

예제로 쉽게 배우는 Ansys Mechanical

1. PCB Trace Pattern을 고려한 PCB Warpage 구조해석

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01 개요

해석개요

학습목표 :

- Ansys Mechanical을 이용한 3차원 구조해석
 - ✓ Ansys Meshing을 이용하여 PCB 모델의 격자 생성
 - ✓ 해석 조건 및 하중 설정 후 구조해석
 - ✓ Ansys Mechanical Post 기능을 사용하여 결과 확인

학습목적 :

- Ansys Mechanical을 이용하여 구조 해석의 전체적인 진행 과정 이해
 - ✓ External Data 시스템을 사용하여 PCB의 Trace pattern 정보를 불러와서 Mesh에 Mapping하는 방법 이해

모델 형상

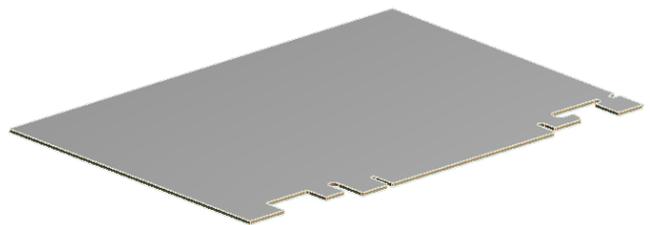
Reflow 공정 후 PCB의 Warpage 구조해석 :

- PKG, Solder, PCB로 구성된 모델
- FR4와 Cu Trace Pattern으로 구성된 7 Layer PCB 모델

■ Die
■ FR-4
■ Solder_Balls



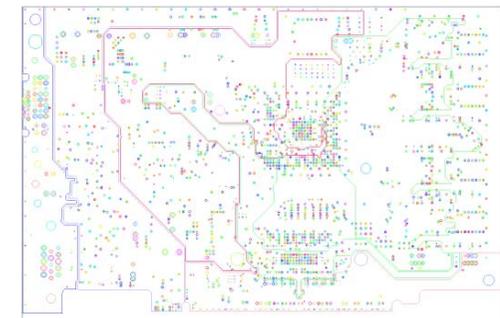
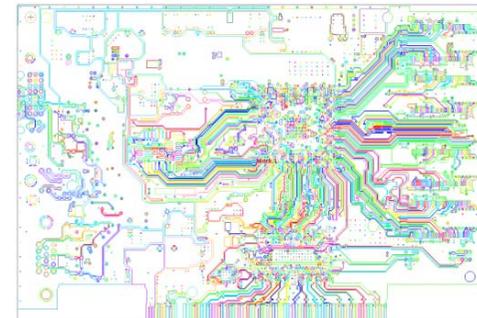
Y축 단면 형상



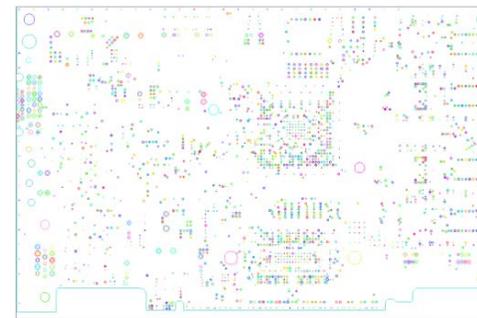
0.00 35.00 70.00 (mm)

PCB 형상

Top



Bottom



PCB 층별 Cu pattern 형상(Dielectric제외)

해석 조건

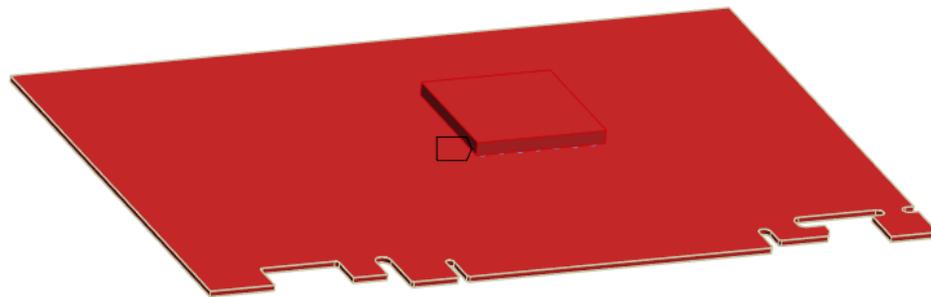
Reflow 공정 후 PCB의 Warpage 구조해석 :

- Reflow 공정의 온도는 150 °C로 초기 온도 조건 설정
- Reflow 공정 후 PCB는 상온 상태로 이때의 온도는 22°C로 설정
- PCB는 선반에 올려진 상태이므로 Free-Free 조건 적용

B: Static Structural
Thermal Condition
Time: 1. s

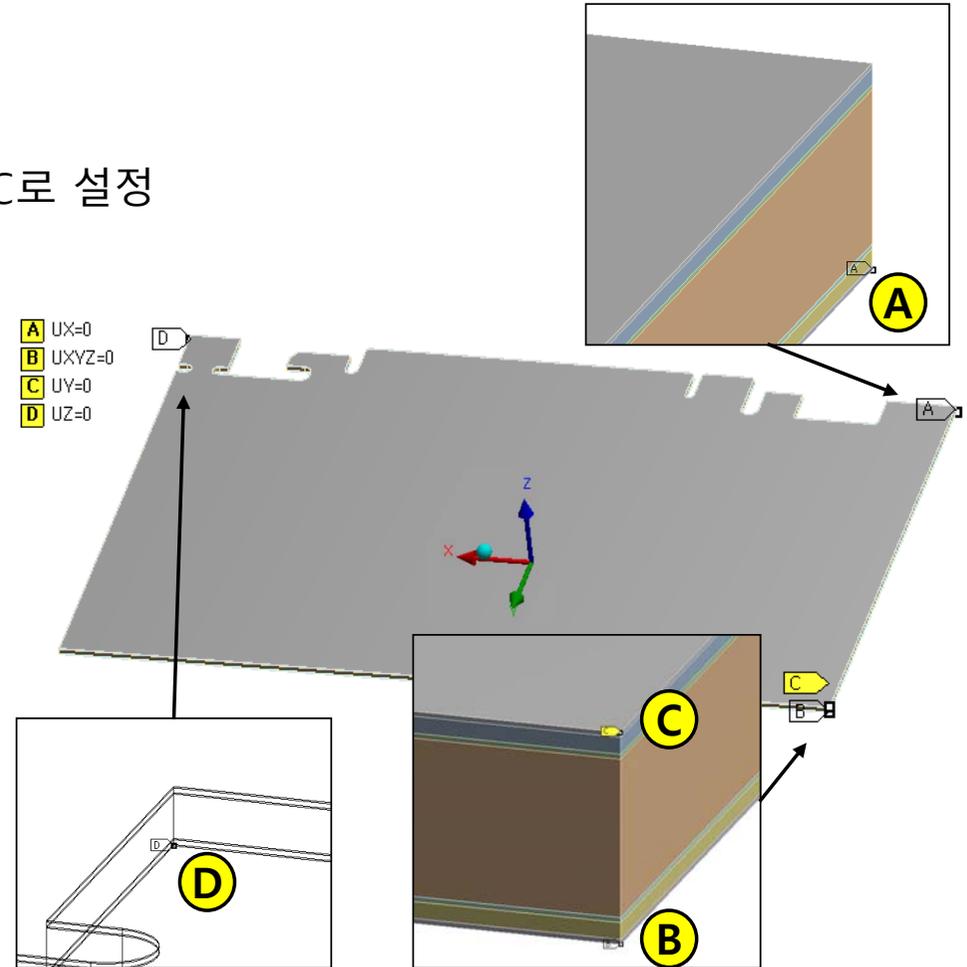
Thermal Condition: 22. °C

Tabular Data			
Steps	Time [s]	Temperature [°C]	
1	0.	= 150	
2	1.	22.	
*			



온도조건

- A UX=0
- B UXYZ=0
- C UY=0
- D UZ=0



Free-Free조건

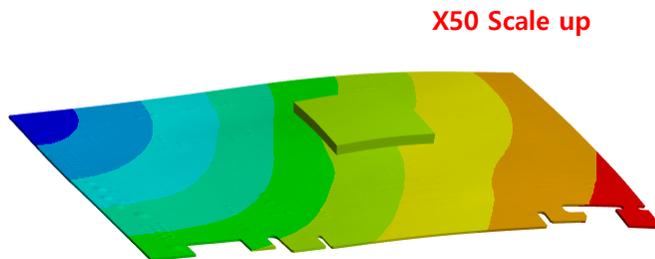
해석 결과

Reflow 공정 후 PCB의 Warpage 구조해석 후 결과 확인

- PCB의 변형량 결과를 통한 Warpage 변형량 확인
- 각 PCB Layer별 응력결과 확인

B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s

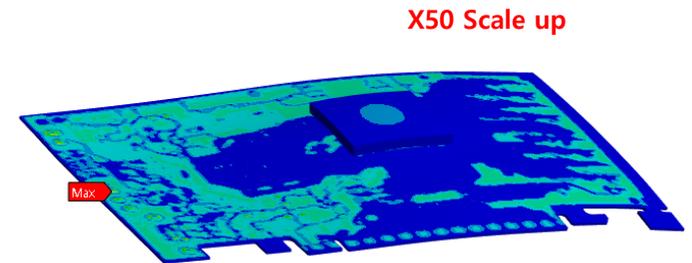
0.36275 Max
0.32244
0.28214
0.24183
0.20153
0.16122
0.12092
0.08061
0.040305
0 Min



변형량(mm)

B: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress (Average Across Bodies)
Unit: MPa
Time: 1 s

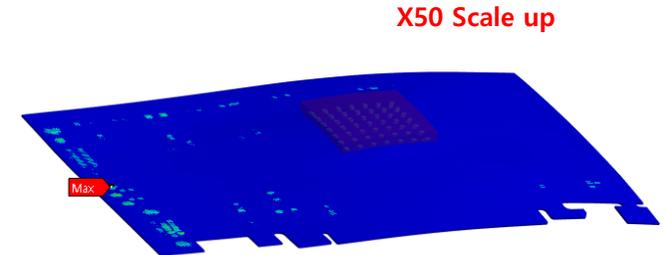
219.35 Max
194.98
170.61
146.23
121.86
97.49
73.118
48.746
24.373
0.0011406 Min



Equivalent Stress of all Bodies(MPa)

B: Static Structural
Equivalent Stress 5
Type: Equivalent (von-Mises) Stress (Average Across Bodies)
Unit: MPa
Time: 1 s

219.35 Max
194.98
170.61
146.23
121.86
97.49
73.118
48.746
24.373
0.0011406 Min



Equivalent Stress of Dielectric_2(MPa)

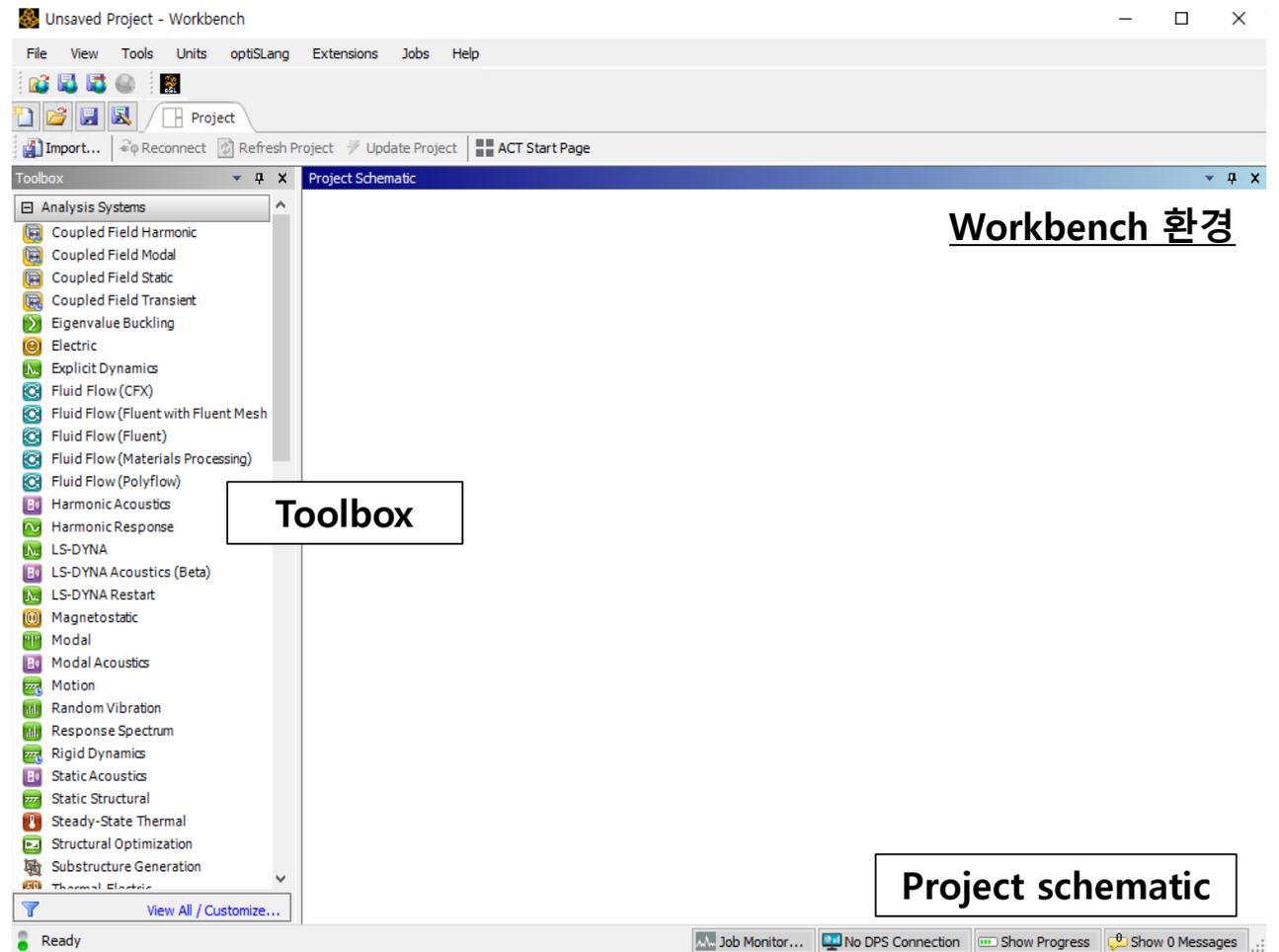
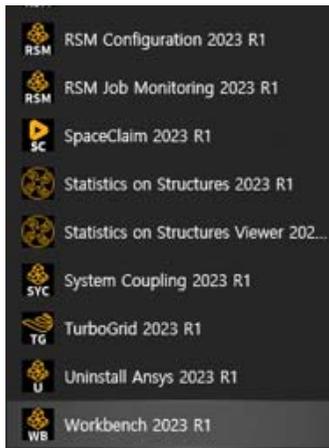


구조해석

02-1 전처리

Running Ansys WB

1. Ansys Workbench 실행



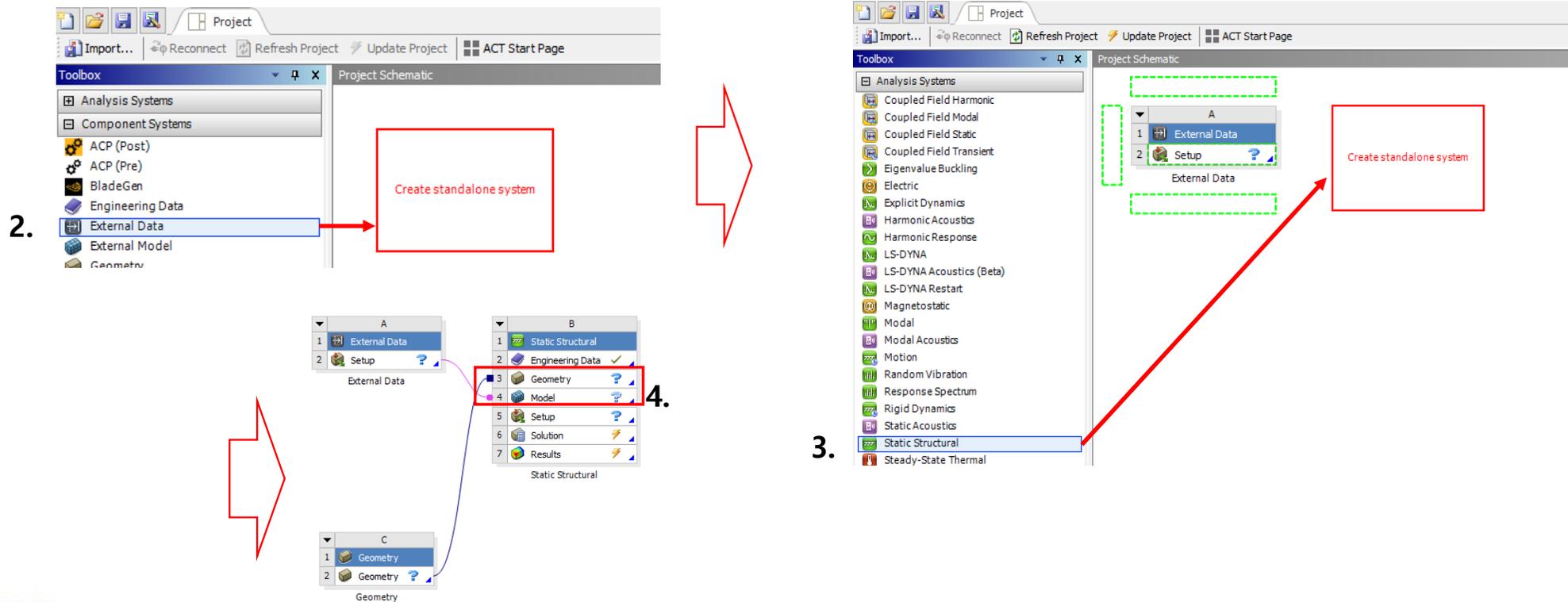
Workbench 환경

Toolbox

Project schematic

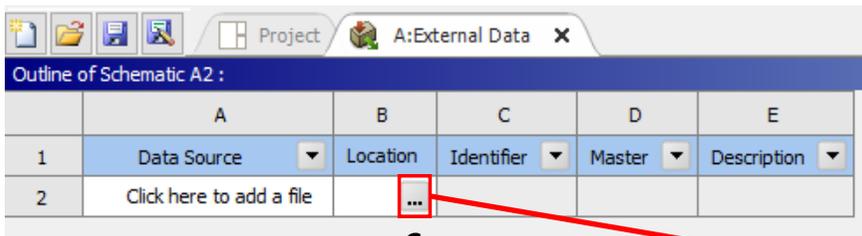
Start Ansys WB

2. Toolbox에서 External Data를 double click하거나 drag & drop으로 System 생성
3. 동일한 방법으로 Static Structural System과 Geometry System을 생성
4. External Data System의 Setup cell을 Static Structural System의 Model에 연결, Geometry System의 Geometry cell을 Static Structural System의 Geometry에 연결



Trace Pattern 정보 입력

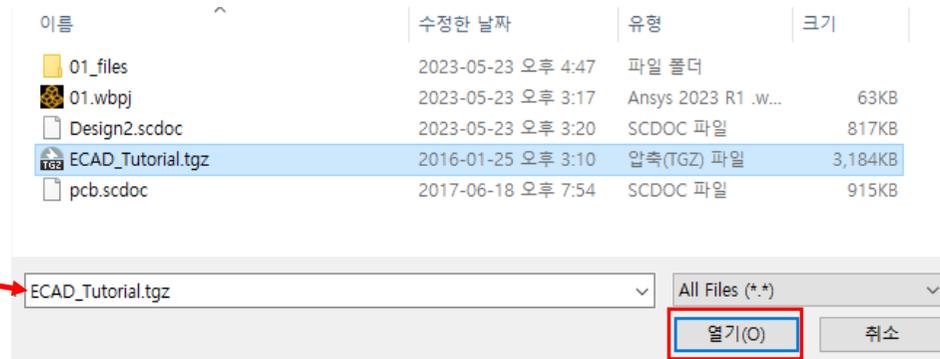
- External Data의 setup cell을 Double click 또는 마우스 우측버튼(RMB) -> Edit... 를 click하여 External Data 환경으로 이동
- B행의 Location아래 ...을 클릭하고 Browse...를 click하여 Trace Pattern 정보가 들어가 있는 ECAD_Tutorial.tgz 파일을 불러오기



6.

평행 이동 및 회전

	A	B	C
1	Property	Value	Unit
2	Definition		
3	Format Type	ODB++ TGZ	
4	Rigid Transformation		
5	Origin X	0	m
6	Origin Y	0	m
7	Origin Z	0	m
8	Theta XY	0	radian
9	Theta YZ	0	radian
10	Theta ZX	0	radian

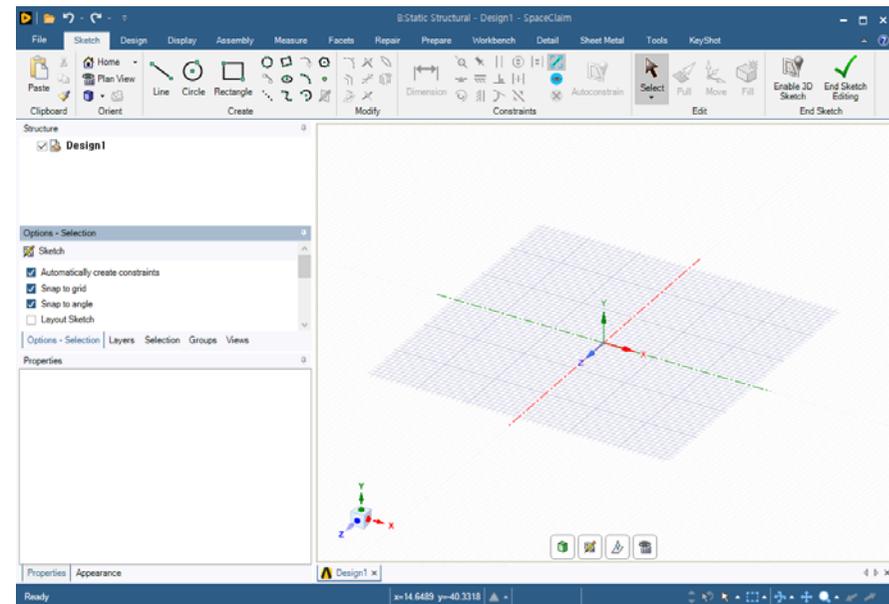
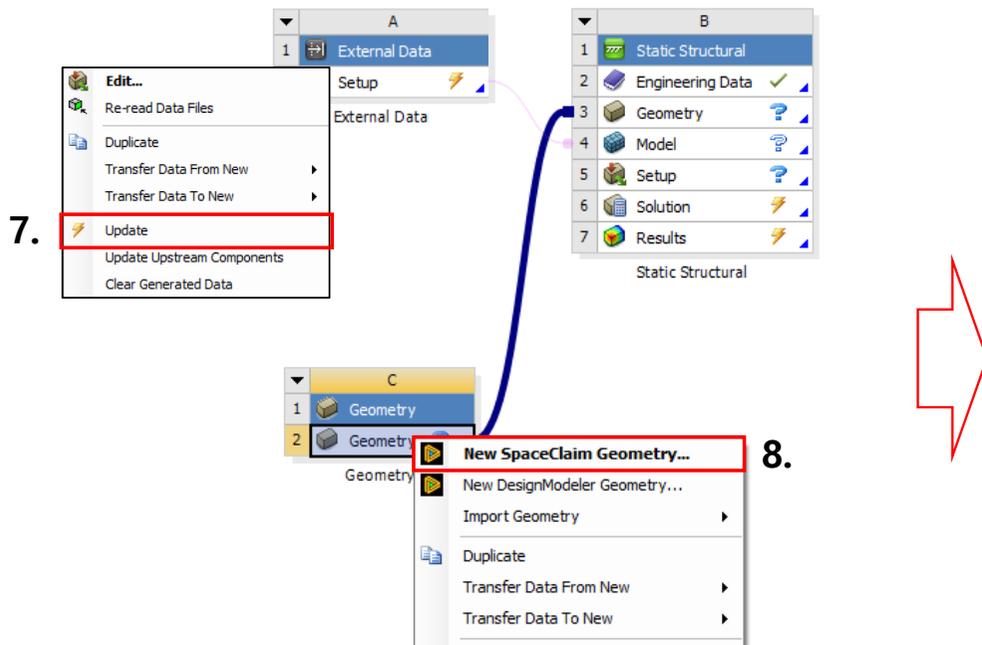


지원되는 파일 형식

- ANSOFT ANF Files (*.anf)
- Cadence BRD Files (*.brd)
- Cadence MCM Files (*.mcm)
- Cadence SIP Files (*.sip)
- ODB++ TGZ Files (*.tgz)
- Icepak BOOL Files (*.bool)
- Icepak COND Files (*.cond)

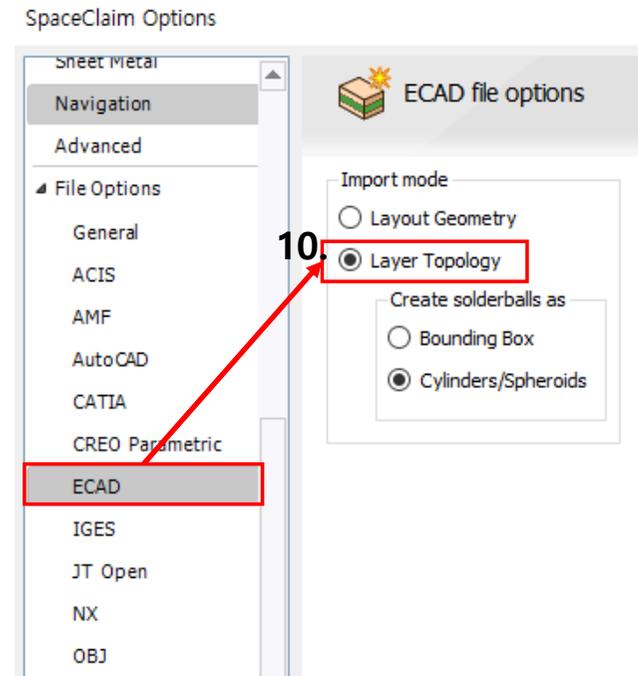
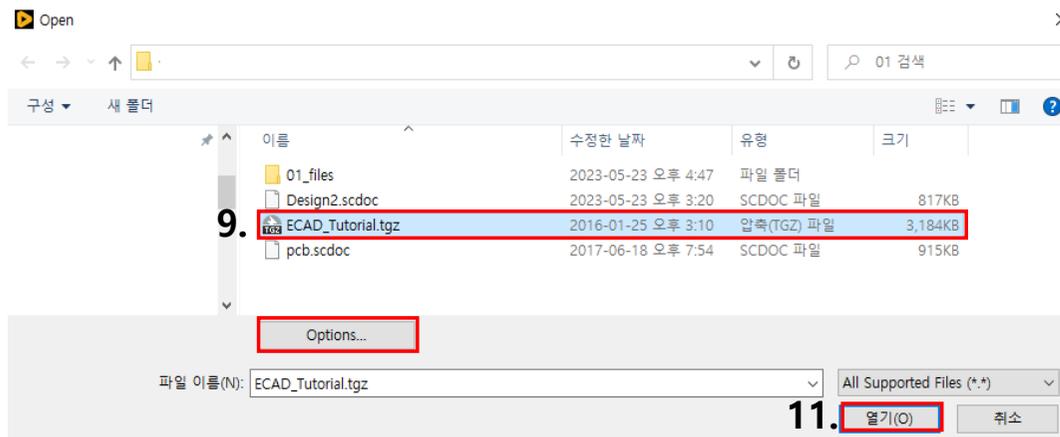
Importing PCB Model

7. External Data의 setup cell을 마우스 우측버튼(RMB) – update click하여 Trace Pattern 정보 전달
8. Geometry System의 Geometry cell을 마우스 우측버튼(RMB) –> New SpaceClaim geometry... click하여 Space Claim Direct Modeler 실행



Importing PCB Model

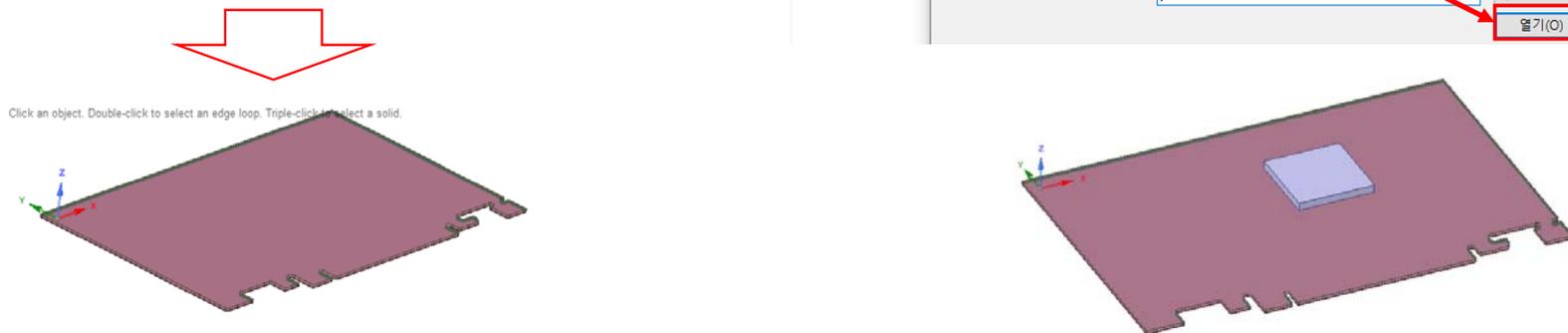
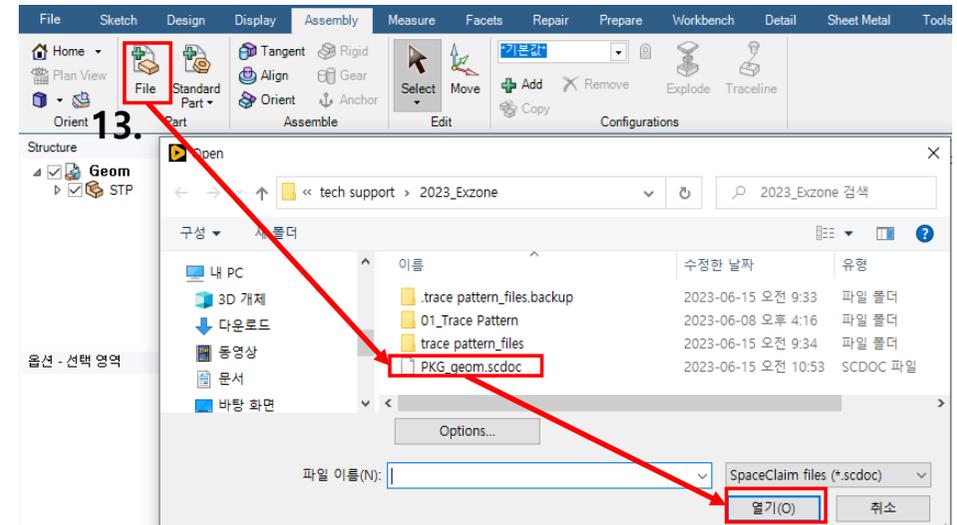
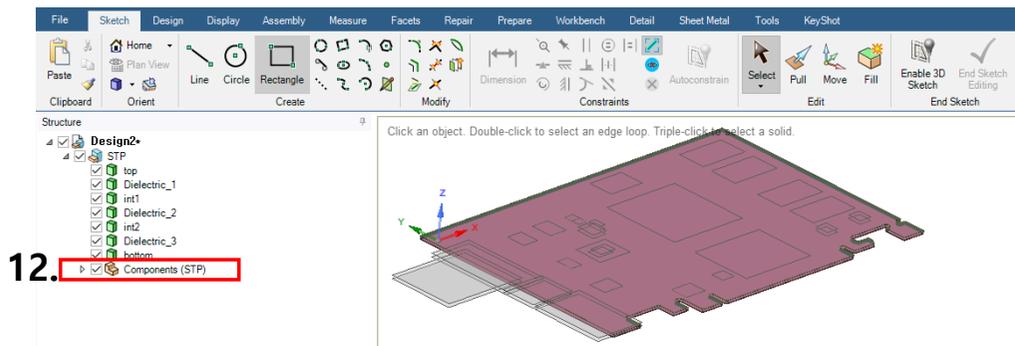
9. Menu bar에서 File -> Open -> ECAD_Tutorial.tgz파일 선택(아직 열기 누르지 마세요!!!)
10. Options... click 후 팝업창이 활성화 되면, File Options -> ECAD -> Layer Topology 선택 후 OK click
11. 열기 click



열기 버튼은 꼭 10.이후에 click

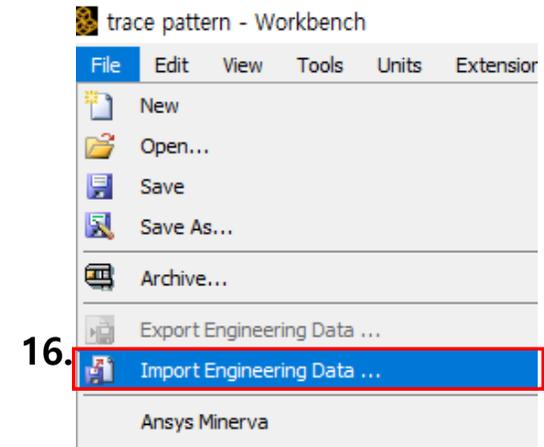
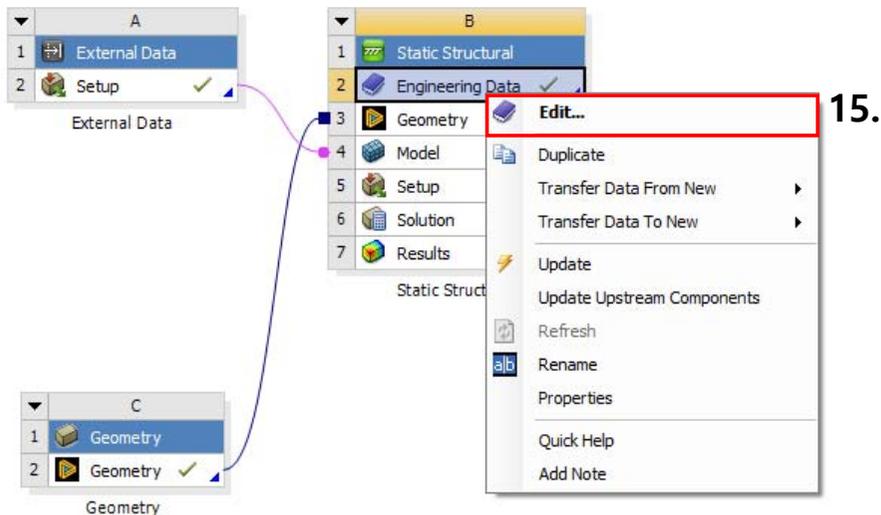
Importing PCB Model

12. Importing된 형상 중 불필요한 부분들 Structure Tree에서 Components (STP) 선택하여 Delete 버튼으로 삭제
13. Assembly tab -> Part -> File 선택하여 PKG_geom.scdoc파일 불러오기
14. 최종 형상 확인



물성 추가(FR-4, Copper Alloy)

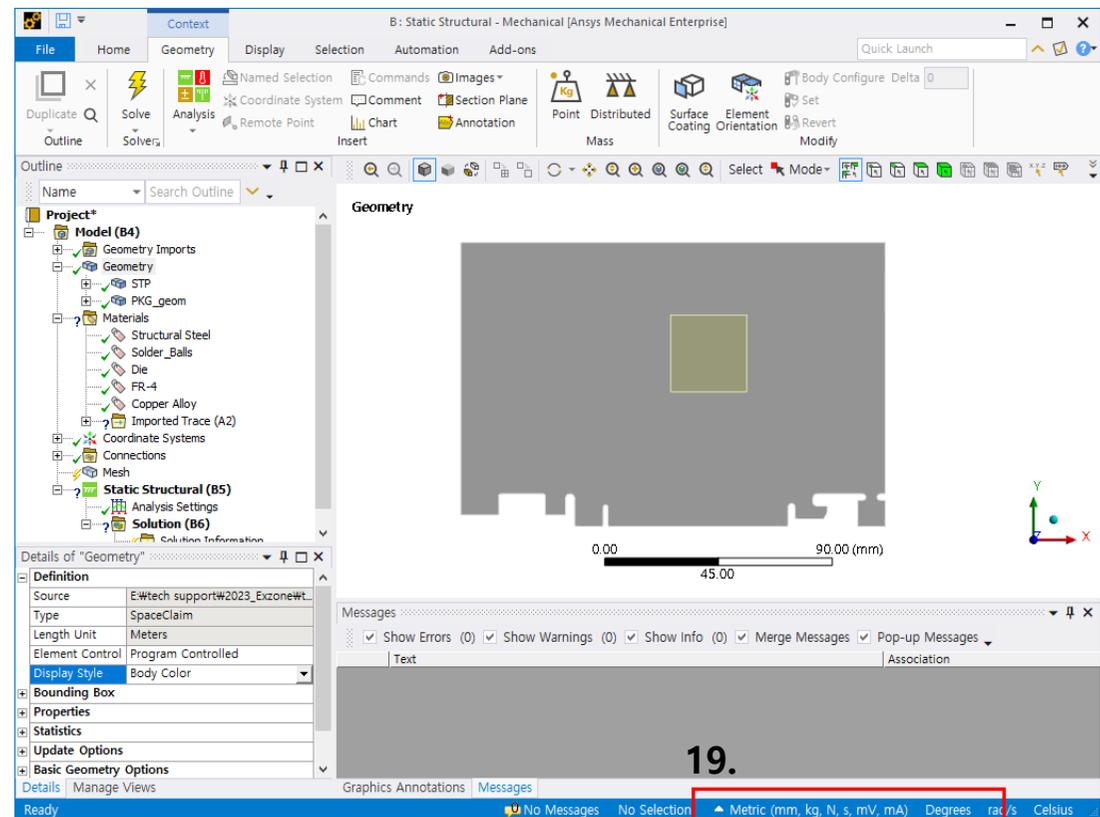
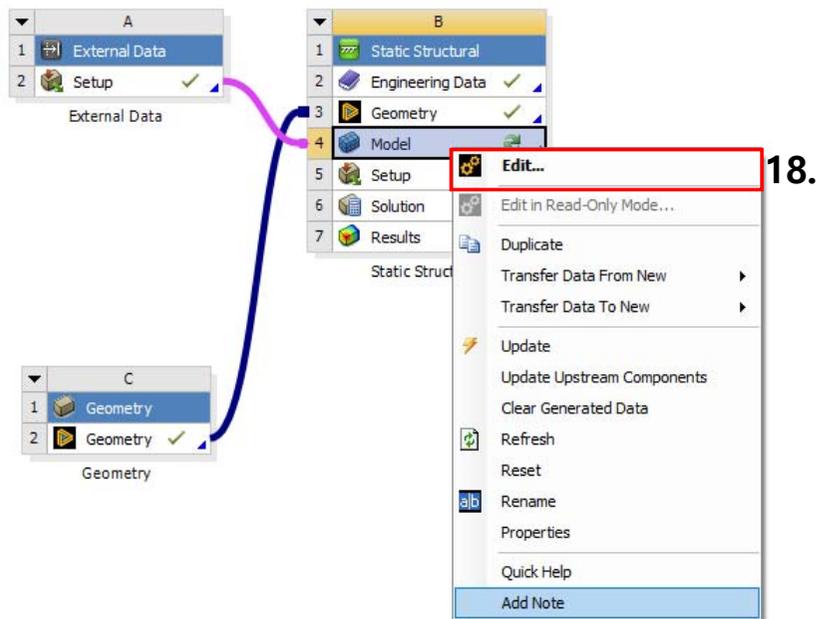
15. Static Structural System의 Engineering Data cell을 double click 또는 마우스 우측버튼(RMB) -> Edit... click하여 재질 물성 정의 환경으로 이동
16. Menu -> File -> Import Engineering Data... 선택하여 PCB_PKG_material.xml 파일 불러오기
17. Project를 click하여 WB환경으로 돌아옴



Outline of Schematic B2: Engineering Data				
	A	B	C	D
1	Contents of Engineering Data			Source
2	Material			
3	Copper Alloy			E:\Wtech support\W2023_Exzone\W01_Trace Pattern\W01\WPCB_PKG_material.xml
4	Die			E:\Wtech support\W2023_Exzone\W01_Trace Pattern\W01\WPCB_PKG_material.xml
5	FR-4			E:\Wtech support\W2023_Exzone\W01_Trace Pattern\W01\WPCB_PKG_material.xml
6	Solder_Balls			E:\Wtech support\W2023_Exzone\W01_Trace Pattern\W01\WPCB_PKG_material.xml
7	Structural Steel			General_Materials.xml

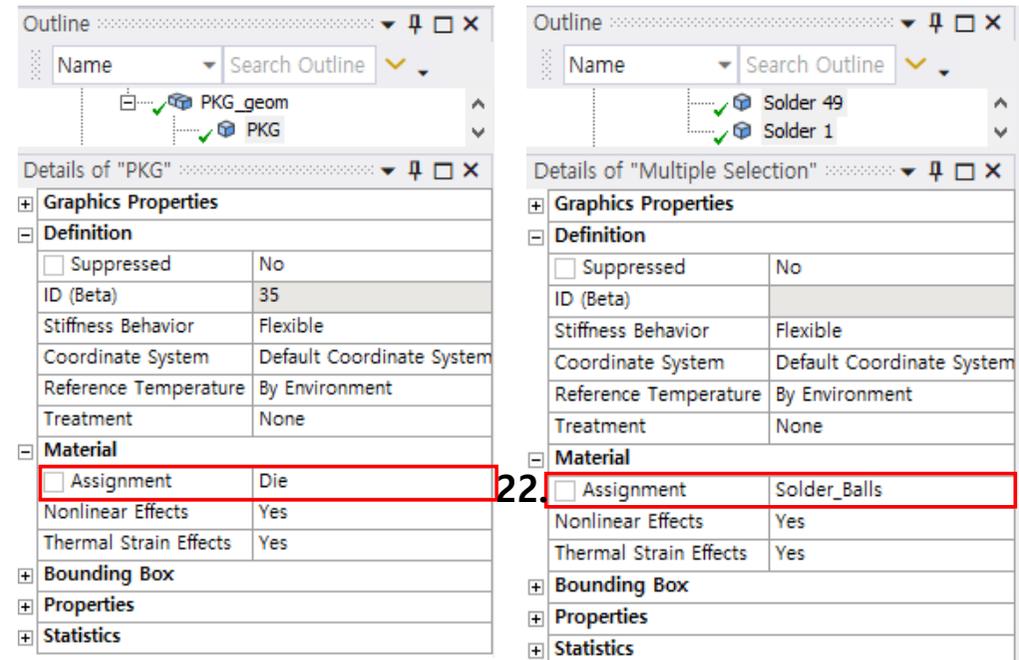
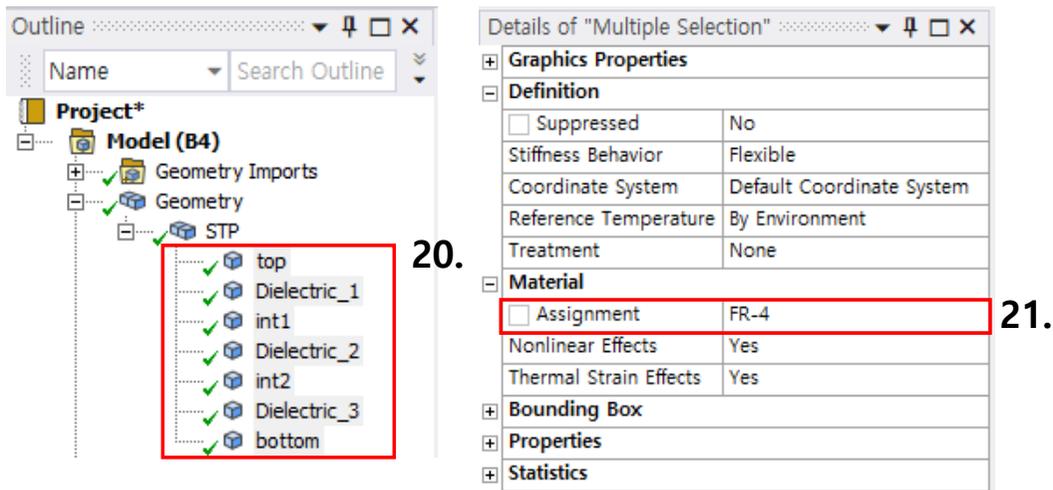
Mechanical 창 실행

18. Project Schematic창에서 Static Structural의 Model을 double click 또는 마우스 우클릭(RMB) -> Edit... click후 Mechanical 환경으로 이동
19. Outline 확인 및 단위계 설정 Metric(mm, kg, N, s, mV, mA)로 설정



PCB 물성 적용 및 Trace 형상 Import

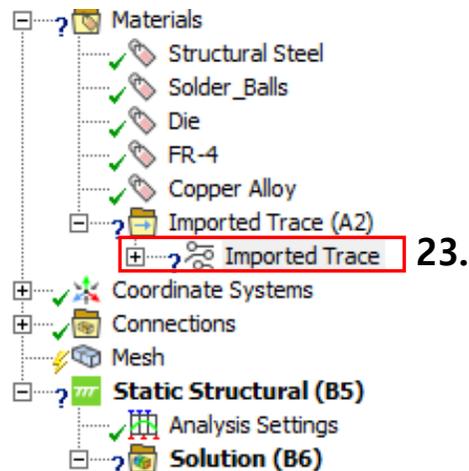
20. Outline의 Geometry -> STP의 모든 Body를 선택(7 Bodies)
21. Details of "Multiple Selection" -> Material -> Assignment에서 재질을 "FR-4"로 설정
22. 동일한 방법으로 PKG -> "die", Solder -> "Solder_Balls"로 설정



PCB 물성 적용 및 Trace 형상 Import

23. Outline의 Materials -> Imported Trace -> Imported Trace에서 아래와 같이 Details of "Imported Trace" 정보 입력

- Scope -> Geometry : STP의 모든 Body 선택(7 Bodies)
- Definition -> External Data Identifier : File 1



Details of "Imported Trace"	
Scope	
Scoping Method	Geometry Selection
Geometry	7 Bodies
Definition	
Type	Imported Trace
Suppressed	No
External Data Identifier	File1
Graphics Controls	
Component	Average
Display Source Points	Off
Settings	
Rigid Transformation	
Legend Controls	
Named Selection Creation	
Material	
Modeling	Averaged
Discretization	
<input type="checkbox"/> X-Discretization	200
<input type="checkbox"/> Y-Discretization	200
Beta Options (Beta)	

Trace 및 Plating 물성 적용

24. Details of "Imported Trace"에서 External Data Identifier : File 1을 선택하면, Data view에 각 층별 Layer, Thickness정보가 자동 입력되고, Trace material 정보는 "Copper Alloy"로 설정

25. 추가로 Worksheet의 Plating Material도 "Copper Alloy"로 설정

-> 3P까지 총 66개 설정 필요(한 개를 Copper Alloy로 변경 후 Ctrl + C -> 1P 모두 선택 후 Ctrl + V)

Data View

Imported Trace

	Layer	Thickness (mm)	Trace Material	Active
1	top	0.03556		<input checked="" type="checkbox"/>
2	Dielectric_1	0.11938		<input checked="" type="checkbox"/>
3	int1	0.03556		<input checked="" type="checkbox"/>
4	Dielectric_2	1.1176		<input checked="" type="checkbox"/>
5	int2	0.03556		<input checked="" type="checkbox"/>
6	Dielectric_3	0.11938		<input checked="" type="checkbox"/>
7	bottom	0.03556		<input checked="" type="checkbox"/>

Worksheet

Imported Trace : Vias

	Name	Diameter (mm)	Plating Thickness (mm)	Filled	Plating Material	Fill Material	Start	End
1	100C118NP	3.	0.	<input checked="" type="checkbox"/>			bottom	top
2	114X160_94P	2.39	0.	<input checked="" type="checkbox"/>			bottom	top
3	120C76P	1.93	0.	<input checked="" type="checkbox"/>			bottom	top
4	150C94P	2.39	0.	<input checked="" type="checkbox"/>			bottom	top
5	165C125P	3.18	0.	<input checked="" type="checkbox"/>			bottom	top
6	42C26P	0.66	0.	<input checked="" type="checkbox"/>			bottom	top
7	42C26P_1	0.66	0.	<input checked="" type="checkbox"/>			bottom	top
8	42C26P_2	0.66	0.	<input checked="" type="checkbox"/>			bottom	top
9	45C28P_MOD	0.711	0.	<input checked="" type="checkbox"/>			bottom	top
10	45C28P_MOD_1	0.711	0.	<input checked="" type="checkbox"/>			bottom	top
11	50C26P_THERM_ORTH	0.66	0.	<input checked="" type="checkbox"/>			bottom	top
12	50C26P_THERM_ORTH_1	0.66	0.	<input checked="" type="checkbox"/>			bottom	top
13	50C31P	0.787	0.	<input checked="" type="checkbox"/>			bottom	top

Data View

Imported Trace

24.

	Layer	Thickness (mm)	Trace Material	Active
1	top	0.03556	Copper Alloy	<input checked="" type="checkbox"/>
2	Dielectric_1	0.11938	Copper Alloy	<input checked="" type="checkbox"/>
3	int1	0.03556	Copper Alloy	<input checked="" type="checkbox"/>
4	Dielectric_2	1.1176	Copper Alloy	<input checked="" type="checkbox"/>
5	int2	0.03556	Copper Alloy	<input checked="" type="checkbox"/>
6	Dielectric_3	0.11938	Copper Alloy	<input checked="" type="checkbox"/>
7	bottom	0.03556	Copper Alloy	<input checked="" type="checkbox"/>

Worksheet

Imported Trace : Vias

25.

	Name	Diameter (mm)	Plating Thickness (mm)	Filled	Plating Material	Fill Material	Start	End
1	100C118NP	3.	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
2	114X160_94P	2.39	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
3	120C76P	1.93	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
4	150C94P	2.39	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
5	165C125P	3.18	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
6	42C26P	0.66	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
7	42C26P_1	0.66	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
8	42C26P_2	0.66	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
9	45C28P_MOD	0.711	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
10	45C28P_MOD_1	0.711	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
11	50C26P_THERM_ORTH	0.66	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
12	50C26P_THERM_ORTH_1	0.66	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top
13	50C31P	0.787	0.	<input checked="" type="checkbox"/>	Copper Alloy		bottom	top

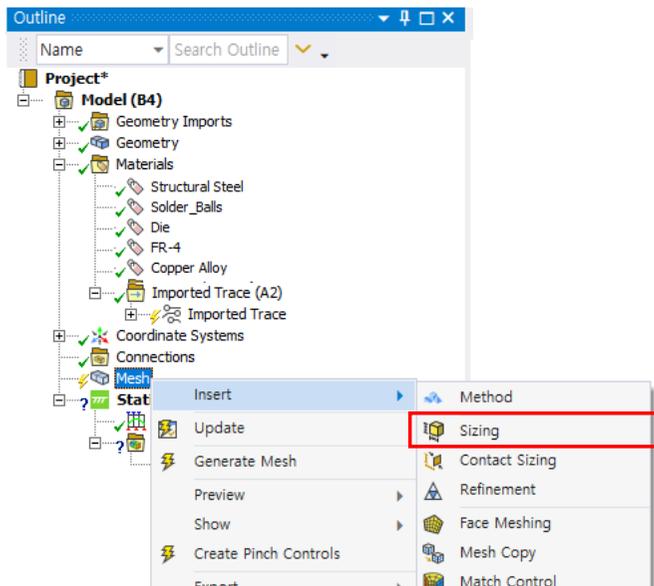
격자 생성

26. Outline의 Mesh 마우스 우클릭(RMB) -> Insert -> Sizing 선택

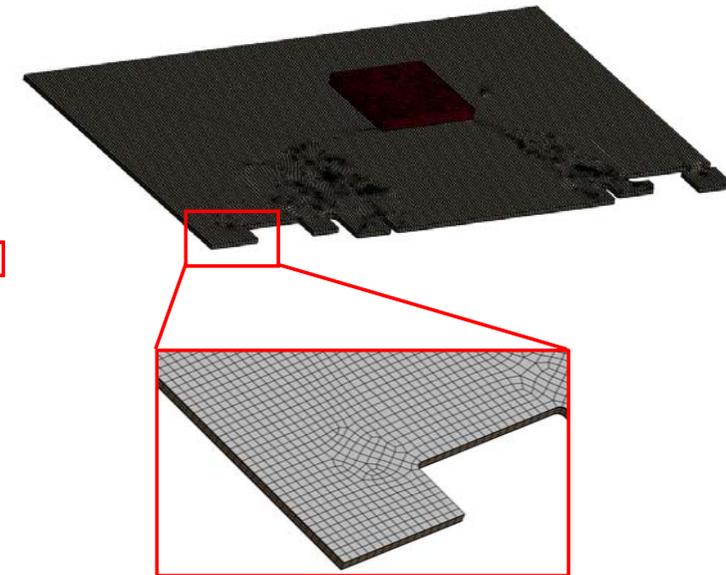
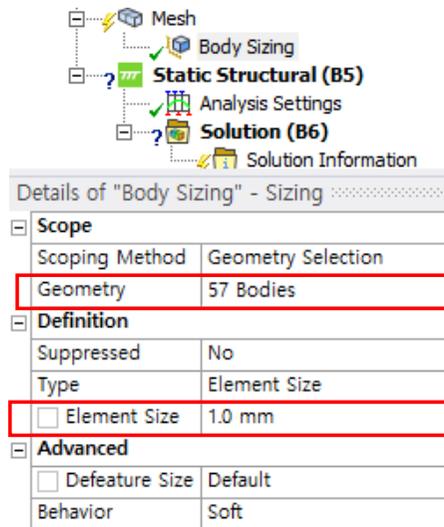
27. Details of "Sizing"에서 아래와 같이 설정 후 마우스 우클릭(RMB)후 Generate Mesh 선택

- Scope -> Geometry : 모든 Body 선택

- Definition -> Element Size : 1mm 입력(단위계 확인 필)



27.

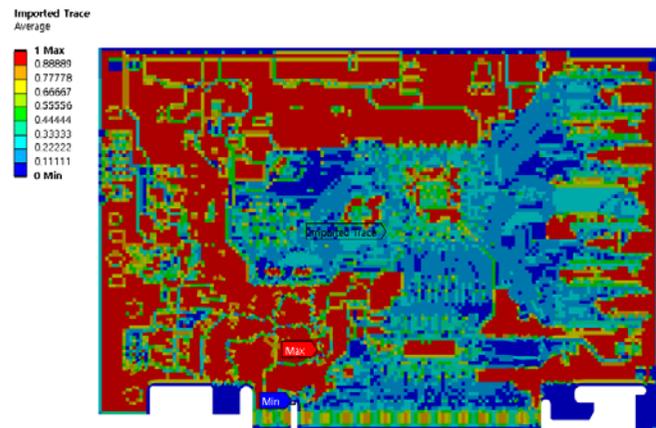
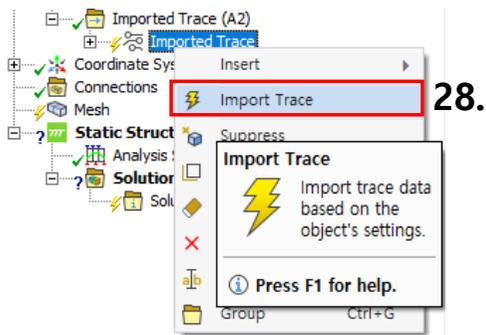


Mapping된 Trace 결과 확인

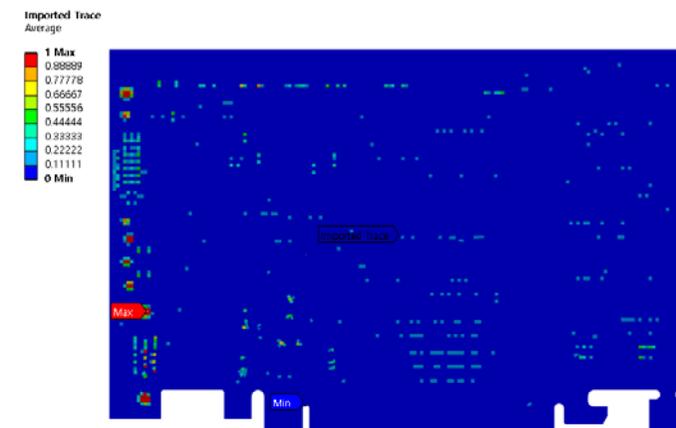
28. Imported Trace에서 마우스 우클릭(RMB) -> Import Trace를 click하여 Mapping된 Trace 결과 확인

붉은색(1) : Trace Material만 분포

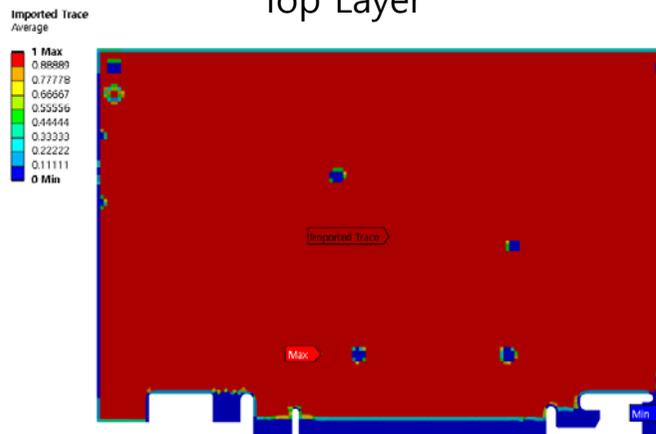
파란색(0) : 기저 Material만 분포



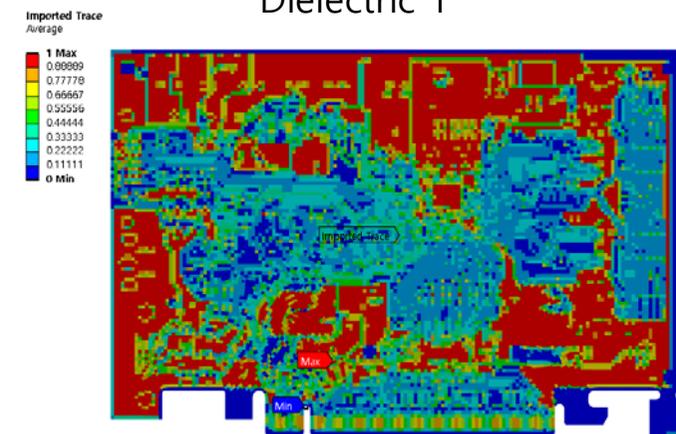
Top Layer



Dielectric 1



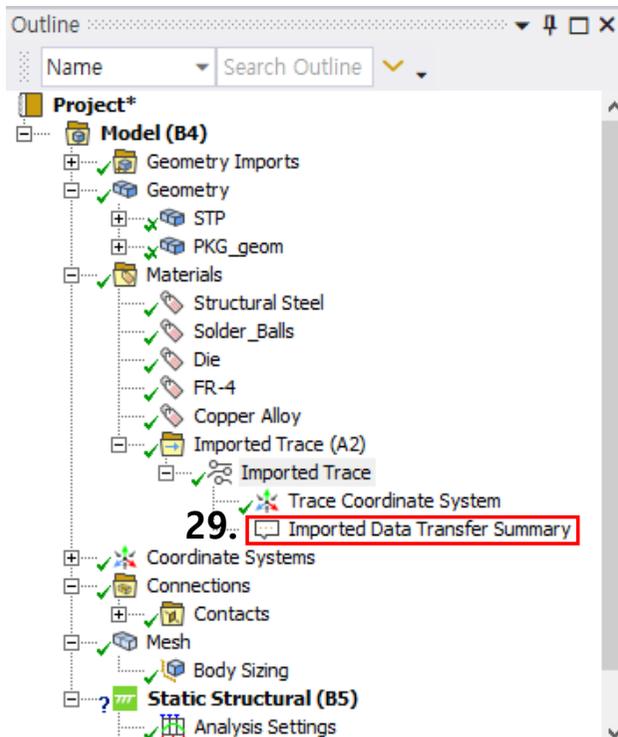
Int1



Bottom Layer

Mapping된 Trace 결과 Summary

29. Outline -> Import Trace -> Imported Data Transfer Summary에서 최종 Imported Trace 정보 확인 가능



Number of source elements: 288463
 Number of target elements: 149104

Number of elements mapped : 149104
 Number of elements not mapped : 0
 Number of elements outside : 0

Percent nodes mapped: 100%
 Weight calculation time: 1.714 (s)
 Number of variables to interpolate: 5.
 Interpolation time: 0.782 (s)

Results:

Average Metal Fraction:

Row	Source		
	X	Y	Z
1	0.5004695	0.5004695	0.5004695
2	1.311789e-002	1.311789e-002	1.311789e-002
3	0.8073331	0.8073331	0.8073331
4	1.311789e-002	1.311789e-002	1.311789e-002
5	0.8467903	0.8467903	0.8467903
6	1.311789e-002	1.311789e-002	1.311789e-002
7	0.4734688	0.4734688	0.4734688

Metal Volume (mm³):

Row	Source			Target		
	X	Y	Z	X	Y	Z
1	354.7311	354.7311	354.7311	353.4259	353.4259	353.4259
2	31.21444	31.21444	31.21444	31.87436	31.87436	31.87436
3	572.235	572.235	572.235	567.757	567.757	567.757
4	292.2203	292.2203	292.2203	298.3982	298.3982	298.3982
5	600.2021	600.2021	600.2021	597.2144	597.2144	597.2144
6	31.21444	31.21444	31.21444	31.87436	31.87436	31.87436
7	335.5931	335.5931	335.5931	332.5103	332.5103	332.5103

접촉조건 설정

30. Outline -> Connections -> Contacts 선택 후 Details of "Contacts" -> Auto Detection -> Tolerance Slider : 100으로 설정

31. 마우스 우클릭(RMB) 후 Create Automatic Connection click(49의 접촉 조건 확인 가능)

30.

Details of "Contacts"	
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	100
Tolerance Value	5.03e-005 mm
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	49
Active Connections	49

31.

Details of "Contacts"	
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	100
Tolerance Value	5.03e-005 mm
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	49
Active Connections	49

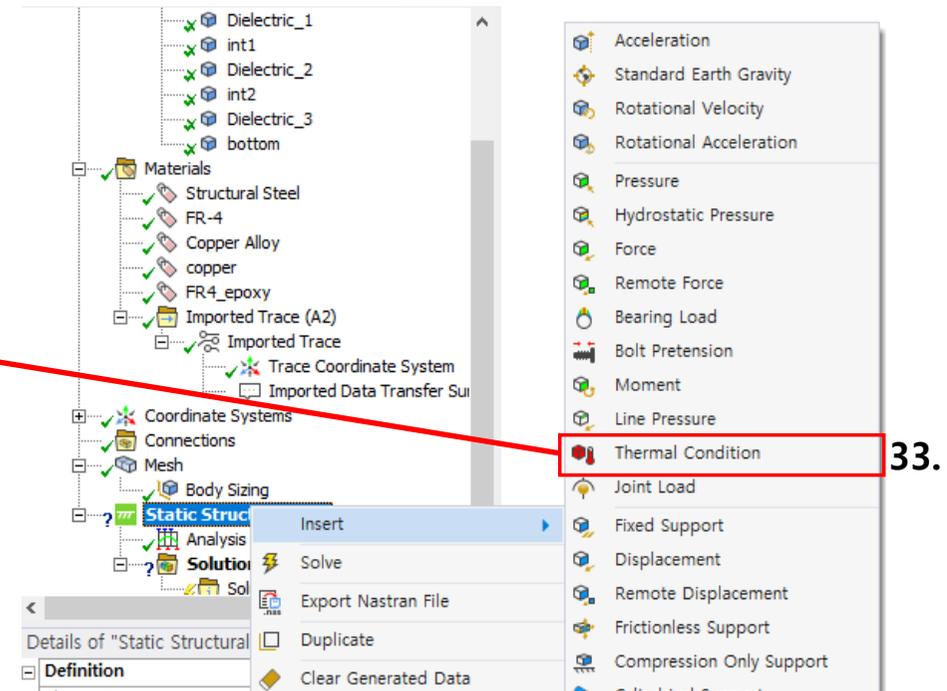
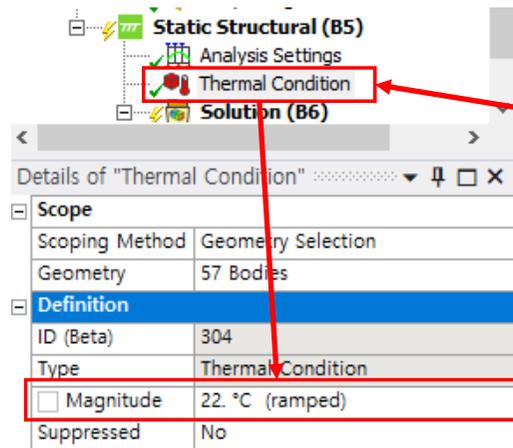
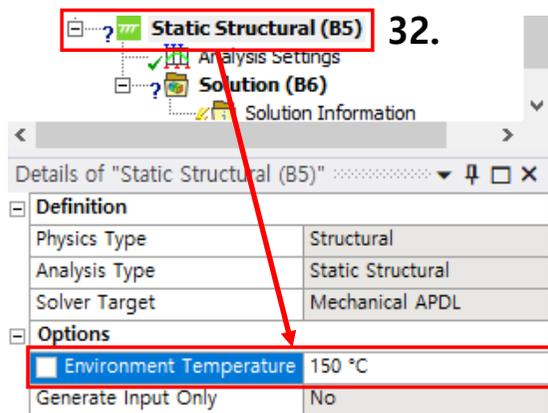
- Create...
- Insert
- Create Automatic Connections**
- Check Overlapping Contact Regions
- Regenerate Connection Mesh (Beta)
- Suppress
- Disable Transparency
- Search Connections for Duplicate Pairs
- Delete Children
- Delete
- Rename F2
- Group Ctrl+G
- Rename Based on Definition

Boundary Condition

32. Outline -> Static Structural(B5) 선택 -> Details of "Static Structural(B5)" -> Options -> Environment Temperature : 150°C로 입력

33. Outline -> Static Structural(B5) 마우스 우클릭(RMB) -> Insert -> Thermal Condition 선택 -> Details of "Thermal Condition" 선택 후 아래와 같이 입력

- Scope -> Geometry : 모든 Body 선택(57 Bodies)
- Definition -> Magnitude : 22°C 설정



Boundary Condition

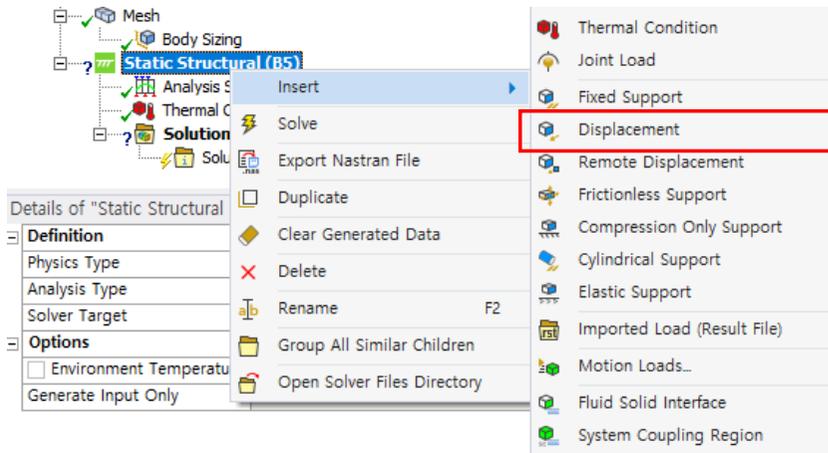
34. Outline -> Static Structural(B5) 마우스 우클릭(RMB) -> Insert -> Displacement 선택 -> Details of "Displacement" 선택 후 각각의 위치별로 아래와 같이 입력

A : $U_x = 0, U_y = 0, U_z = 0$

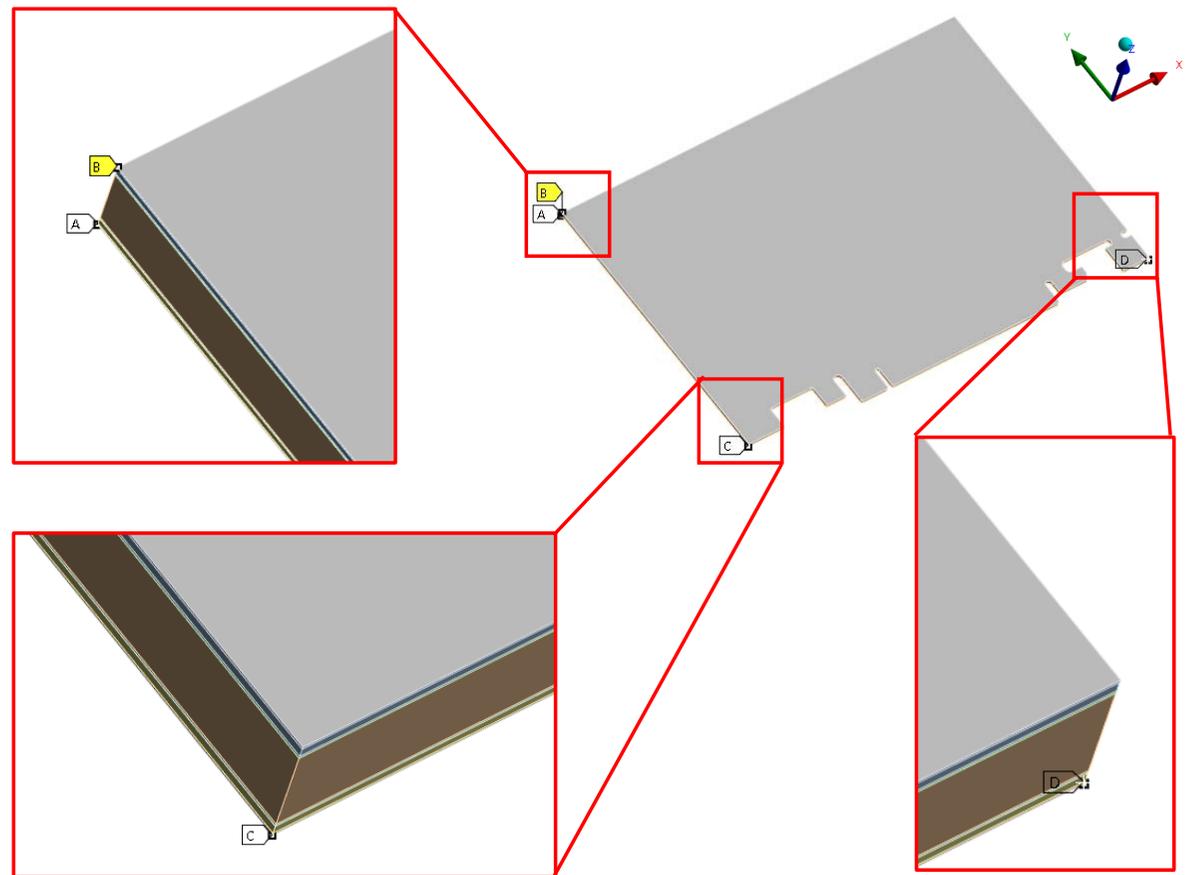
B : $U_y = 0$

C : $U_x = 0$

D : $U_z = 0$



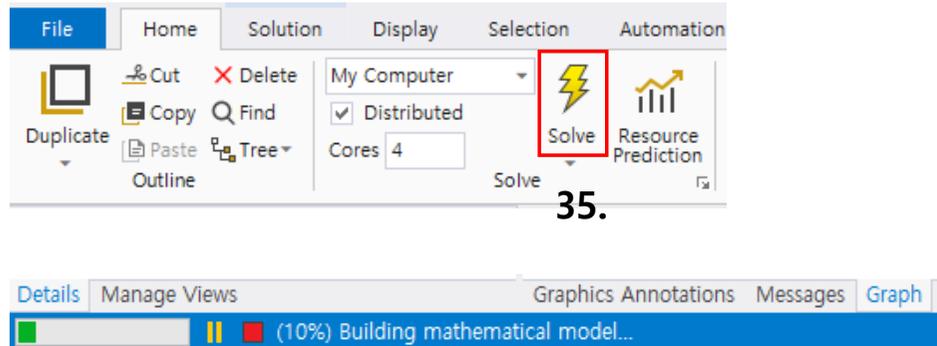
34.



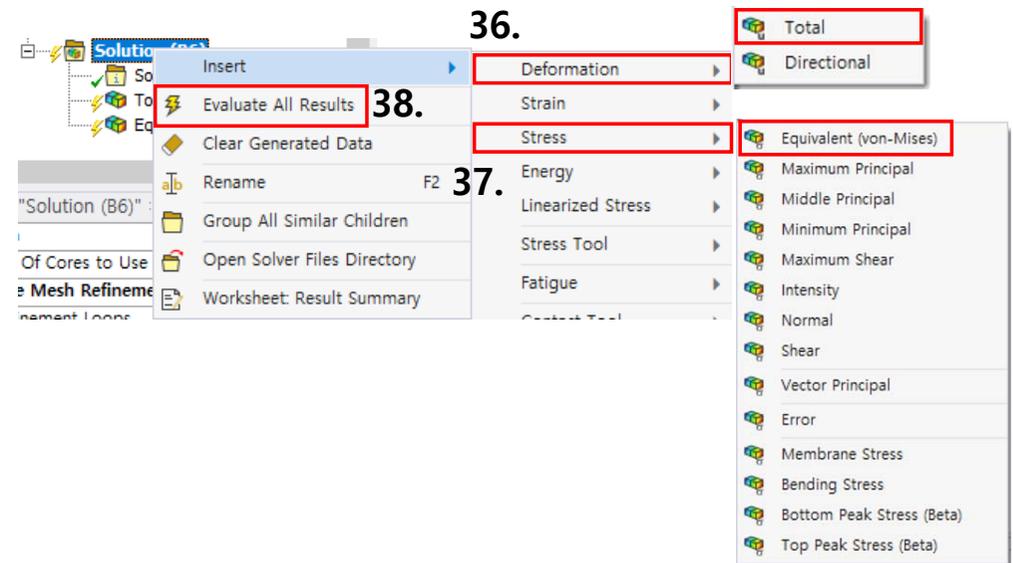
02-2 계산 및 후처리

계산 및 후처리

- 35. Home Tab에서 Solve를 click하여 구조해석 계산 시작(4Core Cpu로 해석시에 대략 7분 정도 소요됨)
- 36. Outline -> Solution(B6) -> 마우스 우클릭(RMB) -> Insert -> Deformation -> Total Deformation
- 37. Outline -> Solution(B6) -> 마우스 우클릭(RMB) -> Insert -> Stress -> Equivalent(von-Mises)
- 38. Outline -> Solution(B6) -> 마우스 우클릭(RMB) -> Evaluate All Results



계산이 진행되는 정도 확인

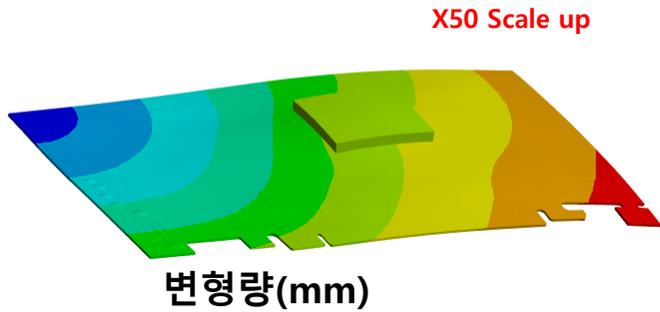


해석결과 확인

39. 변형량 및 응력결과 확인

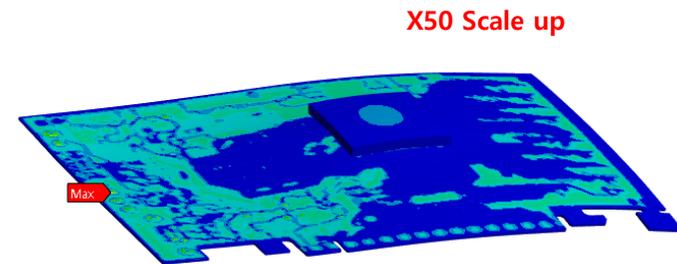
B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s

0.36275 Max
0.32244
0.28214
0.24183
0.20153
0.16122
0.12092
0.08061
0.040305
0 Min



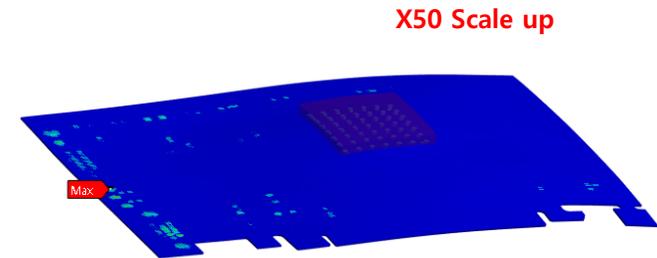
B: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress (Average Across Bodies)
Unit: MPa
Time: 1 s

219.35 Max
194.98
170.61
146.23
121.86
97.49
73.118
48.746
24.373
0.0011406 Min



B: Static Structural
Equivalent Stress 5
Type: Equivalent (von-Mises) Stress (Average Across Bodies)
Unit: MPa
Time: 1 s

219.35 Max
194.98
170.61
146.23
121.86
97.49
73.118
48.746
24.373
0.0011406 Min



감사합니다.

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