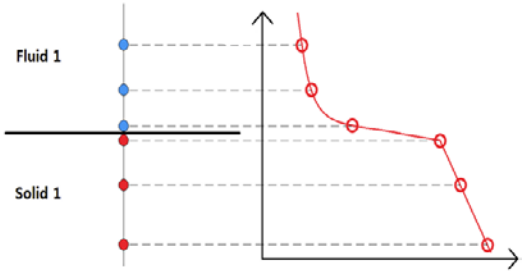
流域

相鄰特徵採**Fluid-Solid接觸定義**



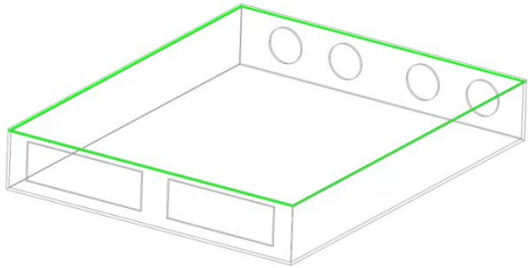


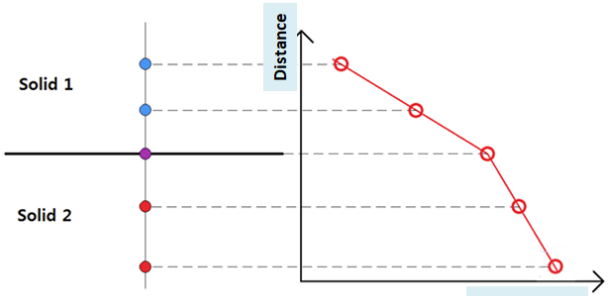
Fluid-Solid接觸–熱邊界層



BOX Top/Box Bottom

Soild1與Solid2 :相鄰邊界採節點相連





3D網格-電子元件固體區域

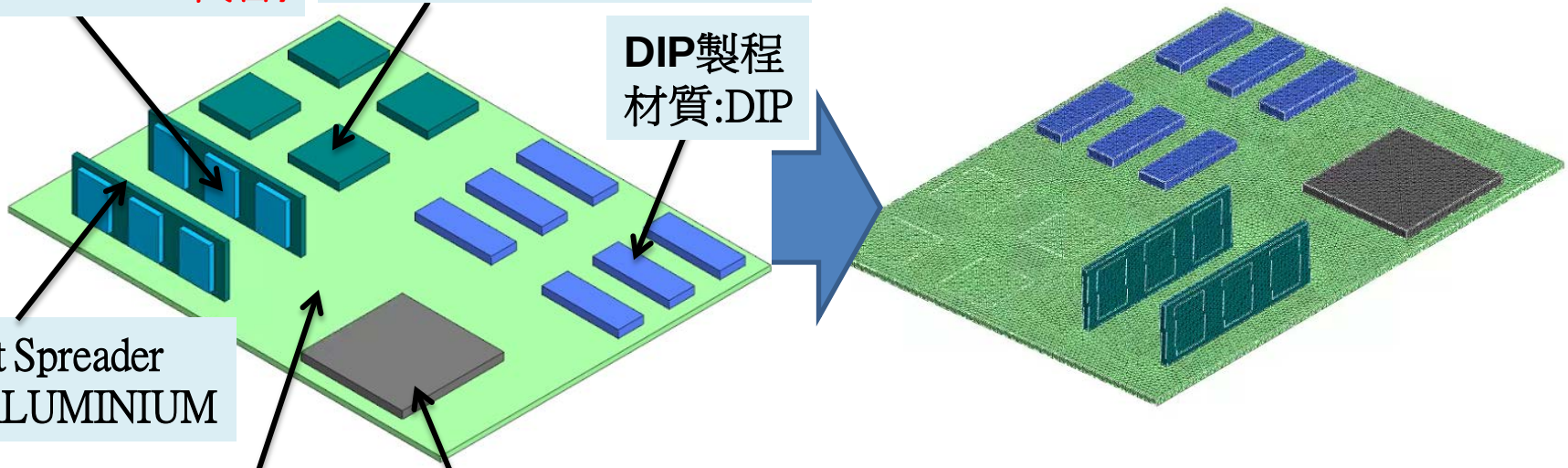
(接觸熱阻)

Tetra Mesher(四面體網格)/網格尺寸1.5(mm)
相鄰面特徵/1階元素/節點不相連

TO-220不需網格
(2-Resistor Model代替)

PBGA不需網格
(2-Resistor Model代替)

DIP製程
材質:DIP



Heat Spreader
材質:ALUMINIUM

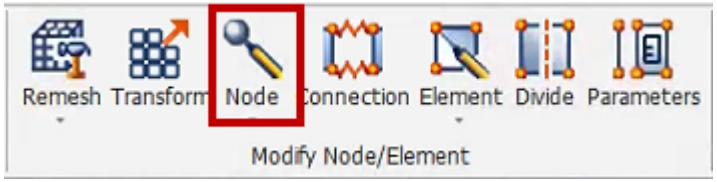
PCB
材質:PCB

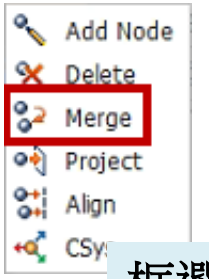
PQFP封裝
材質:PQFP

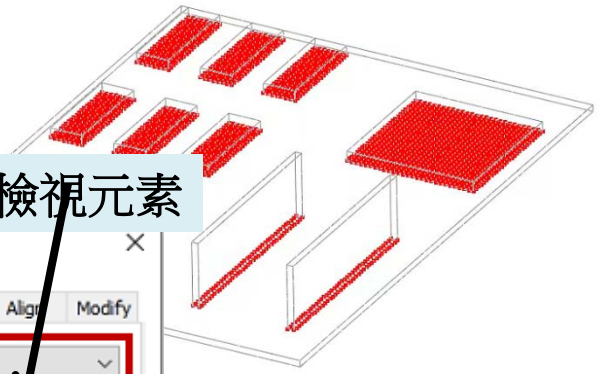
midas NFX-CFD

元素&節點相連接檢視

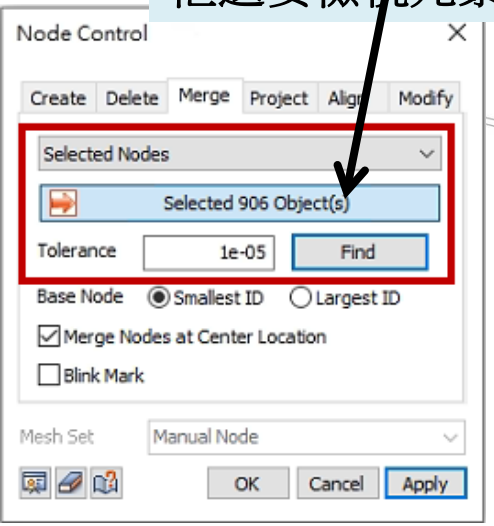
方法一



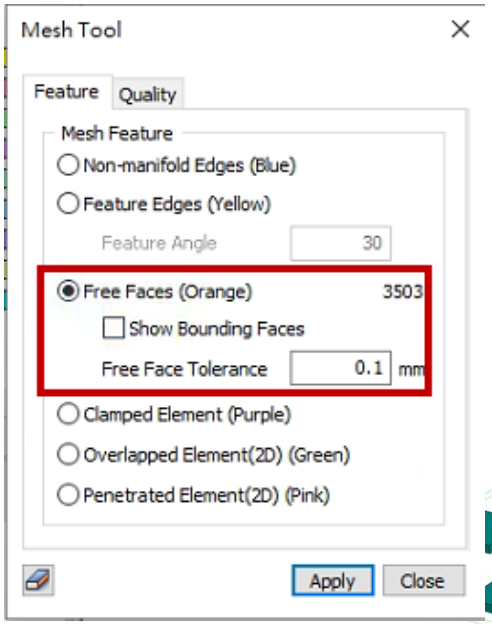


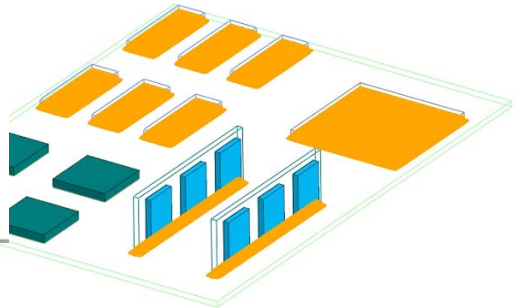


框選要檢視元素



方法二





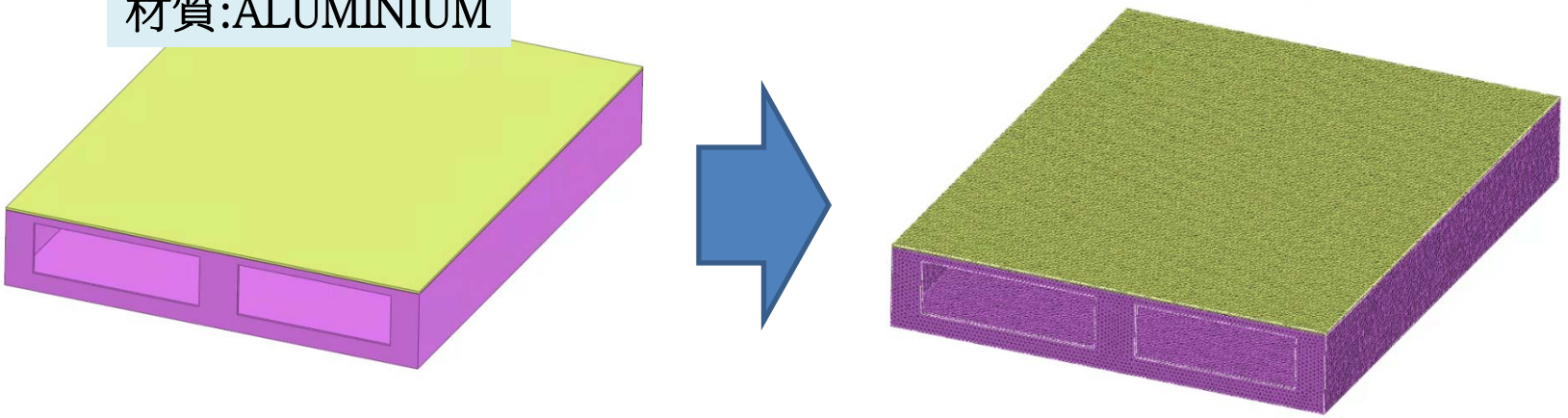
不要執行
(執行後會強制合併節點)

3D網格-外殼固體區域

(節點相連)

Tetra Mesher(四面體網格)/網格尺寸1.5(mm)
相鄰面特徵/1階元素/節點相相連

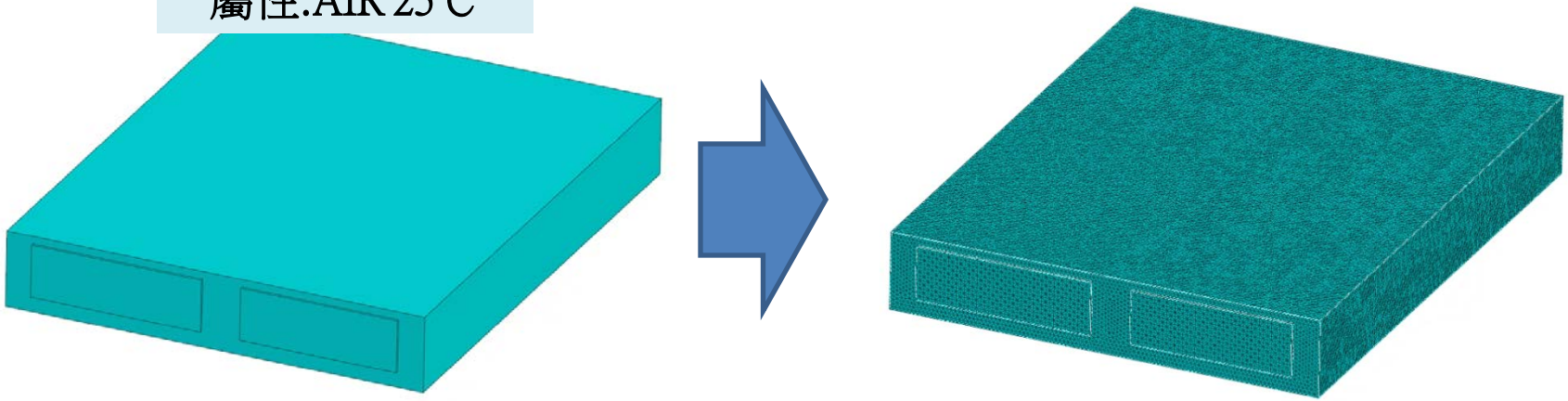
Heat Spreader
材質:ALUMINIUM



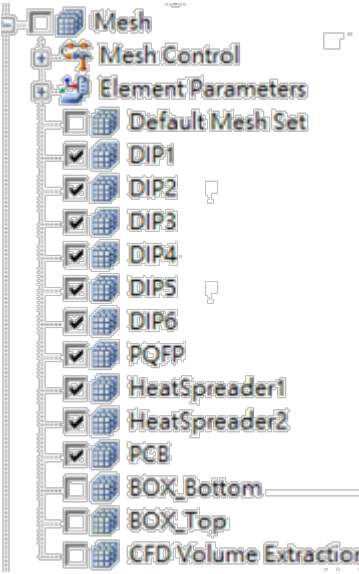
3D網格-流體區域

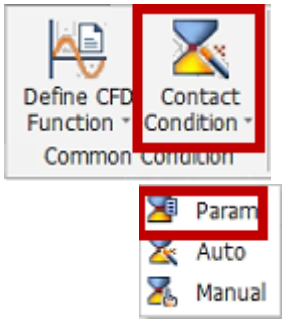
屬性:AIR
Tetra Mesher(四面體網格)/網格尺寸2.5(mm)
相鄰面特徵/1階元素/節點不相連

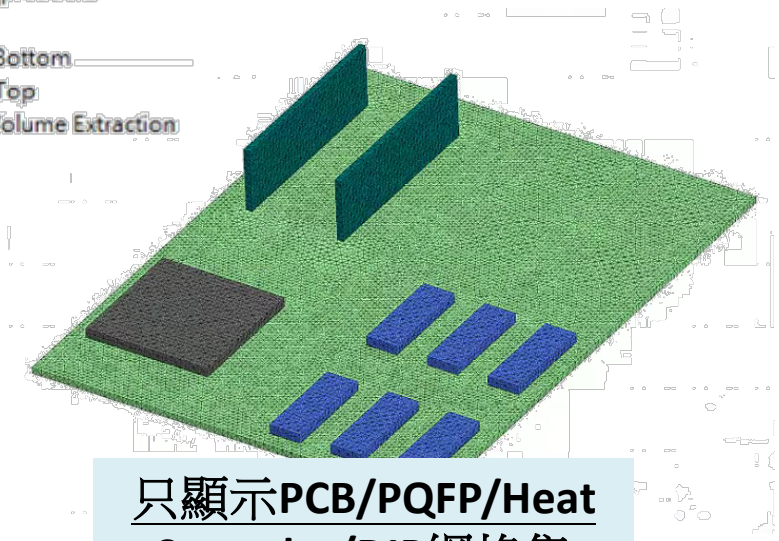
流域
屬性:AIR 25℃



Solid-Solid接觸定義-1

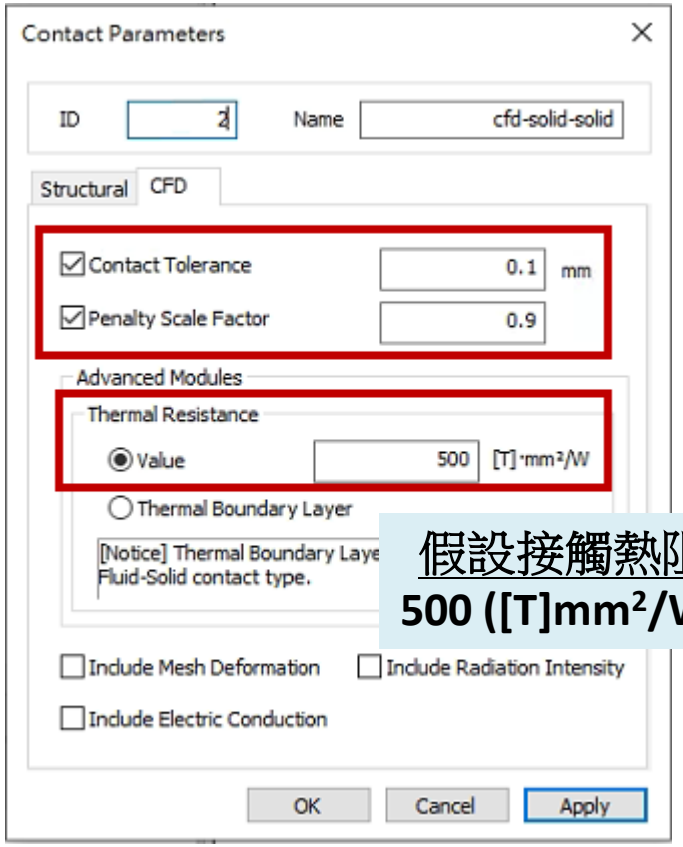






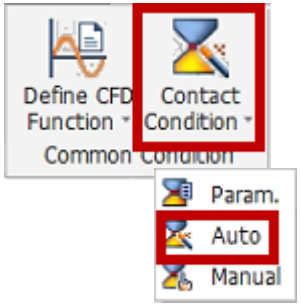
只顯示PCB/PQFP/Heat Spreader/DIP網格集

接觸間隙和懲罰函數
=>分析數值計算過程穩定

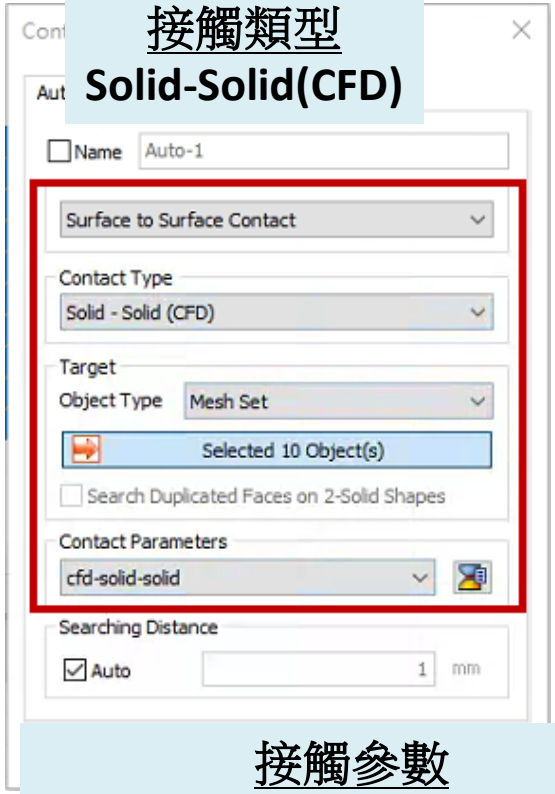


假設接觸熱阻
500 ([T]mm²/W)

Solid-Solid接觸定義-2

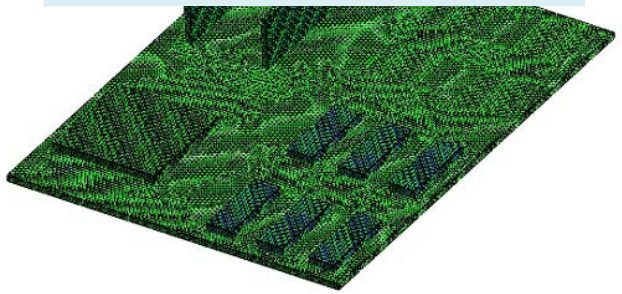


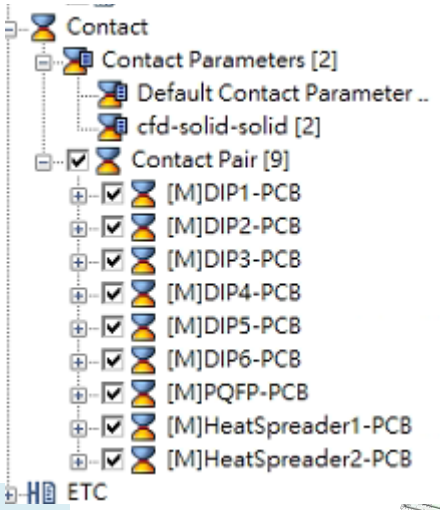
接觸類型
Solid-Solid(CFD)



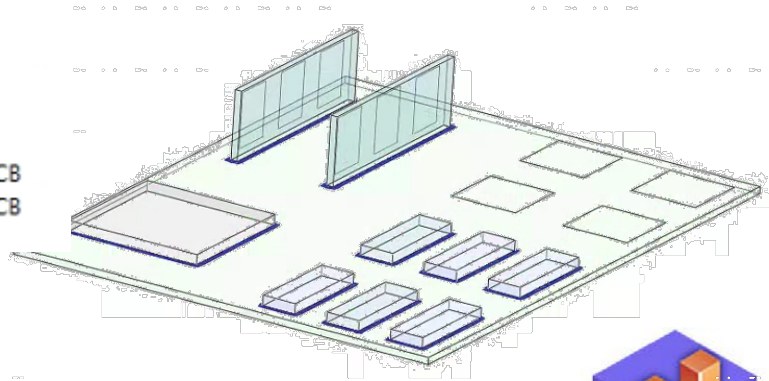
接觸參數
指定CFD-Solid-Solid(上頁操作)

選取PCB/PQFP/Heat Spreader/DIP網格集

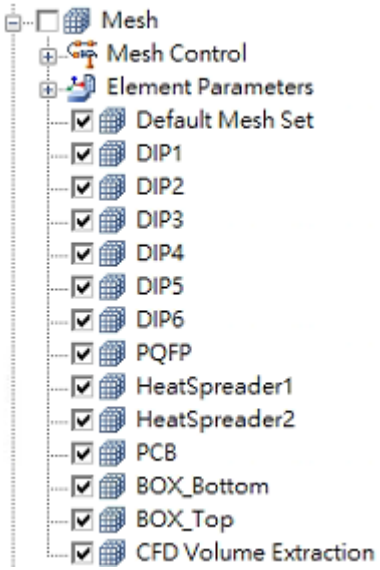


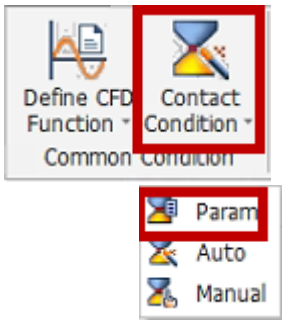


接觸對檢視

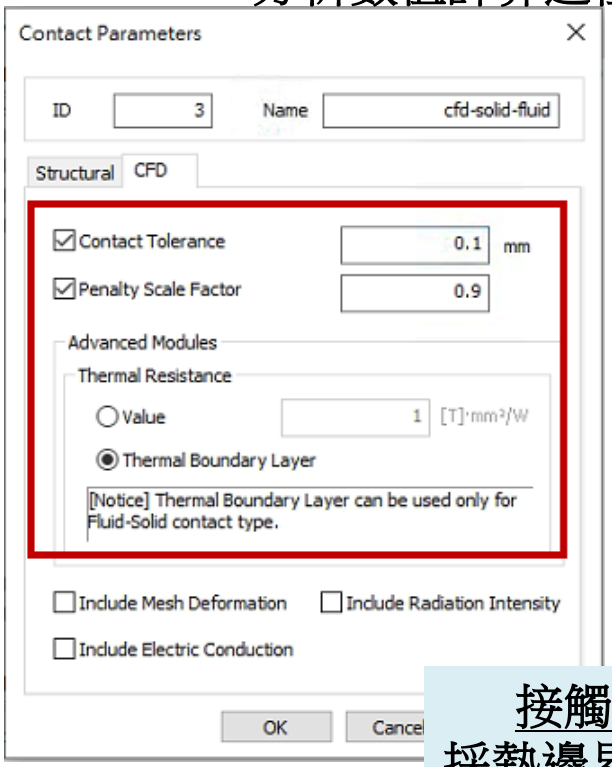


Fluid-Solid接觸定義-1

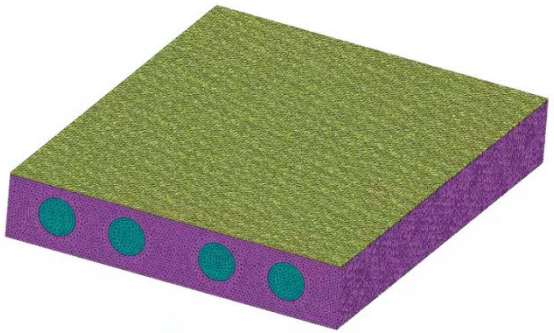




接觸間隙和懲罰函數
=>分析數值計算過程穩定

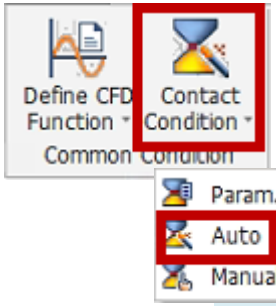


接觸熱阻
採熱邊界層計算

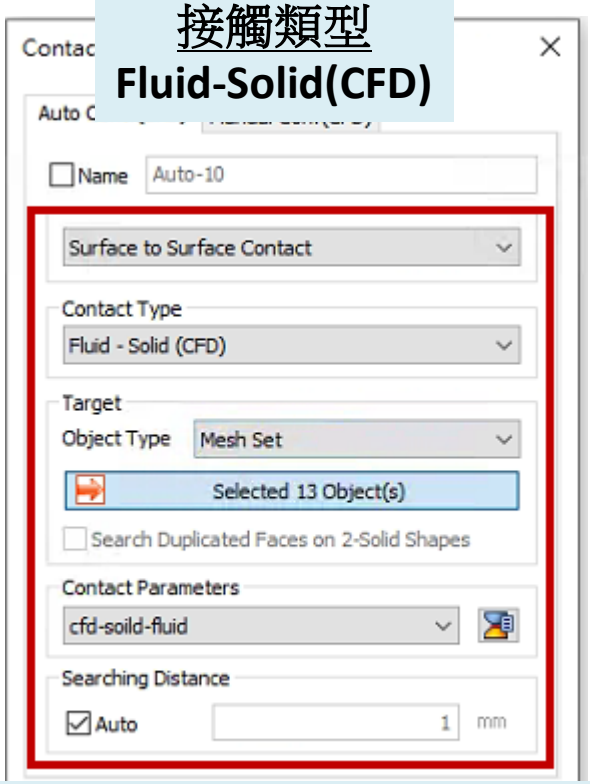


顯示所有網格集

Fluid-Solid接觸定義-2

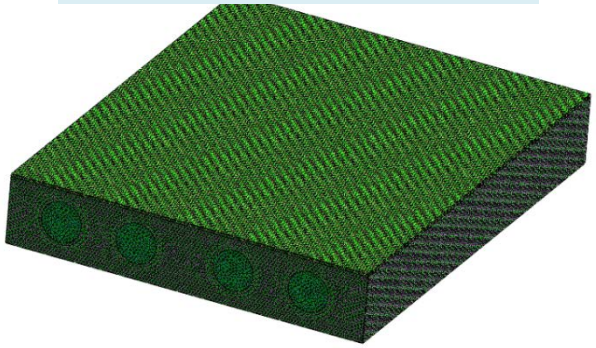


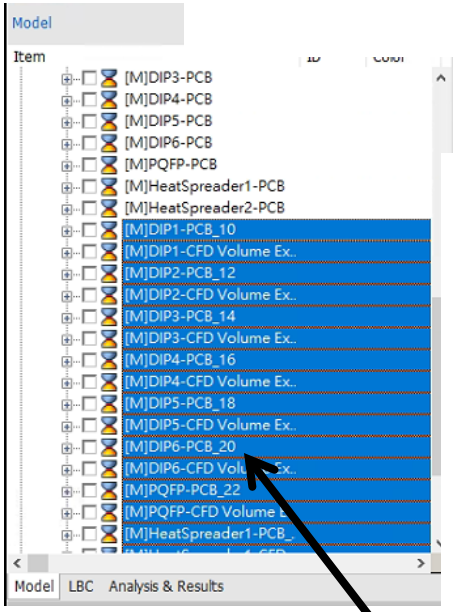
接觸類型
Fluid-Solid(CFD)



接觸參數
指定CFD-solid-fluid(上頁操作)

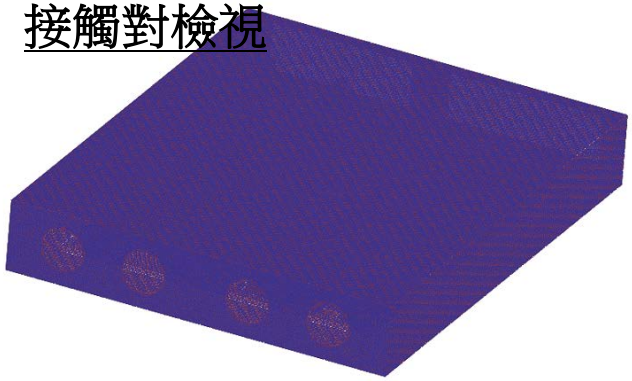
選擇所有網格集





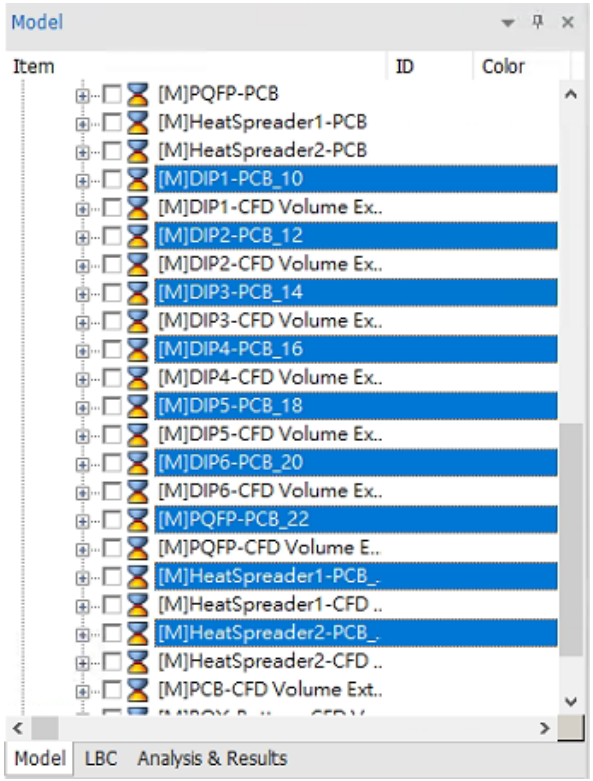
包含了固體網格集

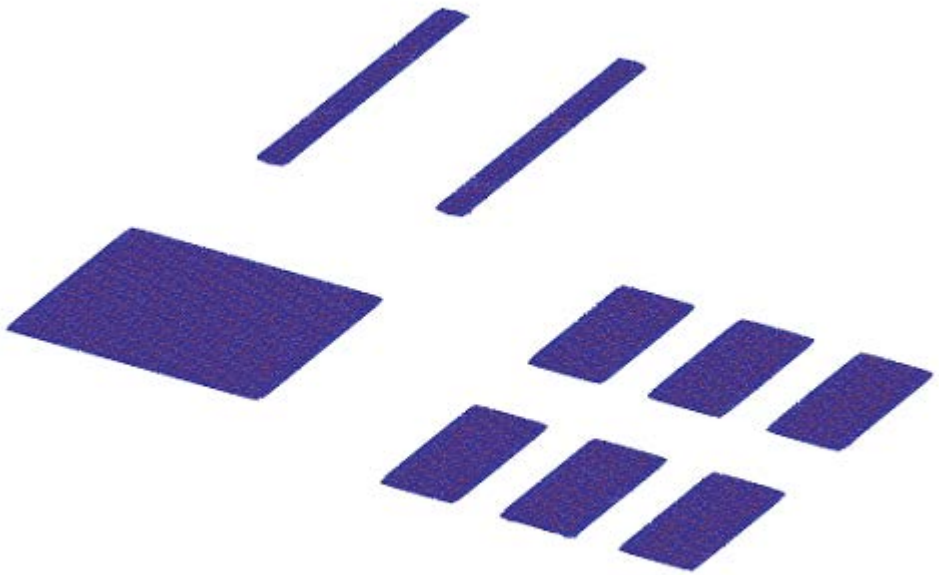
接觸對檢視



Fluid-Solid接觸定義-3

選取無流域網格集接觸對
鍵盤Delete鍵





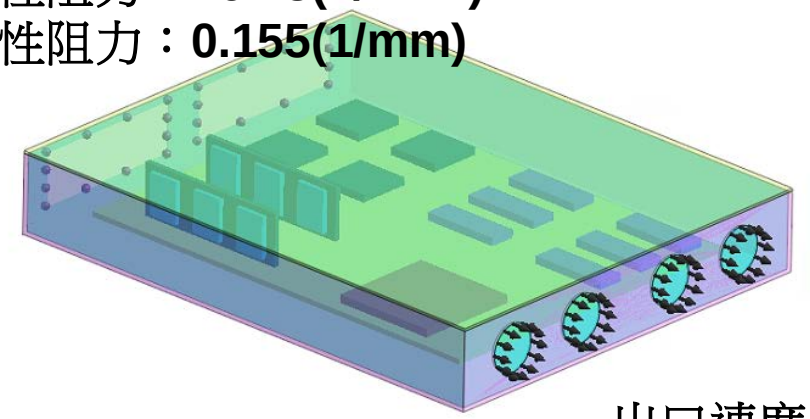
邊界條件說明

入口多孔過濾器

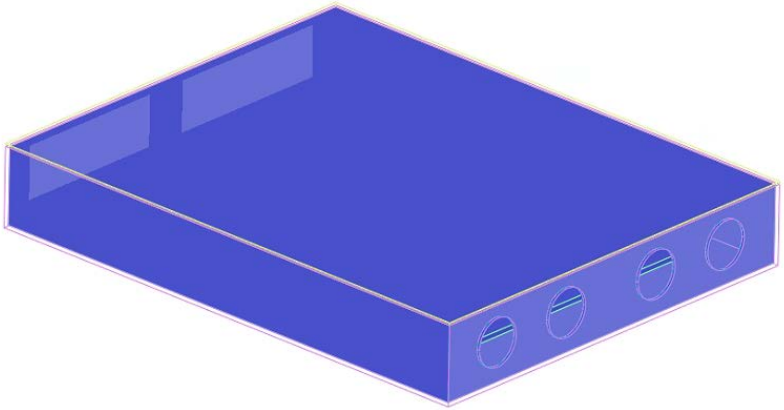
厚度：**5 mm**

黏性阻力：**26.23(1/mm²)**

慣性阻力：**0.155(1/mm)**



壁函數(Wall)流體與實體接觸面



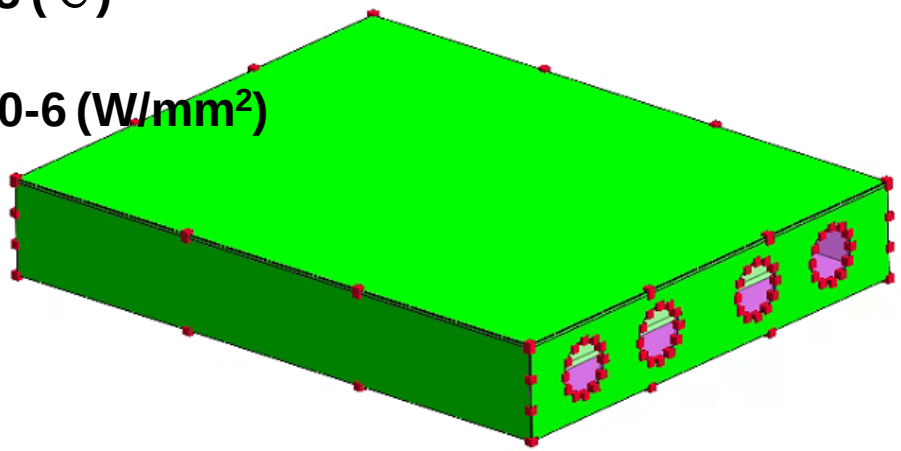
出口速度

3000(mm/sec)

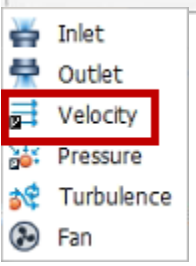
流體固體初始溫度:**25 (℃)**

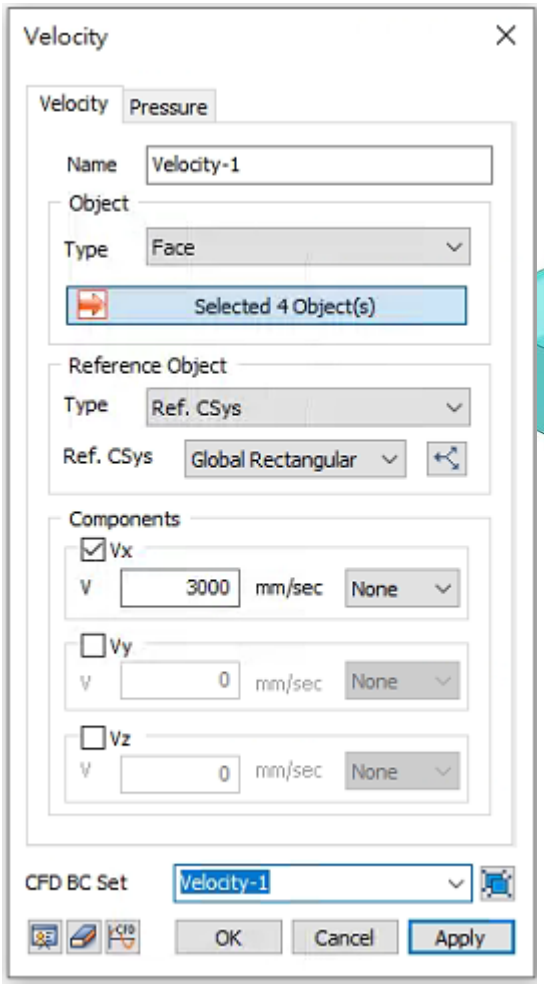
環境溫度**25 (℃)**

空氣熱對流係數:**5x10-6 (W/mm²)**

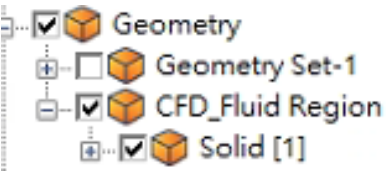


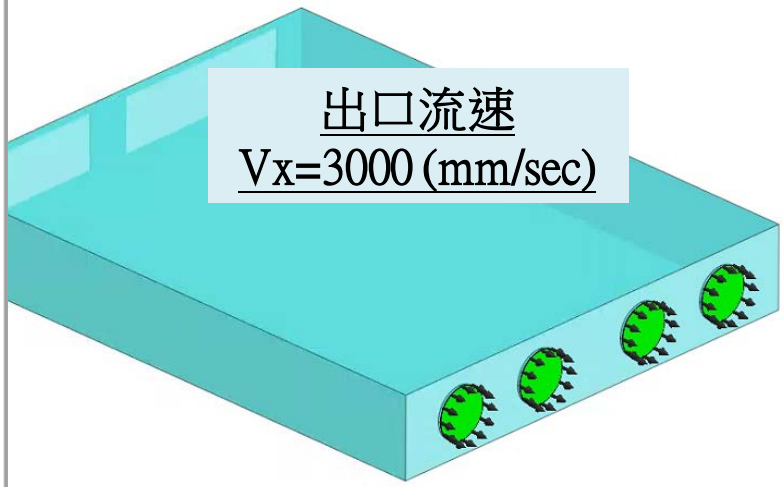
出口流速





只顯示流域幾何特徵





出口流速
Vx=3000 (mm/sec)

midas NFX-CFD

孔隙邊界

(Porous Jump)

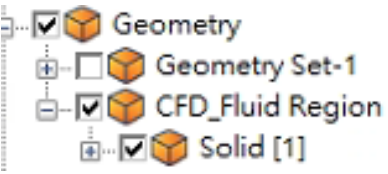
入口多孔過濾器

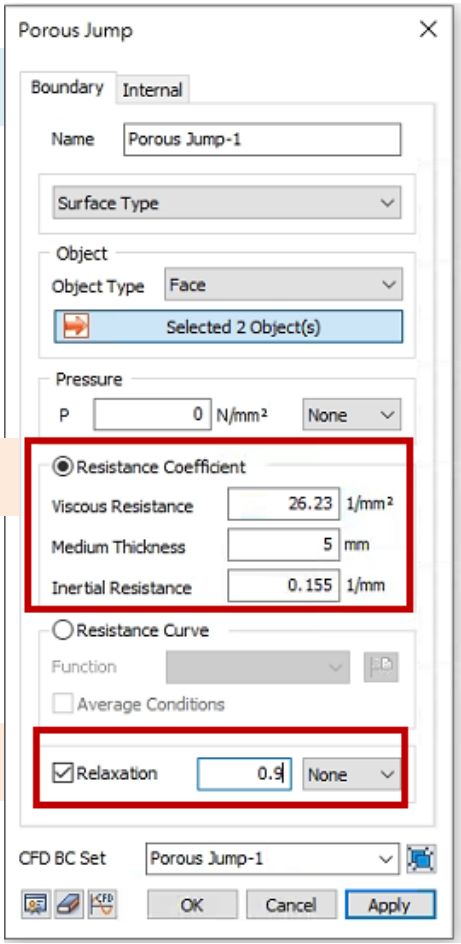
黏性阻力：**26.23(1/mm²)**

厚度：**5 mm**

慣性阻力：**0.155(1/mm)**

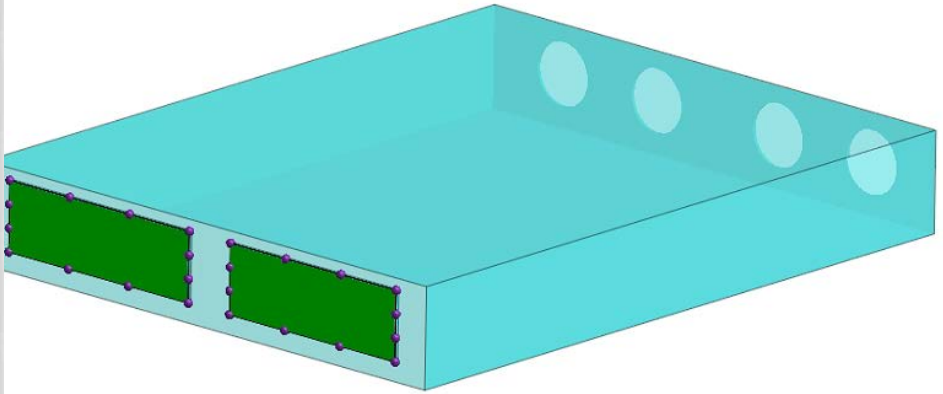
只顯示流域幾何特徵





多孔板推導之數據

鬆弛係數

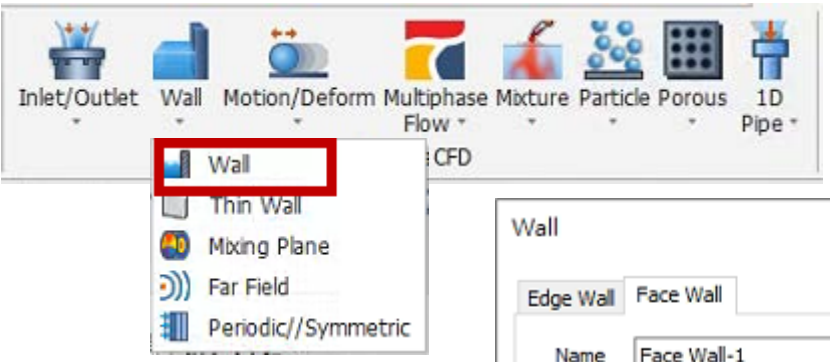


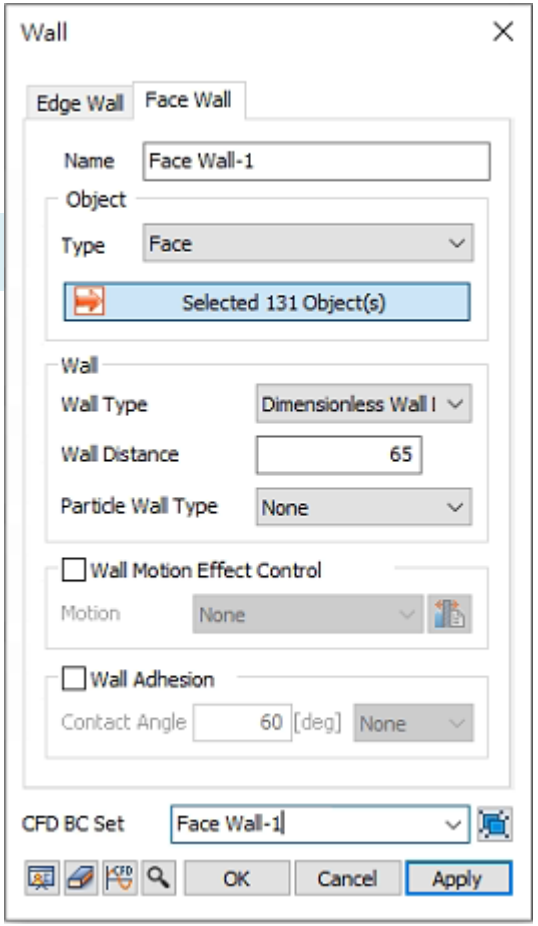
鬆弛係數:壓力值=(當前壓力)×鬆弛係數+(1-鬆弛係數)×(上一步壓力)

midas NFX-CFD

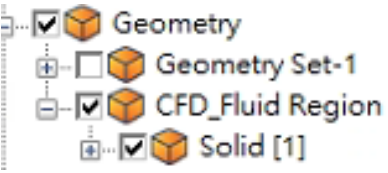
壁函數

(Dimensionless Wall Applied)

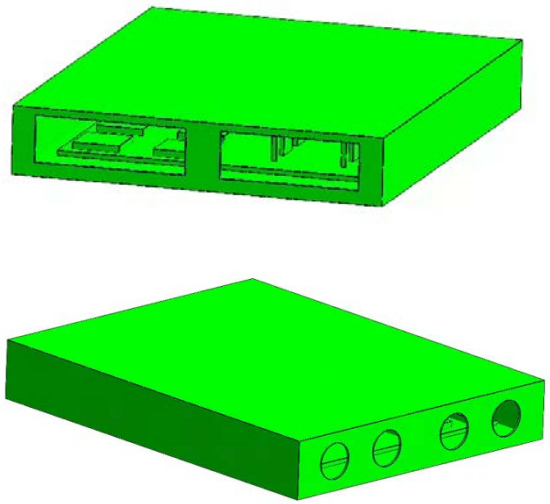




只顯示流域幾何特徵



選取流域與實體接合特徵
(出入流口不施加)



壁函數(Dimensionless Wall Applied)
Y+=65

註:壁函數施加在流體特徵與固體接觸區域。

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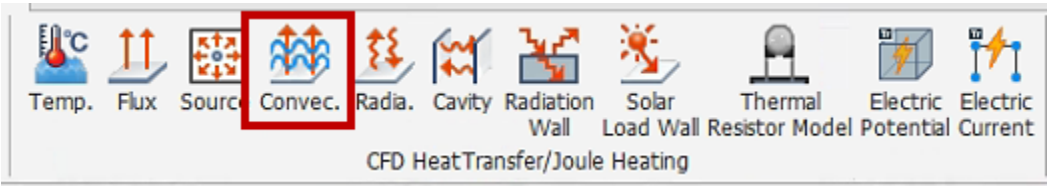
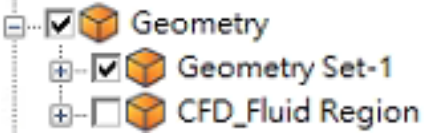
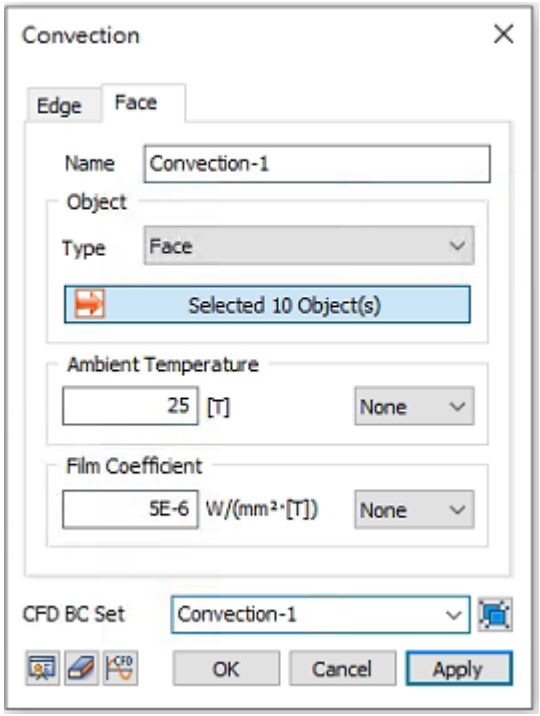
熱對流



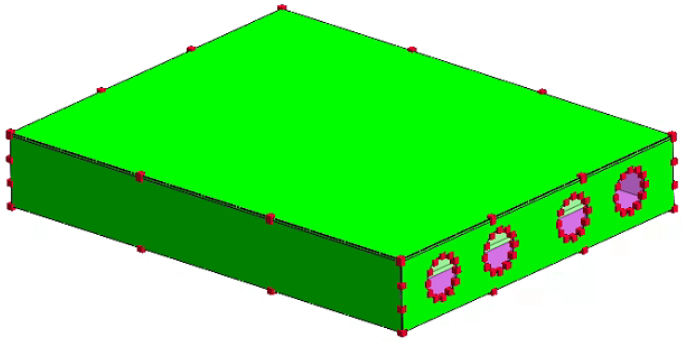
顯示實體幾何特徵





環境溫度:25

熱對流係數:5×10^{-6} (W/mm^2 ℃)



施加在外部空氣與結構接觸特徵

一般空氣熱對流係數

1.自然對流: 3×10^{-6}~12×10^{-6} (W/mm^2 ℃)

2.強制對流: 10×10^{-6}~100×10^{-6} (W/mm^2 ℃)

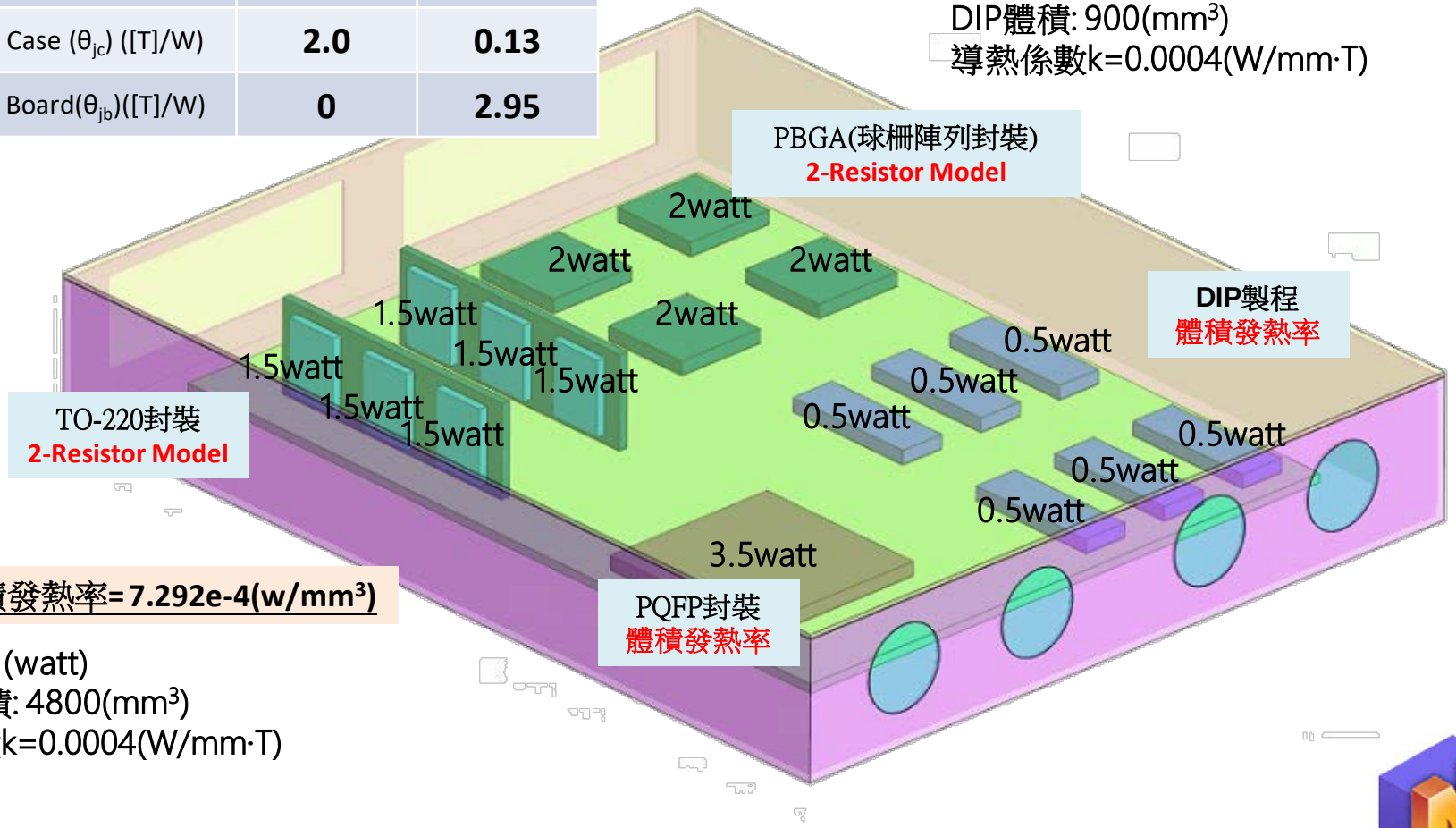
MIDAS

熱阻&體積發熱率

	TO-220	PBGA
Junction Power (W)	**1.5**	**2.0**
Resistance Case (θ_{jc}) ([T]/W)	**2.0**	**0.13**
Resistance Board(θ_{jb})([T]/W)	**0**	**2.95**

DIP體積發熱率= 5.556e-4(w/mm³)

DIP:0.5 (watt)
DIP體積: 900(mm³)
導熱係數k=0.0004(W/mm·T)

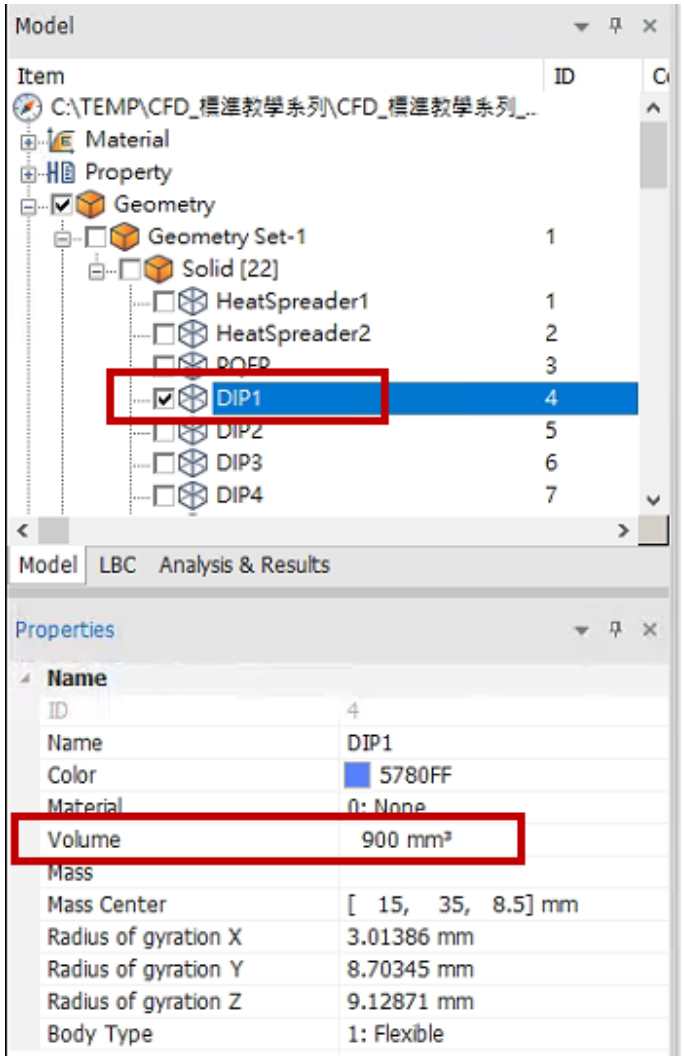


PQFP體積發熱率= 7.292e-4(w/mm³)

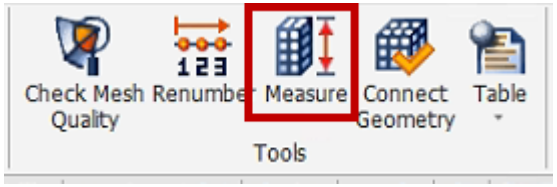
PQFP:3.5 (watt)
PQFT體積: 4800(mm³)
導熱係數k=0.0004(W/mm·T)

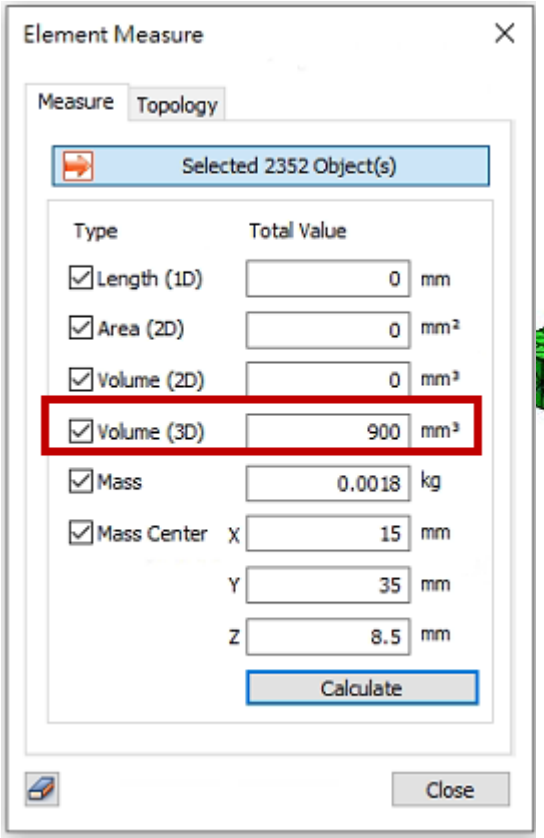
補充:體積量測

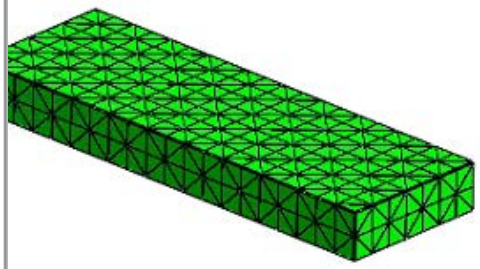
方法一(幾何體積特徵量測)



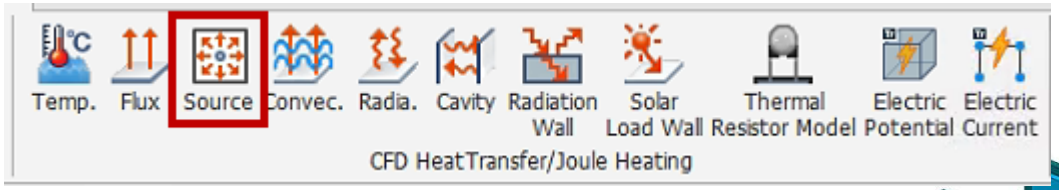
方法二(網格體積量測)

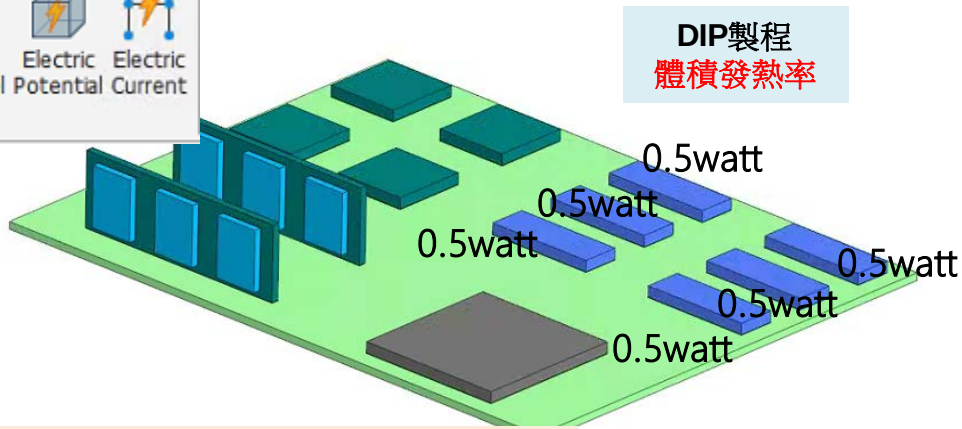


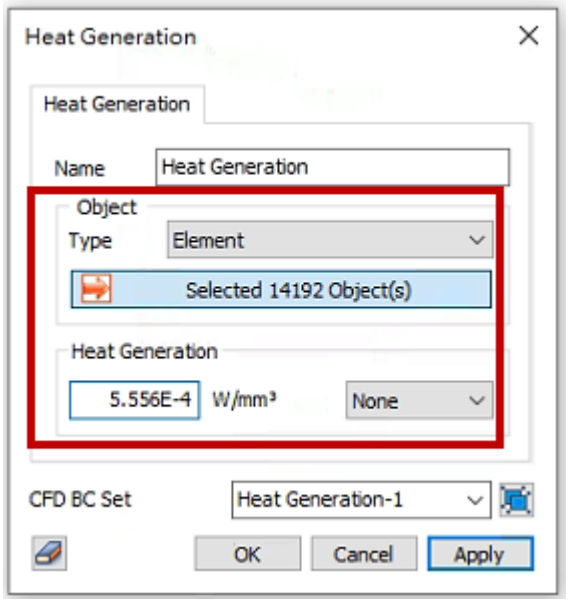




DIP體積發熱率

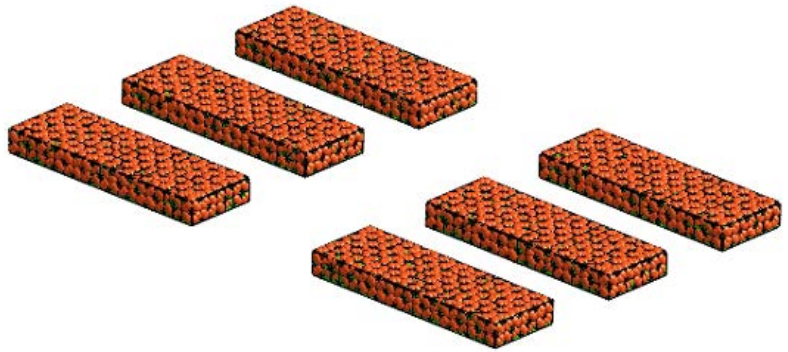






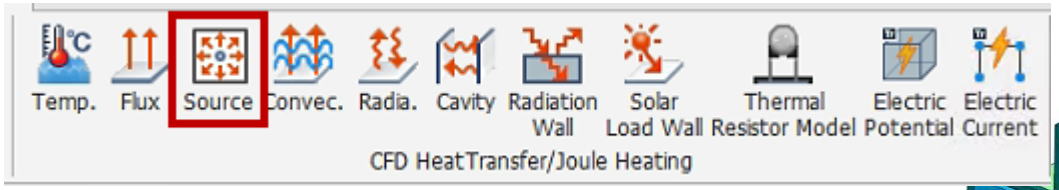
DIP體積發熱率= 5.556e-4(w/mm³)

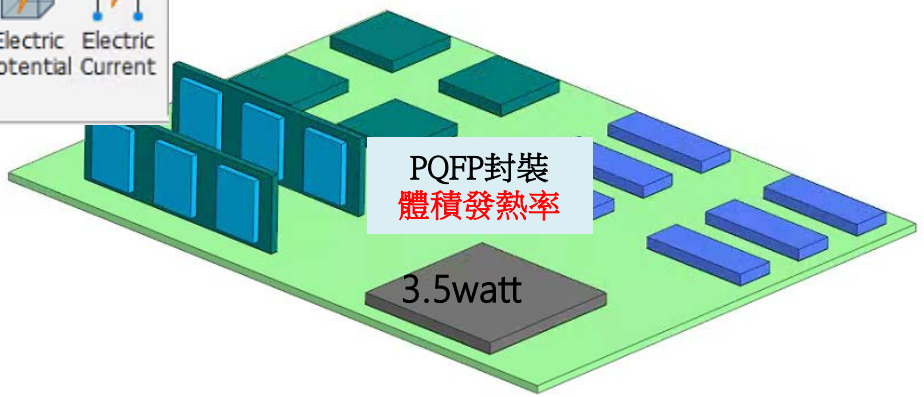
單顆DIP:0.5 (watt)
單顆DIP體積: 900(mm³)

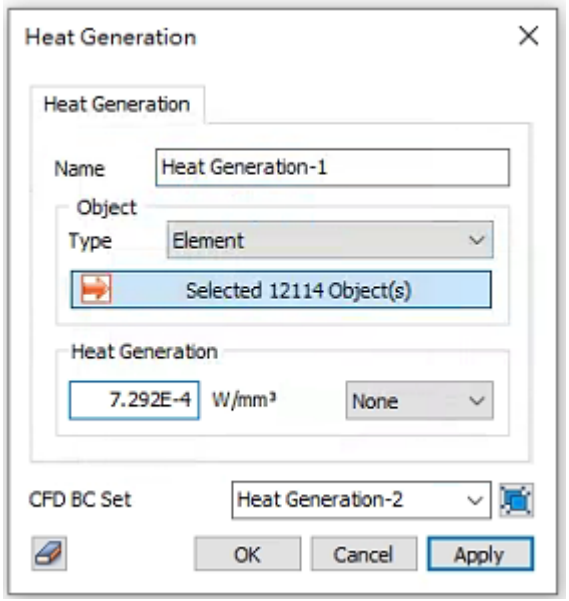


選取所有DIP製程網格集

PQFP體積發熱率



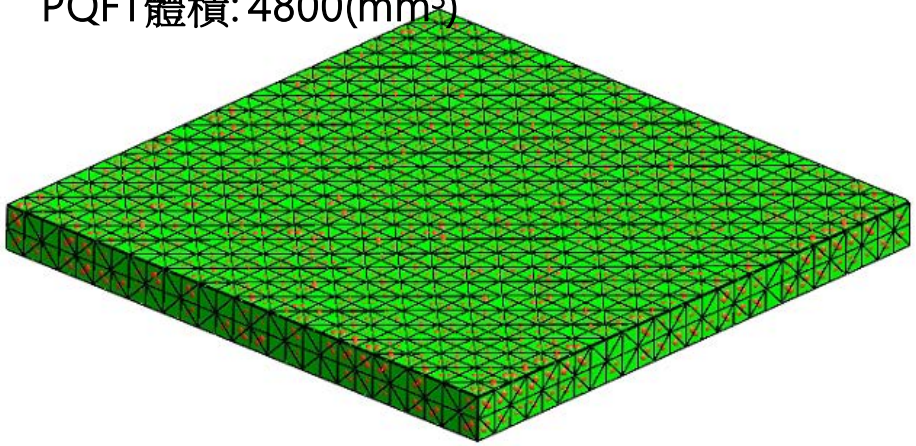




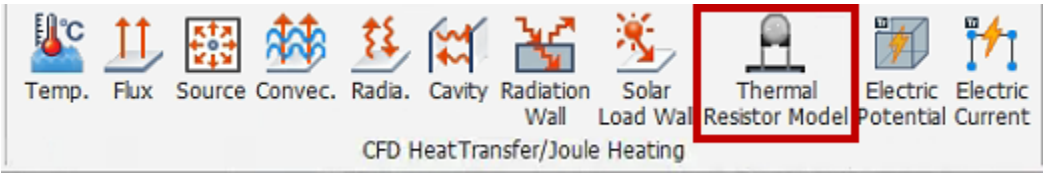
PQFP體積發熱率= 7.292e-4(w/mm³)

PQFP:3.5 (watt)

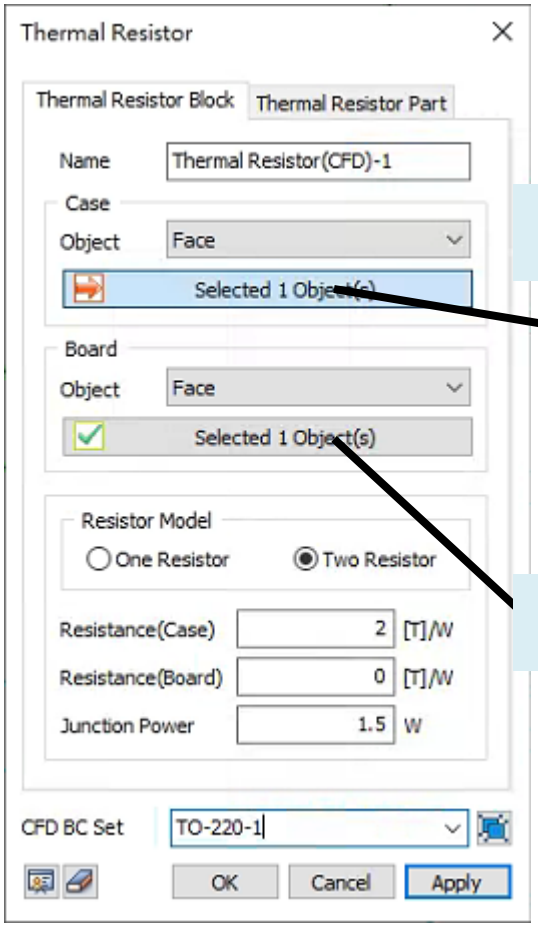
PQFT體積: 4800(mm³)



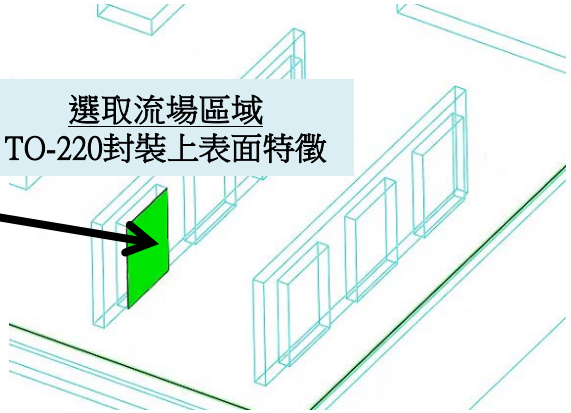
TO-220熱阻



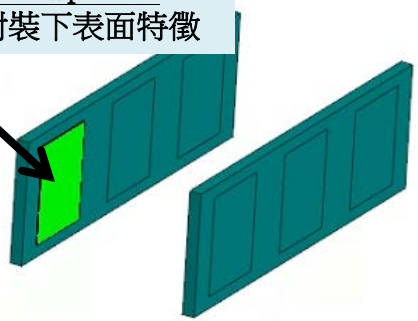
	TO-220
Junction Power (W)	**1.5**
Resistance Case (θ_{jc}) ([T]/W)	**2.0**
Resistance Board(θ_{jb})([T]/W)	**0**



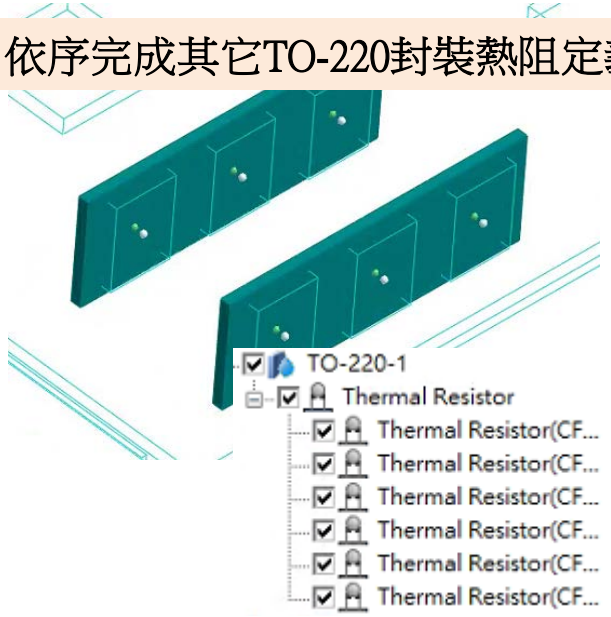
選取流場區域
TO-220封裝上表面特徵



選取Heat Spreader
TO-220封裝下表面特徵



依序完成其它TO-220封裝熱阻定義



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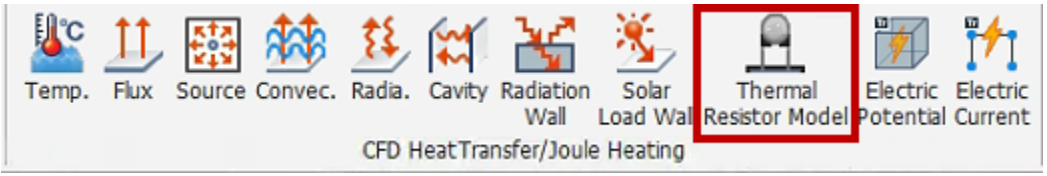
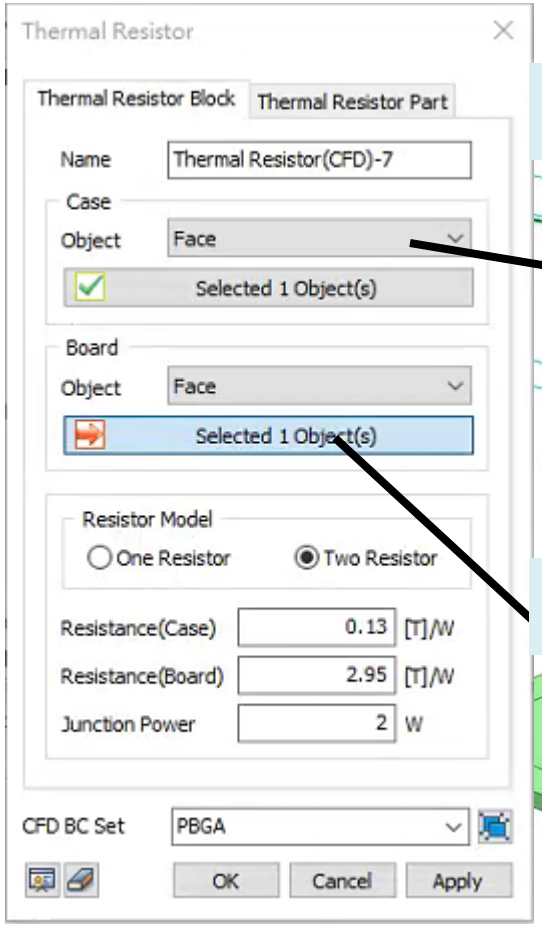
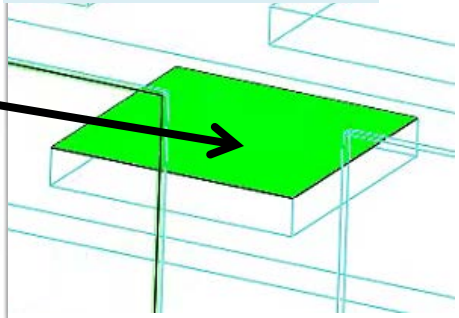
PBGA熱阻



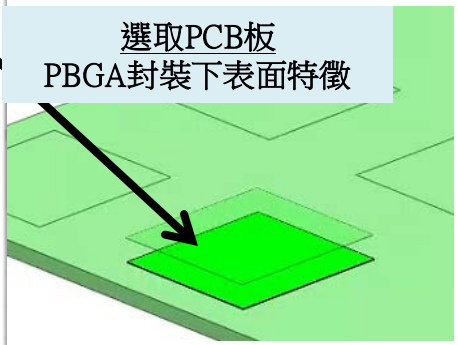
	PBGA
Junction Power (W)	**2.0**
Resistance Case (θ_{jc}) ([T]/W)	**0.13**
Resistance Board(θ_{jb})([T]/W)	**2.95**



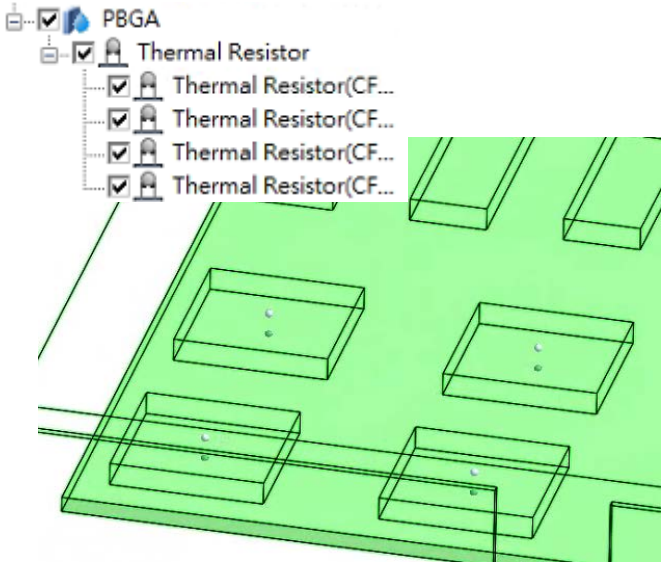
選取流場區域
PBGA封裝上表面特徵



選取PCB板
PBGA封裝下表面特徵

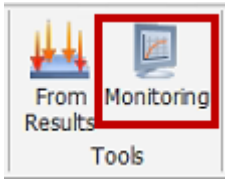


依序完成其它PBGA封裝熱阻定義



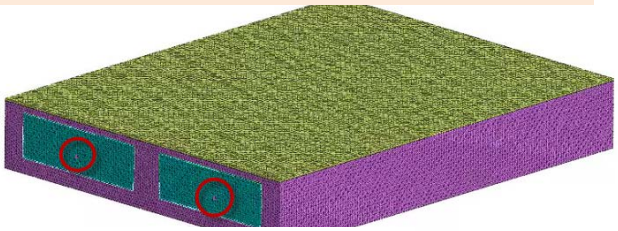
MIDAS

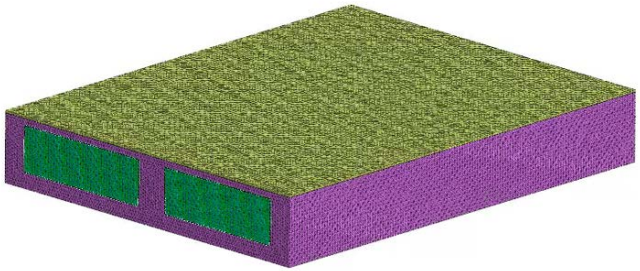
觀測點-流速/流量/溫度

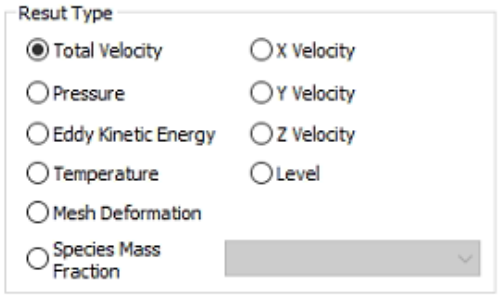


選取出入口特徵面觀測流量

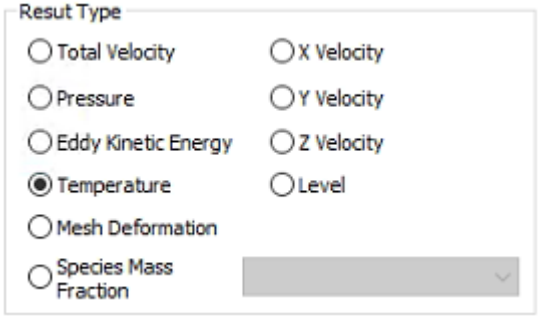
選取入流口節點觀測流速

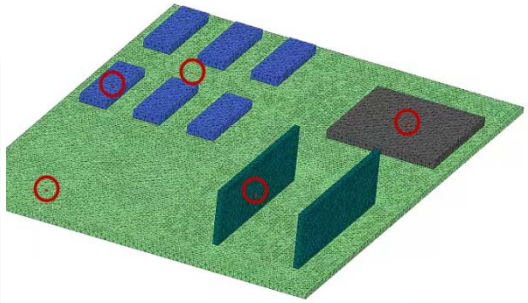


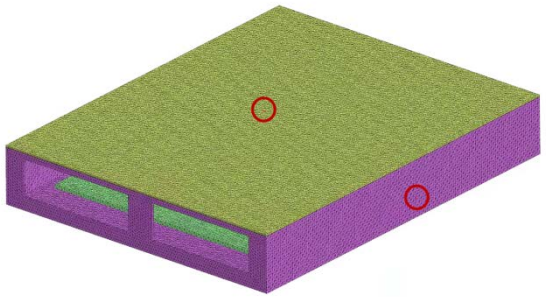




選取各部區域節點觀測溫度







註:輸出特定節點數據同時能協助判斷收斂穩定

熱對流-間接法

midas NFX-CFD

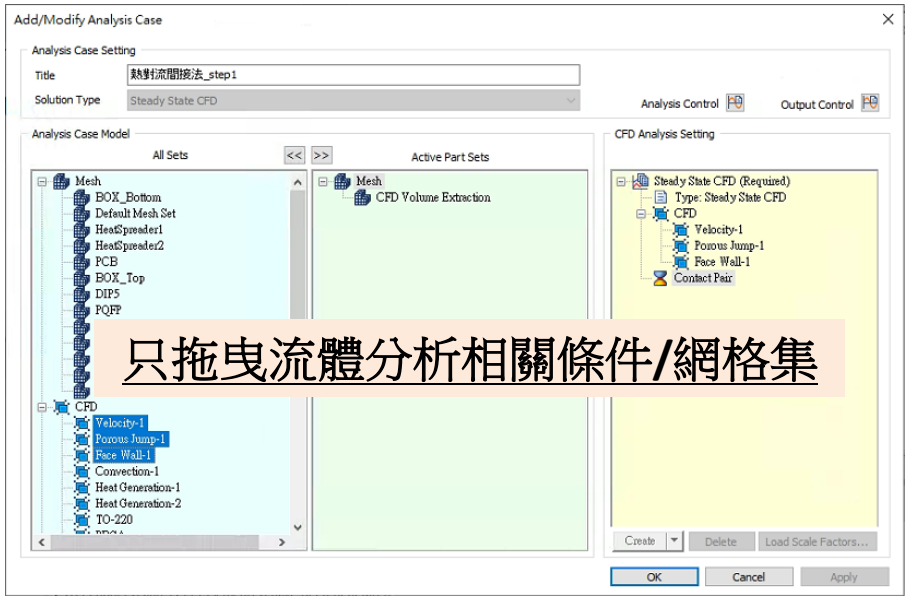
熱對流間接法 -1

(Step1. 流場計算)

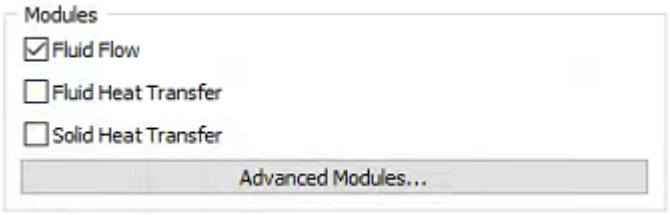
分析工況定義

Solution Type : Steady State CFD

熱對流間接法_step1



只拖曳流體分析相關條件/網格集

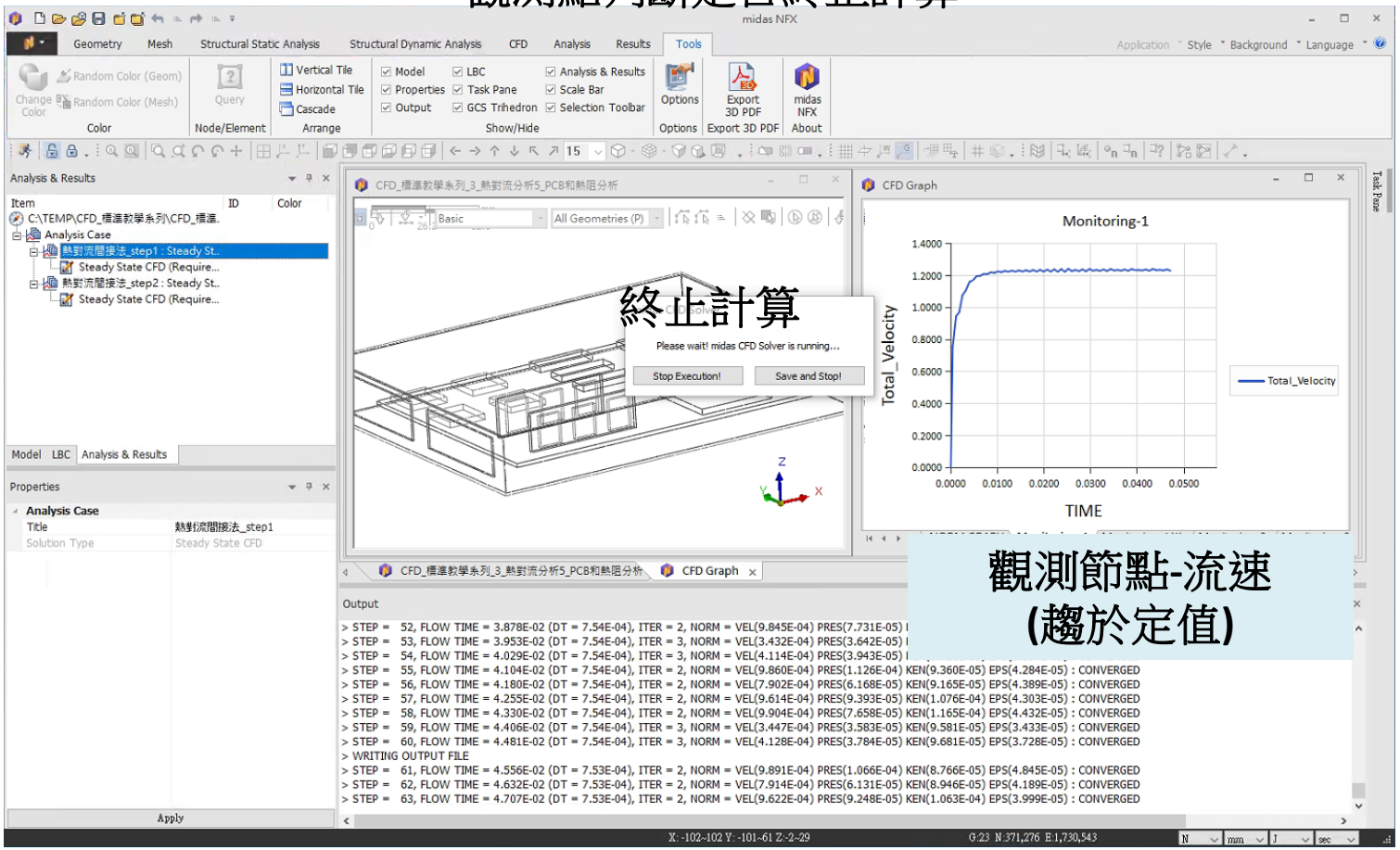


分析模組勾選
流體流動

熱對流間接法 -2

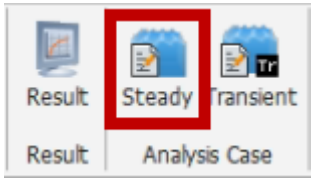
(Step1. 流場計算)

觀測點判斷是否終止計算



熱對流間接法 -3

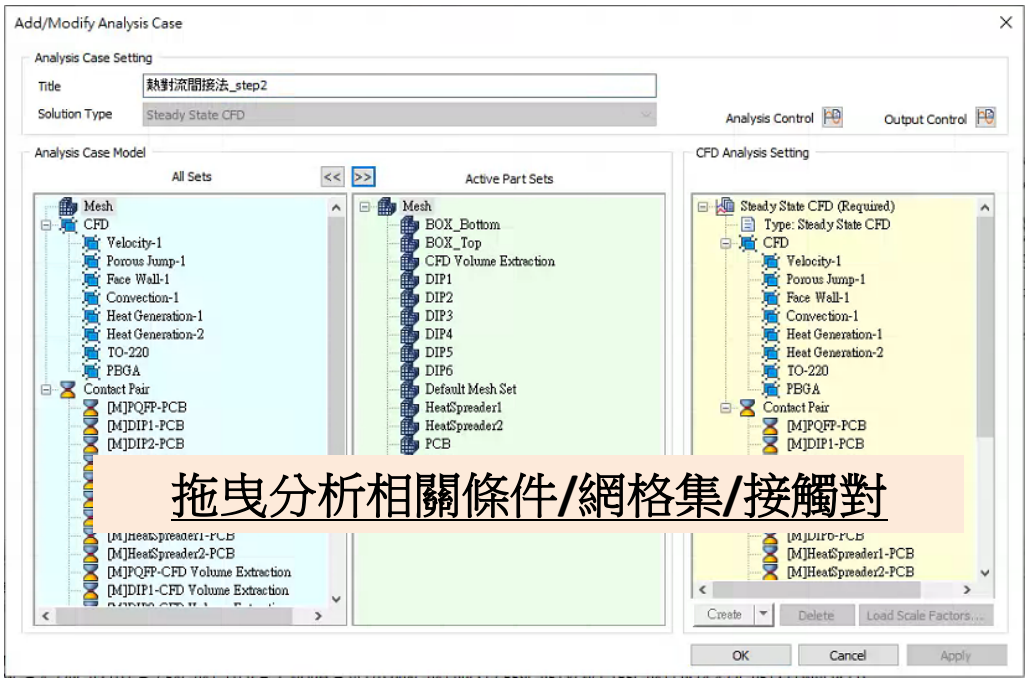
(Step2. 熱傳計算)



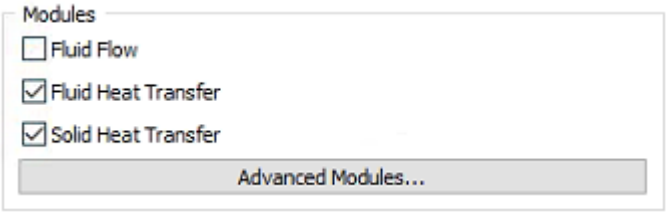
Solution Type : Steady State CFD

分析工況定義

熱對流間接法_step2



拖曳分析相關條件/網格集/接觸對



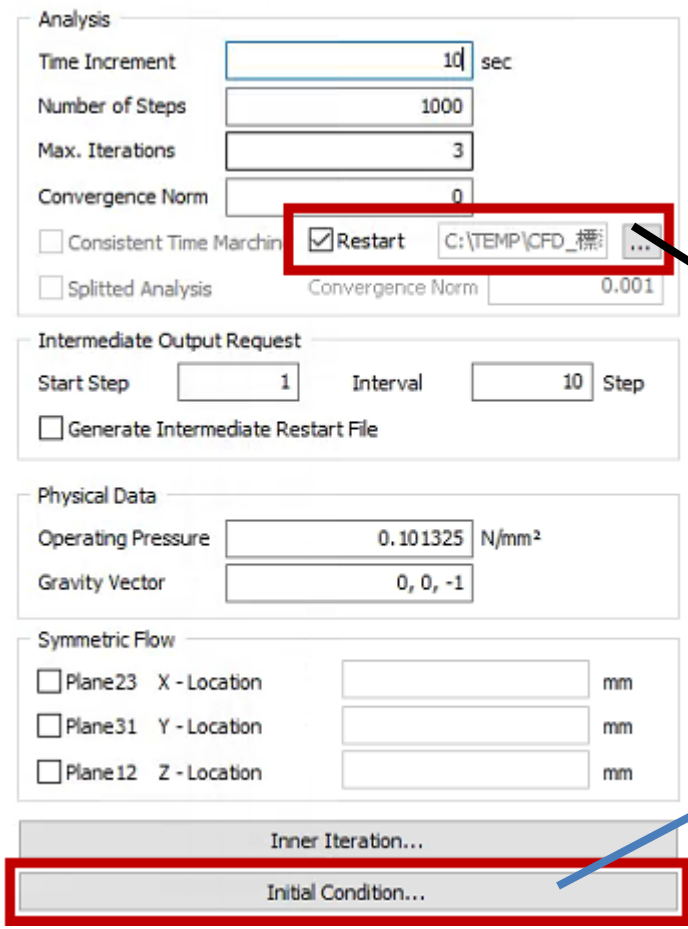
分析模組勾選
流體熱傳/固體熱傳

熱對流間接法 -4

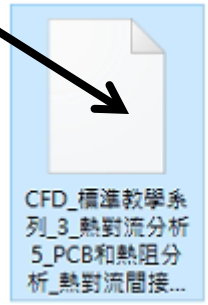
(Step2. 熱傳計算)

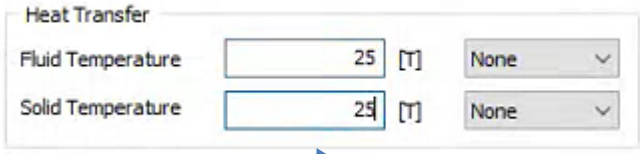
調整預設增量

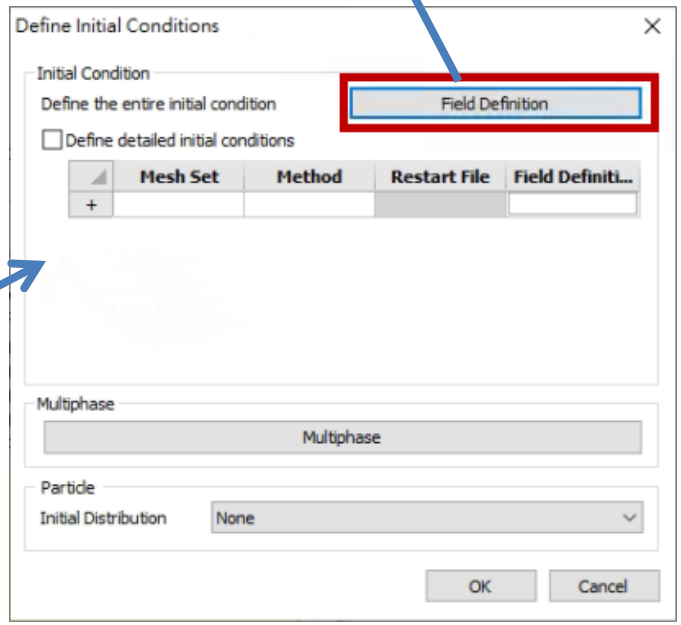
初始溫度25 ℃



讀取step1.rst檔案





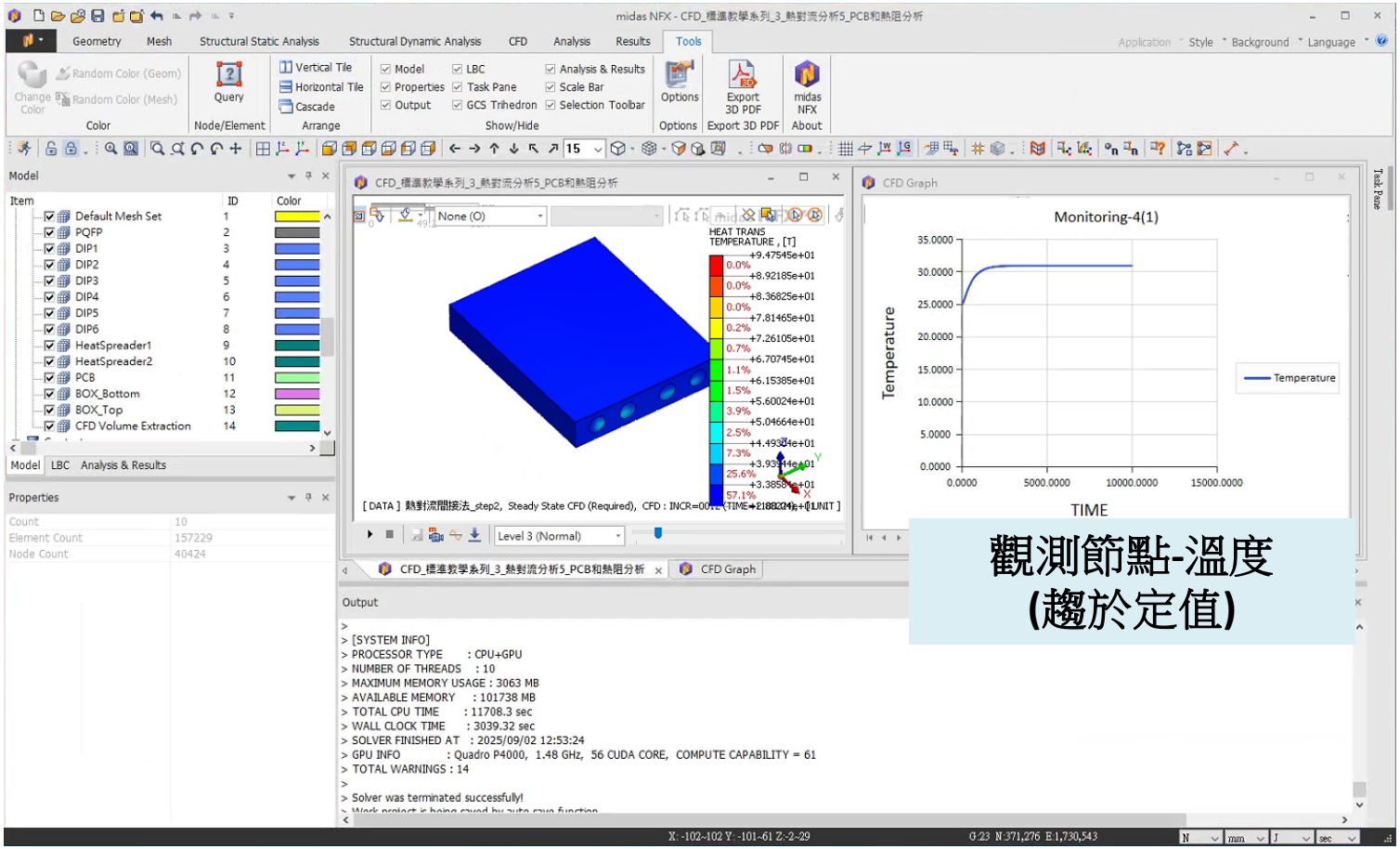


초기條件定義

熱對流間接法 -5

(Step2. 熱傳計算)

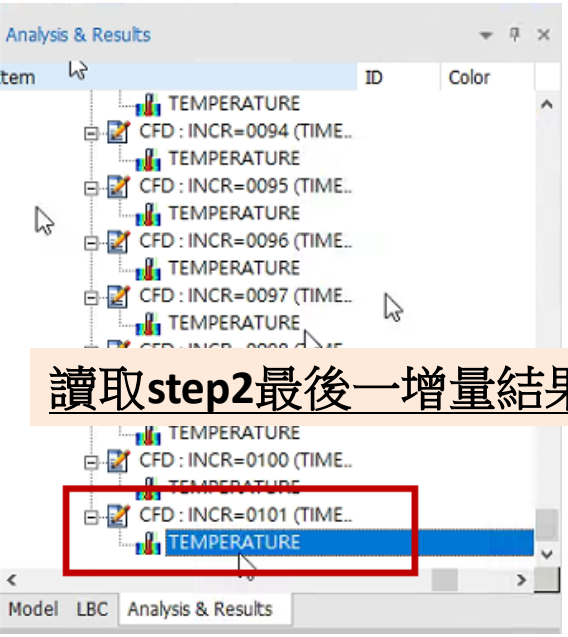
觀測點判斷是否終止計算



觀測節點-溫度
(趨於定值)

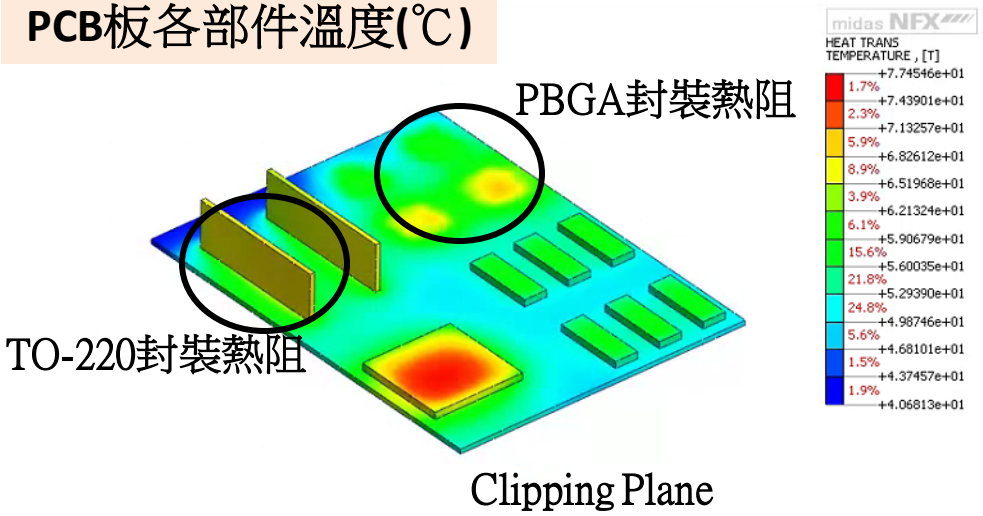
midas NFX-CFD

分析結果
(熱對流間接法)



讀取step2最後一增量結果

PCB板各部件溫度(℃)



Clipping Plane

流域溫度(℃)