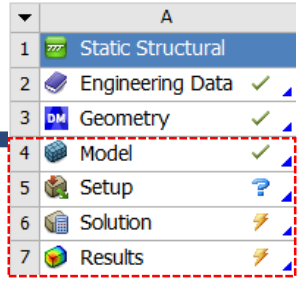
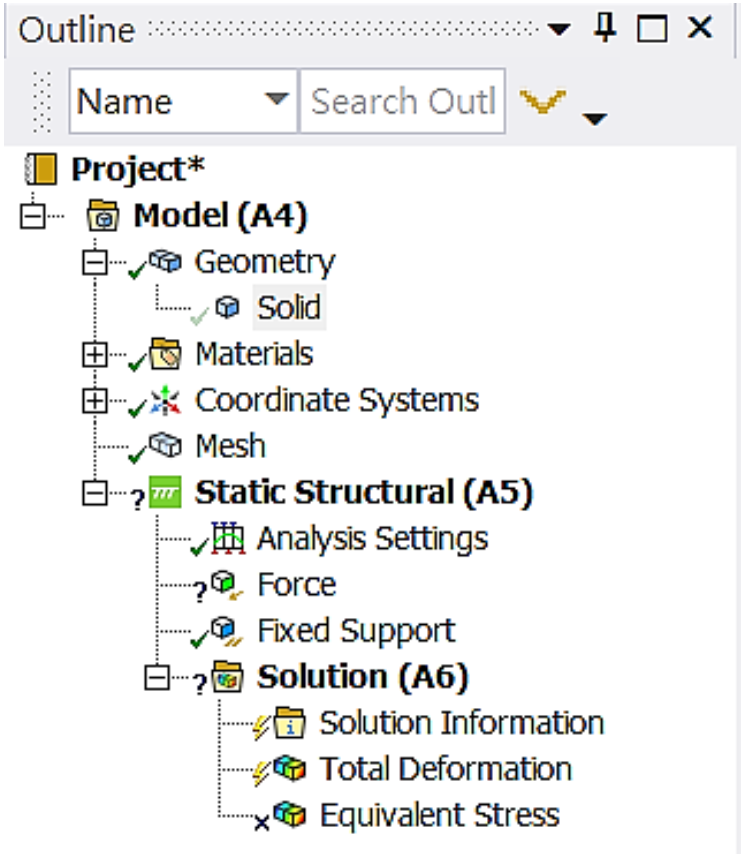
# 04 Static Structural Analysis

結構分析介紹

# Introduction of ANSYS Workbench




- 結構樹狀態顯示





說明分支全部被定義

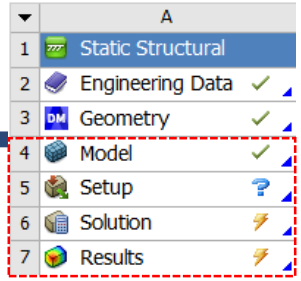

說明輸入的數據不完整


說明需要求解


說明被抑制，不能被求解


說明體積或零件被隱藏

# Introduction of ANSYS Workbench




## Detail視窗

Details of "Force"

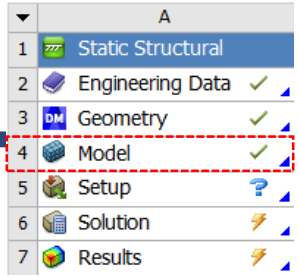
| Scope | |
|---|---|
| Scoping Method | Geometry Selection |
| Geometry | 1 Edge |
| **Definition** | |
| Type | Force |
| Define By | Components |
| Coordinate System | Global Coordinate System |
| X Component | 0. N (ramped) |
| Y Component | 0. N (ramped) |
| Z Component | 0. N (ramped) |
| Suppressed | No |

Details of "Total Deformation"

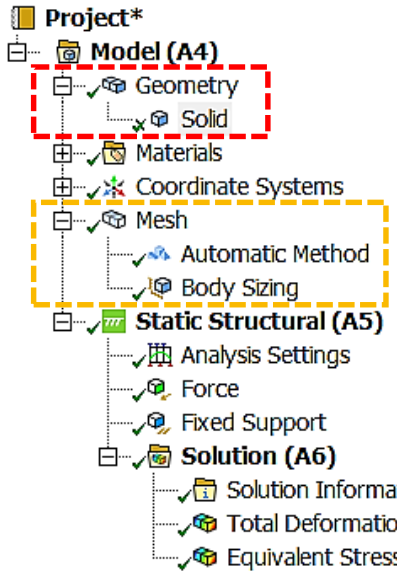
| Scope | |
|---|---|
| Scoping Method | Geometry Selection |
| Geometry | All Bodies |
| **Definition** | |
| Type | Total Deformation |
| By | Time |
| Display Time | Last |
| Calculate Time History | Yes |
| Identifier | |
| Suppressed | No |
| **Results** | |
| Minimum | 0. mm |
| Maximum | 2.6374e-003 mm |

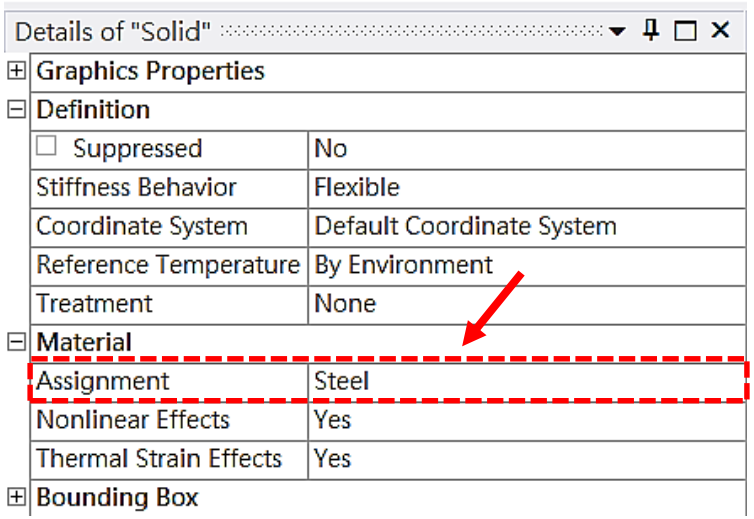
| | |
|---|---|
| 白色區域 | 可編輯的資料設定 |
| 灰色區域 | 不可編輯的資料，僅供顯示信息數據 |
| 黃色區域 | 未完成的資料設定(待輸入) |
| 粉色區域 | 尚未更新的結果數據(需重新求解) |

# Introduction of ANSYS Workbench




- **Model**
  - **Geometry: 模型材料給定**
  - **Mesh: 網格分割**



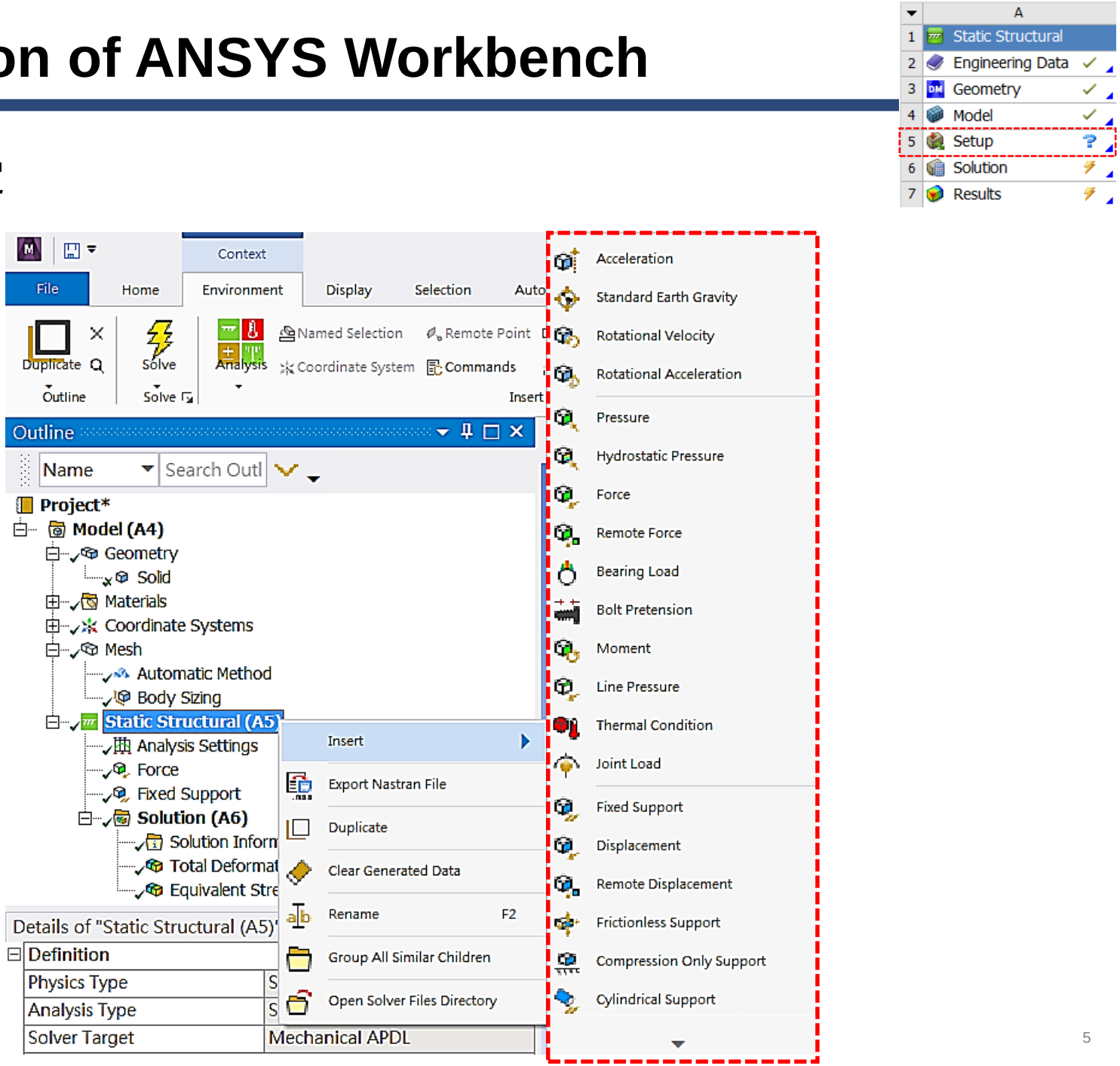





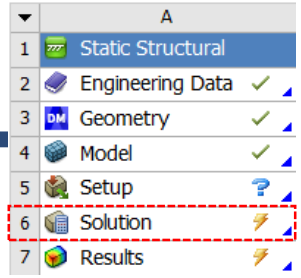

4

# Introduction of ANSYS Workbench

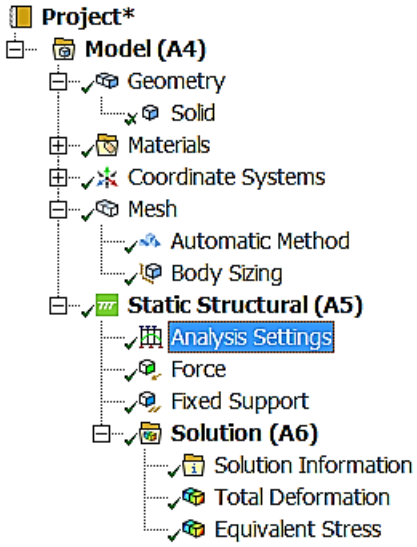
- 邊界條件給定

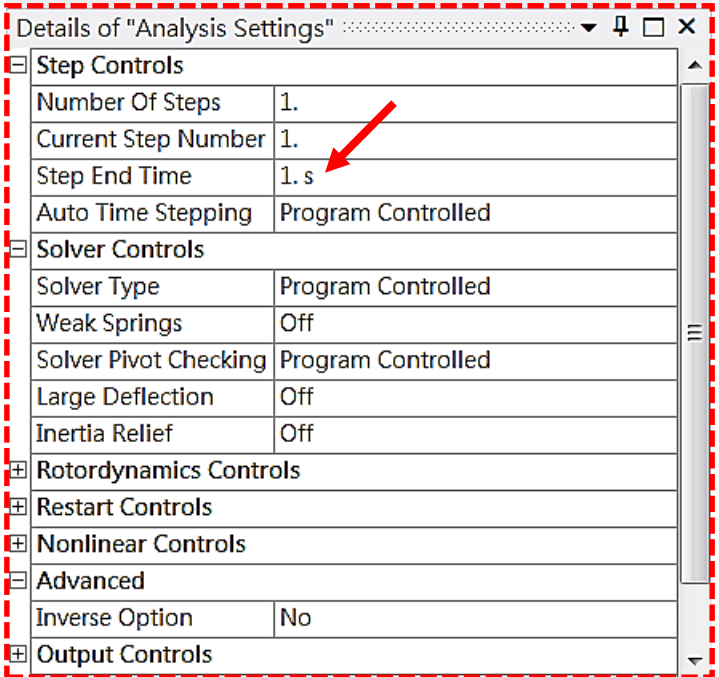


# Introduction of ANSYS Workbench



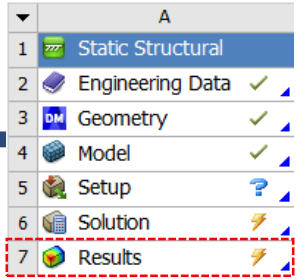

- 解題條件設定
  - Step Control
  - Number of steps
  - Current Step Number
  - Step Ends
- Solver Control
  - 解題形式
  - 大變形等



# Introduction of ANSYS Workbench

- 後處理(Post-processing)



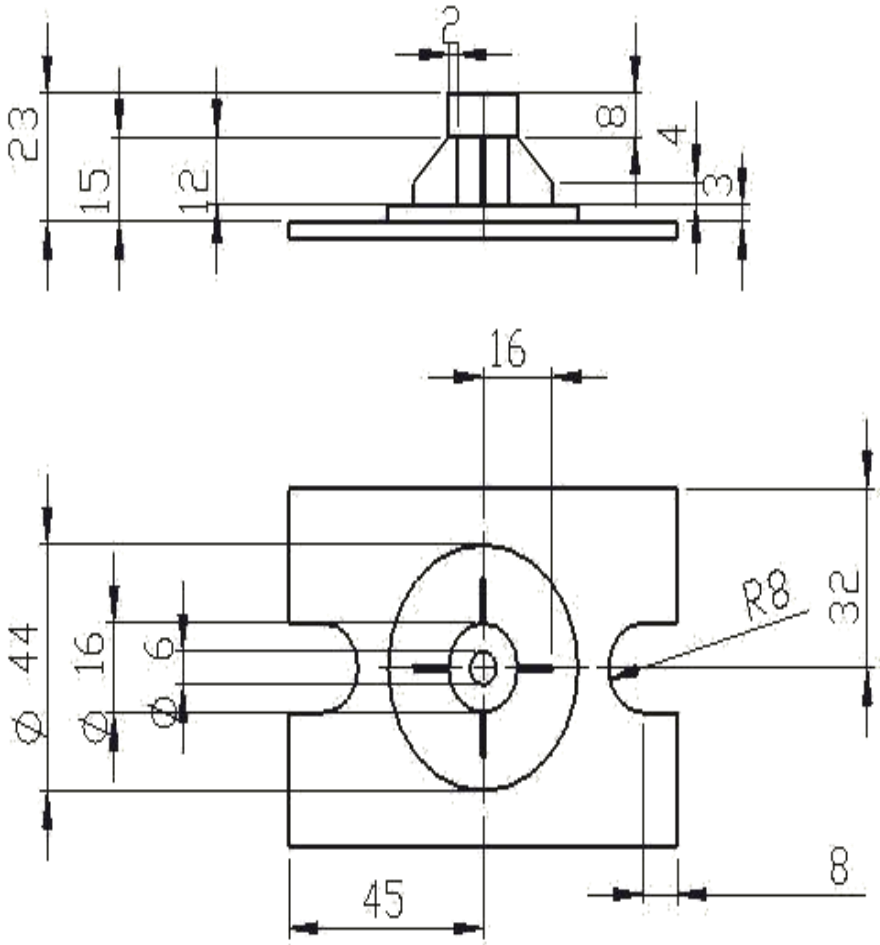

設定顯示方式

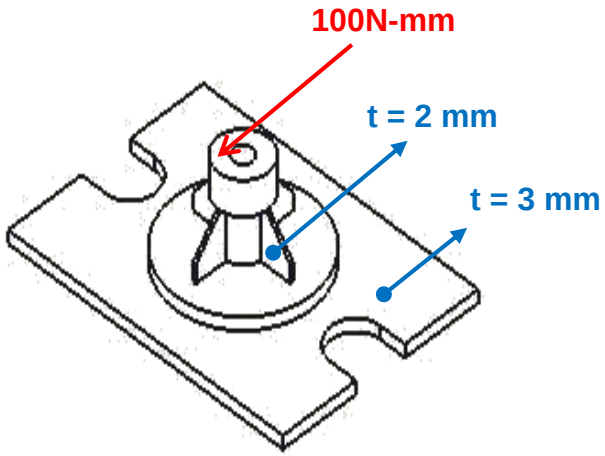
選取結果項目

Contour設定
- 自訂數值
- 增加色塊
- 自訂色彩

# 3D Solution – Ex.5 (來源：ANSYS Workbench有限元分析從入門到精通)

**試建構機蓋模型，尺寸如圖所示，於中央孔頂端面給一100N-mm順時針方向扭轉，觀察其等效應力，材料選用鋼，設定ELEMENT SIZE為3的MESH 。**

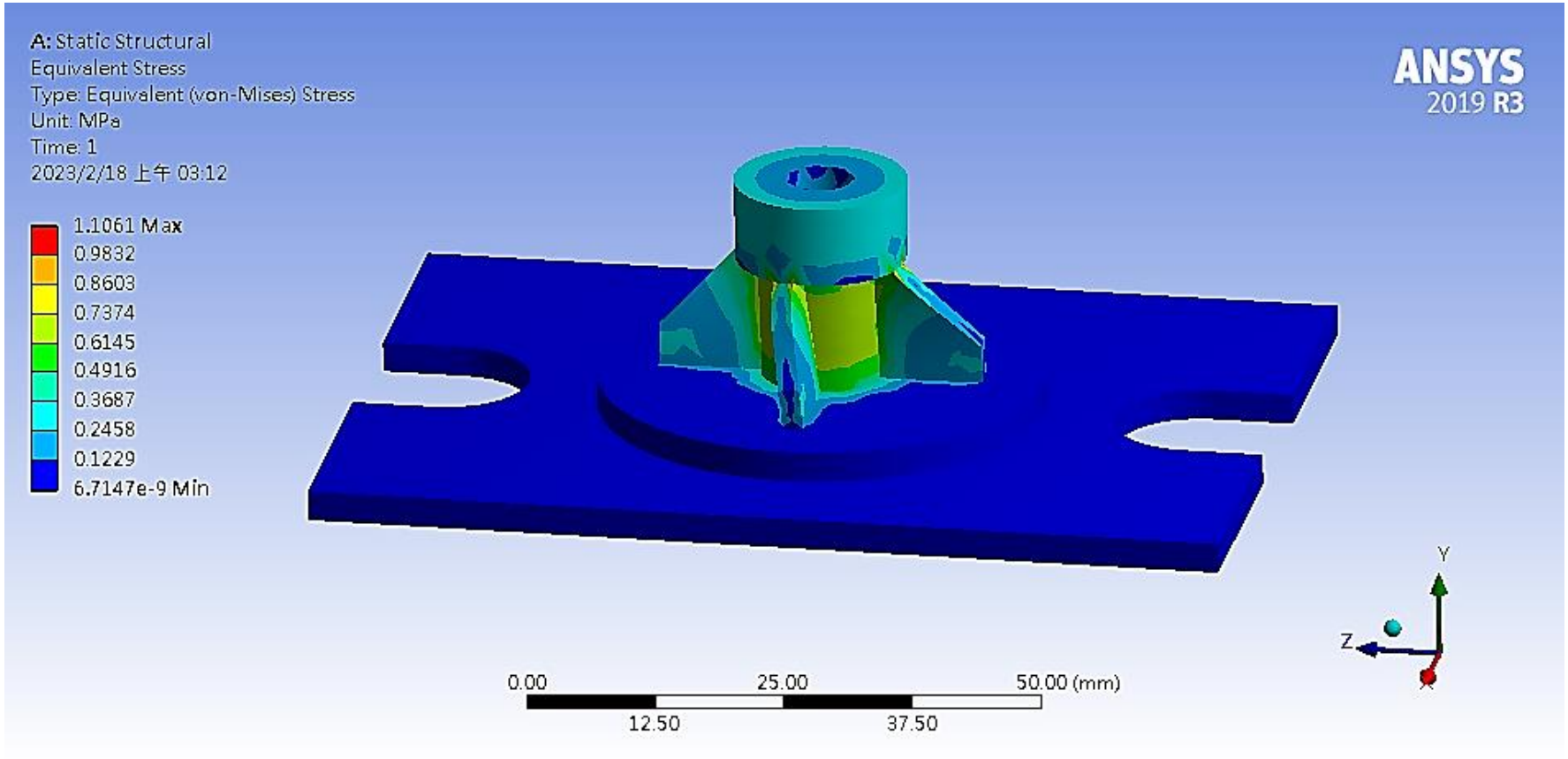


# 3D Solution – Ex.5

學習目標
- Revolve
- Pattern
- Mesh-*Sizing*
- 解題步驟
- 基本後處理

**試建構機蓋模型，尺寸如圖所示，於中央孔頂端面給一100N-mm順時針方向扭轉，觀察其等效應力，材料選用鋼，設定ELEMENT SIZE為3的MESH 。**

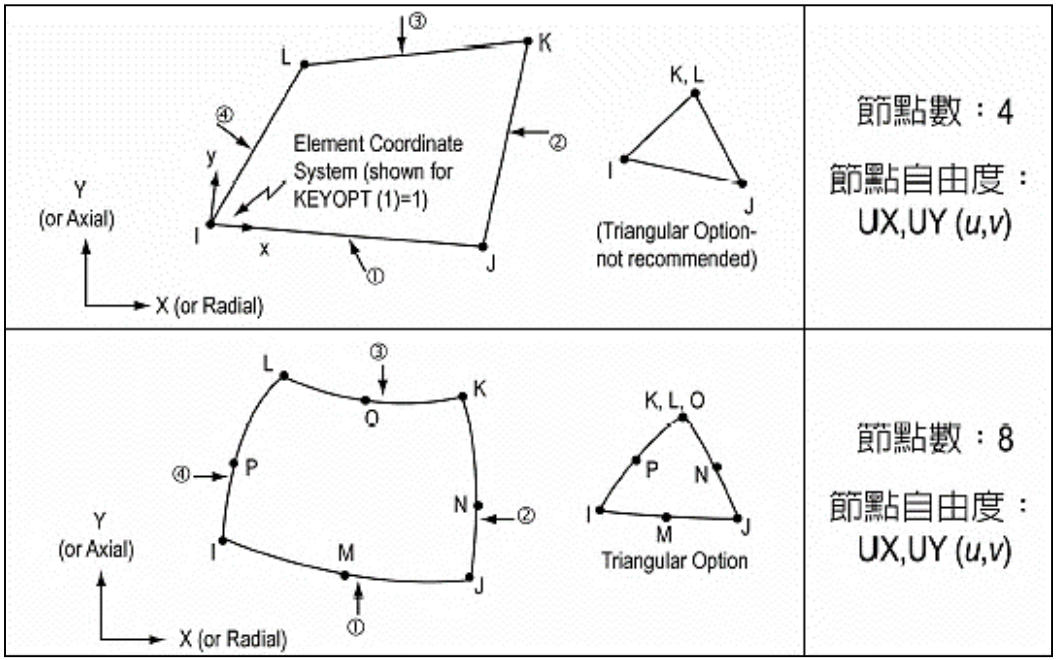



等效應力
Equivalent Stress

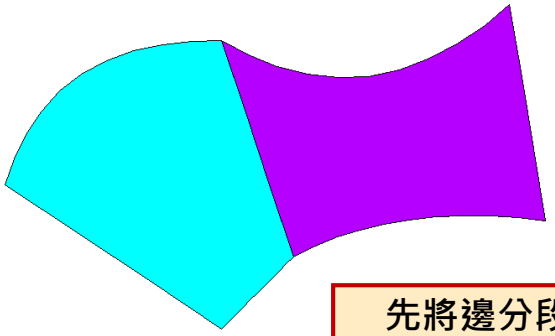
# Mesh

- **Mesh Approach**
  - **Solid modeling**
    - ✓ **Free mesh**
    - ✓ **Mapped mesh**
    - ✓ **…**

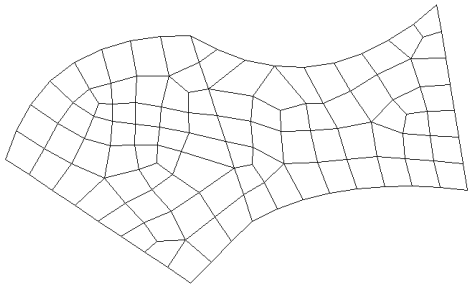
網格控制方法非常多元，實際情況依模型、受力狀態、邊界條件而定



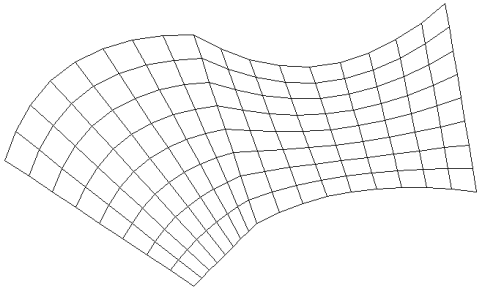

**Solid Model**



先將邊分段

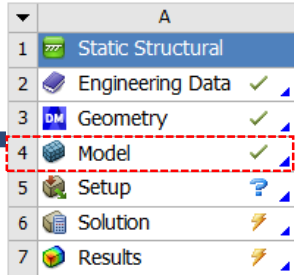


**Free Mesh**



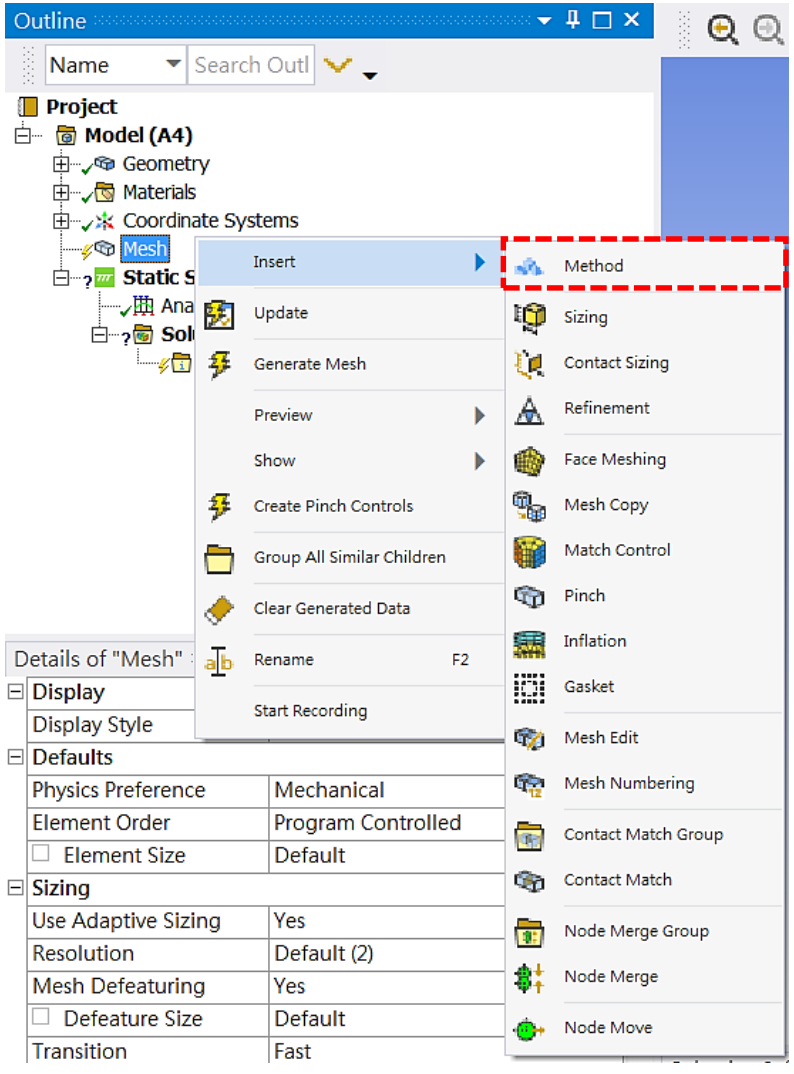
**Mapped Mesh**

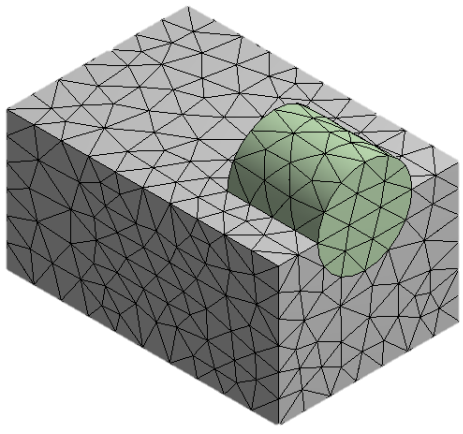
# Introduction of ANSYS Workbench



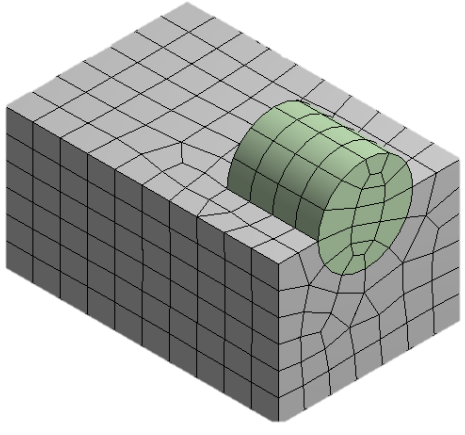

## ■ 局部網格處理

### ➢ Method



四面體



六面體

Details of "Mesh"

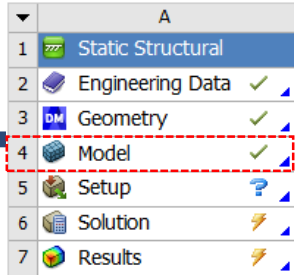
| | |
|---|---|
| **Display** | |
| Display Style | |
| **Defaults** | |
| Physics Preference | Mechanical |
| Element Order | Program Controlled |
| Element Size | Default |
| **Sizing** | |
| Use Adaptive Sizing | Yes |
| Resolution | Default (2) |
| Mesh Defeaturing | Yes |
| Defeature Size | Default |
| Transition | Fast |

Details of "Automatic Method" - Method

| | |
|---|---|
| **Scope** | |
| Scoping Method | Geometry Selection |
| Geometry | 1 Body |
| **Definition** | |
| Suppressed | No |
| Method | Automatic |
| Element Order | Automatic |

Automatic
Tetrahedrons
Hex Dominant
Sweep
MultiZone
Cartesian
Layered Tetrahedrons

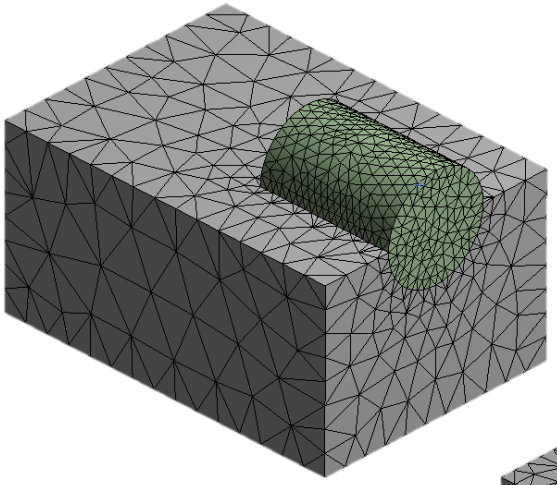
# Introduction of ANSYS Workbench



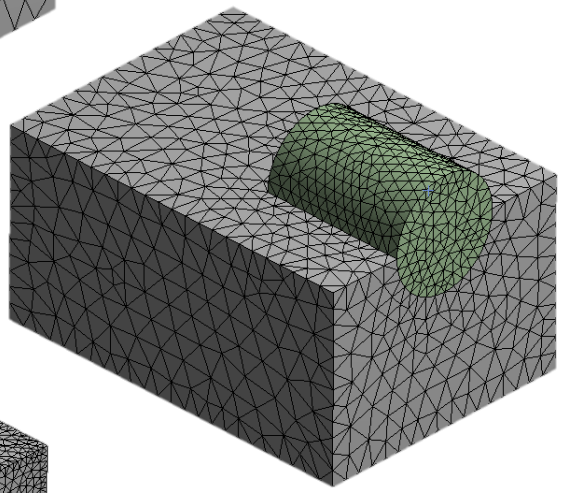

- 全域網格處理
  - Sizing
    - ✓ Resolution

Details of "Mesh"

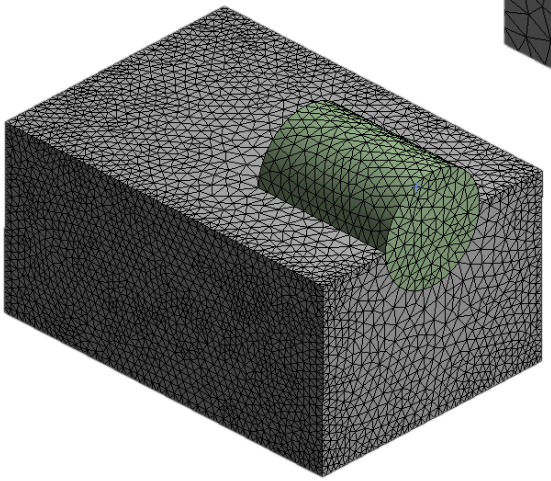
| | |
|---|---|
| **Display** | |
| Display Style | Use Geometry Setting |
| **Defaults** | |
| Physics Preference | Mechanical |
| Element Order | Program Controlled |
| Element Size | Default |
| **Sizing** | |
| Use Adaptive Sizi... | Yes |
| Resolution | Default (2) |
| Mesh Defeaturing | Yes |
| Defeature Size | Default |
| Transition | Fast |
| Span Angle Center | Coarse |
| Initial Size Seed | Assembly |
| Bounding Box Di... | 5.2715 in |
| Average Surface ... | 1.4345 in² |
| Minimum Edge L... | 0.61842 in |
| **Quality** | |
| **Inflation** | |
| **Advanced** | |
| **Statistics** | |



Resolution = 2



Resolution = 4



Resolution = 7

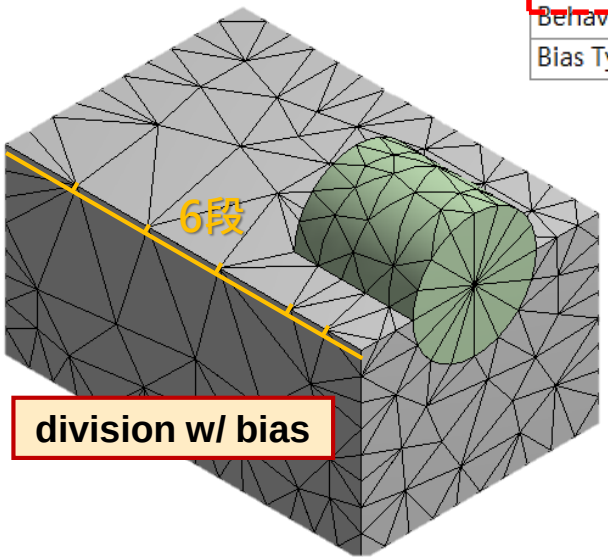
# Introduction of ANSYS Workbench

| | A |
|---|---|
| 1 | Static Structural |
| 2 | Engineering Data ✓ |
| 3 | Geometry ✓ |
| 4 | Model ✓ |
| 5 | Setup ? |
| 6 | Solution ⚡ |
| 7 | Results ⚡ |

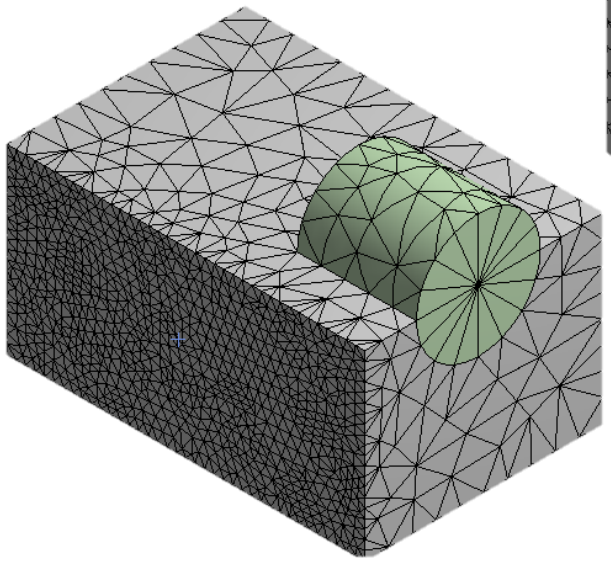
- 局部網格處理
  - Sizing

Details of "Edge Sizing" - Sizing

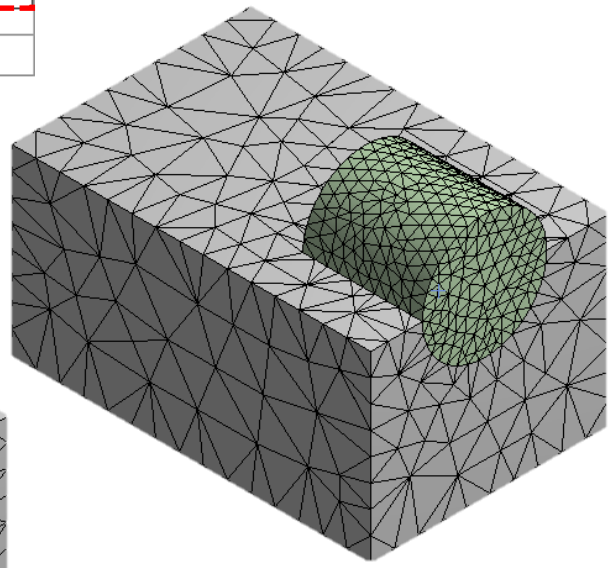
| | |
|---|---|
| **Scope** | |
| Scoping Method | Geometry Selection |
| Geometry | 1 Edge |
| **Definition** | |
| Suppressed | No |
| Type | Element Size |
| Element Size | Element Size |
| **Advanced** | Number of Divisions |
| Behavior | Sphere of Influence |
| Bias Type | No Bias |




Edge



Face

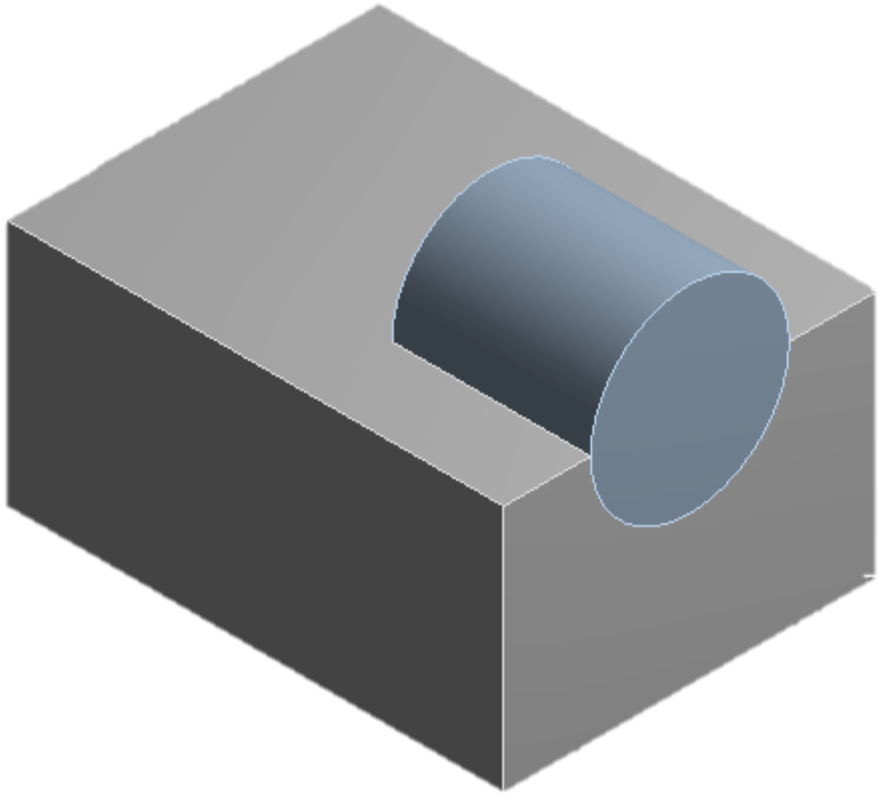


Body

# Mesh – Ex.6

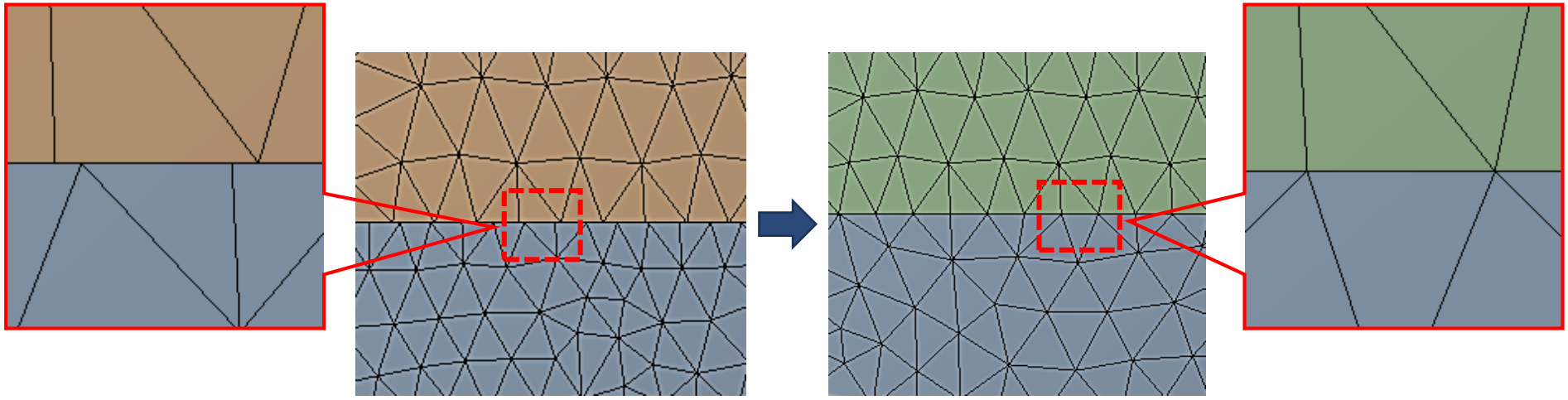
**試繪製模型如圖所示，方塊長寬高分別為20mm、15mm、10mm，圓柱半徑4mm、深8mm，請以不同功能進行網格化練習(Method、Resolution、指定不同幾何之Sizing)**

學習目標
- Add frozen
- Boolean
- Mesh-*Method*
- Mesh-*Resolution*
- Mesh-局部*Sizing*



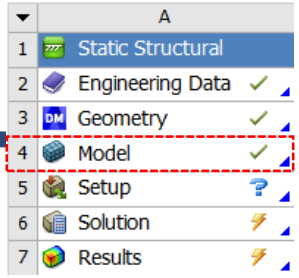
# Mesh

- 元素的連續性，相鄰元素需使用共同的節點和自由度
- 三角形和契形元素可被使用於過度區
- 元素需盡可能保持其原來的形狀，即不能扭曲太嚴重
- 在施力處的網格分割需良好
- 在預期應力集中處如孔洞、凹槽等處的分割，元素尺寸需較小且分佈良好
- 網格的分割的密度需盡可能隨應力分佈而調整



網格不連續　　網格連續

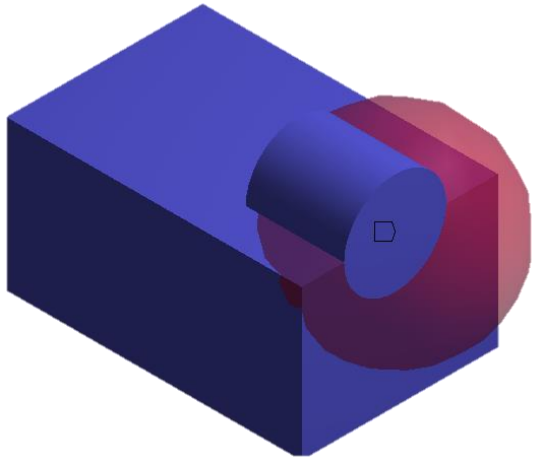
# Introduction of ANSYS Workbench



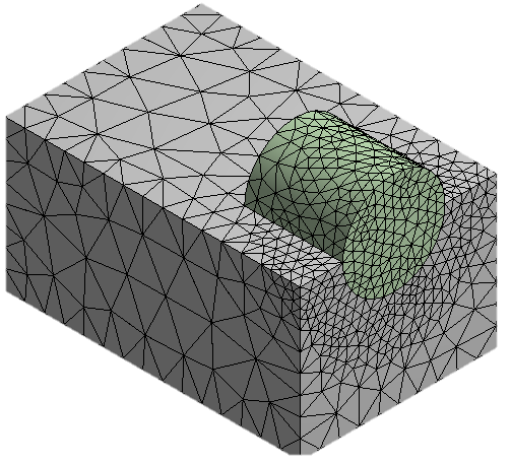

- 局部網格處理
  - Sizing
    - ✓ Sphere of influence (Pinball)

Details of "Body Sizing" - Sizing

| | |
|---|---|
| **Scope** | |
| Scoping Method | Geometry Selection |
| Geometry | 1 Body |
| **Definition** | |
| Suppressed | No |
| Type | Sphere of Influence |
| Sphere Center | Global Coordinate System |
| Sphere Radi... | 0.5 in |
| Element Size | 5.e-002 in |



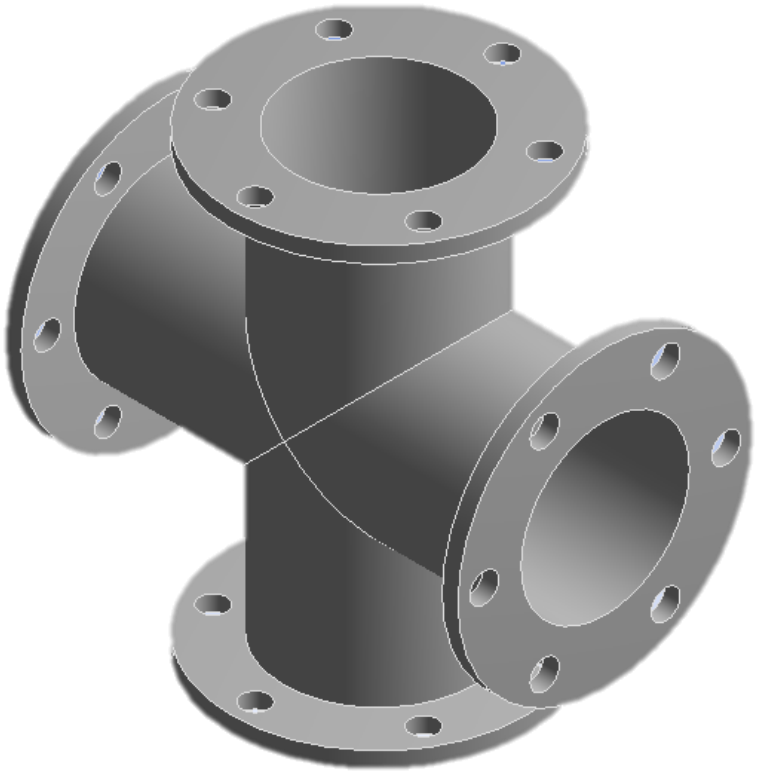
Pinball



Pinball mesh

# Mesh – Ex.7 (來源：ANSYS Workbench有限元分析從入門到精通)

**請依下列實體模型(pipe.agdb)進行不同功能之網格化練習**

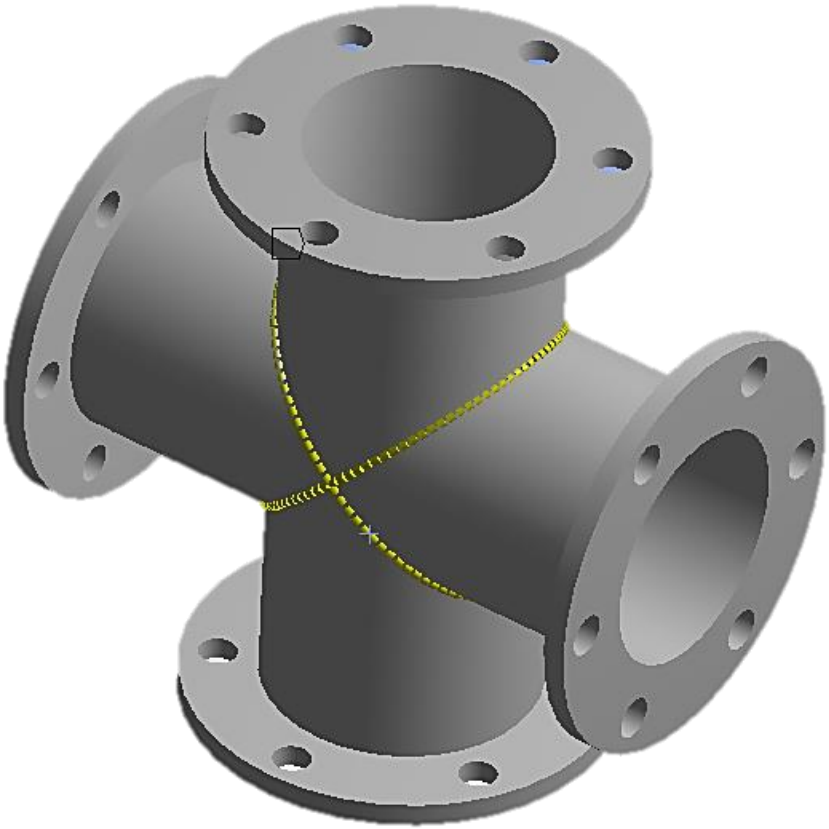


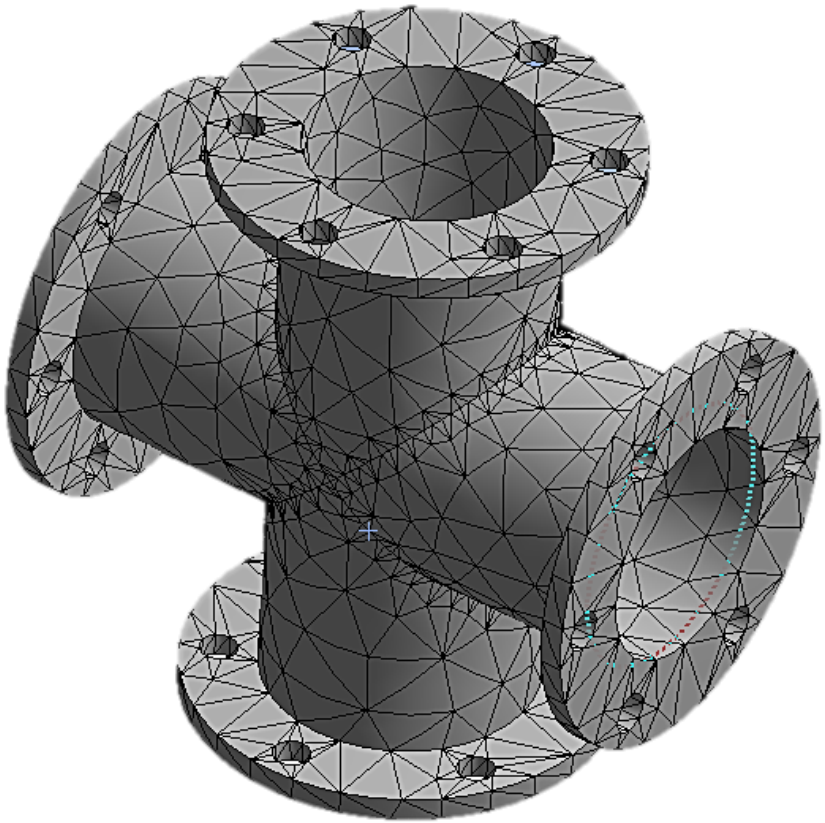
# Mesh – Ex.7

學習目標
- Mesh-*Division*
- Mesh-*Refinement*
- Mesh-*Pinball*
- 剖面觀察

## 局部網格A

- **Sizing**
  - ✓ **Number of division**



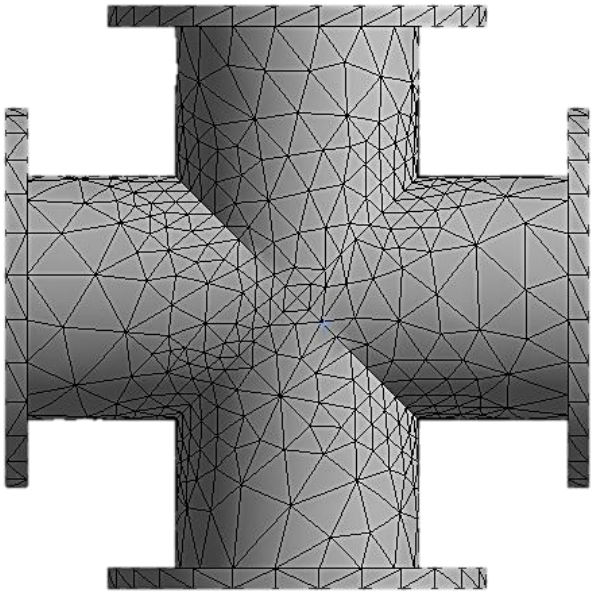


# Mesh – Ex.7

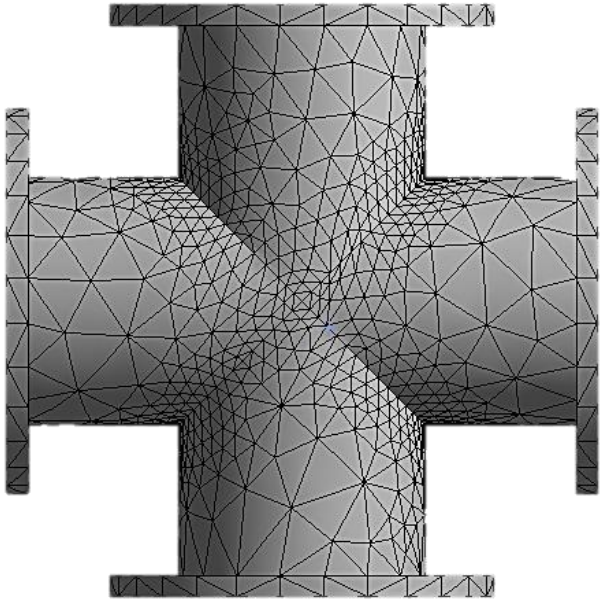
學習目標
- Mesh-*Division*
- Mesh-*Refinement*
- Mesh-*Pinball*
- 剖面觀察

## 局部網格B

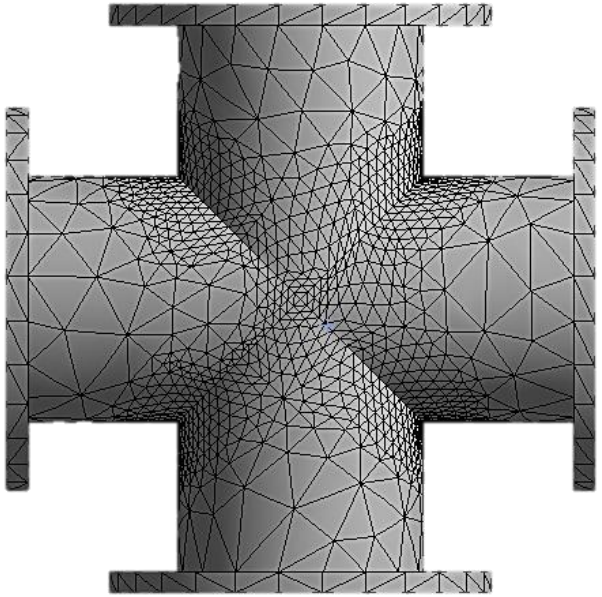
- **Refinement**



**Refinement = 1**



**Refinement = 2**



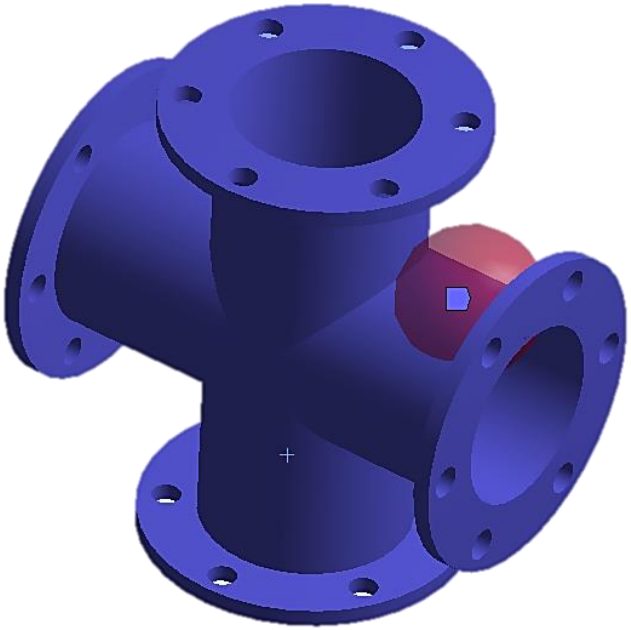
**Refinement = 3**

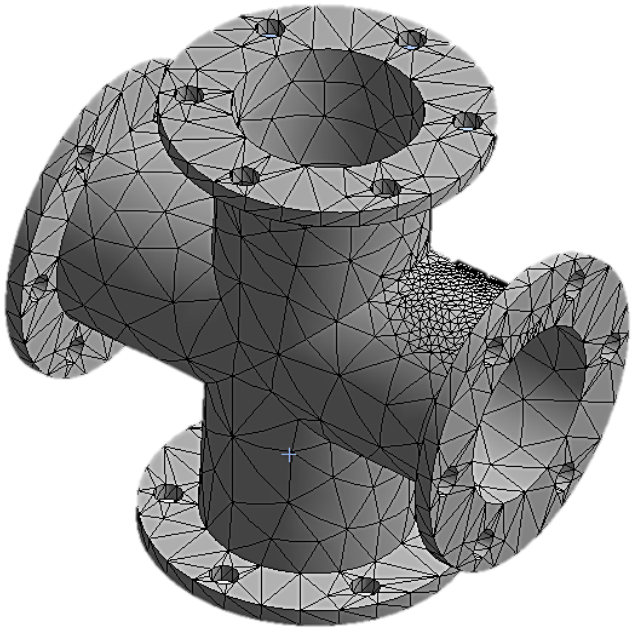
# Mesh – Ex.7

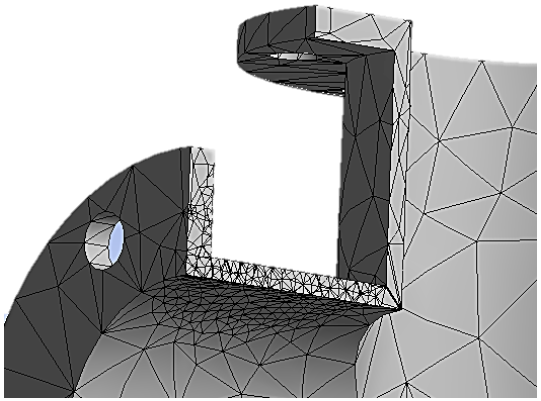
學習目標
- Mesh-*Division*
- Mesh-*Refinement*
- Mesh-*Pinball*
- 剖面觀察

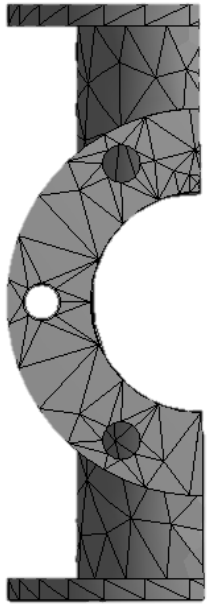
## 局部網格C

- **Sizing**
  - ✓ **Sphere of influence (Pinball)**



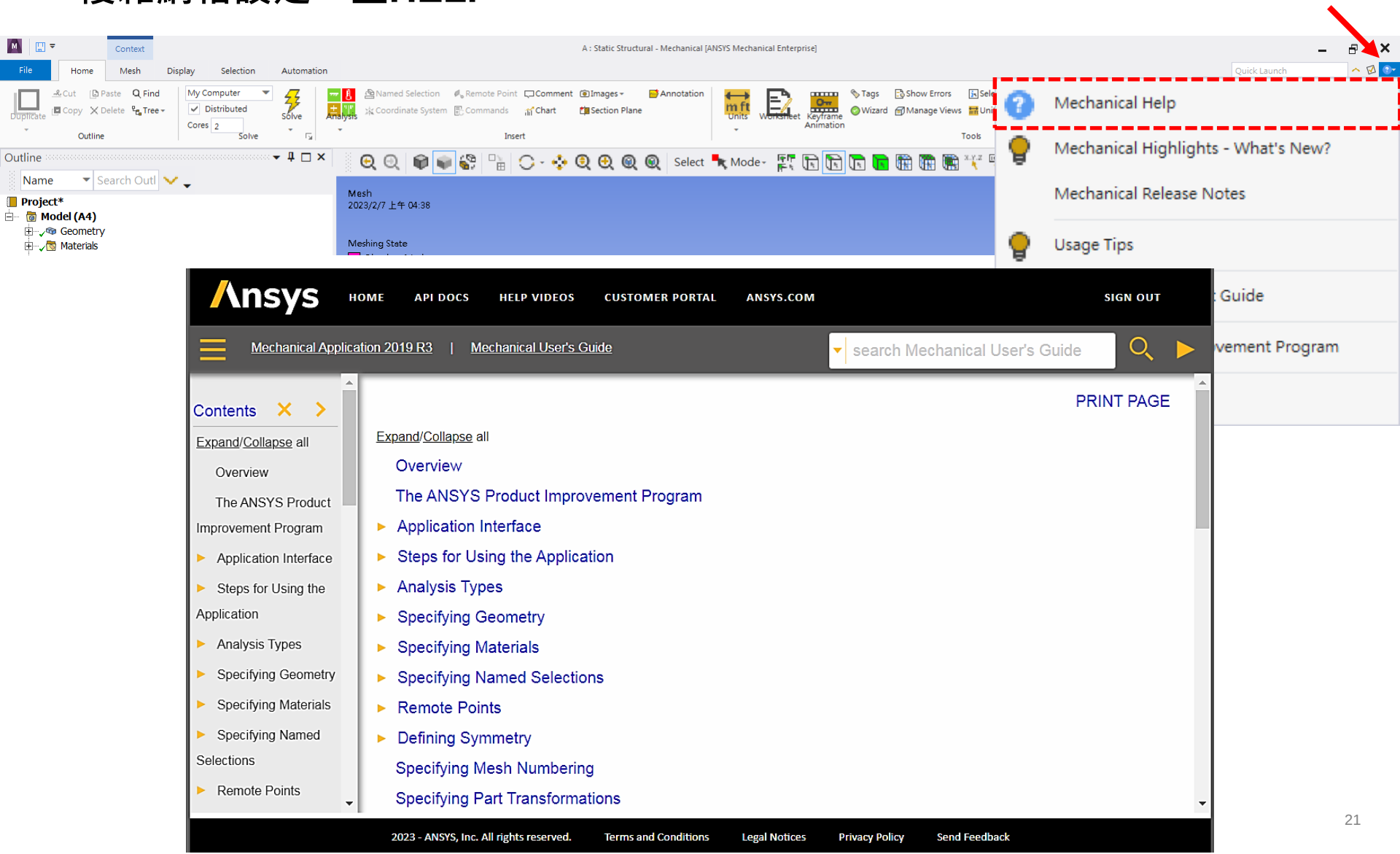






# Introduction of ANSYS Workbench

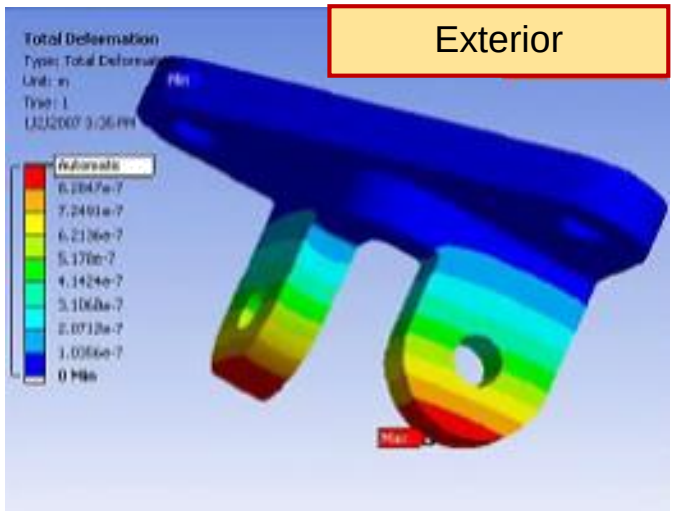
- 複雜網格設定→查HELP

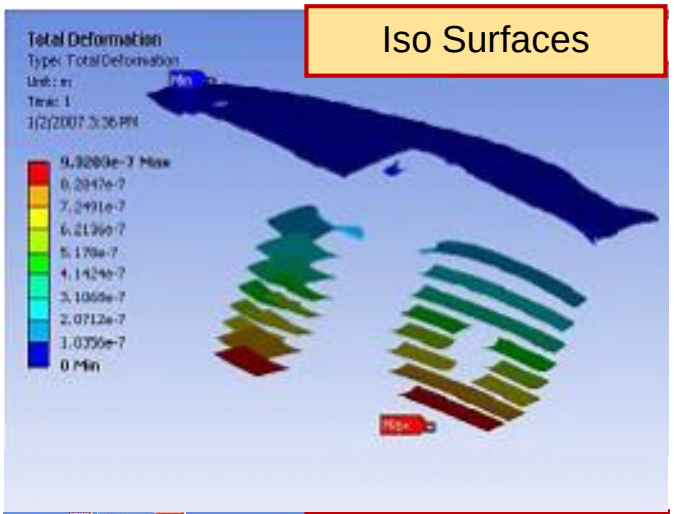


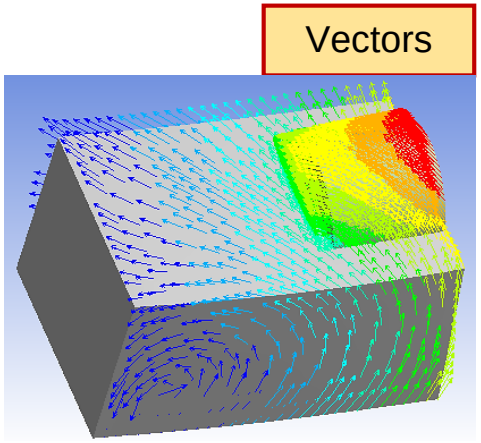
# Introduction of ANSYS Workbench

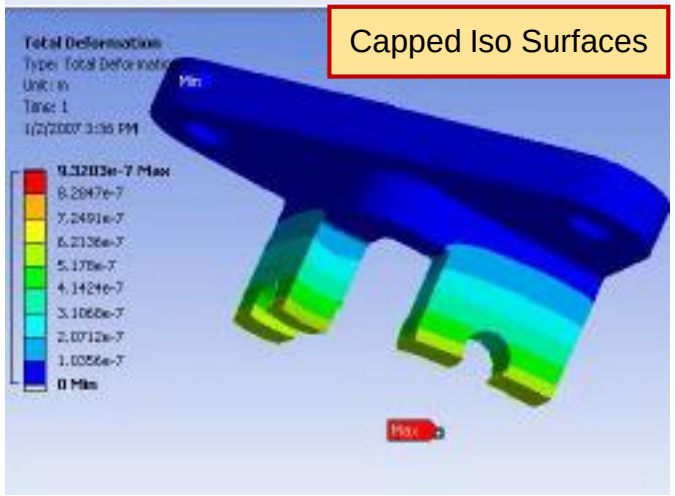
| | A |
|---|---|
| 1 | Static Structural |
| 2 | Engineering Data ✓ |
| 3 | Geometry ✓ |
| 4 | Model ✓ |
| 5 | Setup ? |
| 6 | Solution ⚡ |
| 7 | Results ⚡ |

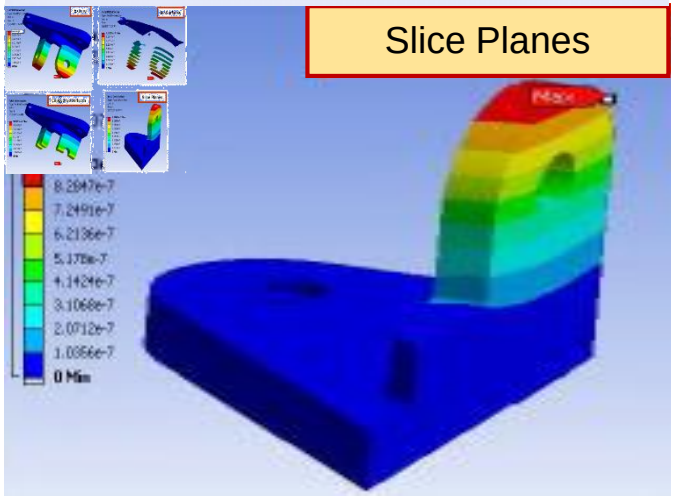
- **後處理(Post-processing)**
  - 結果顯示方式



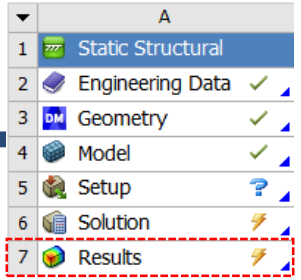



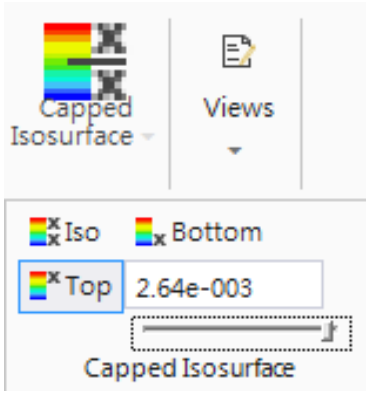



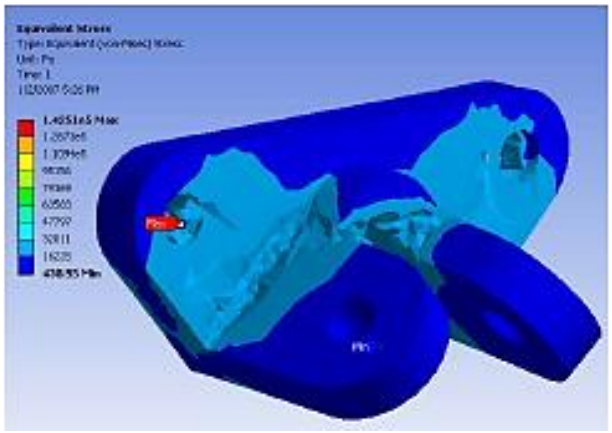
# Introduction of ANSYS Workbench



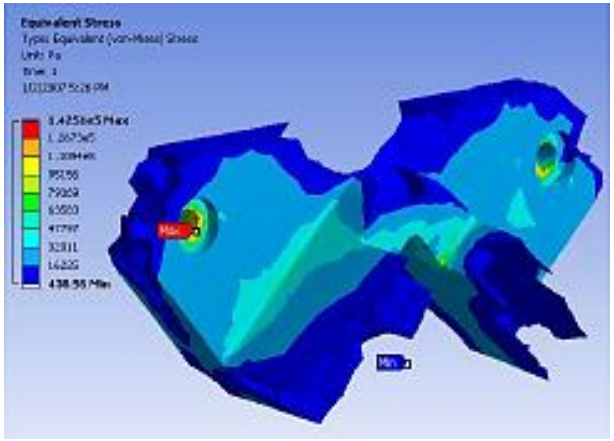

- 後處理(Post-processing)
  - Capped ISO surface
    - ✓ 可設定閥值以外區域之圖案不顯示




**Top capped** ：超過閥值區域不顯示
**Bottom capped**：低於閥值區域不顯示



頂部封頂等值面



底部封頂等值面



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# Introduction of ANSYS Workbench

| | A |
|---|---|
| 1 | Static Structural |
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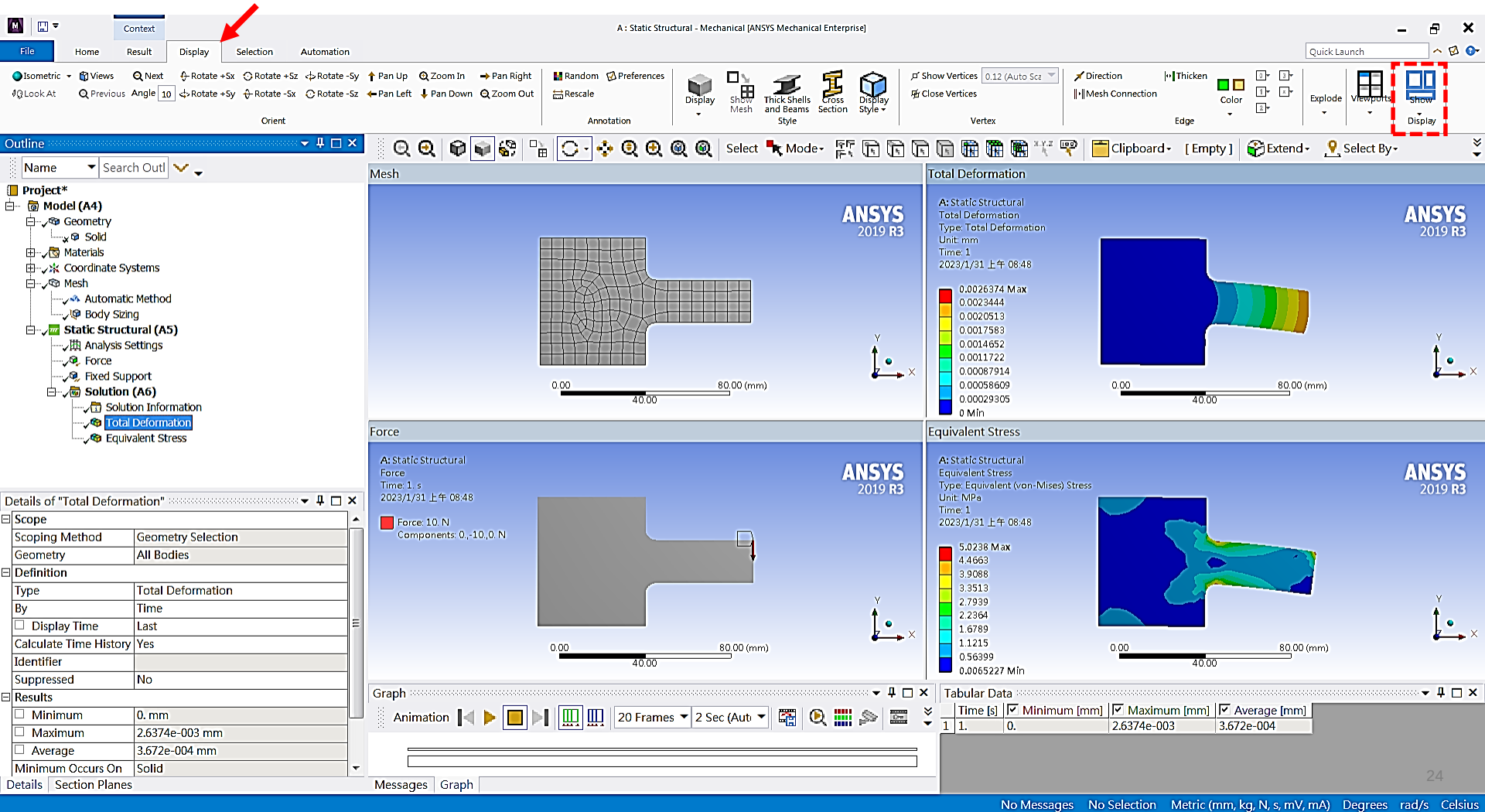
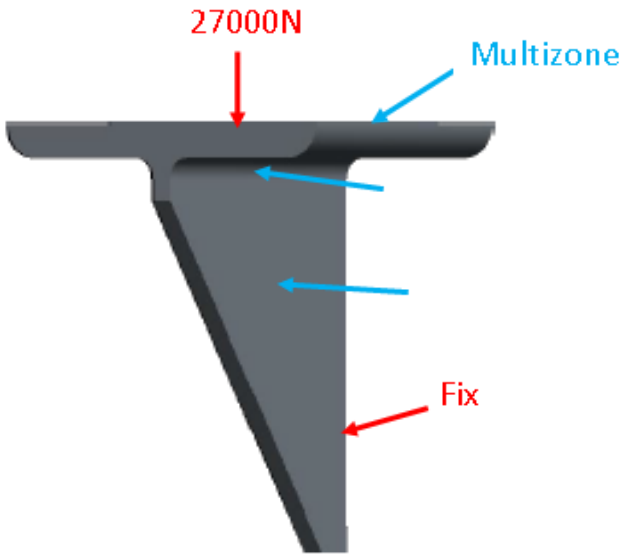
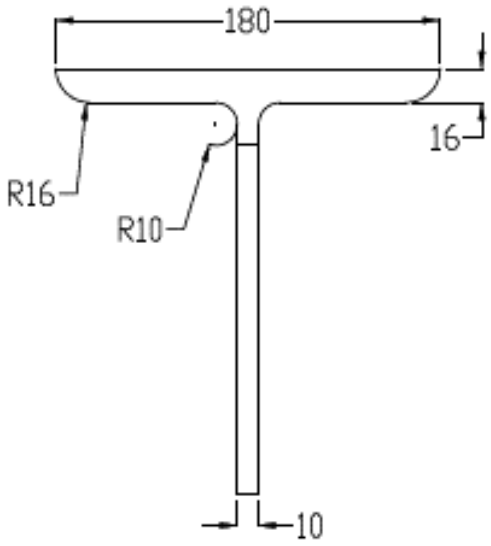
- 後處理(Post-processing)
  - 多觀察視窗

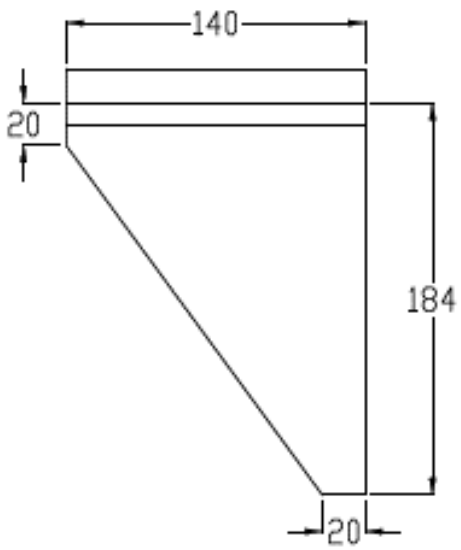


# 3D Solution – Ex.8 (來源：成功大學李輝煌教授)

**機翼模型，尺寸如下所示，使用MultiZone之網格方法將翼板頂面、腹板側面、接合處圓角面進行mesh設定，並將翼板與腹板接合處之圓角兩面設定element size為7的mesh。邊界條件如圖所示，板子後方之面固定，上方施予頂面一力。觀察其等效應力、位移量變化、結構誤差及Safety Factor。材料選用鋼。(單位：MM, N)**



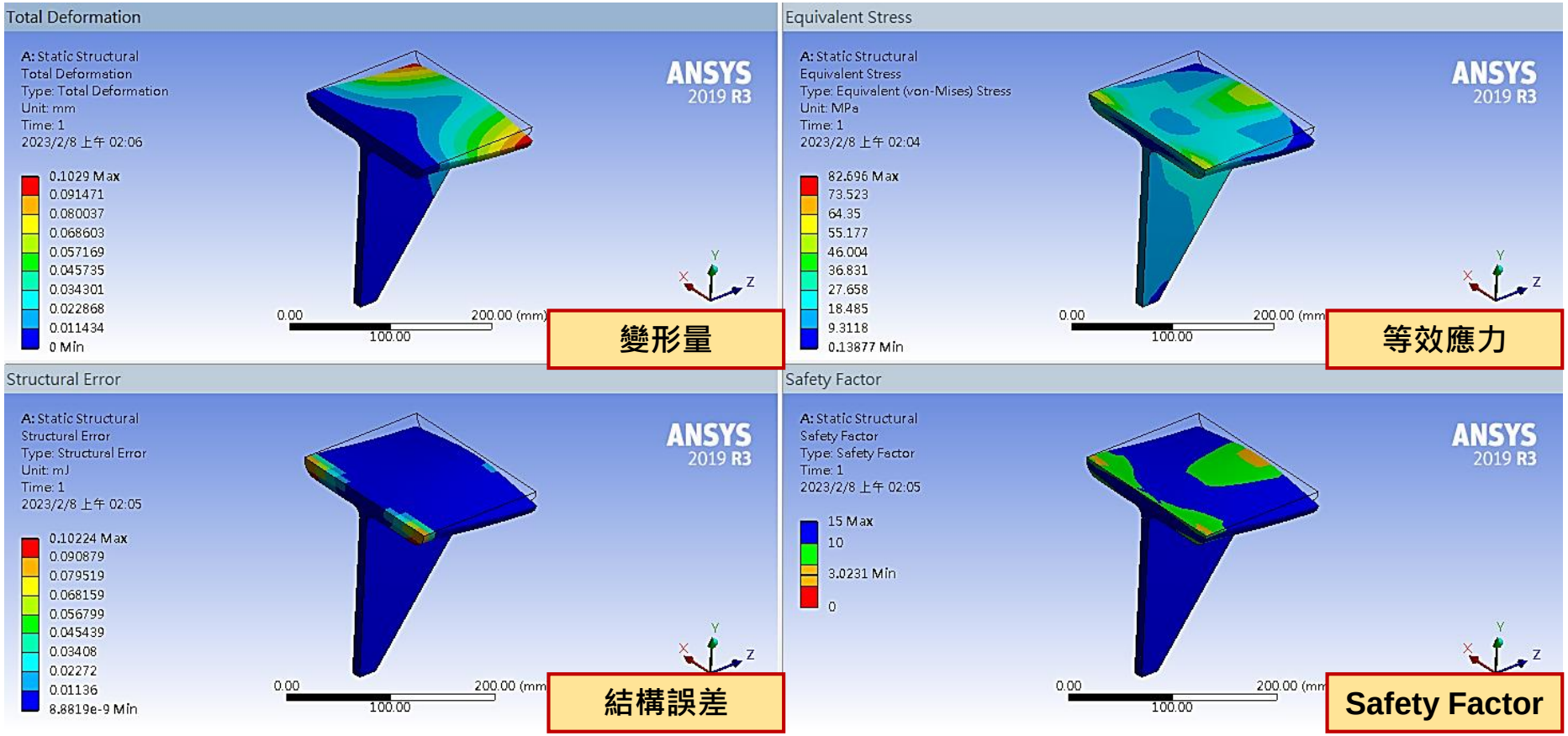



# 3D Solution – Ex.8

學習目標
- Blend
- Mesh-*MultiZone*
- 後處理顯示

**機翼模型，尺寸如下所示，使用MultiZone之網格方法將翼板頂面、腹板側面、接合處圓角面進行mesh設定，並將翼板與腹板接合處之圓角兩面設定element size為7的mesh。邊界條件如圖所示，板子後方之面固定，上方施予頂面一力。觀察其等效應力、位移量變化、結構誤差及Safety Factor。材料選用鋼。(單位：MM, N)**

## 多視窗顯示

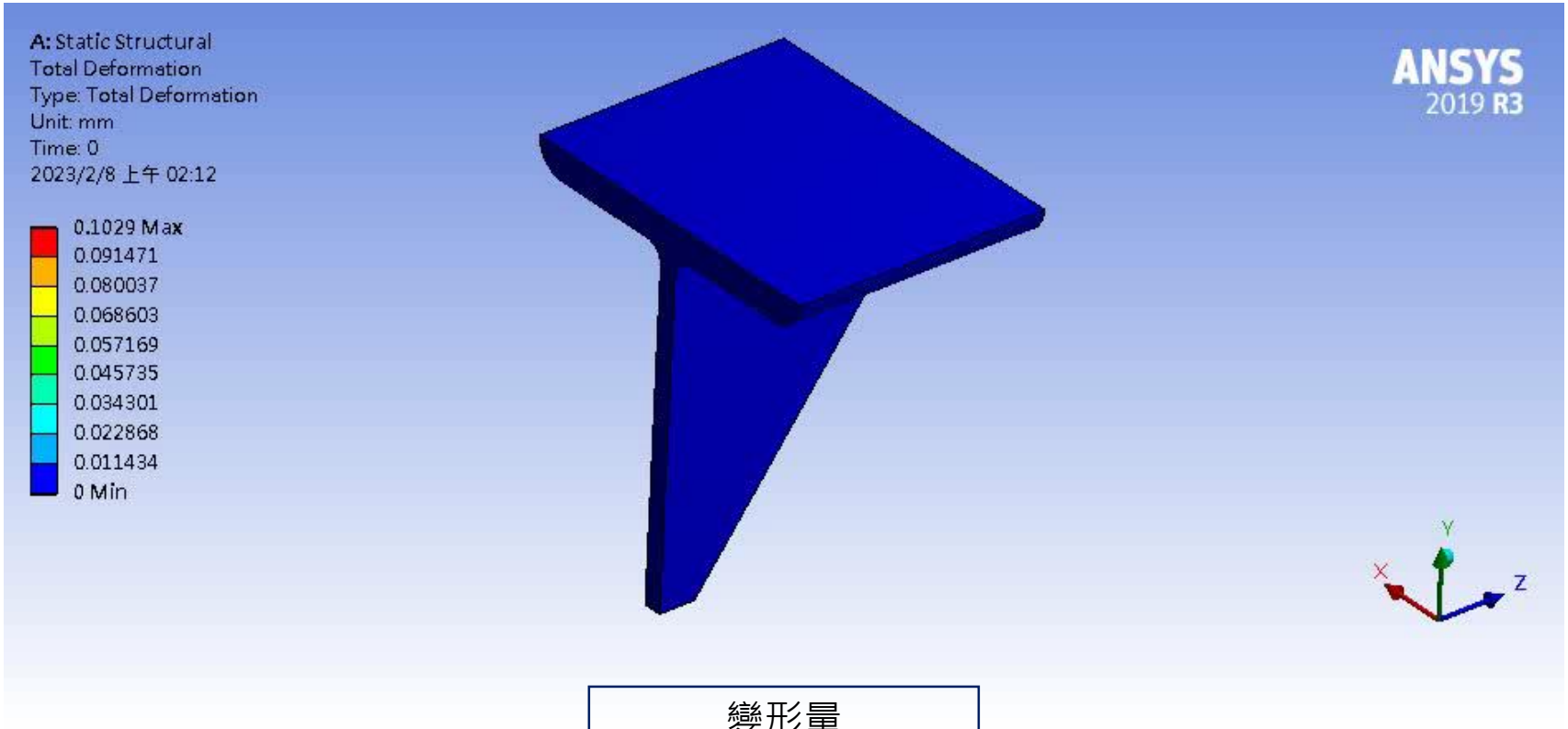


# 3D Solution – Ex.8

學習目標
- Blend
- Mesh-*MultiZone*
- 後處理顯示

**機翼模型，尺寸如下所示，使用MultiZone之網格方法將翼板頂面、腹板側面、接合處圓角面進行mesh設定，並將翼板與腹板接合處之圓角兩面設定element size為7的mesh。邊界條件如圖所示，板子後方之面固定，上方施予頂面一力。觀察其等效應力、位移量變化、結構誤差及Safety Factor。材料選用鋼。(單位：MM, N)**

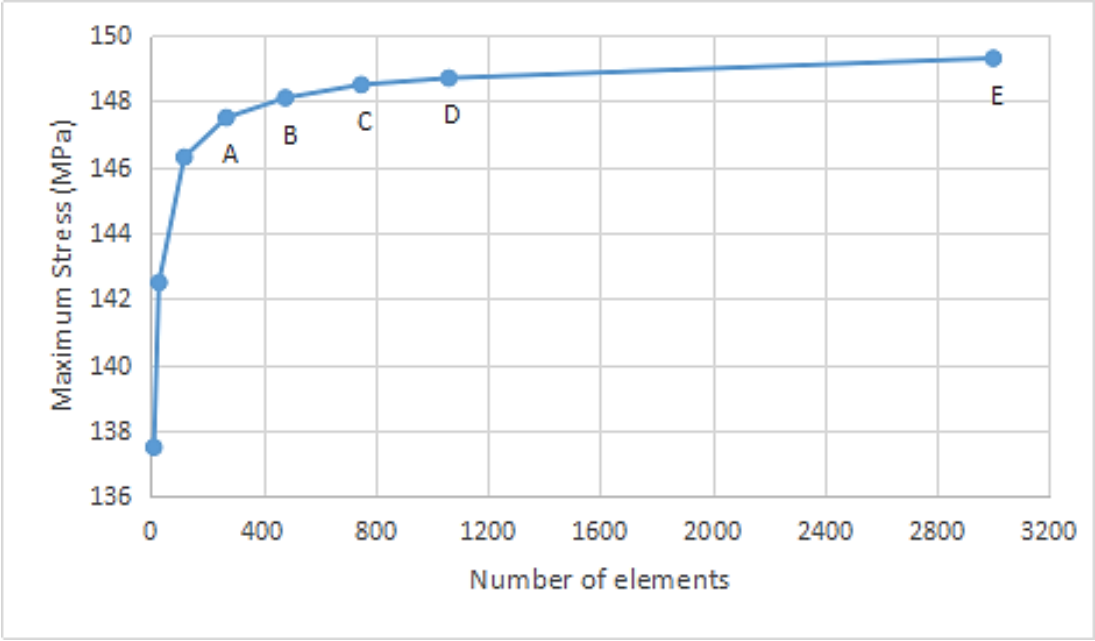
<u>動畫顯示</u>




變形量
Total Deformation

# Convergence

- 隨著網格密度增加(即元素增加、mesh尺寸減小)，有限元素分析所求出的解會趨近於一個定值，即為該題目的正確解(exact solution)，但隨著網格變得更精細，所消耗的運算資源也會增加
- 收斂性分析：當進一步細分網格後所求得的解變化很小時，即可認為網格已經收斂了
- 收斂物理量通常可為應力/位移/能量，誤差最好於5%內

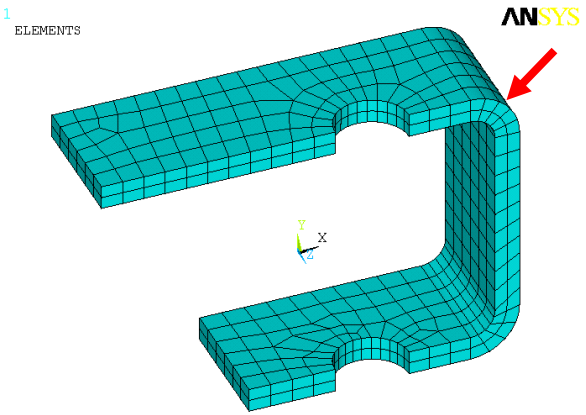




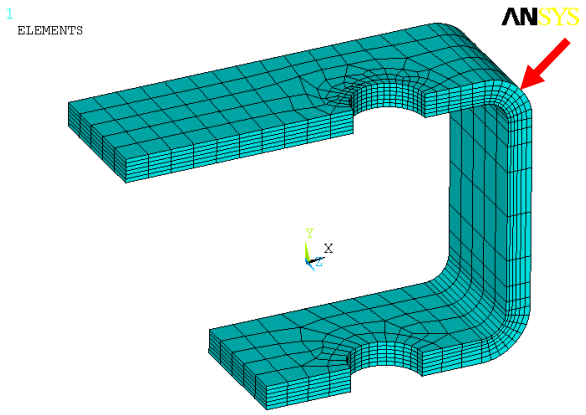

圖片來源https://caeuniversity.com/mesh-convergence-modern/

# Convergence

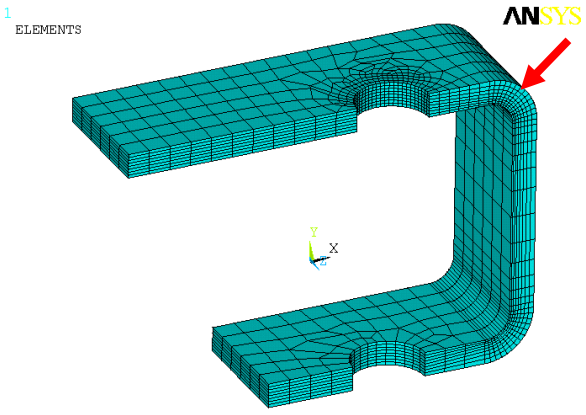
## 圓角處Mesh元素大小




5.00 mm



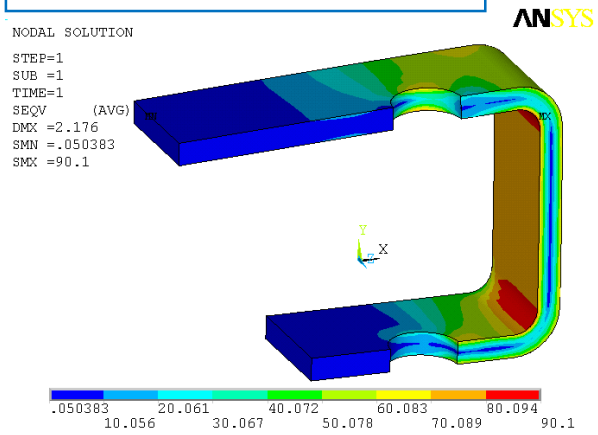

1.15 mm



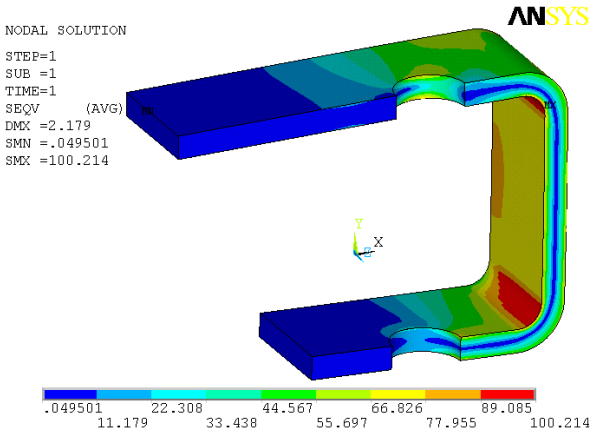

0.67 mm

模型收斂

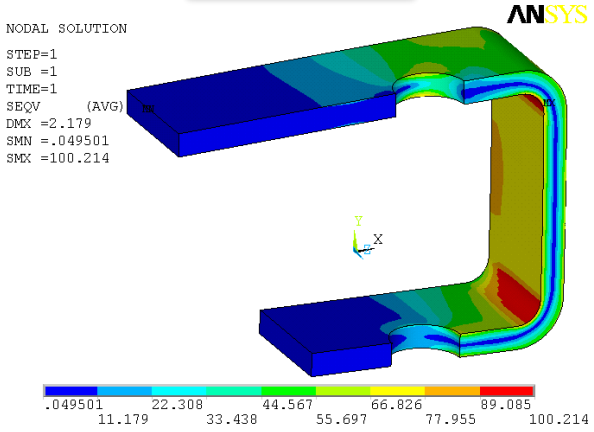
## 圓角處最大等效應力值




90.100 MPa




100.214 MPa



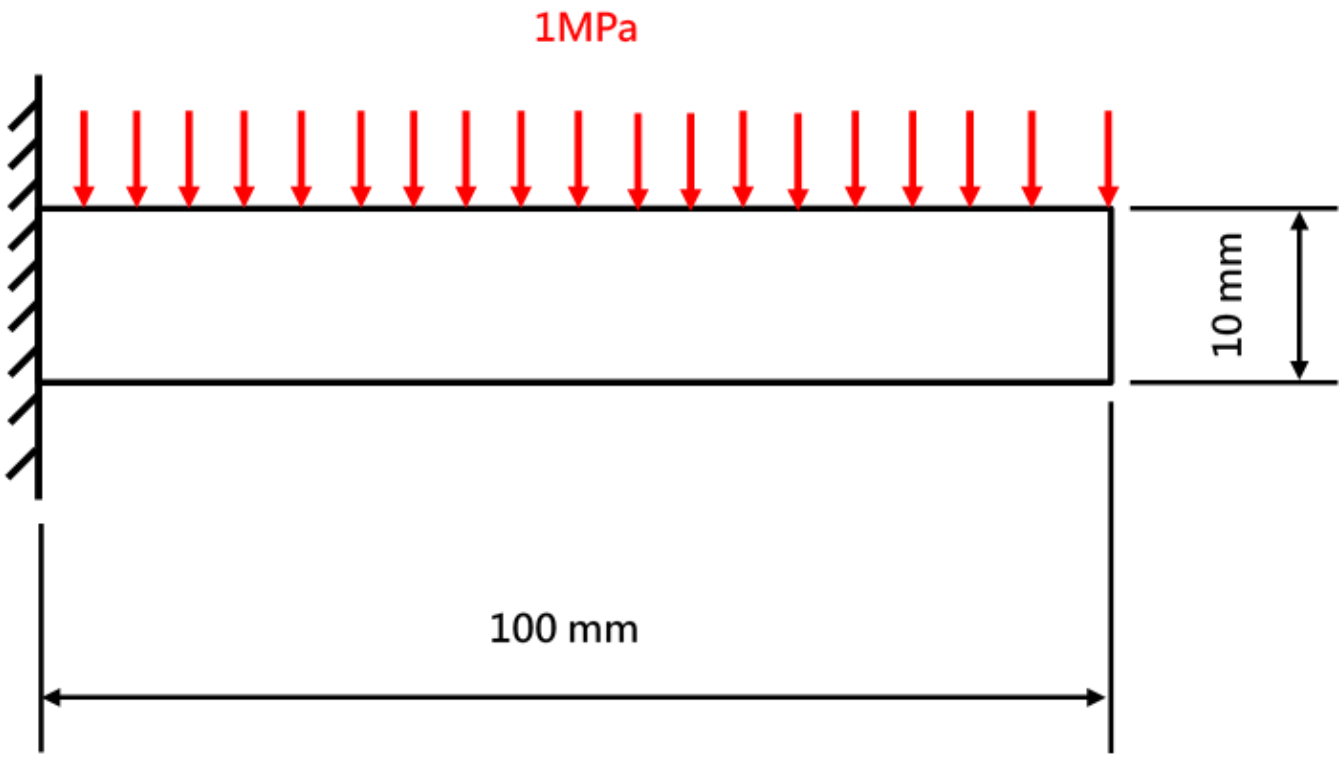

100.333 MPa

11.2%

0.12%

# Convergence – Ex.9 (來源：成功大學李輝煌教授)

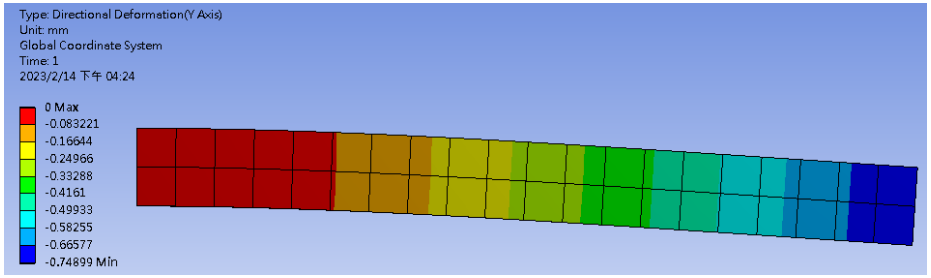
**一材料為鋼(steel)製成之懸臂樑，尺寸為100x10x10mm，上端平面施以1MPa均佈負載，請應用不同元素大小(element size)探討懸臂樑模型之收斂性(1)Hex mesh、(2)Tet mesh**

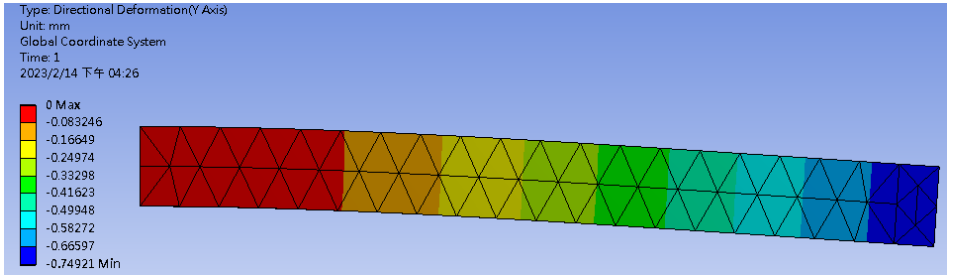


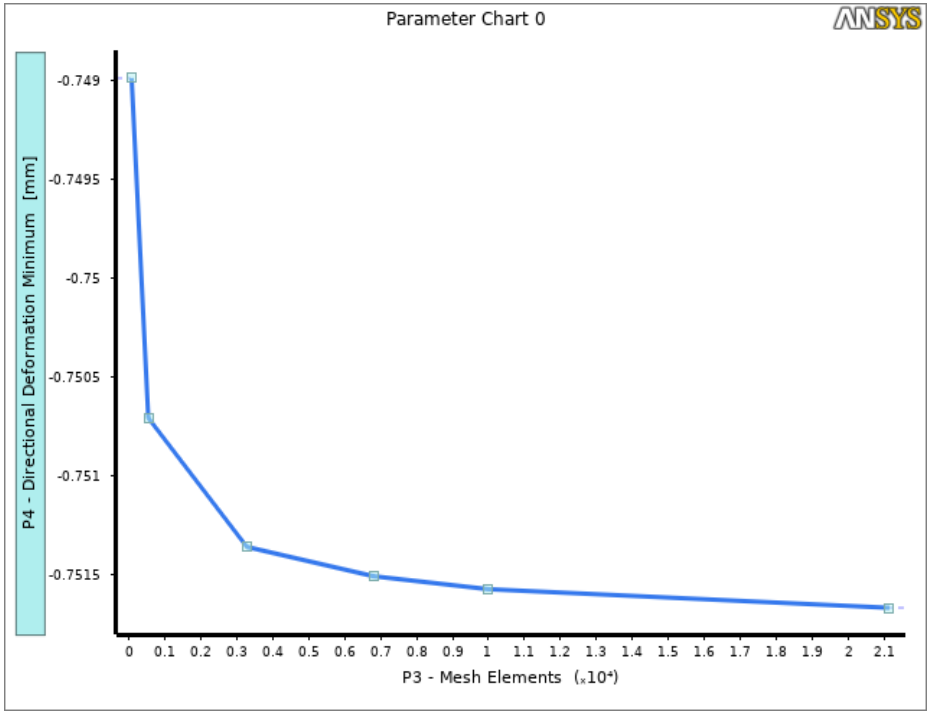
# Convergence – Ex.9

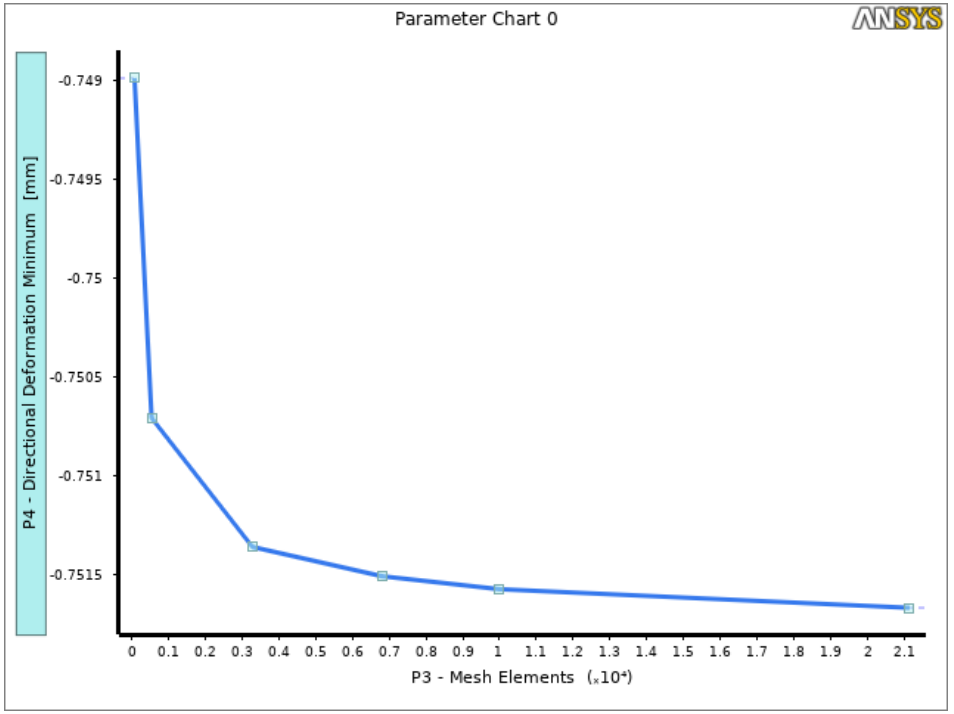
學習目標
• 收斂性分析

一材料為鋼(steel)製成之懸臂樑，尺寸為100x10x10mm，上端平面施以1MPa均佈負載，請應用不同元素大小(element size)探討懸臂樑模型之收斂性(1)Hex mesh、(2)Tet mesh




**Hex mesh**

**Tet mesh**