

Solidworks를 활용한 최적설계 입문

E-Formula Powertrain

13기 백채원

목차

소개

1. Setting Up Topology Study
2. Optimizing the Model
3. Stress Simulation
4. Fatigue Stress

소개

-Stress란?

물체에 압력, 굽힘, 인장력 등의 외력을 가했을 때, 물체의 내부에는 **외력의 크기에 대응하여 저항력이 생깁니다.** 이를 Stress(응력)라 합니다.

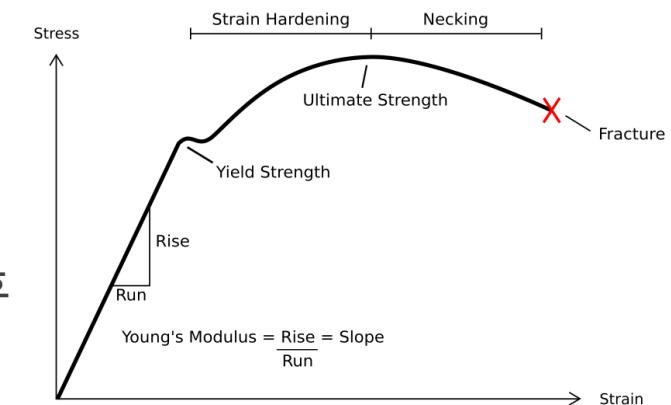
-Strain이란?

물체에 응력이 발생하면 모양에 변형이 생깁니다. 이 때, **변형된 양의 원래 길이에 대한 비율**을 Strain(변형률)이라고 합니다.

-Yielding Stress란?

쇠로 된 자에 약한 힘을 가하면 **변형 후 원래의 상태**로 되돌아옵니다(탄성변형). 하지만 자를 강하게 구부리면 **영구적인 변형이 일어납니다**(소성변형). **Yielding Stress는 물체에 영구적인 변형이 일어나는 시점의 Stress입니다.**

물체에 힘을 걸어주었을 때 Yielding Stress를 초과하는 부분이 있다면 영구적인 변형이 일어나 물체가 제 형체를 유지하지 못합니다. 그러므로 본 ppt에서는 부품의 최적설계 이후 실제 작동 환경을 재현한 시뮬레이션을 통해 부품 내에 Yielding Stress를 초과하는 부분이 있는지 체크해볼 것입니다.



소개

-Safety Factor란?

Safety Factor은 아래의 수식으로 정의됩니다.

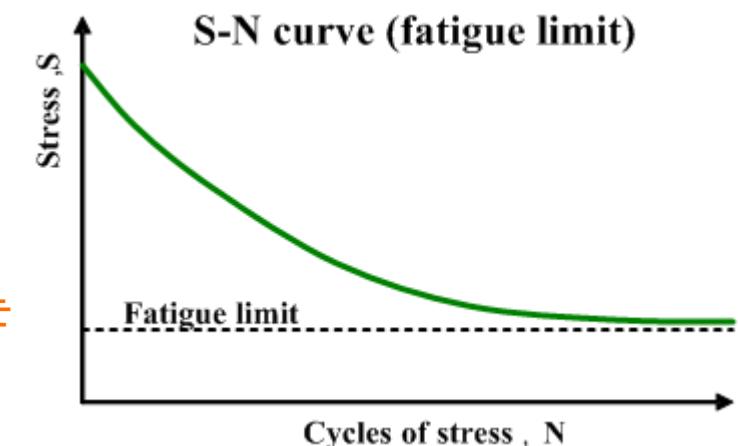
$$\text{Safety Factor} = \frac{\text{Yielding Stress}}{\text{Working Stress}}$$

주어진 부품에 걸리는 최대 Stress가 Yielding Stress라면 외부에서 조금만 충격을 받아도 부품이 망가집니다. 그러므로 보통 부품에 걸리는 **최대 Stress는 Yielding Stress에 비해 몇배 작게 설계**하는데, 이 수치를 Safety Factor이라 합니다. 자동차의 경우 선호되는 Safety factor는 3 정도입니다.

-Fatigue란?

철사를 구부렸다 펴다 반복하면 쉽게 절단되는 것을 보셨을 겁니다. 이와 같이 금속에 가해지는 Stress가 Yielding Stress 이하더라도 **같은 Stress를 여러 번 반복적으로** 받다 보면 **금속이 파괴됩니다**. 이를 Fatigue Failure(피로 파괴)이라 합니다.

반복적으로 가해지는 Stress가 클수록 수명(금속이 Stress를 버티는 횟수)이 줄어들게 되고, Stress가 일정 한계치 이하가 되면 수명이 거의 무한해집니다. **수명이 무한해지는 시점에서의 Stress를 Fatigue Limit이라 합니다.**



※기계공학부에서 개설되는 고체역학, 역학과 설계 과목을 들으면 본 ppt에서 소개된 여러 개념에 대해 심도 있게 배울 수 있습니다.

소개

Solidworks에서는 2018 버전부터 Topology study를 지원합니다.

부품이 작동할 때에 가해지는 힘과 토크에 따라 부품 내에 stress가 생깁니다.

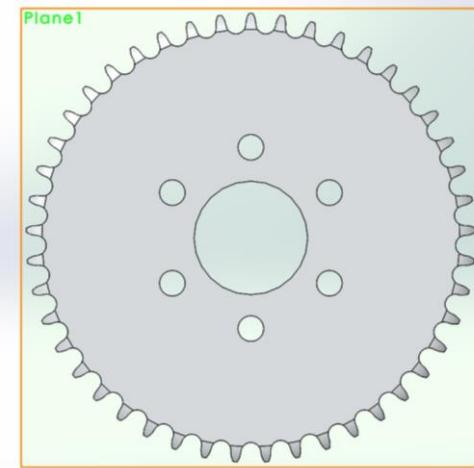
이 때 stress가 높지 않은 부분을 제거한다면 모델의 무게를 감량할 수 있을 것입니다.

Topology Study는 이를 가능하게 하는 기능입니다.

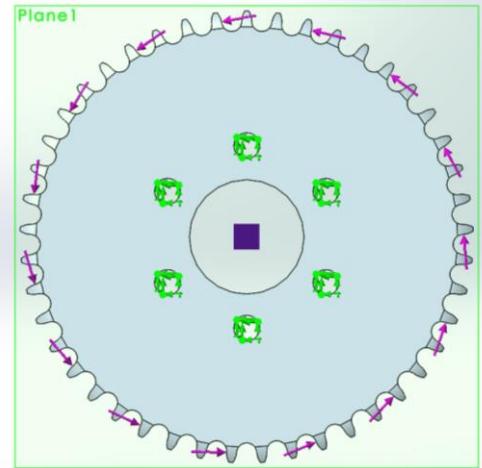
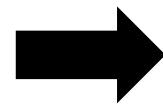
본 자료에서는 Topology study를 활용하여 부품 최적설계를 하는 방법을 알아봅니다.

※Topology Study의 기능에는 무게 감량 외에도 여러가지가 있지만 본 자료는 무게 감량에 초점을 맞추고 있습니다.

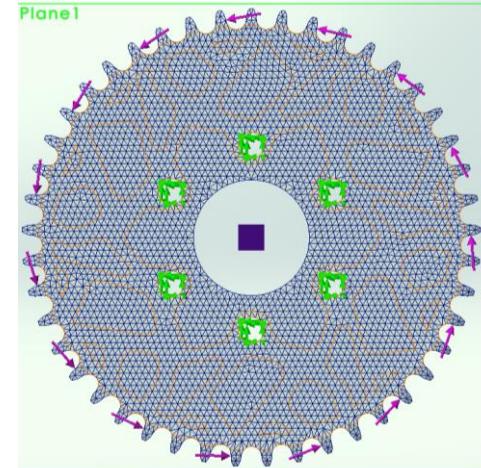
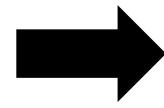
소개



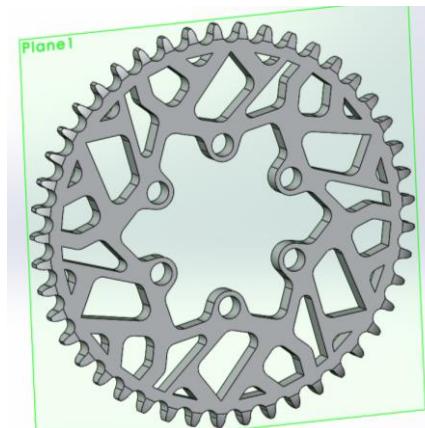
1. 모델 준비



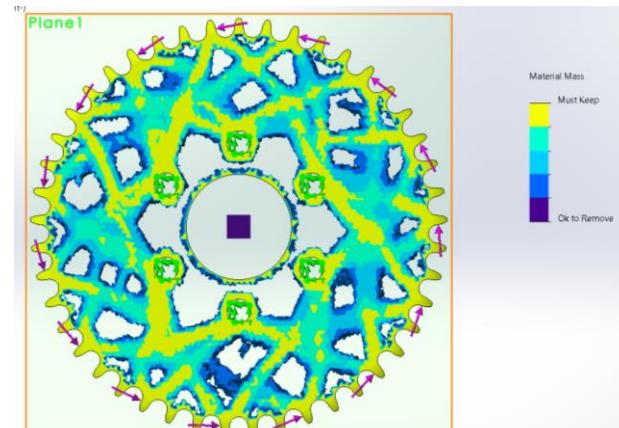
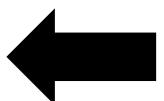
2. 구속조건 설정



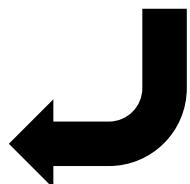
3. 메쉬 생성



4. 결과 반영



4. 시뮬레이션



소개

FEA(Finite Element Analysis)란?

해석하고 싶은 모델이 단순하다면 최대 응력 및 변위 지점을 쉽게 알 수 있습니다. 하지만 실제로는 모델의 형상과 하중조건 모두 복잡한 경우가 대부분입니다. 이를 컴퓨터로 계산하기 위해서 FEA를 사용합니다.

모든 연속적인 물체는 자유도가 무한이라고 가정할 수 있습니다. 하지만 컴퓨터는 이를 계산할 수 없으므로 구조물을 가상적으로 유한한 크기의 element로 분할하고, element의 집합체(Mesh)로서 구조물을 해석합니다. 이 때 계산은 Element가 만나는 점인 Node에서 이루어집니다.

당연하지만 Mesh가 촘촘할수록 Node의 개수가 많아지므로 시뮬레이션 결과는 더 정확해지지만 실행시간이 기하급수적으로 증가합니다. 즉 사용하고 있는 컴퓨터와 물체 형상의 복잡도에 따라 Mesh의 생성을 달리 하는 것 또한 최적설계에서 굉장히 중요한 부분입니다.

I. Setting Up Topology Study

SOLIDWORKS Driven Gear *

Search Community Forum

New Study Apply Material Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures External Loads Goals and Constraints(-Best Stiffn Mass Constraint 1 (-Default-) Manufacturing Controls Mesh Results

Axis1

1. 해석하고 싶은 모델을 준비합니다.

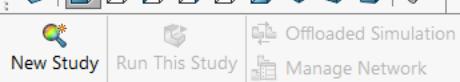
To help you create the proper study, select one of the following:

- I am concerned about excessive deformation or stresses.
- I am concerned about the effect of load/unload cycles.
- I am concerned about sudden collapse under compression.
- I am concerned about excessive shaking.
- I am concerned about...

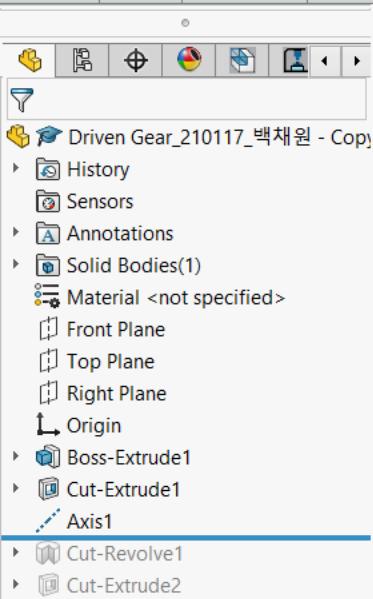
Model 3D Views Motion Study 1 Topology Study 1

SOLIDWORKS Student Edition - Academic Use Only

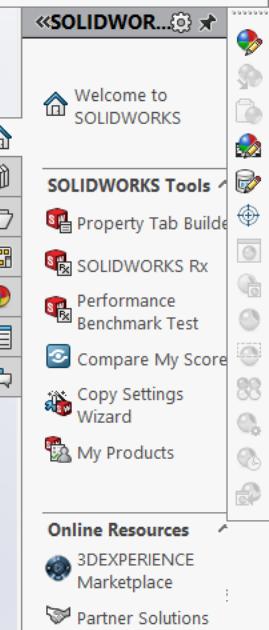
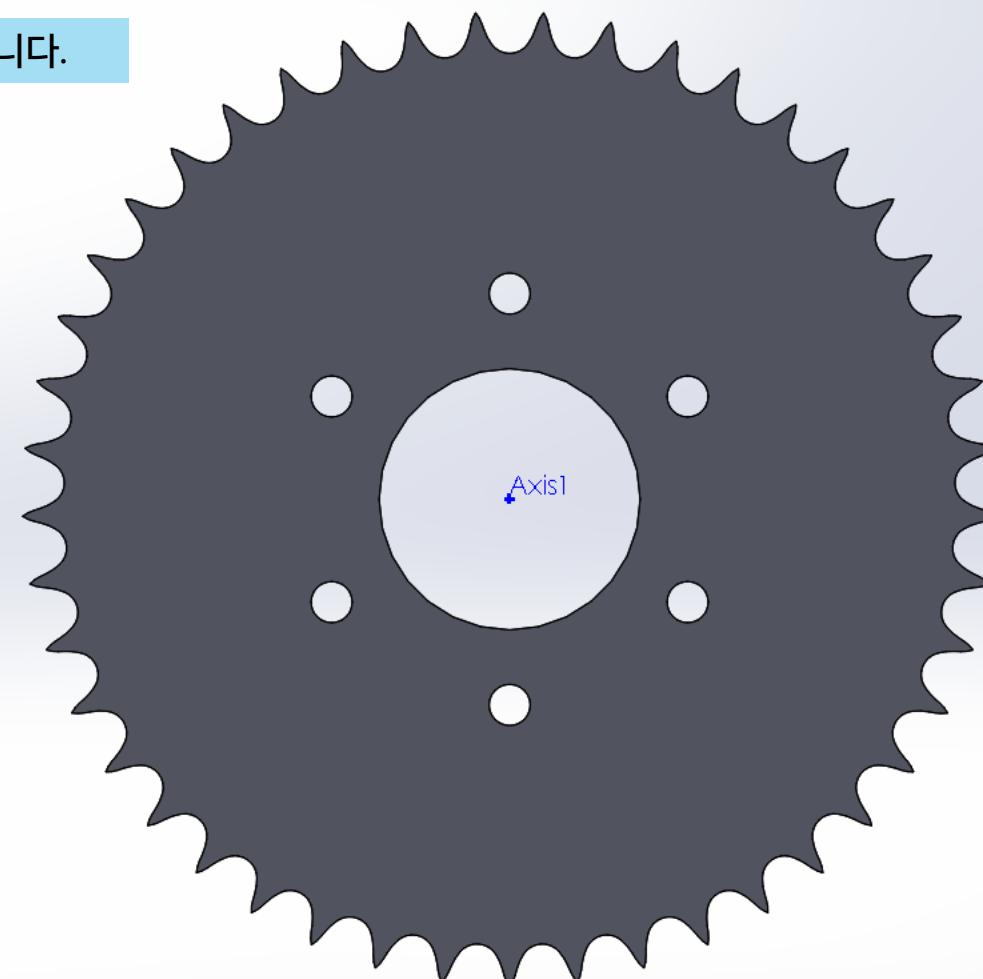
Editing Part IPS

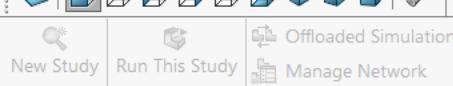


Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins **Simulation** MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM



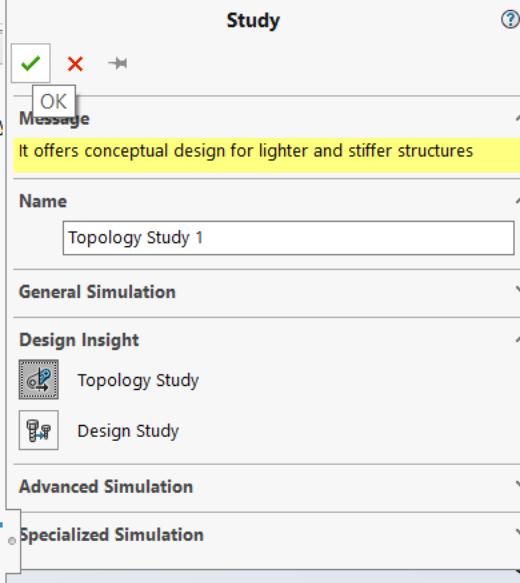
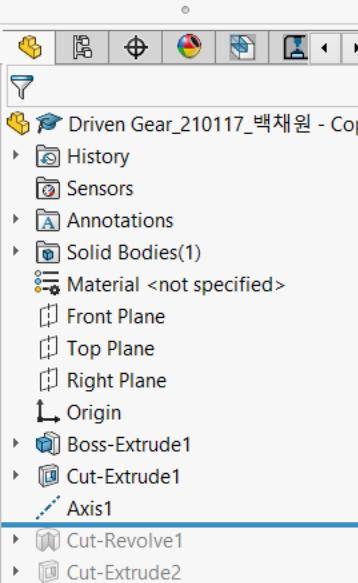
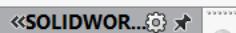
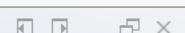
2. Simulation 탭에 들어갑니다.



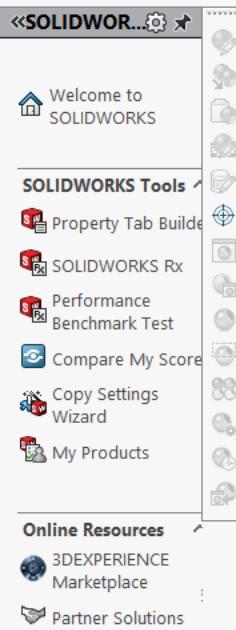
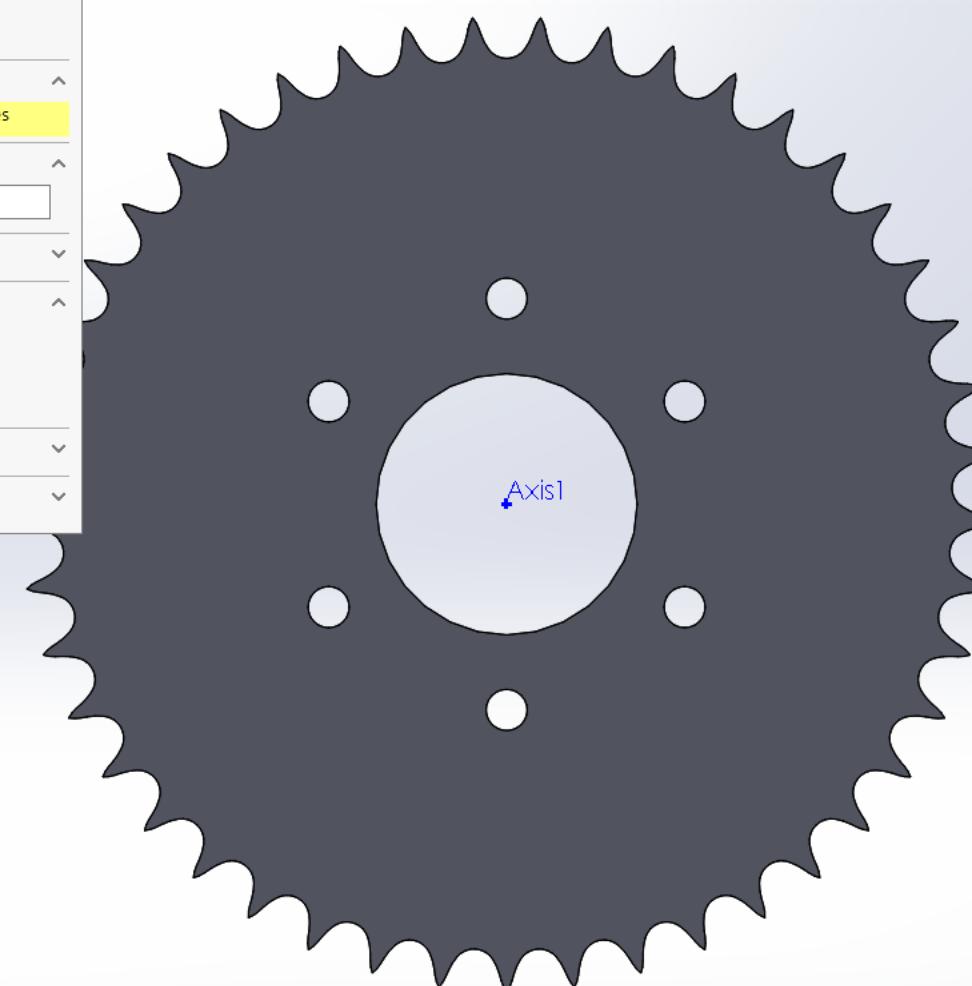


Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins

Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM



3. New Study를 누르고 Topology Study를 선택해줍니다.



Material

Search...

Features Sketch

6061-T4 (SS)
6061-T6 (SS)
6063-O
6063-O, Extruded Rod (SS)
6063-T1
6063-T4
6063-T5
6063-T6
6063-T6, Rod (SS)
6063-T83
7050-T73510
7050-T7451
7050-T7651
7075-O (SS)
7075-T6 (SN)
7075-T6, Plate (SS)
7079 Alloy
AA356.0-F
AA380.0-F die
Alumina
C355.0-T61 Permanent Mold cast (SS)

Copper Alloys
Titanium Alloys
Zinc Alloys
Other Alloys

Click [here](#) to access more materials using the SOLIDWORKS Materials Web Portal.

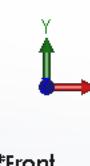
Properties Tables & Curves Appearance CrossHatch Custom Application Data

Material properties
Materials in the default library can not be edited. You must first copy the material to a custom library to edit it.

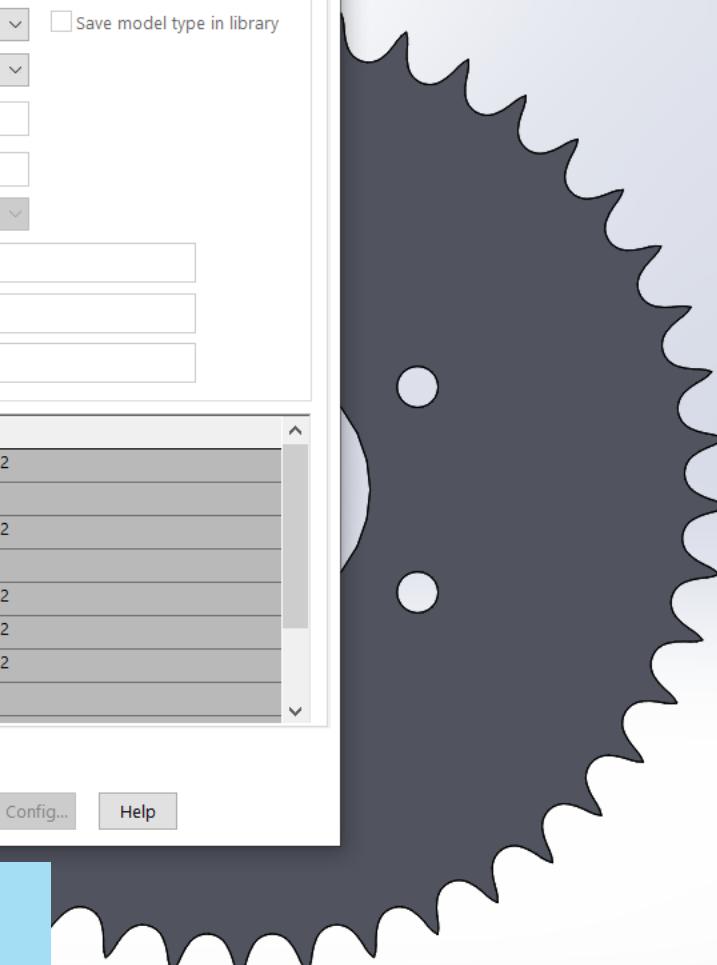
Model Type: Linear Elastic Isotropic Save model type in library
Units: SI - N/mm² (MPa)
Category: Aluminium Alloys
Name: 7075-T6 (SN)
Default failure criterion: Max von Mises Stress
Description:
Source:
Sustainability: Defined

Property	Value	Units
Elastic Modulus	72000	N/mm ²
Poisson's Ratio	0.33	N/A
Shear Modulus	26900	N/mm ²
Mass Density	2810	kg/m ³
Tensile Strength	570	N/mm ²
Compressive Strength		N/mm ²
Yield Strength	505	N/mm ²
Thermal Expansion Coefficient	2.36e-05	/K

Apply Close Save Config... Help



4. Apply Material을 누른 다음 원하는 재료를 선택해줍니다.
본 ppt에서는 Aluminum Alloy – 7075-T6(SN)을 선택하였습니다.



Plot Tools Report
Compare Results
Include Image for Report

SOLIDWORKS CAM TBM

SOLIDWORKS CAM TBM

SOLIDWORKS...

Welcome to
SOLIDWORKS

SOLIDWORKS Tools
Property Tab Builder
SOLIDWORKS Rx
Performance Benchmark Test
Compare My Score
Copy Settings Wizard
My Products

Online Resources
3DEXPERIENCE Marketplace
Partner Solutions

Subscription Services
Subscription Services

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Search Community Forum

New Study Apply Simulation
Material Evaluator

Fixture Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report
Include Image for Report

Features Sketch Weldment Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Fixtures Advisor Fixed Geometry Roller/Slider Fixed Hinge Elastic Support Advanced Fixtures

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures External Loads Goals and Constraints(-Best Stiffness-) Mass Constraint 1 (-Default-) Manufacturing Controls Mesh Results

Axis1

5. Fixtures Advisor을 클릭하고 원하는 구속조건을 설정해줍니다.
본 ppt에서는 Fixed Geometry를 선택했습니다.

To help you create the proper study, select one of the following:

- I am concerned about excessive deformation or stresses.
- I am concerned about the effect of load/unload cycles.
- I am concerned about sudden collapse under compression.
- I am concerned about excessive shaking.
- I am concerned about...

Model 3D Views Motion Study 1 Topology Study 1

Defines a fixed restraint on the selected entities for the active study.

Editing Part IPS

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New Study Apply Material Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Fixture

Type Split

Example

Standard (Fixed Geometry)

Fixed Geometry

Roller/Slider

Fixed Hinge

Face<2>
Face<3>
Face<4>
Face<5>
Face<6>

Advanced

Symbol Settings

6. 고정시키고 싶은 면을 선택합니다.

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1 Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures External Loads Goals and Constraints(-Best Stiffn Mass Constraint 1 (-Default-) Manufacturing Controls Mesh Results

Axis1

Simulation ...

1 Study Bodies and Material Interactions Mesh and Run Results

To help you create the proper study, select one of the following:

- I am concerned about excessive deformation or stresses.
- I am concerned about the effect of load/unload cycles.
- I am concerned about sudden collapse under compression.
- I am concerned about excessive shaking.
- I am concerned about...

Total area: 909.96683601 millimeters²

Editing Part IPS

Model 3D Views Motion Study 1 Topology Study 1

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New Study Apply Simulation Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Events External Loads Advisor KS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures Fixed-2 External Loads Force-2 (:Per item: 2,500 N:) Goals and Constraints(-Best Stiffn Mass Constraint 1 (-Default-) Manufacturing Controls Mesh Results

7. 힘 조건을 추가하기 위해 External Loads Advisor를 클릭합니다. 원하는 외력의 형태를 선택해줍니다.

Axis1

Total area: 323.89792801 millimeters²

Editing Part IPS

1 Study Bodies and Material Interactions Mesh and Run Results

To help you create the proper study, select one of the following:

- I am concerned about excessive deformation or stresses.
- I am concerned about the effect of load/unload cycles.
- I am concerned about sudden collapse under compression.
- I am concerned about excessive shaking.
- I am concerned about...

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New Study Apply Material Simulation Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Force/Torque

Type Split

Force/Torque

Face<11> Face<12> Face<13> Face<14> Face<15>

Normal Selected direction SI

Force Value (N): 1

2500 N Reverse direction Per item Total

Nonuniform Distribution Symbol Settings

8. 힘을 가해주고 싶은 면을 선택한 다음 힘의 크기를 설정해줍니다.

Driven Gear

Axis1

주의: 한번에 선택된 개체들은 힘의 크기를 다르게 설정할 수 없습니다. 힘의 크기를 다르게 하려면 External load를 여러 개 만들어 따로 선택해주어야 합니다.

Total area: 323.89792801 millimeters²

Editing Part IPS

Simulation ...

1 Study Bodies and Material 2 Interactions 3 Mesh and 4 Run 5 Results

To help you create the proper study, select one of the following:

- I am concerned about excessive deformation or stresses.
- I am concerned about the effect of load/unload cycles.
- I am concerned about sudden collapse under compression.
- I am concerned about excessive shaking.
- I am concerned about...

SOLIDWORKS Driven Gear *

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New Study Apply Material Simulation Evaluator Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS

Goals and Constraints Minimize Mass... Best Stiffness to Weight ratio (default)... Minimize Maximum Displacement... Add Stress Constraint... Add Displacement Constraint... Add Factor of Safety Constraint... Add Frequency Constraint...

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN-)) Connections Fixtures Fixed-2 External Loads Force-2 (:Per item: 2,500 N:) Goals and Constraints(-Best Stiffn Mass Constraint 1 (-Default-) Manufacturing Controls Mesh Results

Axis1

9. Goals and Constraints를 클릭한 다음 Best Stiffness to Weight ratio를 선택합니다.

주의: Minimize mass를 선택하면 뒷단계에서 걸어줄 목표질량 구속조건을 무시하고 질량을 줄여버립니다. 그러므로 Best Stiffness to Weight를 선택하는 것이 좋습니다.

Total area: 323.89792801 millimeters²

IPS

Simulation ...

1 Study Bodies and Material Interactions Mesh and Run Results

To help you create the proper study, select one of the following:

- I am concerned about excessive deformation or stresses.
- I am concerned about the effect of load/unload cycles.
- I am concerned about sudden collapse under compression.
- I am concerned about excessive shaking.
- I am concerned about excessive vibration.

SOLIDWORKS Driven Gear *

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New Study Apply Material Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures Fixed-2 External Loads Force-2 (:Per item: 2,500 N:) Goals and Constraints(-Best Stiffn Mass Constraint 1 (-Default-) Manufacturing Controls Mesh Results

Goals and Constraints

A default constraint will be chosen when a goal is selected. You can create additional constraints based on your design requirements.

Frequency constraint always run with 'Intel direct sparse' solver.

Select Goal Best Stiffness to Weight ratio (default)

Displacement Constraint

Mass Constraint (Default)

Mass Constraint Reduce mass by (percentage) 80 Current mass of part: 0.460204 kg Final mass of part: 0.092041 kg

Frequency Constraint

Stress/Factor of Safety Constraint

Factor of Safety Constraint is greater than 1.25 Default failure criterion: Maximum von Mises Stress Material yield strength: 5.05e+08 N/m² Final stress value: 4.04e+08 N/m²

10. Mass constraint에서 없애고 싶은 질량의 퍼센티지를 입력합니다.

11. Stress constraint를 줍니다.

Simulation ...

1 Study Bodies and Material Interactions Mesh and Run Results

To help you create the proper study, select one of the following:

I am concerned about excessive deformation or stresses.

I am concerned about the effect of load/unload cycles.

I am concerned about sudden collapse under compression.

I am concerned about excessive shaking.

I am concerned about excessive bending.

Total area: 323.89792801 millimeters²

Editing Part IPS

Model 3D Views Motion Study 1 Topology Study 1

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SOLIDWORKS Driven Gear *

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New Study Apply Material Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation

Manufacturing Controls Add Preserved Region... Specify Thickness Constraint... Specify De-Mold Direction... Specify Symmetry Plane(s)...

WORKS CAM SOLIDWORKS CAM TBM

12. Manufacturing Controls에서 Preserved Region을 클릭합니다.

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures Fixed-2 External Loads Force-2 (:Per item: 2,500 N:) Goals and Constraints(-Best Stiffness-) Mass Constraint 1 (-Default-) Factor of Safety Constraint 1 (-Default-) Manufacturing Controls Mesh Results

Axis1

To help you create the proper study, select one of the following:

- I am concerned about excessive deformation or stresses.
- I am concerned about the effect of load/unload cycles.
- I am concerned about sudden collapse under compression.
- I am concerned about excessive shaking.
- I am concerned about...

Add Preserved Region...

Model 3D Views Motion Study 1 Topology Study 1

Total area: 323.89792801 millimeters²

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Preserved Region

Message

Select additional faces which cannot be removed by the solver. These faces need to be preserved because they are part of the design or they are faces used as connection points with other parts in the assembly.

Note: Faces selected for loads and restraints are automatically preserved.

It is recommended that you mesh the model with a size smaller than the preserved area depth

Selection

Face<1>
Face<2>
Face<3>
Face<4>
Face<5>

Preserved Area Depth

0 mm

Geometry Preview
Mesh Element Preview
Edit Color...

Top Plane
Right Plane
Origin
Boss-Extrude1
Cut-Extrude1

Topology Study 1 (-Default-)
Driven Gear (-7075-T6 (SN)-)
Connections
Fixtures
Fixed-2
External Loads
Force-2 (:Per item: 2,500 N:)
Goals and Constraints(-Best Stiffness-)
Mass Constraint 1 (-Default-)
Factor of Safety Constraint 1 (-Default-)
Manufacturing Controls
Mesh
Results

Axis1

13. Study 이후에도 남아있어야 하는 부분을 선택해줍니다.

주의: Preserved Area Depth를 설정하면 선택한 면에서 원하는 깊이까지 남겨줄 수 있습니다. 다만 말이 안되는 수치를 입력하면 오류가 납니다.

1 Study
2 Bodies and Material
3 Interactions
4 Mesh and Run
5 Results

To help you create the proper study, select one of the following:

I am concerned about excessive deformation or stresses.
I am concerned about the effect of load/unload cycles.
I am concerned about sudden collapse under compression.
I am concerned about excessive shaking.
I am concerned about...

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New Study Apply Simulation Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Material Evaluator

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation

Manufacturing Controls Run This Study Results Advisor Plot Tools Report Compare Results

WORKS CAM SOLIDWORKS CAM TBM

Task List

14. (추가조건) Symmetry Plane을 선택합니다.

Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures Fixed-2 External Loads Force-2 (:Per item: 2,500 N:) Goals and Constraints(-Best Stiffness-) Mass Constraint 1 (-Default-) Factor of Safety Constraint 1 (-) Manufacturing Controls Preserved Region 1 Mesh Results

Axis

Model 3D Views Motion Study 1 Topology Study 1

Specify Symmetry Plane(s)... Editing Part IPS

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Symmetry control

Message

Half symmetry: Select a single plane which cuts the model into two identical bodies.

Quarter symmetry: Select two orthogonal planes which cut the model into four identical bodies.

One-eighth symmetry: Select three orthogonal planes which cut the model into eight identical bodies.

Type

Half Symmetry

Select First Symmetry Plane

Front Plane

Front Plane

Axis

I5. Symmetry Control은 Study 후의 형상이 Symmetry Plane에 대해 대칭이도록 구속해줍니다.

주의: Symmetry Plane을 추가할수록 계산시간과 램 사용량이 늘어납니다. 제 경우에는 Symmetry Plane을 세 개 추가한 다음 해석을 시작하자 아예 램 용량이 부족하다는 경고가 뜨면서 계산을 시작하지도 못했습니다.

Task List

Select a Single body to study strength

- 1 Select Material
- 2 Add Fixture
- 3 Define External Loads
- 4 Set Goals and Constraints
- 5 Run
- 6 View Results in Material Mass Plot In Model tab, turn on Simulation
- 7 Display to view plot over study body for editing model.

Model 3D Views Motion Study 1 Topology Study 1

Driven Gear * Editing Part IPS



Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

New Study Apply Simulation Material Evaluator

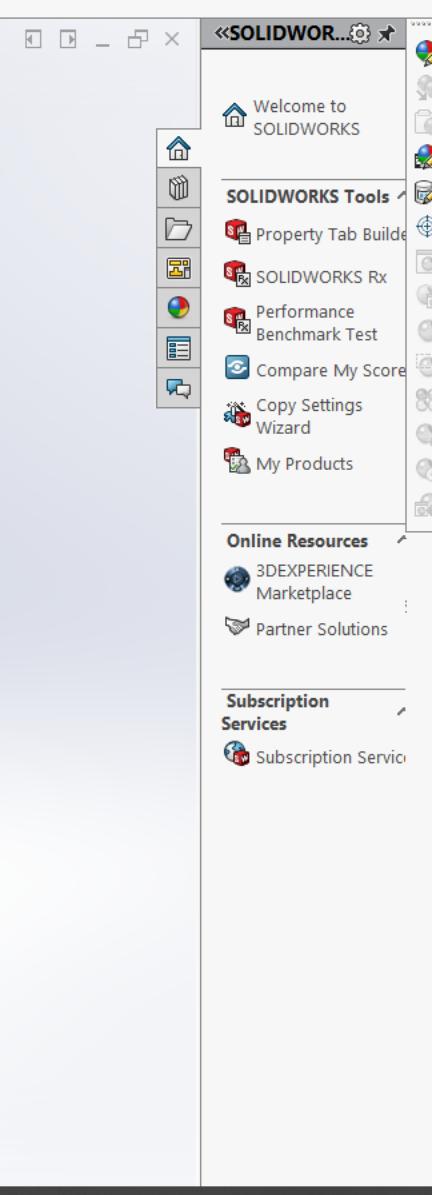
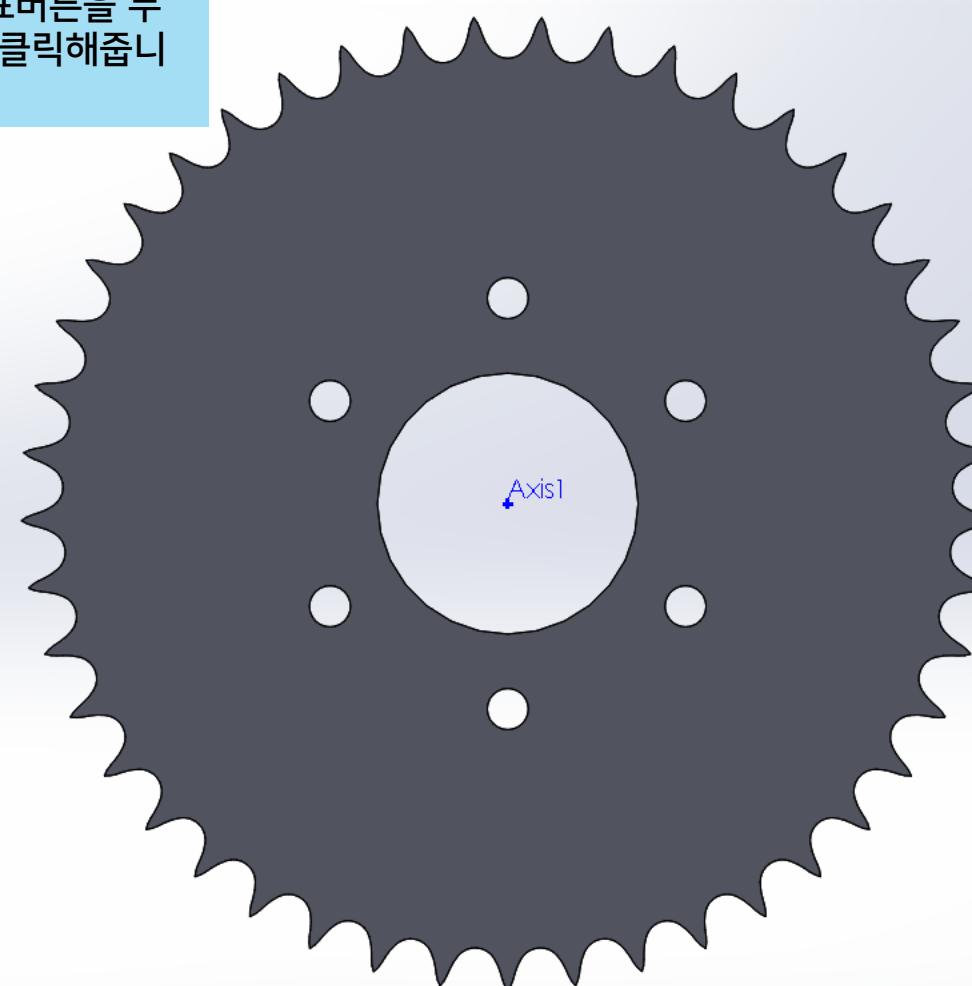
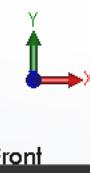
Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins

Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

16. New Study 아래의 화살표버튼을 누른 다음 Study Properties를 클릭해줍니다.

Driven Gear_210117_백채원 - C History Sensors Annotations Solid Bodies(1)

Topology Study 1 (-Default-) Driven Gear_210117_백채원 - C Connections Fixtures External Loads Goals and Constraints Manufacturing Controls Mesh



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New Study Apply Simulation Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

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Topology Options Notification Advanced Remark

Convergence Check (Draft quality)

Maximum number of Iterations
 Automatic
 User-defined
10 (> 20 and < 101)

Preserved Contacts and Connectors settings
 Regions with contacts only
 Regions with connectors only
 Regions with contacts and connectors
 None (user-defined)

OK Cancel Apply Help

Annotations Solid Bodies(1) Material <not specified> Front Plane Top Plane

Topology Study 1 (-Default-) Driven Gear (-7075-T6 (SN)-) Connections Fixtures Fixed-2 External Loads Force-2 (Per item: 2,500 N) Goals and Constraints(-Best Stiffn Mass Constraint 1 (-Default-) Factor of Safety Constraint 1 (-)) Manufacturing Controls Preserved Region 1 Symmetry control 1 (-Half Syn Mesh Results

Task List - ... Select a Single body 1 to study strength 2 Select Material 3 Add Fixture 4 Define External Loads 5 Set Goals and Constraints 6 Run View Results in 7 Material Mass Plot In Model tab, turn on Simulation 8 Display to view plot over study

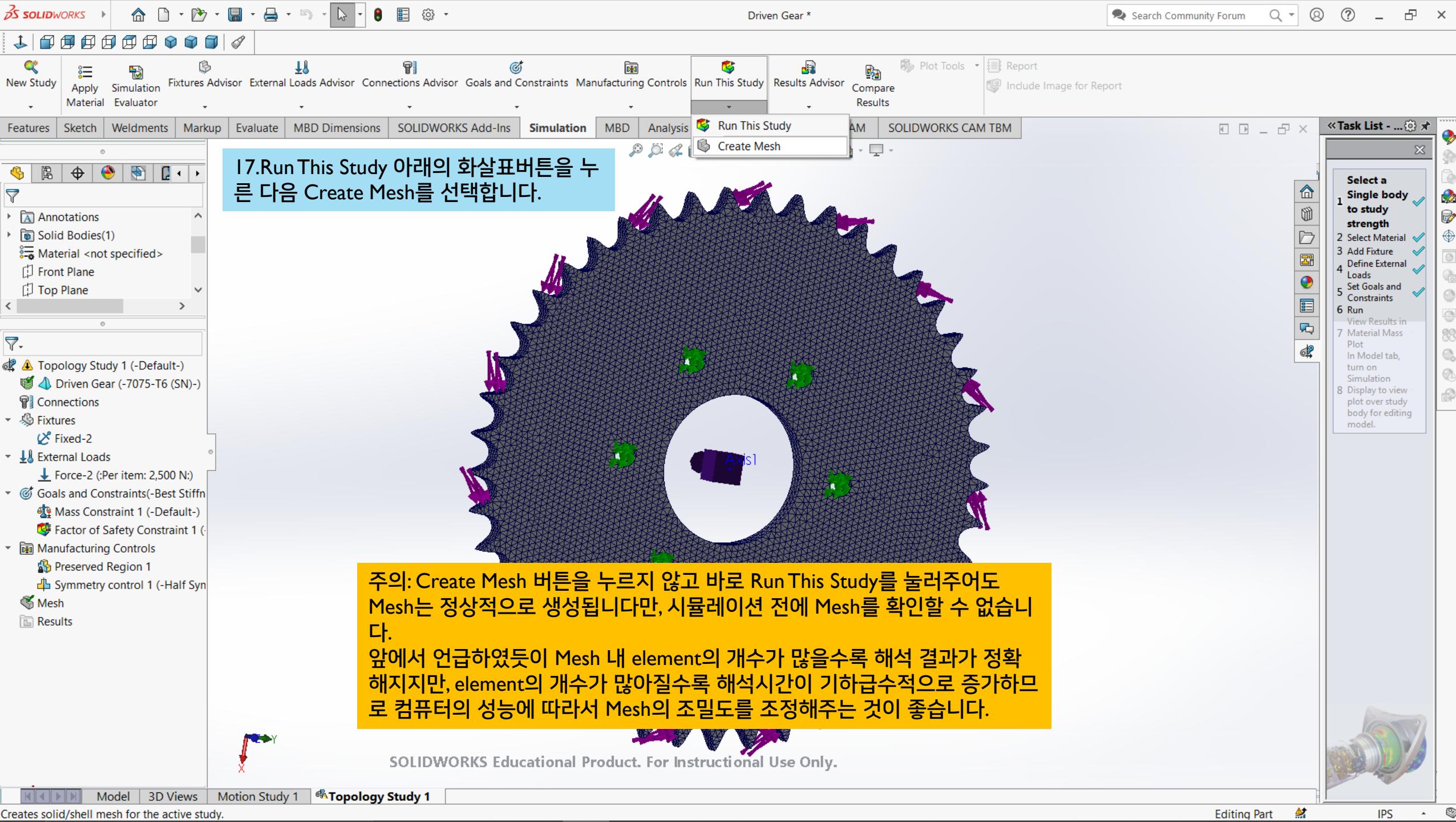
주의: 복잡한 해석의 경우 Advanced 탭에서 반드시 Convergence Check를 선택해주고, Maximum number을 User-defined로 바꾸어 줍니다. 그렇지 않으면 Iteration이 너무 많아져서 해석 시간이 너무 길어지고, 심지어 해석 도중 컴퓨터에 용량이 부족해 해석이 실패하는 경우도 있습니다.

Topology Study는 생각보다 용량을 많이 차지합니다. 결과값은 용량이 얼마 되지 않지만, 해석을 실행하는 도중에는 용량이 20GB 이상까지 차솟기도 하니 복잡한 해석의 경우에는 여유 용량을 꼭 체크한 다음 해석을 돌려주세요!

Model 3D Views Motion Study 1 Topology Study 1

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Driven Gear_210117_백채원 - Copy *

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Ne... Apply Material Simulation Fixtur... External Load... Connectio... Goals and... Manufacturi... Run Th... Result... Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Front Plane Top Plane Right Plane Origin

Topology Study 1 (-Default-) Driven Gear_210117_백채원 - Co Connections Fixtures Fixed-1 External Loads Force-1 (:Per item: 2,000 N:) Goals and Constraints(-Best Stiffness Mass Constraint 1 (-Default-) Factor of Safety Constraint 1 (-1.0)) Manufacturing Controls Preserved Region 1 Symmetry control 1 (-Half Symm Mesh

Mesh Definition Mesh Quality

Message A high quality mesh is recommended for a Stress/Factor of Safety constraint

Mesh Density Coarse Fine Reset Check for distorted elements

Mesh Parameters Advanced Options Save settings without meshing Run (solve) the analysis

18.Mesh Density를 원하는 정도로 세팅한 다음 Mesh를 생성합니다.

Axis1

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New Study Apply Material Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Include Image for Report

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Task List - ...

주의: Study를 실행하기 전에 Ctrl+s를 일단 눌러 저장해주세요.
시뮬레이션 도중에 오류가 생기면 그대로 지금까지 걸어준 모든 조건이 통째로 날아가버리는 애석한 상황이 발생할 수 있습니다.

19.Run This Study에서 Study를 시작 합니다.

Topology Study 1
Running iteration 1
0%
Elapsed Time : 8s
 Show static/frequency study run progress dialog
View Convergence Data and Graphs
Stop and Save Results Cancel

Driven Gear (-7075-T6 (SN-))
Connections
Fixtures
External Loads
Goals and Constraints(-Best Stiffn
Manufacturing Controls
Preserved Region 1
Symmetry control 1 (-Half Syn
Mesh
Results

Model 3D Views Motion Study 1 Topology Study 1

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Convergence Data

Iteration : 4

Goal/Constraint Name	Current Value	Show Graph
Goal : Best Stiffness	29.2696	
Mass(Target : 0.0922018 kg)	0.141133	
Factor of Safety(Target : 1.25)	0.21017	

Close

Topology Study 1 (-Default-)
Driven Gear (-7075-T6 (SN)-)
Connections
Fixtures
Fixed-2
External Loads
Force-2 (Per item: 2,500 N)
Goals and Constraints(-Best Stiffn
Mass Constraint 1 (-Default-)
Factor of Safety Constraint 1 (-
Manufacturing Controls
Preserved Region 1
Symmetry control 1 (-Half Syn
Mesh
Results

Driven Gear *

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Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Goals and Constraints Manufacturing Controls Run This Study Results Advisor Plot Tools Report Compare Results Include Image for Report

Topology Study 1

Running iteration 5

Elapsed Time : 24m:17s

Show static/frequency study run progress dialog

View Convergence Data and Graphs

Stop and Save Results Cancel

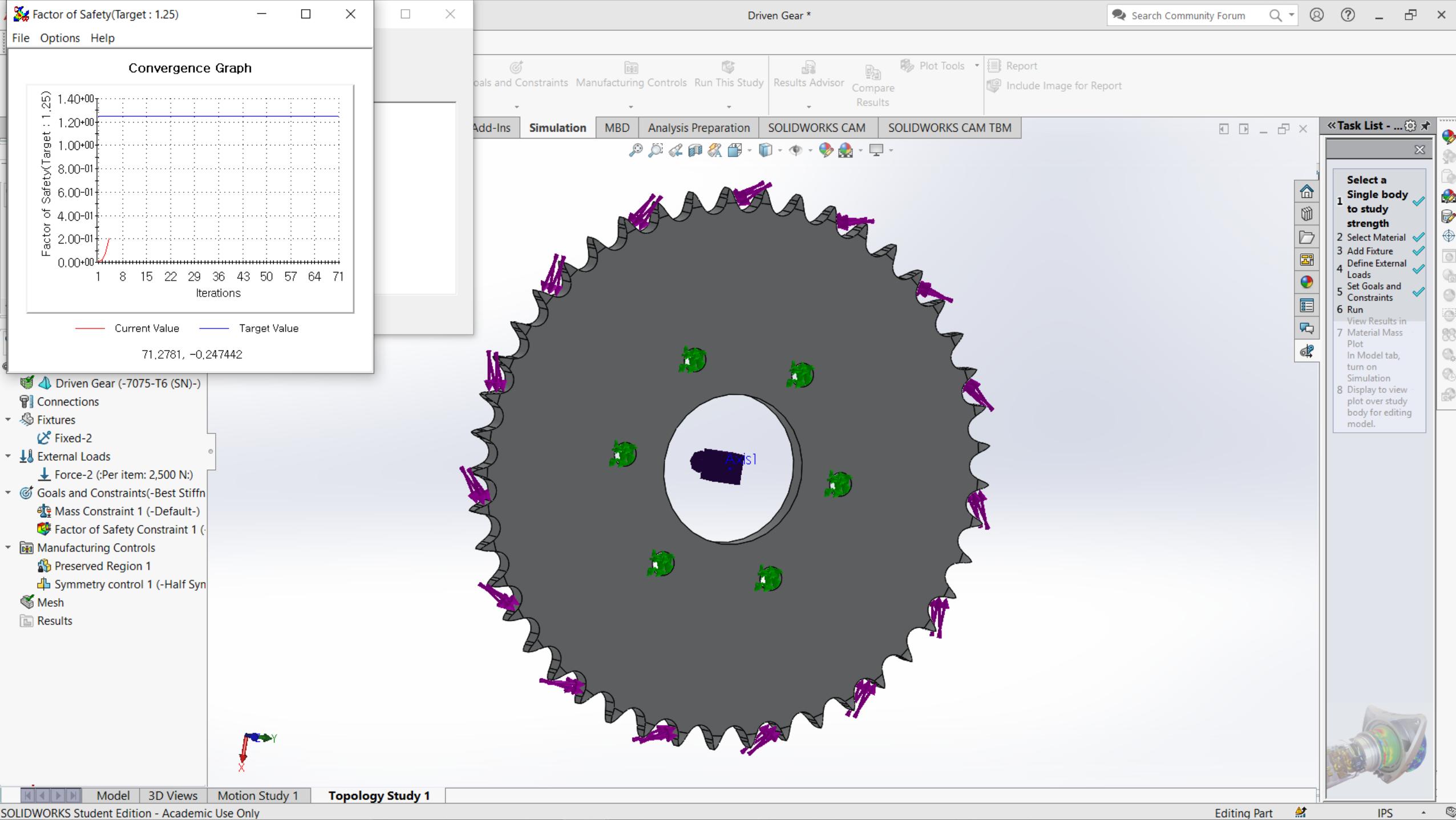
Task List

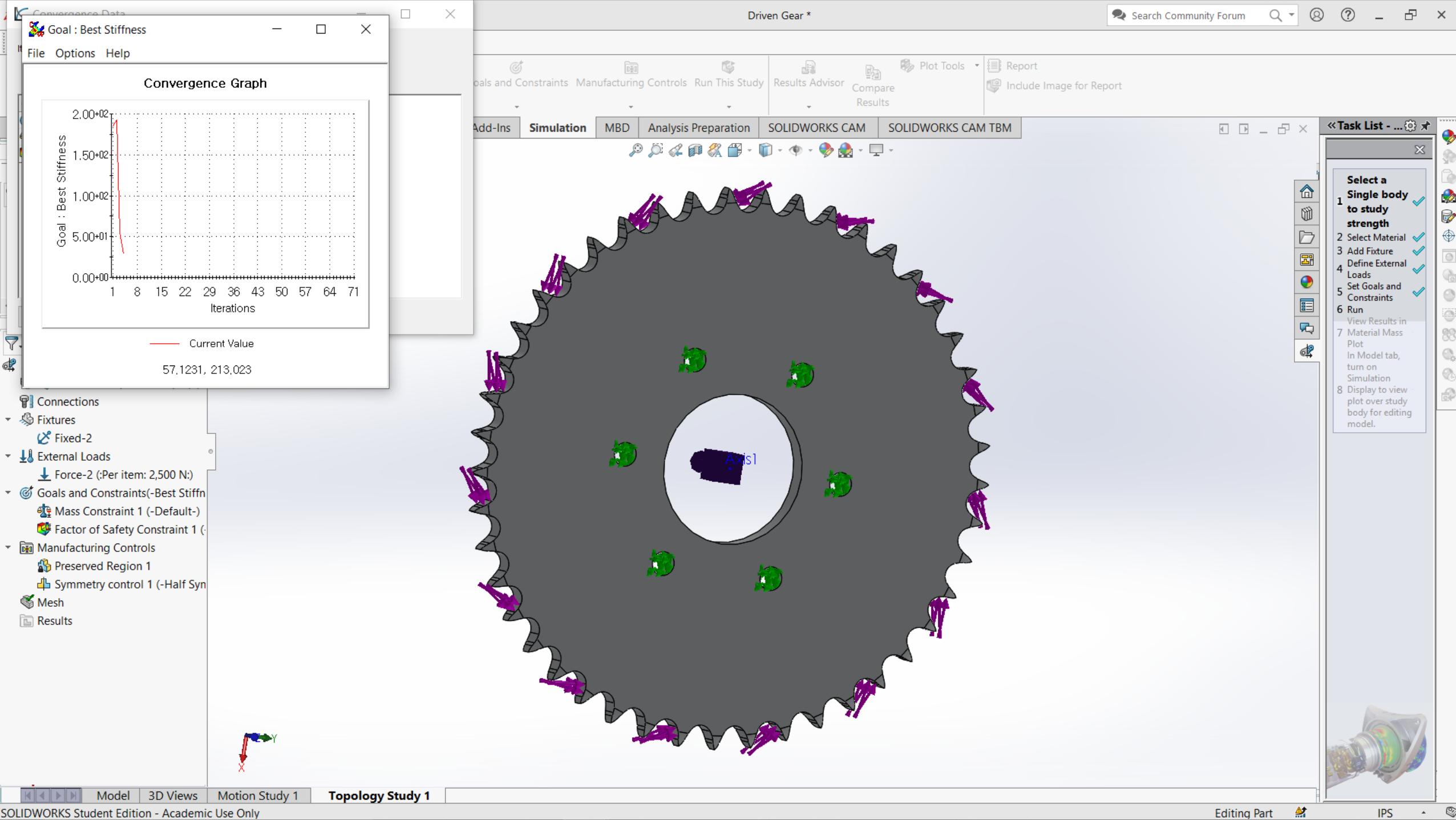
Select a Single body to study strength

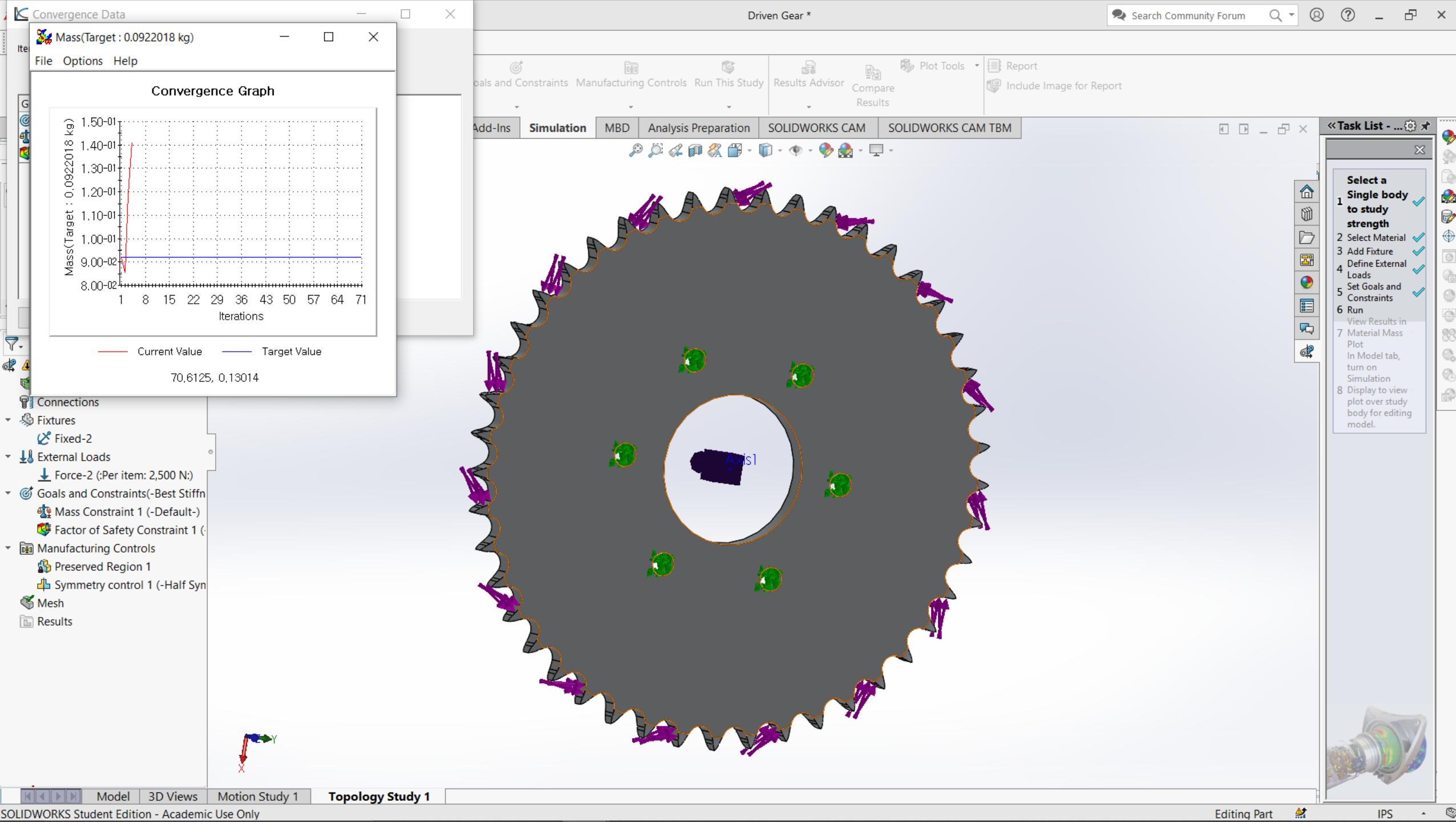
- 1 Select Material
- 2 Add Fixture
- 3 Define External Loads
- 4 Set Goals and Constraints
- 5 Run
- 6 View Results in Material Mass Plot In Model tab, turn on Simulation
- 7 Display to view plot over study body for editing model.

IPS

20. View Convergence Data and Graphs 를 선택하면 원하는 값에 얼마나 근접했는지 그래프를 확인할 수 있습니다.







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대기어 *

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New Study

Apply Material

Simulation Evaluator

Fixtures Advisor External Loads Advisor Connections Advisor Goals and Constraints Manufacturing Controls Run This Study

Results Advisor

Plot Tools

Report

Compare Results

Include Image for Report

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Cut-Revolve1 Cut-Extrude1 Axis1 Plane1

Cut-Extrude2

Topology Study 2 (-Default-) 대기어 (-7075-T6 (SN)-)

Connections

Fixtures Fixed-1

External Loads Force-1 (:Per item: 2,500 N)

Goals and Constraints(-Best Stiffness t)

Manufacturing Controls Preserved Region 1 Symmetry control 1 (-Half Symmet)

Mesh

Results

Material Mass1 (-Material Mass-) Factor of Safety1 (-FOS-) Topology Variable Stress1 (-vo

Model name: 대기어
Study name: Topology Study 2(-Default-)
Plot type: Material Mass

Plane1

Material Mass

Must Keep

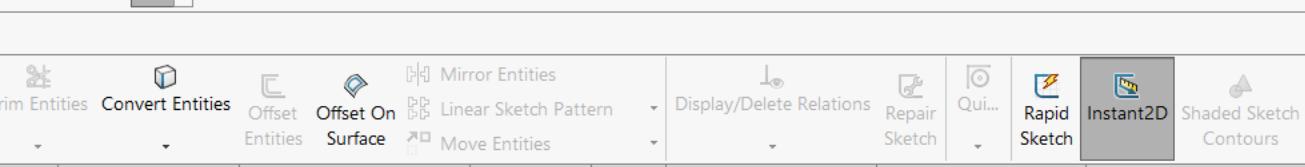
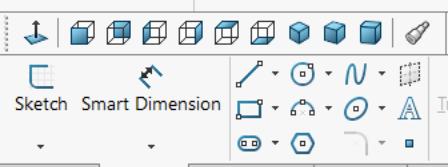
Ok to Remove

21. 해석이 끝나면 Material Mass 분포도가 자동으로 표시됩니다.
좌측의 Material Mass 탭을 우클릭한 다음 Properties 항목에서 화면에 표시하고 싶은 Material의 양을 조절할 수 있습니다.
Topology Variable Stress 탭을 더블클릭하면 각 element에 가해지는 stress를 표시할 수 있습니다.
Results 탭을 우클릭하면 시뮬레이션 결과를 내보낼 수 있는 옵션이 있습니다.

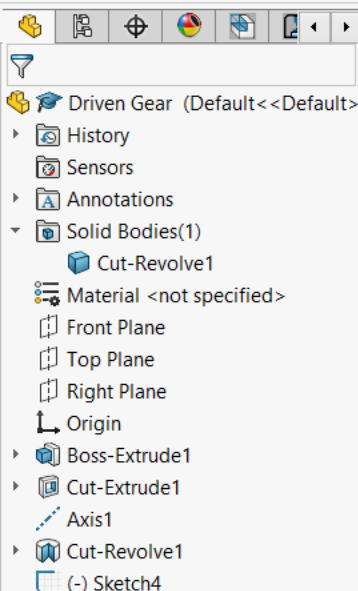
X

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2. Optimizing the Model

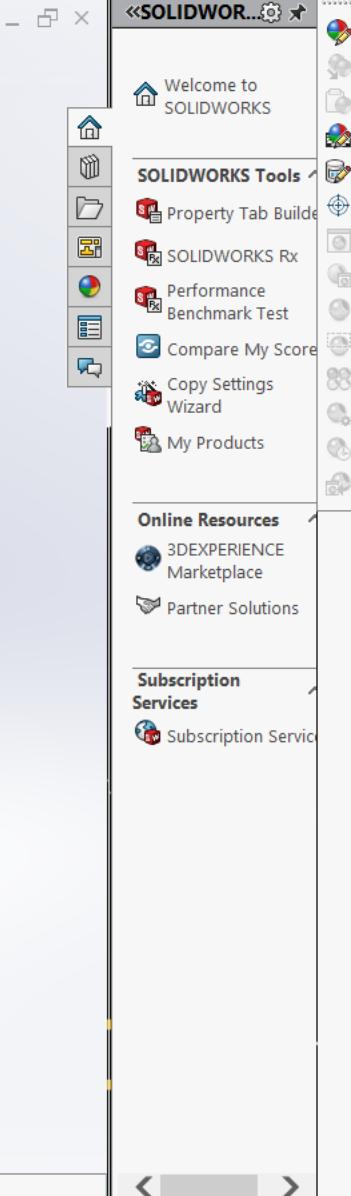
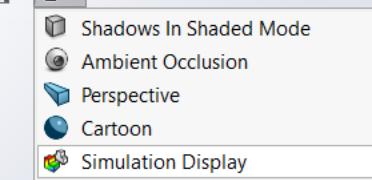
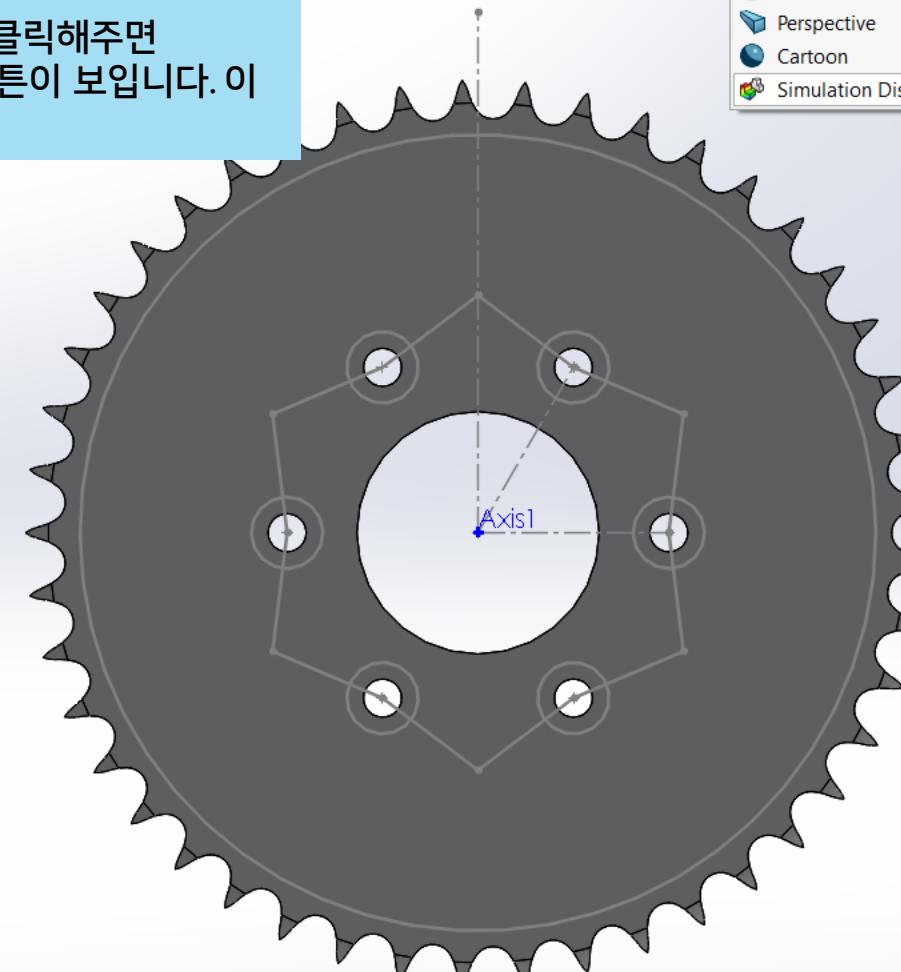


Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM



22. 좌측 하단에 위치한 Model 탭으로 넘어갑니다.

우측 모니터 모양 버튼을 클릭해주면
Simulation Display라는 버튼이 보입니다. 이를 선택해줍니다.



Simulation Display

Message
Select the Simulation to display on the selected components or bodies

Selected Result

Studies and Results
Study: Topology Study 1
<input checked="" type="checkbox"/> Material Mass1 (-Material Mass-)
<input type="checkbox"/> Factor of Safety1 (-FOS-)
<input type="checkbox"/> Topology Variable Stress1 (-vonMises-)

Simulation Display will be used for:

- Display in RealView and OpenGL
- Display in RealView and OpenGL
- Design Guidance
- Deformed results
- Show mesh
- Show legend
- Reflection amount (RealView only): 0
- Transparent amount: 0
- Brightness: 0

Simulation results are out of date

Driven Gear *

Instant2D

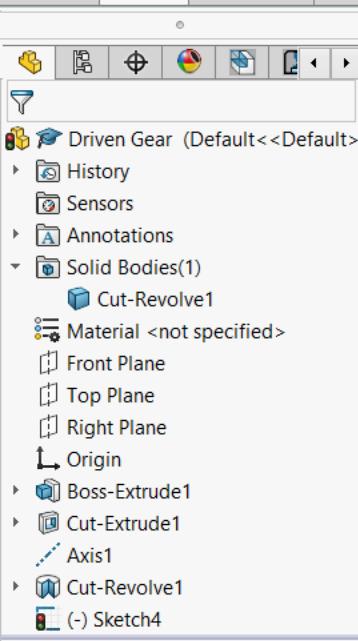
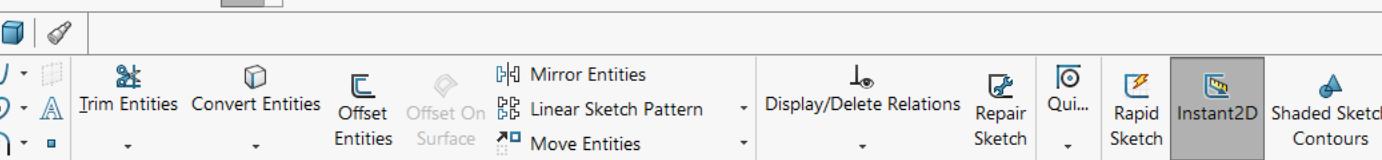
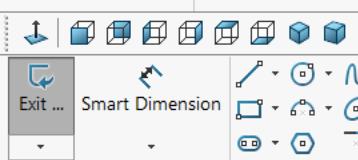
Material Mass plot

Topology Study 1

Notes:

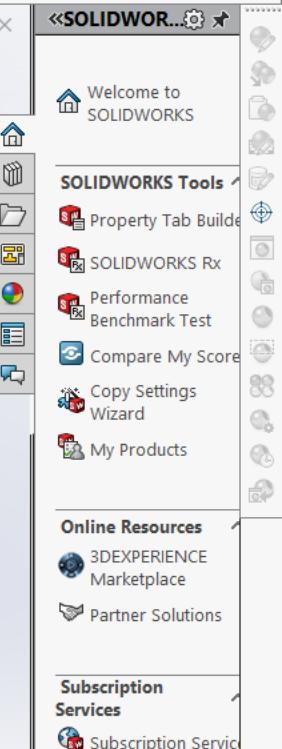
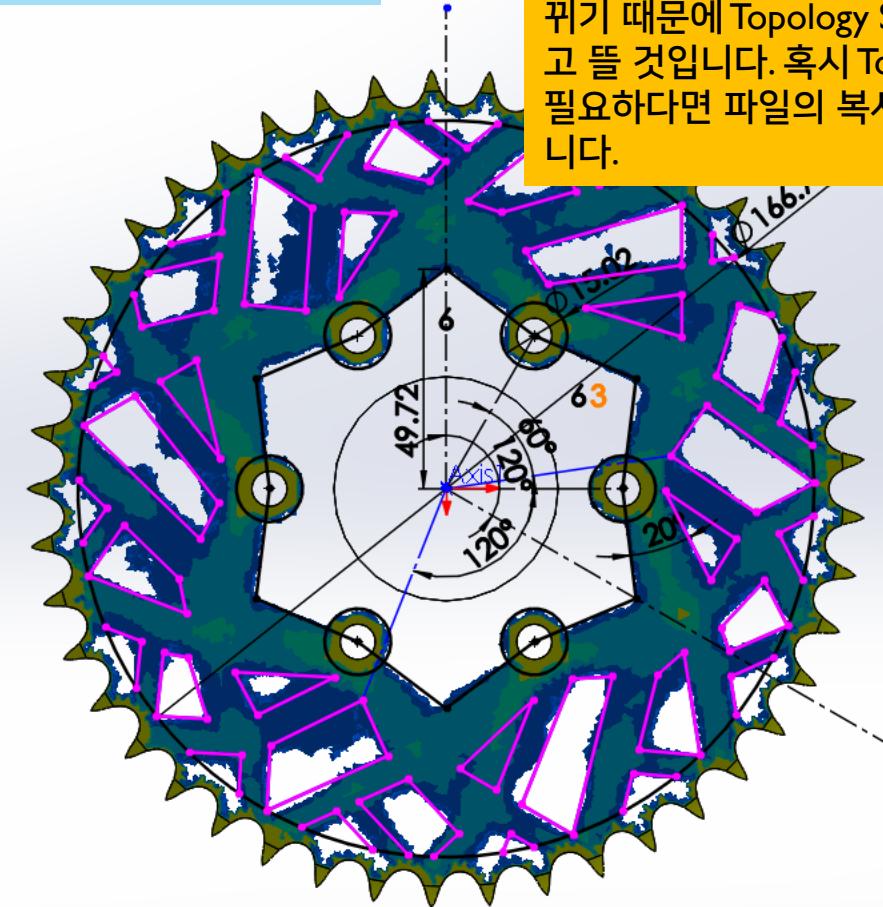
23. 좌측에 뜬 창에서 Material Mass plot을 선택합니다. 선택을 하면 모델에 시뮬레이션 결과가 입혀지는 것을 확인할 수 있습니다.

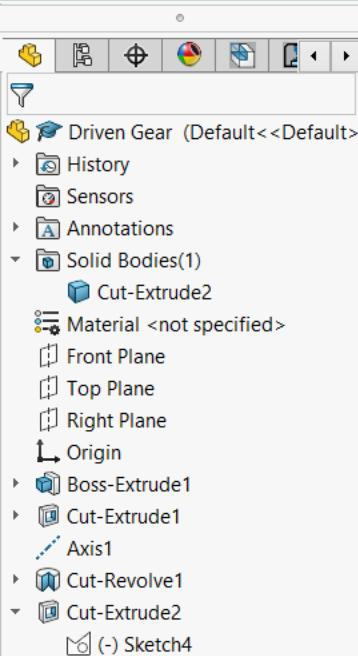
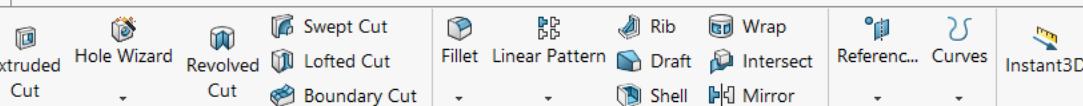
주의: 만약 Studies and Results에 아무것도 표시되지 않는다면 Topology study가 제대로 실행되지 못한 것이니 시뮬레이션을 다시 돌려주셔야 합니다.



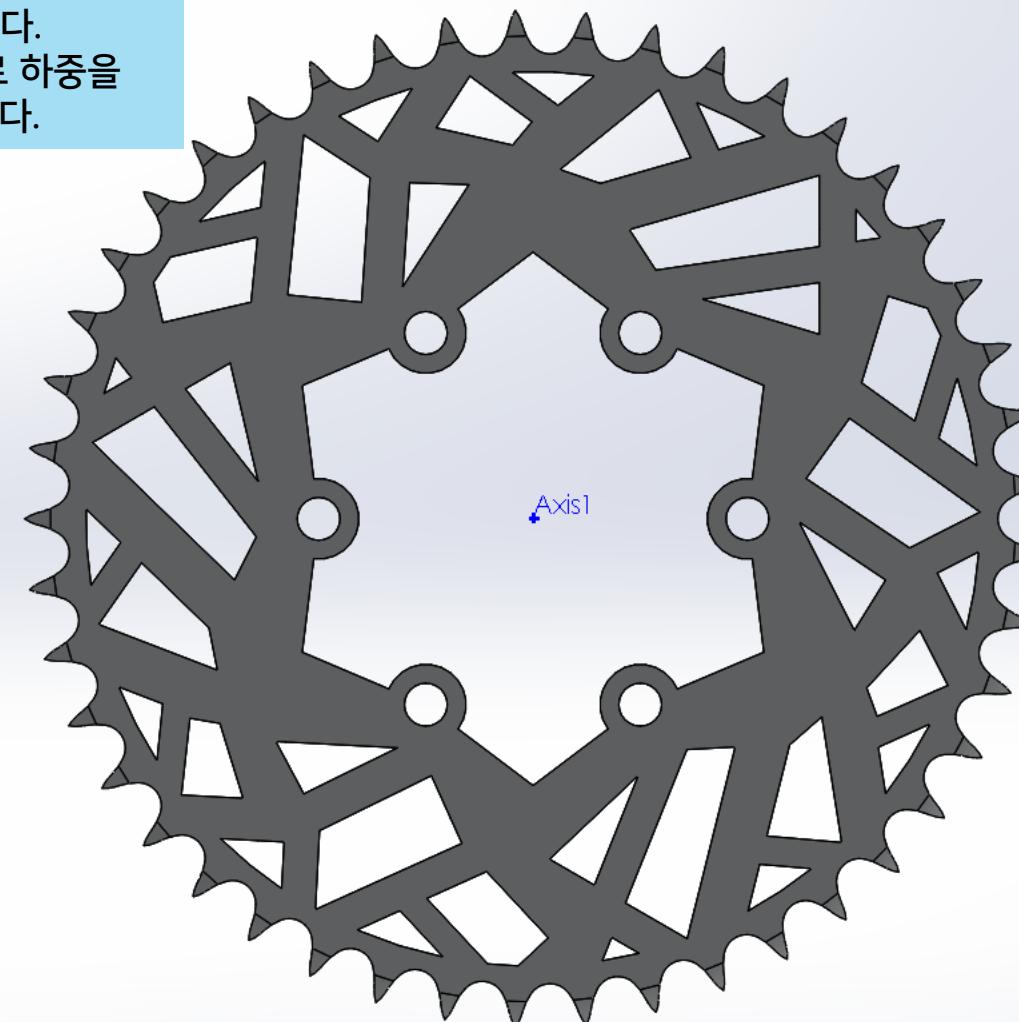
24. 시뮬레이션 결과대로 모델에 구멍을 내줍니다.

주의: 모델에 구멍을 낸 다음에는 모델의 형상이 바뀌기 때문에 Topology Study의 결과가 out of date라고 뜰 것입니다. 혹시 Topology Study의 결과가 계속 필요하다면 파일의 복사본을 생성하는 것을 권장합니다.





25. 최적화된 기어 모델입니다.
이제 이 기어 모델이 실제로 하중을
버틸 수 있는지 확인해봅시다.



3. Stress Simulation

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New Study Run This Study Offloaded Simulation Manage Network

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Study

Message

Study stresses, displacements, strains and factor of safety for components with linear material

Name Static 1

General Simulation

Static Use 2D Simplification Frequency

Design Insight

Topology Study Design Study

Advanced Simulation

Thermal Buckling Fatigue Nonlinear Linear Dynamic

Specialized Simulation

Submodeling Drop Test

26. 시뮬레이션 탭에서 Static Study를 선택합니다.

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Driven Gear (Default<<Default>>)

- History
- Sensors
- Annotations
- Solid Bodies(1)
 - Cut-Extrude2
- Material <not specified>
 - Front Plane
 - Top Plane
 - Right Plane
 - Origin
- Boss-Extrude1
- Cut-Extrude1
 - Axis1
- Cut-Revolve1
- Cut-Extrude2
 - (-) Sketch4

Axis1

주의: 2D Simplification 옵션은 모델을 2D로 근사하여 해석하여 줍니다.
모델이 평면적일 경우 선택하면 꽤 정확도가 높은 결과를 더 짧은 시간 내에 얻을 수 있습니다.
다만 추후 모델을 사용하여 Fatigue Stress 해석을 하기 위해서는 3D Static Study 결과가 필요합니다.

Model 3D Views Motion Study 1 Topology Study 1

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MMGS

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New Study Apply Simulation Fixtures Advisor External Loads Advisor Connections Advisor Shell Manager Run This Study Results Advisor Deformed Result Compare Results Design Insight Report Include Image for Report Offloaded Simulation Manage Network

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Material Evaluator

Static 1 (2D Simplification)

Study Type: Plane stress, Plane strain, Axi-symmetric

Section Definition: Section plane: Front Plane, Section depth: 0.00mm, Show preview

Front Plane, Axis1

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Subscription Services: Subscription Services

27. 2D Simplification을 선택한 경우 Plane stress, Plane strain, Axisymmetric 옵션을 선택하게 됩니다.

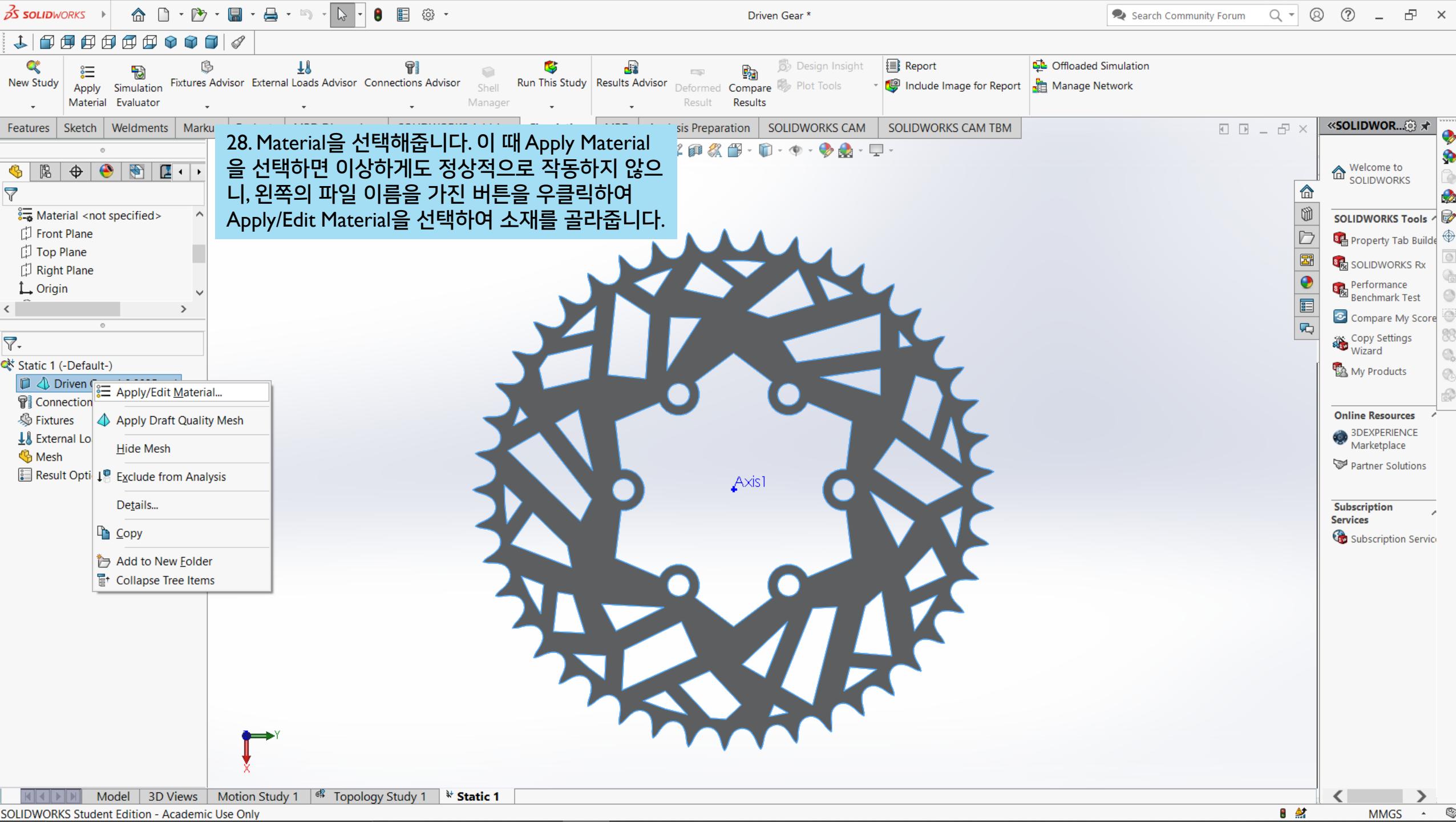
Plane stress는 z방향으로 가해지는 힘이 없다고 가정하고 해석합니다.

Plane strain은 z방향으로의 deformation이 없다고 가정하고 해석합니다.

Axisymmetric은 축대칭인 물체에 축대칭인 힘이 가해질 때 단면만을 가져와 해석하는 기법입니다.

본 자료에서는 z방향으로 가해지는 힘이 존재하지 않으므로 Plane stress를 선택했습니다.

해석할 모델의 단면을 선택해줍니다. 혹시 원하는 단면을 지나는 plane이 존재하지 않는다면 insert – reference geometry – plane 을 선택하여 원하는 plane을 정의해줍니다.



SOLIDWORKS Driven Gear *

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New Study Apply Simulation Fixtures Advisor External Loads Advisor Connections Advisor Shell Manager Run This Study Results Advisor Deformed Result Compare Results Report Include Image for Report Offloaded Simulation Manage Network

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Fixture Example

Material <not specified>
Front Plane
Top Plane
Right Plane
Origin

Standard (Fixed Geometry)
Fixed Geometry
Roller/Slider
Fixed Hinge
Edge<2>
Edge<3>
Edge<4>
Edge<5>
Edge<6>

Advanced

Symbol Settings

29. Fixture과 Load를 가해줍니다.
(자세한 과정은 Topology Study와 같으므로 생략하겠습니다)

Driven Gear * Model 3D Views Motion Study 1 Topology Study 1 Static 1 Total Length: 125.66370614mm Editing Part MMGS

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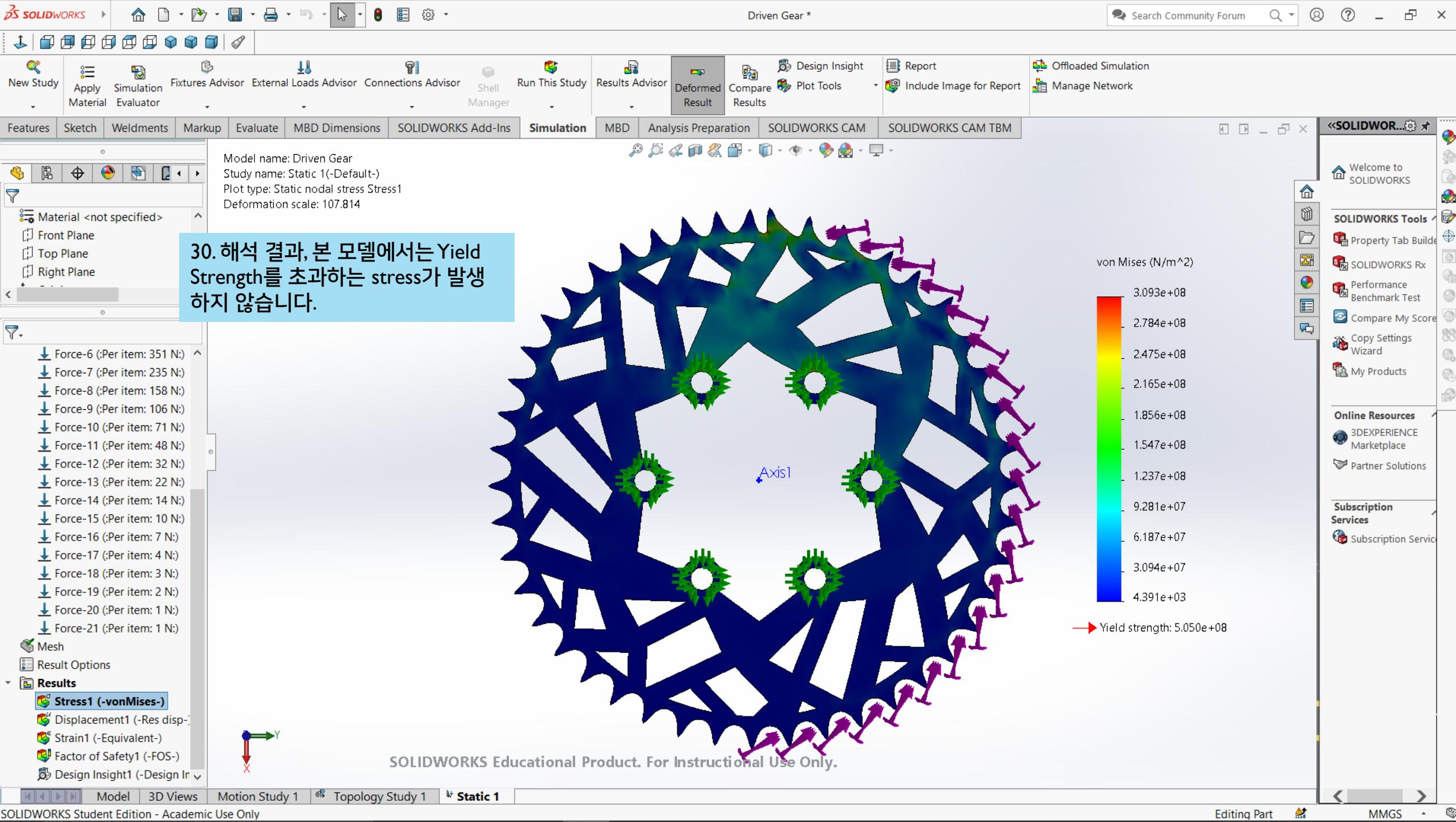
Online Resources

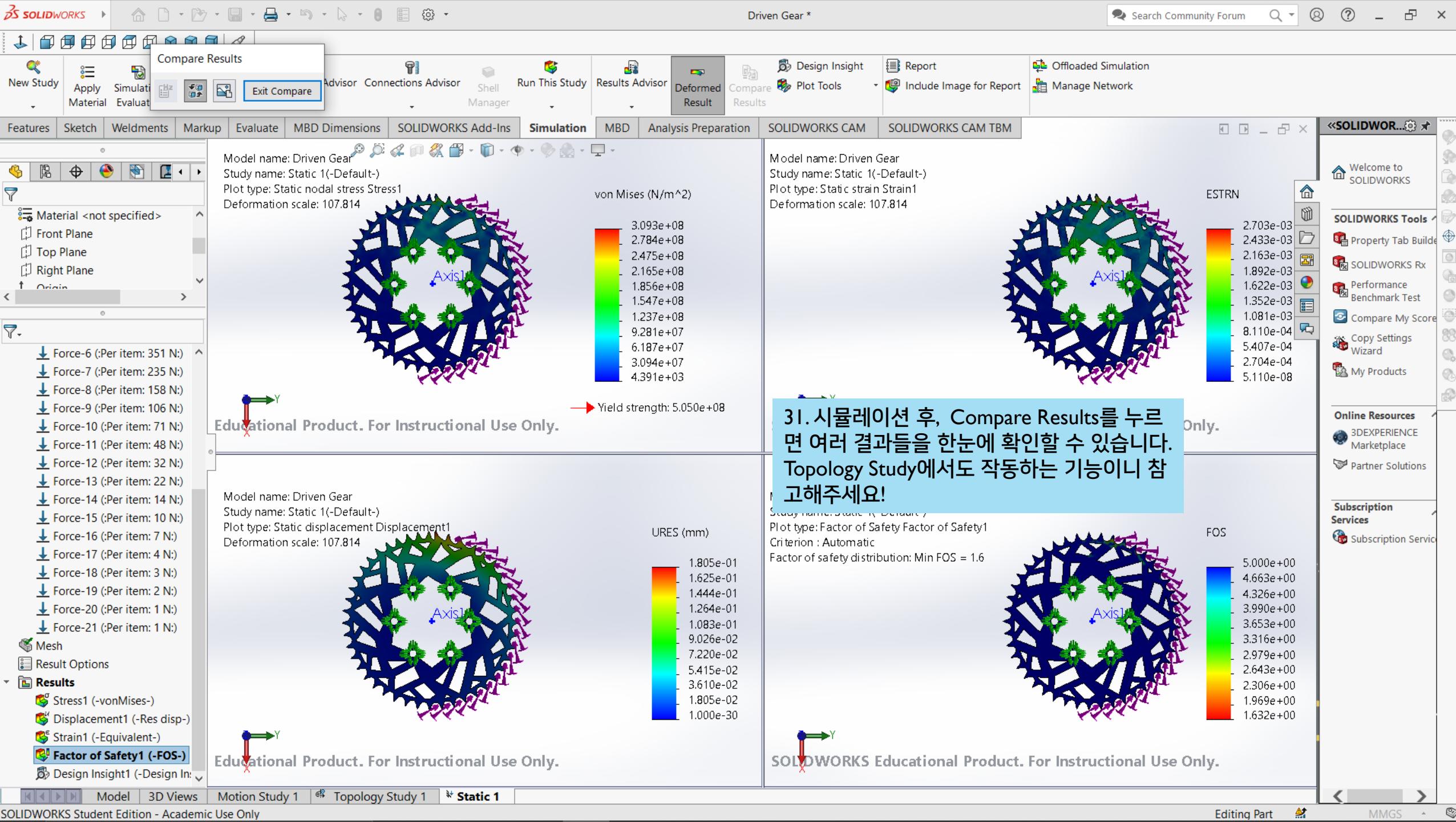
3DEXPERIENCE Marketplace

Partner Solutions

Subscription Services

Subscription Services





자동 저장 (●) 표 도구 Driven Gear_210117_백채원-Static 2-2 - 이 PC에 저장됨 백채원

파일 홈 삽입 디자인 레이아웃 참조 편지 검토 보기 도움말 디자인 레이아웃 검색

바탕(본문 한글) 11 가 가 가 내친 가
가 가 가 커나 x₂ 가 가 가
글꼴 글꼴 단락 스타일 편집

찾기 바꾸기 선택 편집

클립보드 복사 복사 서식 복사 받아 쓰기 음성

32. 우측 상단의 Report 버튼을 누르면 해석 결과에 대한 보고서를 자동으로 얻을 수 있습니다.

Simulation of Driven Gear_210117_백채원

Date: Sunday, January 17, 2021
Designer: Cheewon Baek
Study name: Static 2nd
Analysis type: Static

Table of Contents

- Description 1
- Assumptions 2
- Model Information 2
- Study Properties 3
- Units 4
- Material Properties 4
- Loads and Fixtures 5
- Connector Definitions 8
- Contact Information 8
- Mesh Information 9
- Sensor Details 10
- Resultant Forces 11
- Beams 11
- Study Results 12
- Conclusion 17

Description
The topology was generated from the topology study under following condition:
Six bolt holes fixed
2000N forces applied to 15 teeth axisymmetrically

Model Information

Model name: Driven Gear_210117_백채원
Current Configuration: Default

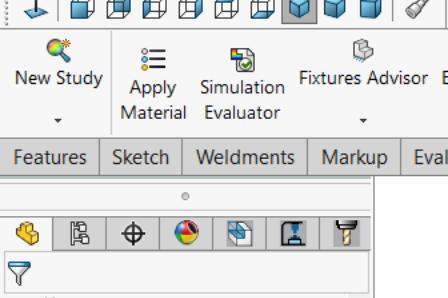
Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Cut-Extrude2	Solid Body	Mass: 0.289022 kg Volume: 0.000102855 m ³ Density: 2,810 kg/m ³ Weight: 2.83242 N	D:\학업\서울대대학교민두유\2021 대회\Powertrain\2021_1_16_기어설계\Driven Gear_210117_백채원.SLDprt

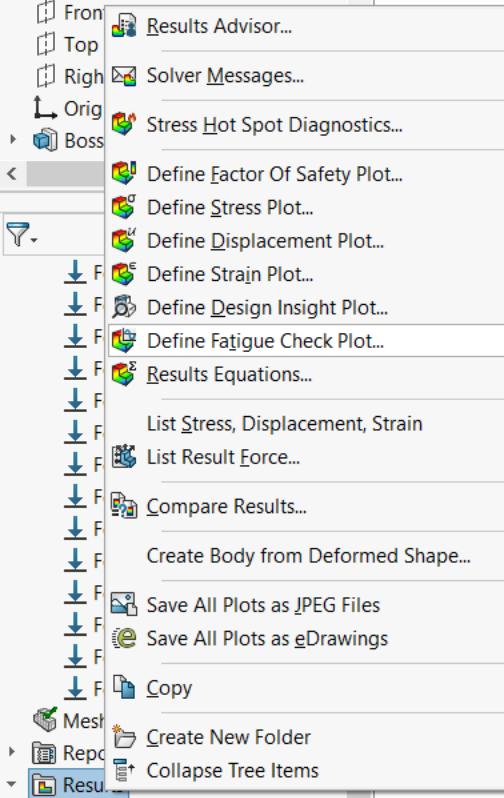
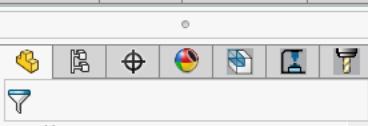
Study Properties

Study name:	Static 2 nd
Analysis type:	Static
Mesh type:	Solid Mesh
Thermal Effect:	On
Thermal option:	Include temperature loads
Zero strain temperature:	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation:	Off
Solver type:	FIEPLUS
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options:	Automatic
Large displacement:	Off
Compute free body forces:	On
Friction:	Off
Use Adaptive Method:	Off
Result folder:	SOLIDWORKS document (D:\학업\서울대대학교민두유\2021 대회\Powertrain\2021_1_16_기어설계)

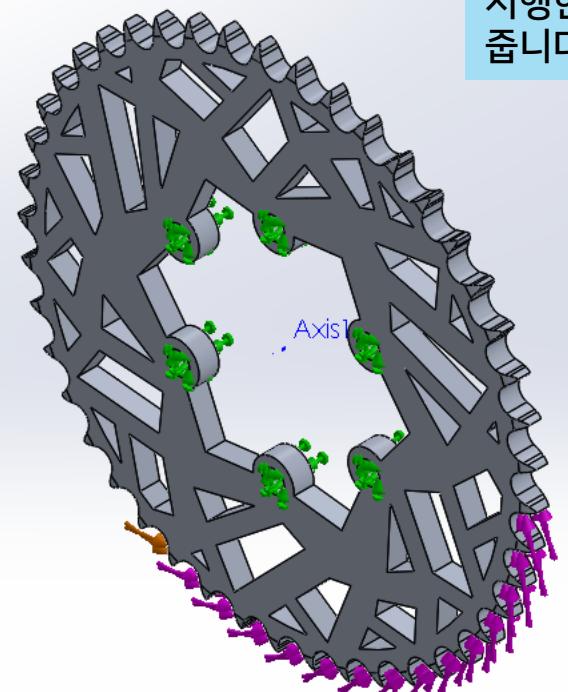
4. Fatigue Stress



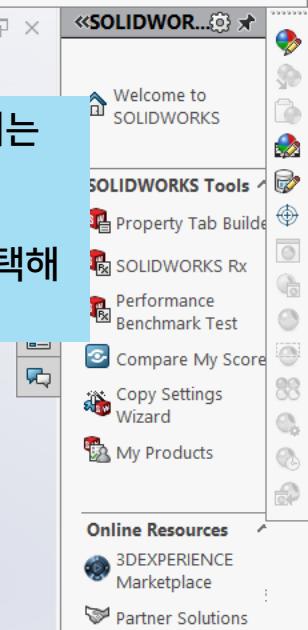
Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM



#Isometric

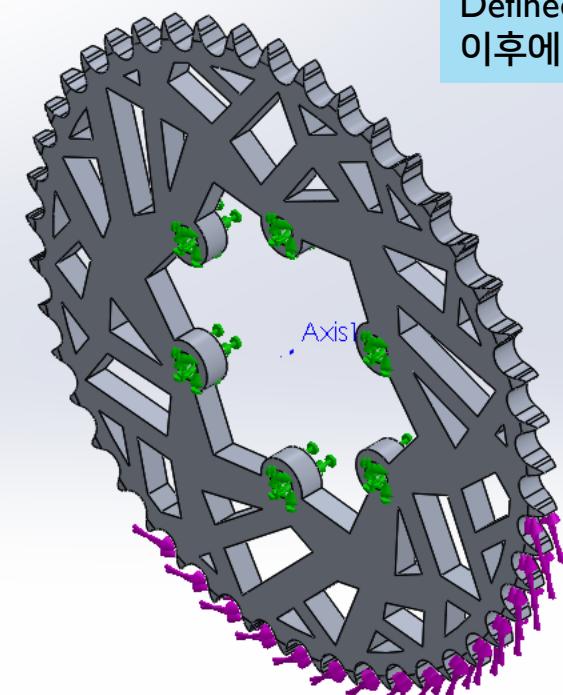
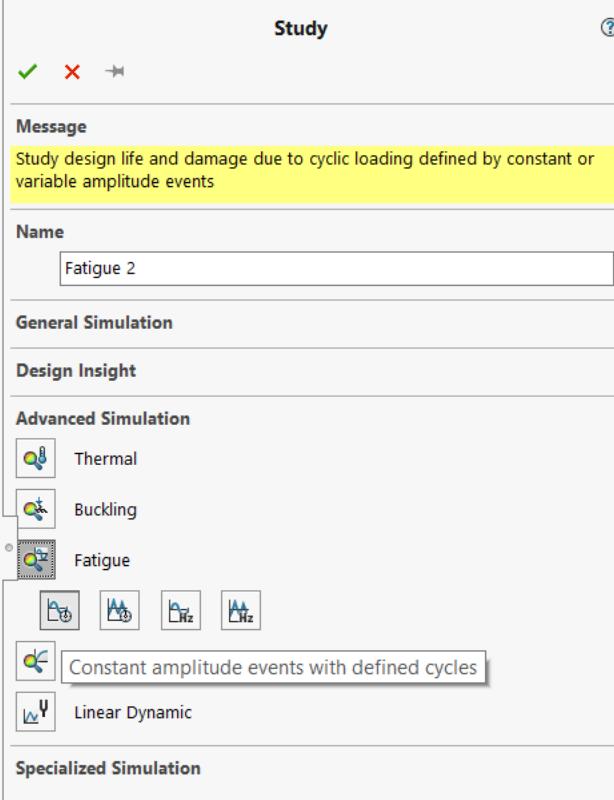
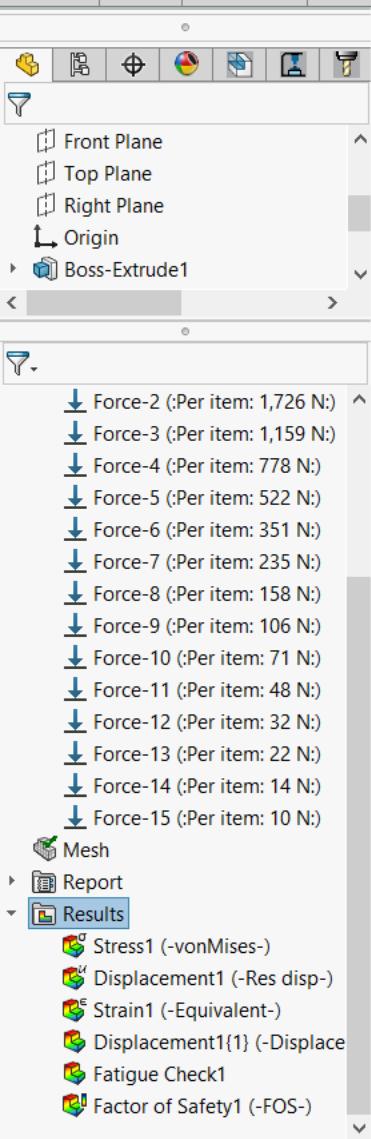


33. Fatigue stress(피로 응력) 해석을 위해서는
하나 이상의 3D static study 또는 Dynamic
study를 시행해주어야 합니다.
시행한 Study에서 Fatigue Check Plot을 선택해
줍니다.

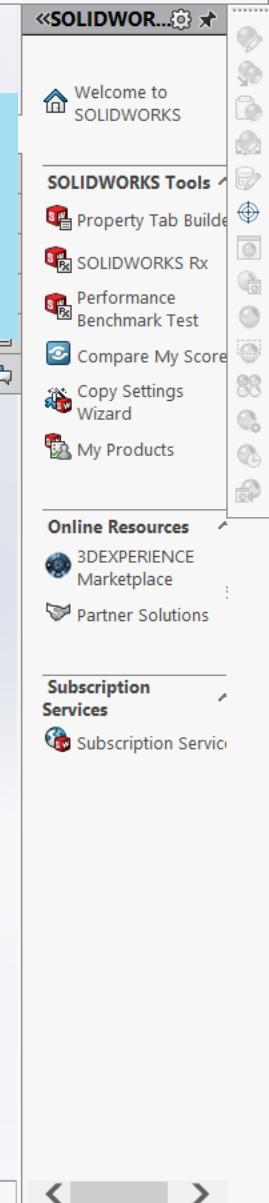




Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM



34. New study에서 Fatigue study를 선택해줍니다.
Fatigue study 아래에 여러 가지 옵션이 나오는데, 일단 Constant Amplitude Events with Defined Cycles를 선택해줍니다.(이외의 옵션은 이후에 다룰 예정입니다)



SOLIDWORKS > Home > Sketch > Weldments > Markup > Evaluate > MBD Dimensions > SOLIDWORKS Add-Ins > Simulation > MBD > Analysis Preparation > SOLIDWORKS CAM > SOLIDWORKS CAM TBM

Driven Gear_210117_백채원 *

Search Community Forum

New Study Simulation Run This Study Results Advisor Deformed Result Compare Results Report Include Image for Report Fatigue

Features Sketch Weldments Markup Evaluate MBD Dimensions SOLIDWORKS Add-Ins Simulation MBD Analysis Preparation SOLIDWORKS CAM SOLIDWORKS CAM TBM

Front Plane Top Plane Right Plane Origin Boss-Extrude1 Cut-Extrude1

Fatigue 2 (-Default-) Loading (-Constant-) Result Options

Add Event... Delete All Copy

Isometric

35. 좌측의 Loading 버튼을 우클릭한 다음, Add Event를 선택해줍니다.

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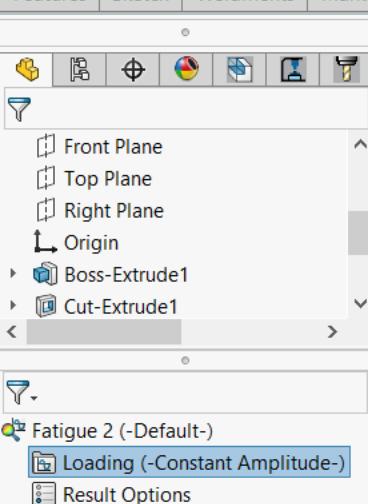
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Model 3D Views Motion Study 1 Topology Study 1 Static 1 Static 2 Fatigue 1 Fatigue 2

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MMGS



Add Event (Constant)

Load

1000

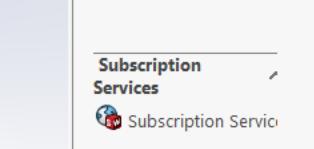
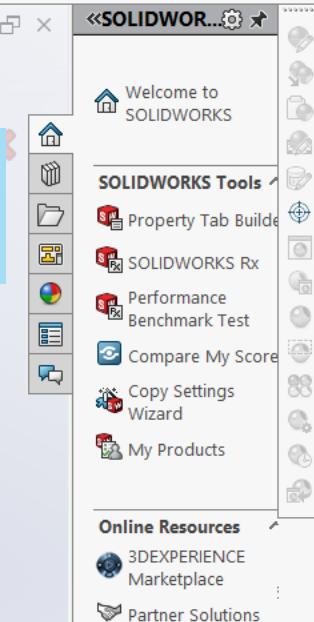
Fully Reversed (LR=-1)

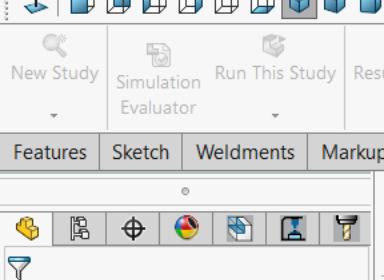
No.	Study	Scale	Step
1	Static 2	1	N/A

Study Association



36. 지금까지 수행한 Study들 중 Fatigue Study에 사용 가능한 Study 결과들이 아래에 표시되는 것을 확인할 수 있습니다.





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Front Plane

Top Plane

Right Plane

Origin

Boss-Extrude1

Cut-Extrude1

Fatigue 2 (-Default-)

Loading (-Constant Amplitude-)

Result Options

Isometric

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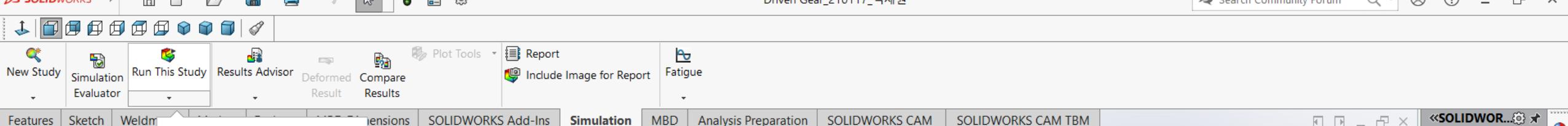
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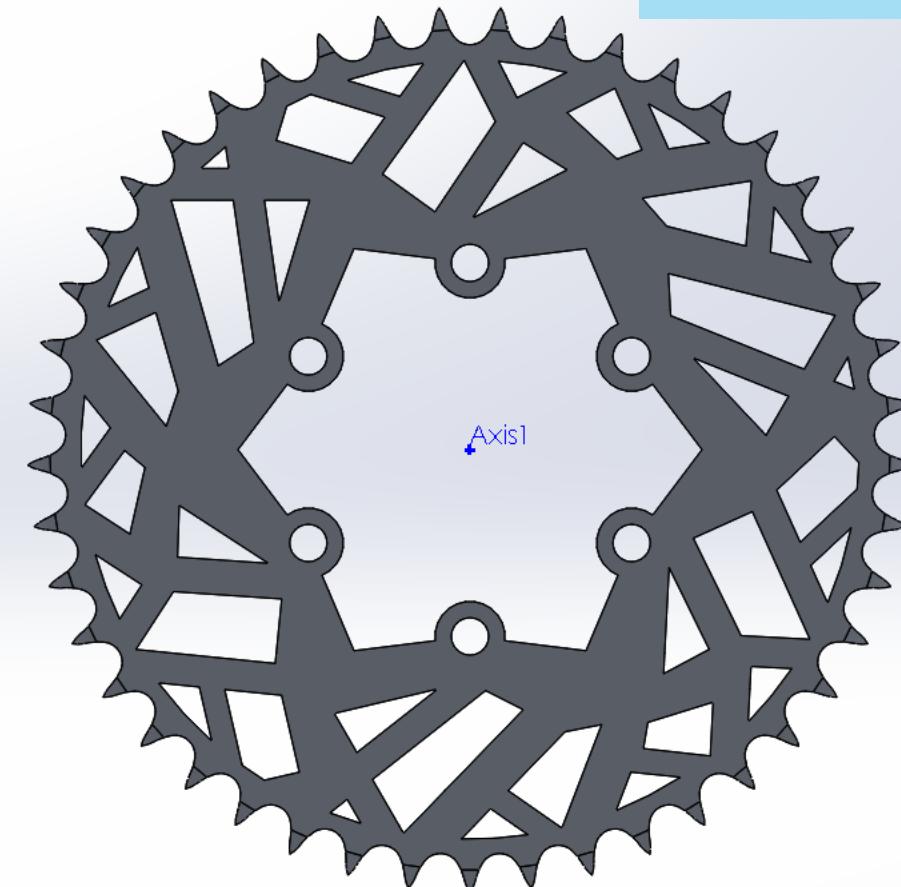
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Run This Study

Starts the solver for the active study.

38. Run this study를 눌러 Study를 실행합니다.



#Front

