

# Omni Directional Wheel Optic design



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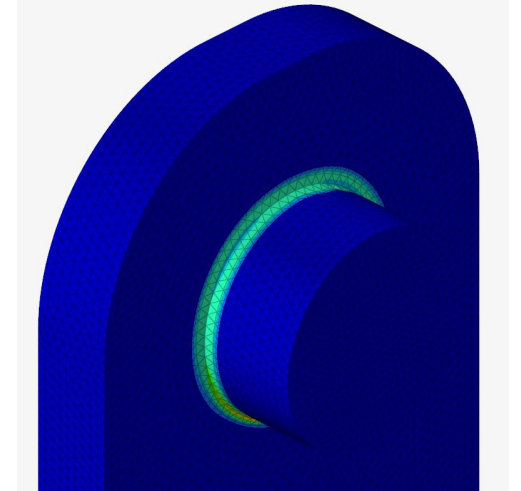
- 1 연구배경
- 2 Roller support free shape design
- 3 Wheel overall mass optimize

# \* Abstract

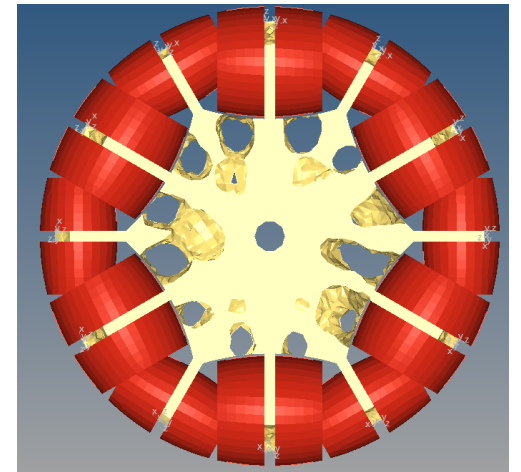
## Omni Wheel



#1 롤러 지지대  
형상 최적화



#2 롤러 제외  
중량 최소화



# #1. Info – What is Omni wheel



드라마 '선재를 업고 뛰어'  
등장 장면

## 새로운 형태의 전동 휠체어



카이로보틱스(Korea)



WHILL(Japan)



ROBOOTER(China)

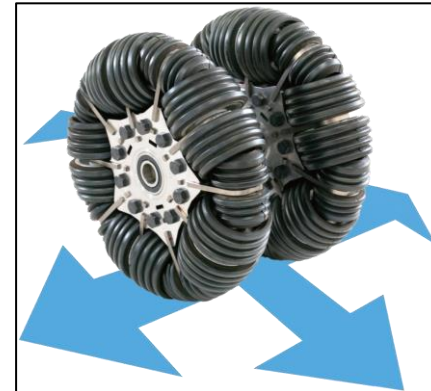
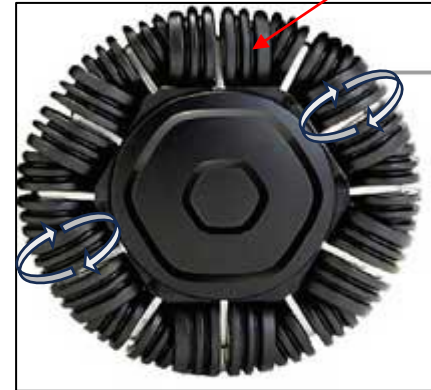
# #1. Info – What is Omni wheel

## # 핵심 부품

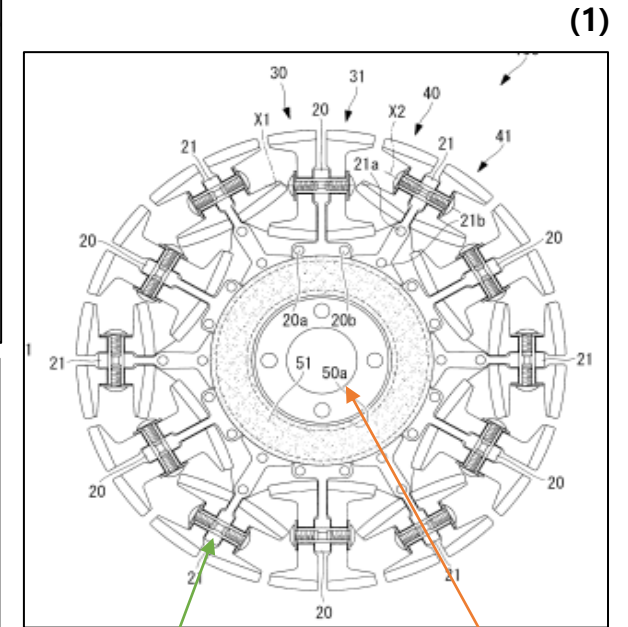
- 허브 → 차축과의 연결점
- 샤프트 → 롤러 고정을 위한 축
- 롤러 → 회전 및 방향 전환

## # 작동 방식 (휠체어 기준)

- 직진  
→ 일반 바퀴처럼 회전
- 방향 회전  
→ 후륜 속도 차이 + 롤러 회전



롤러



샤프트 + 지지대 허브

# #1. Info – Omni wheel movement

(2) [https://youtu.be/\\_ubcktAK0Cw?feature=shared](https://youtu.be/_ubcktAK0Cw?feature=shared)



(3) <https://whill.co.kr/modelc2>





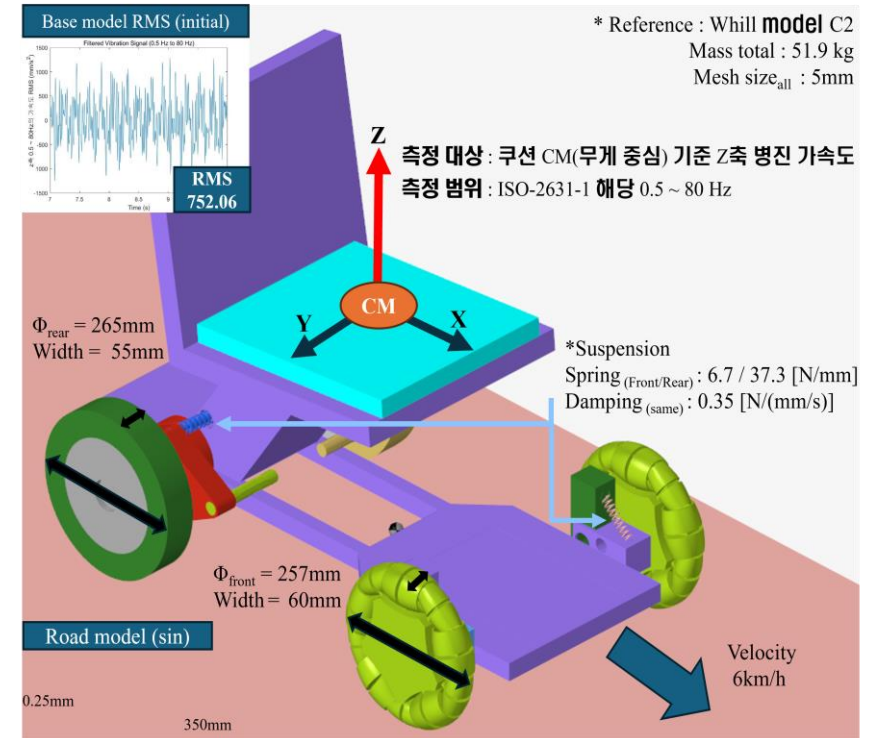
# #1. 연구 방향 선정

## # 진동 해석 진행 및 각종 문제점

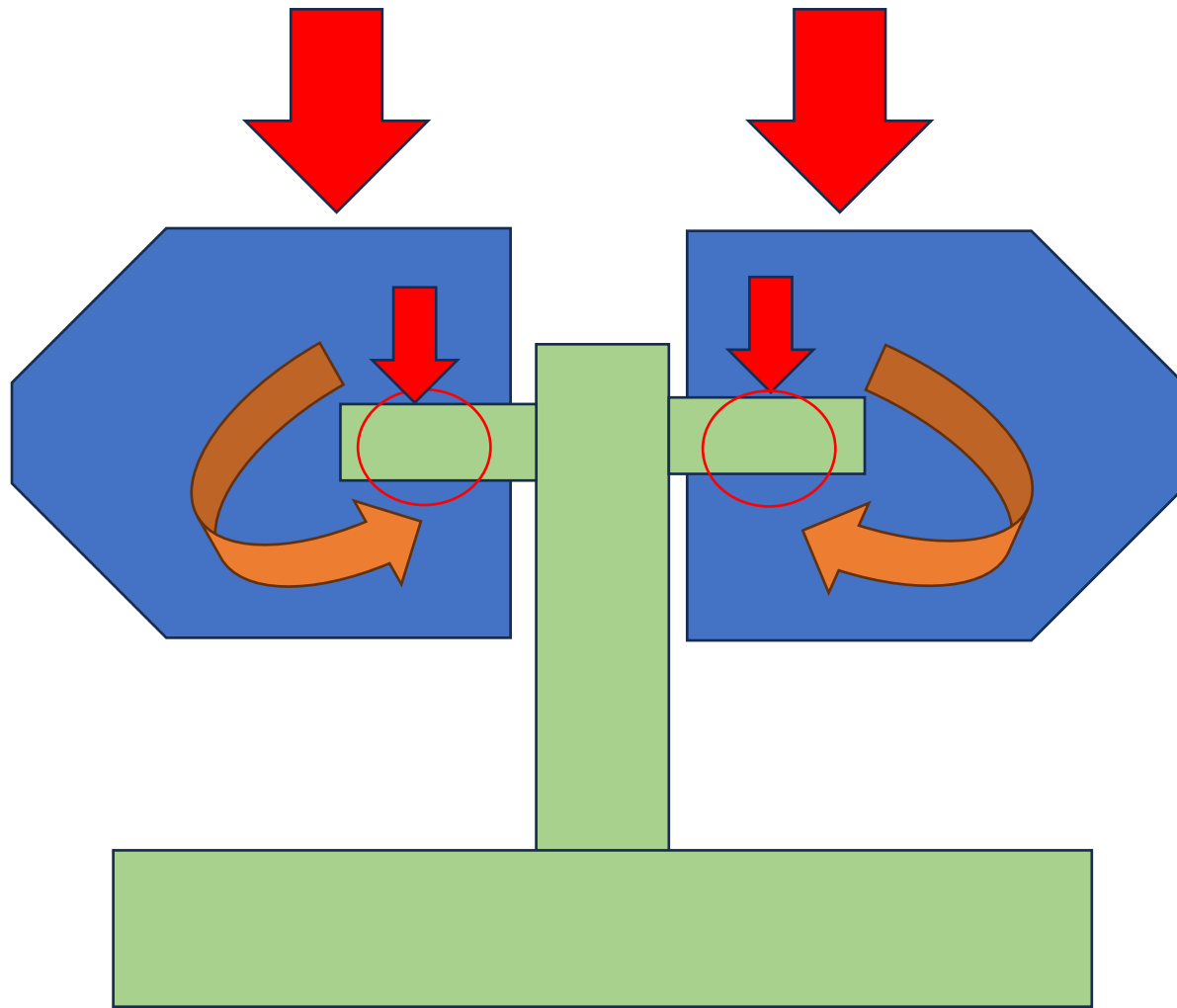
- 차체, 방석, 스프링 등 다양한 요소로 인한 복잡성  
→ 가정 등 고려할 부분이 많음
- 모델 규모에 비례한 mesh 생성 및 해석 진행 시간  
→ Case study로 인한 요구 해석 시간 증가



규모 + 주요 해석 부분 선정(조율) 필요



# #1. 연구 방향 선정



The sample illust of predictable effect  
by stress at roller support

## #휠체어 전진 시, 바퀴 작용 힘

- 지면으로 부터 받는 수직 항력
- 하중으로 인한 힘

→ 롤러 지지 부분에 힘 작용으로  
Bending 등의 변형 가능성



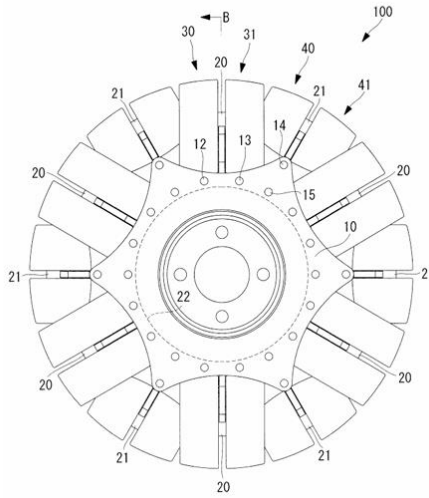
Z축 방향으로의 정적 하중에  
대한 해석 필요성



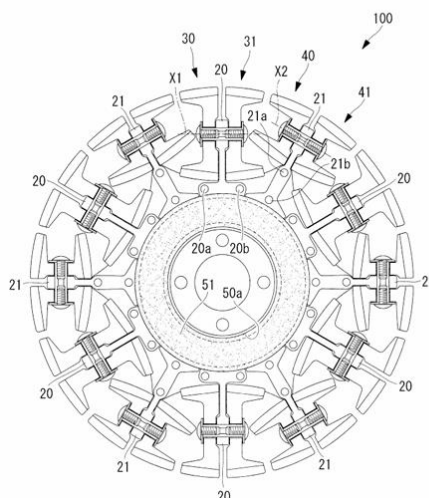
# #1. The base idea

**(1)**

【图 1】



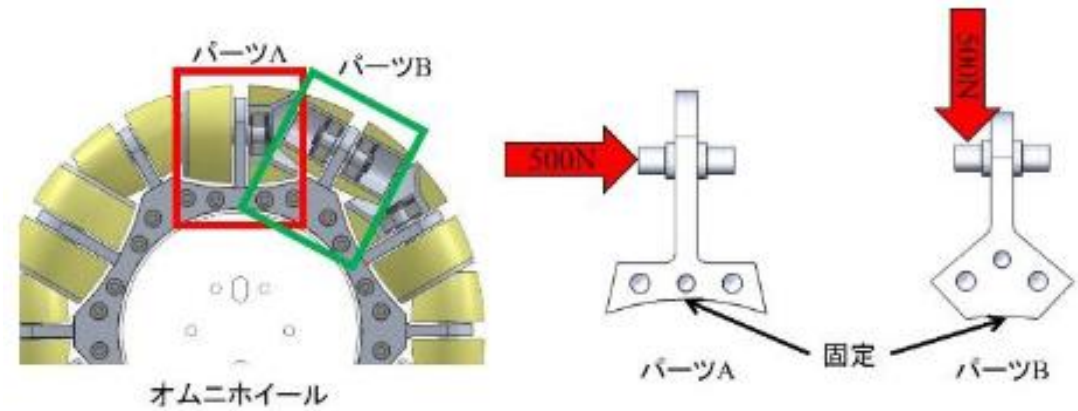
【図 2】



(a) Structural blueprint for Omni wheel

특허 형상을 바탕으로  
롤러 지지대 모델 제작

(4) 藤川知寿, & 王碩玉. (2018, November). インホイールモータ型オムニホイールの開発. In バイオメディカル・ファジィ・システム学会大会講演論文集 31 (pp. 5-8). バイオメディカル・ファジィ・システム学会.



(b)Roller support method  
In pre study

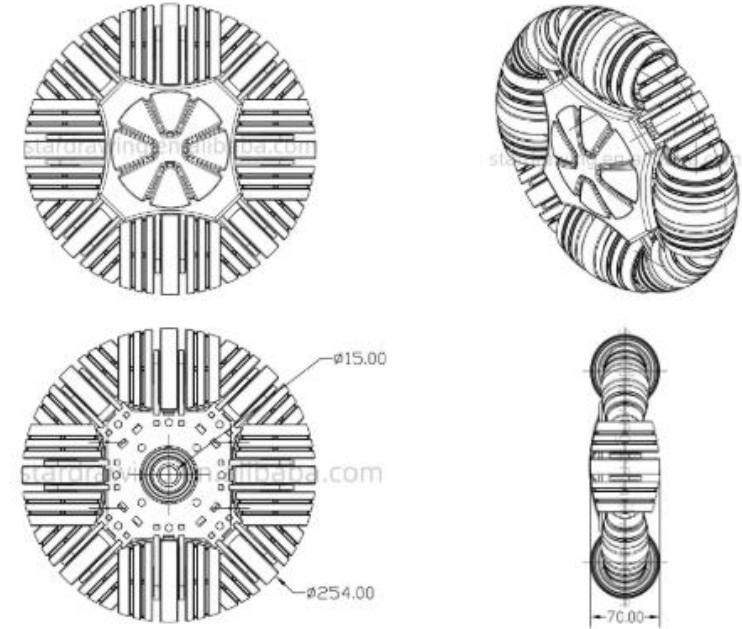
참고 논문<sup>4)</sup>에서 강도 해석  
형, 종 방향으로 하중 부여

# #1. Feasibility for analysis – Static load

(5)[https://www.alibaba.com/product-detail/S-S-254mm-omni-robot-directional\\_1600879114202.html?spm=a2700.7724857.0.0.13761270tCjYnN](https://www.alibaba.com/product-detail/S-S-254mm-omni-robot-directional_1600879114202.html?spm=a2700.7724857.0.0.13761270tCjYnN)

(6)<https://whill.inc/jp/model-c2>

Omni wheel type	Wheel diameter (mm)	Roller Diameter <sub>max</sub> (mm)	Dynamic load (kg)	Static load (kg)
Reference	254	70	100	120
Whill C2	257	62	-	-



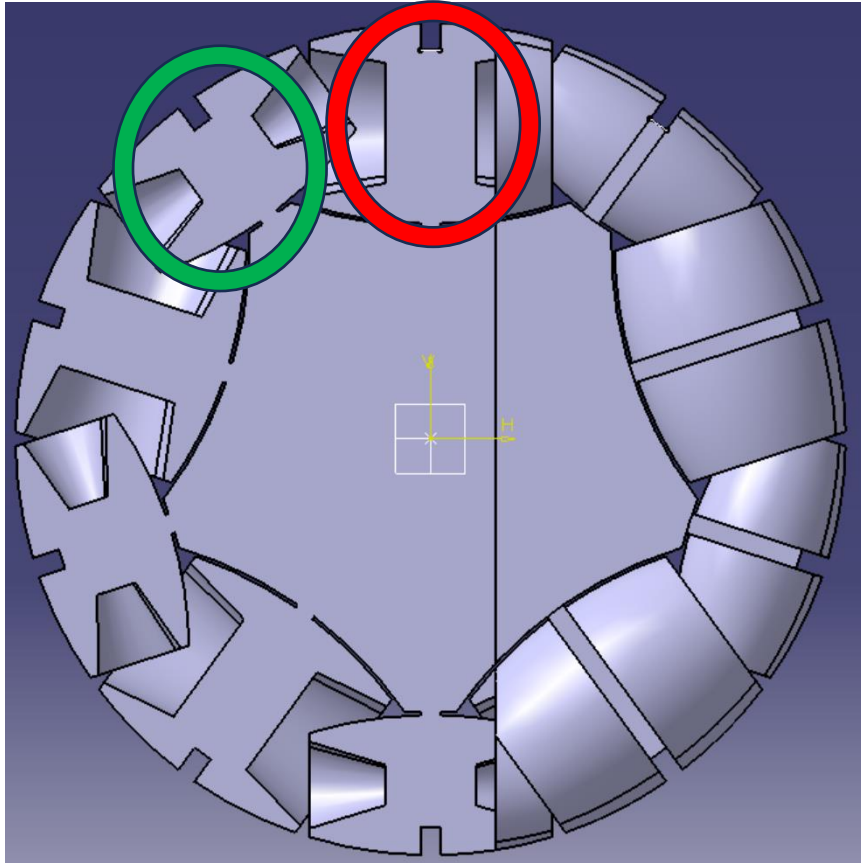
Wheel Diameter (MM)	Roller Diameter (MM)	Dynamic Load (KG)	Static Load (KG)
254	70	100	120

- 제작 모델과 비슷한 치수<sup>5)</sup>를 모델 탐색  
정적 하중 제한 : 120kg
- Whill C2 catalog<sup>6)</sup>에서는 하중 제한이 115kg
- 신뢰성을 높이기 위해 하중 제한을 200kg로 설정  
→ 2000N의 힘을 가하여 해석을 진행

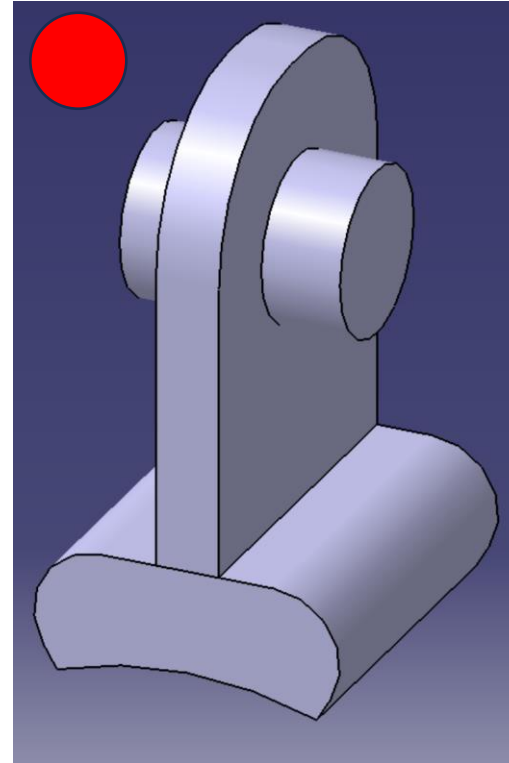
最大荷重	115kg
バッテリー	リチウムイオン 25.3V/10.6Ah
使用環境*2 (保管温度*3)	-15°C~40°C

Free Shape Optimize

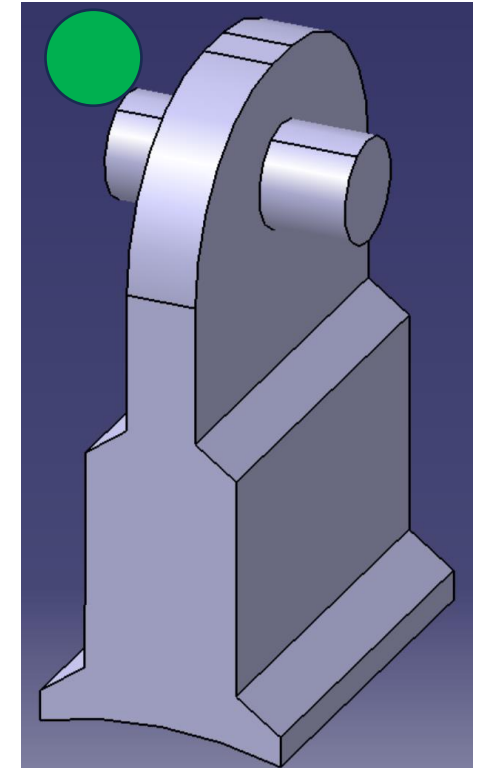
# #2-1 shape optimization – cad model



Section cut for  
Omni wheel



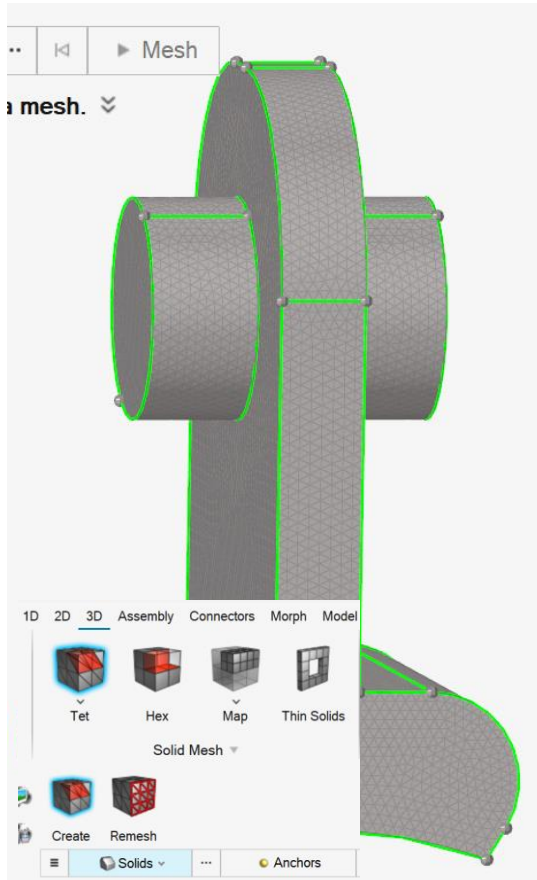
Support for  
Big roller



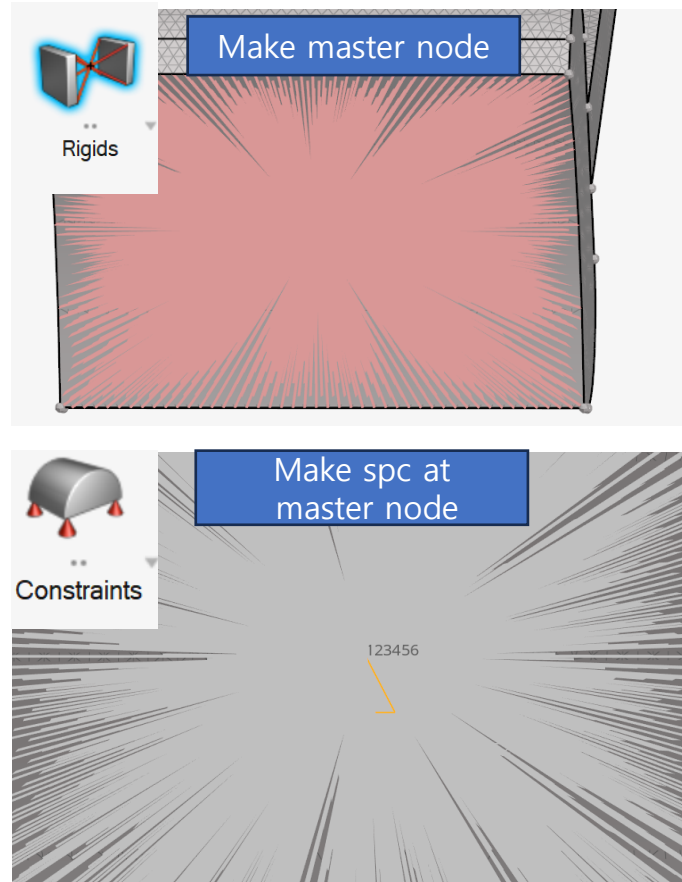
Support for  
small roller

# #2-1 Force analyze method

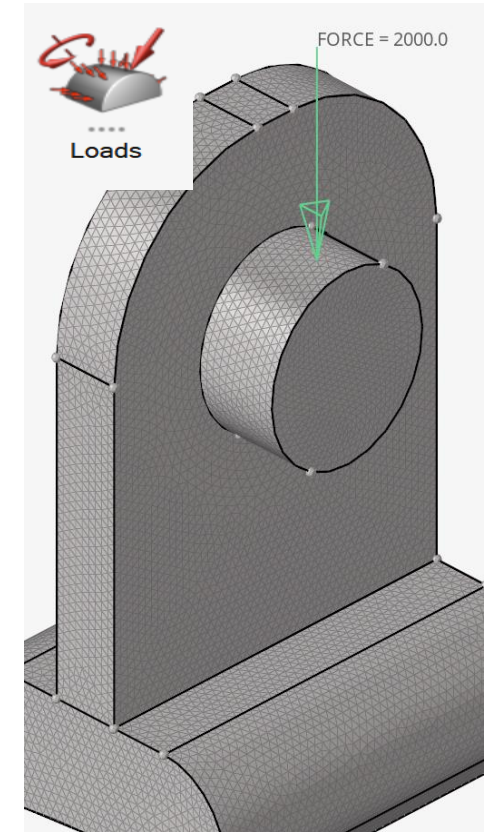
## #1 Mesh generate (1mm)



## #2 Create SPC

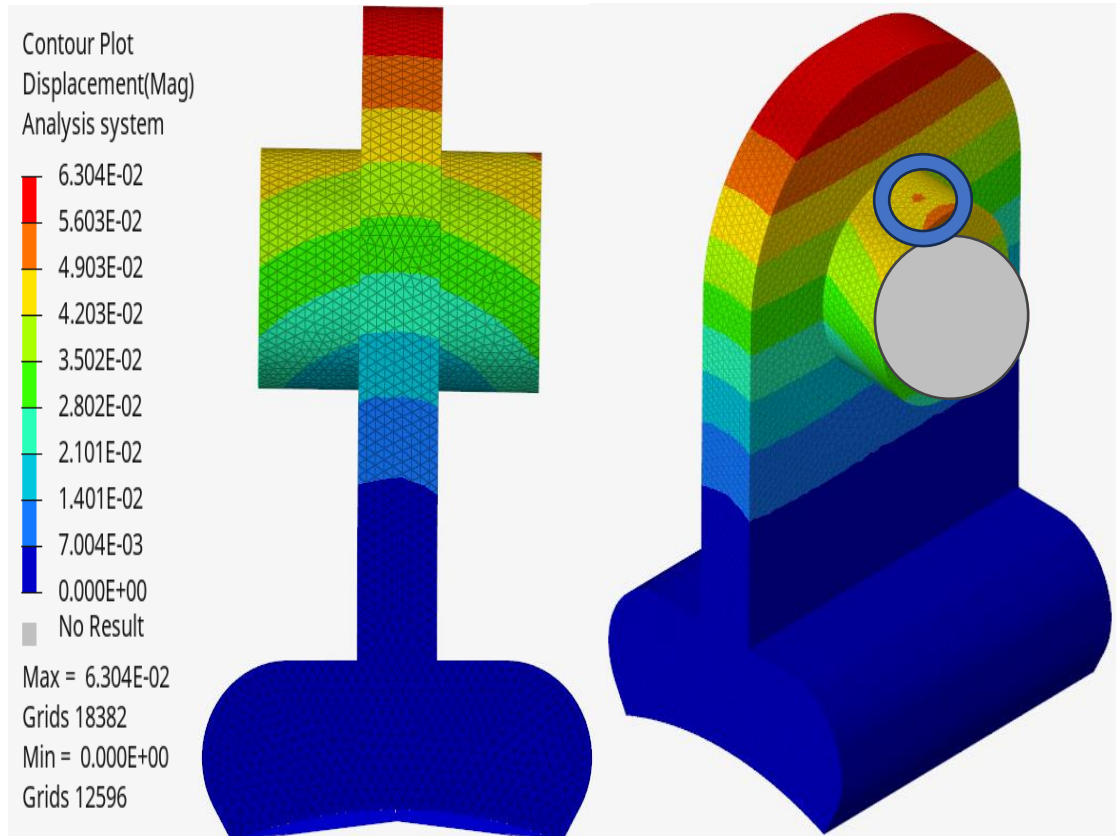


## #3 Create Z force





# #2-1 Force analyze result (base)



- Max displacement = 0.063 mm
  - Cylinder부분의 직경에 대해 고려
- 나사 체결의 경우 나사 직경 고려 필요



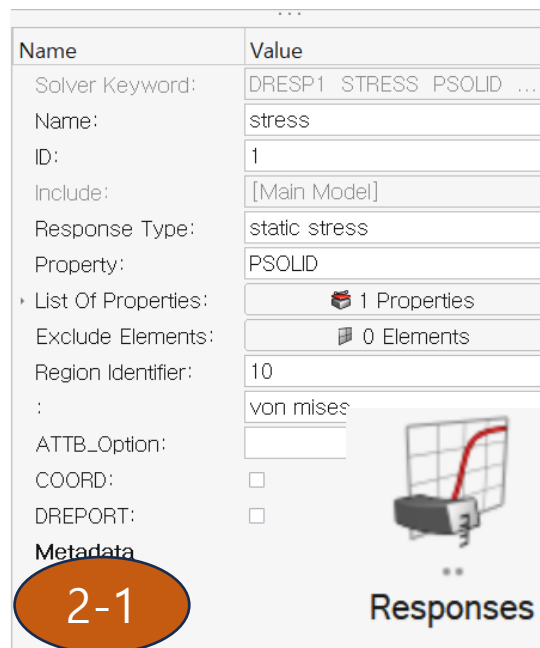
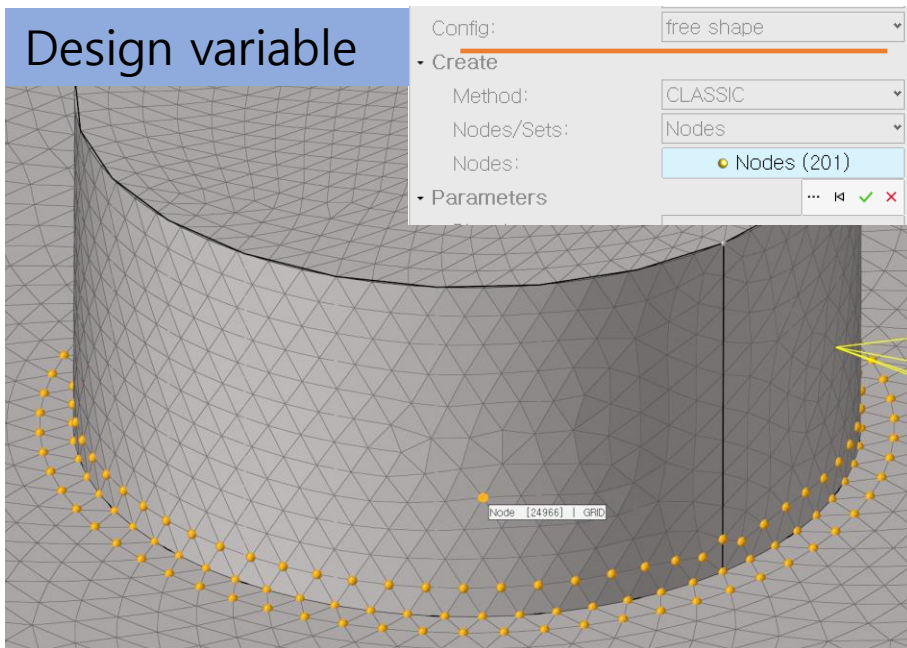
Cylinder와 지지대 체결 부분에  
대한 형상 최적화 진행



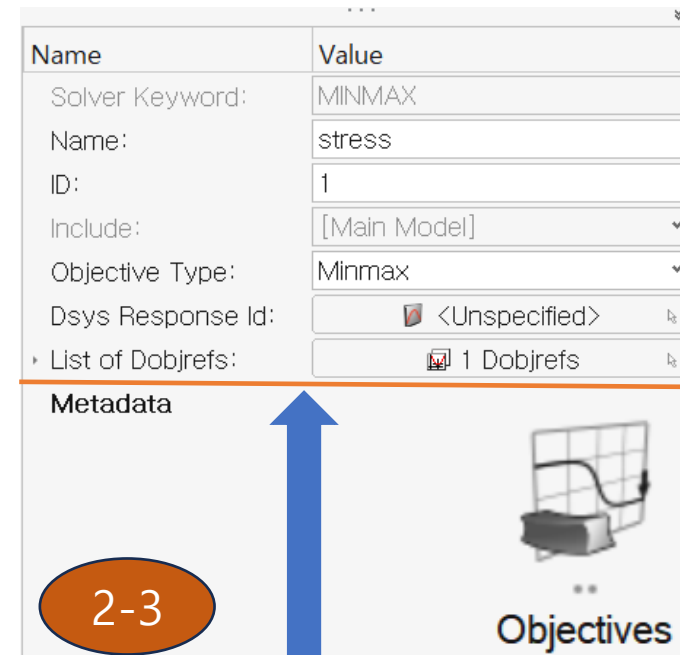
# #2-2 Free shape optimization method

1

## Design variable



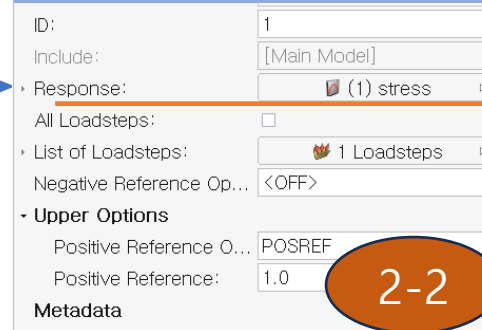
2-1



2-3

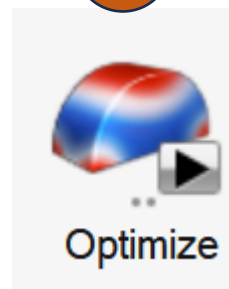
체결 부위 부근의 응력 집중을 고려해 static stress를 최소화하는 것으로 자유 형상 최적화 진행

## Design object references



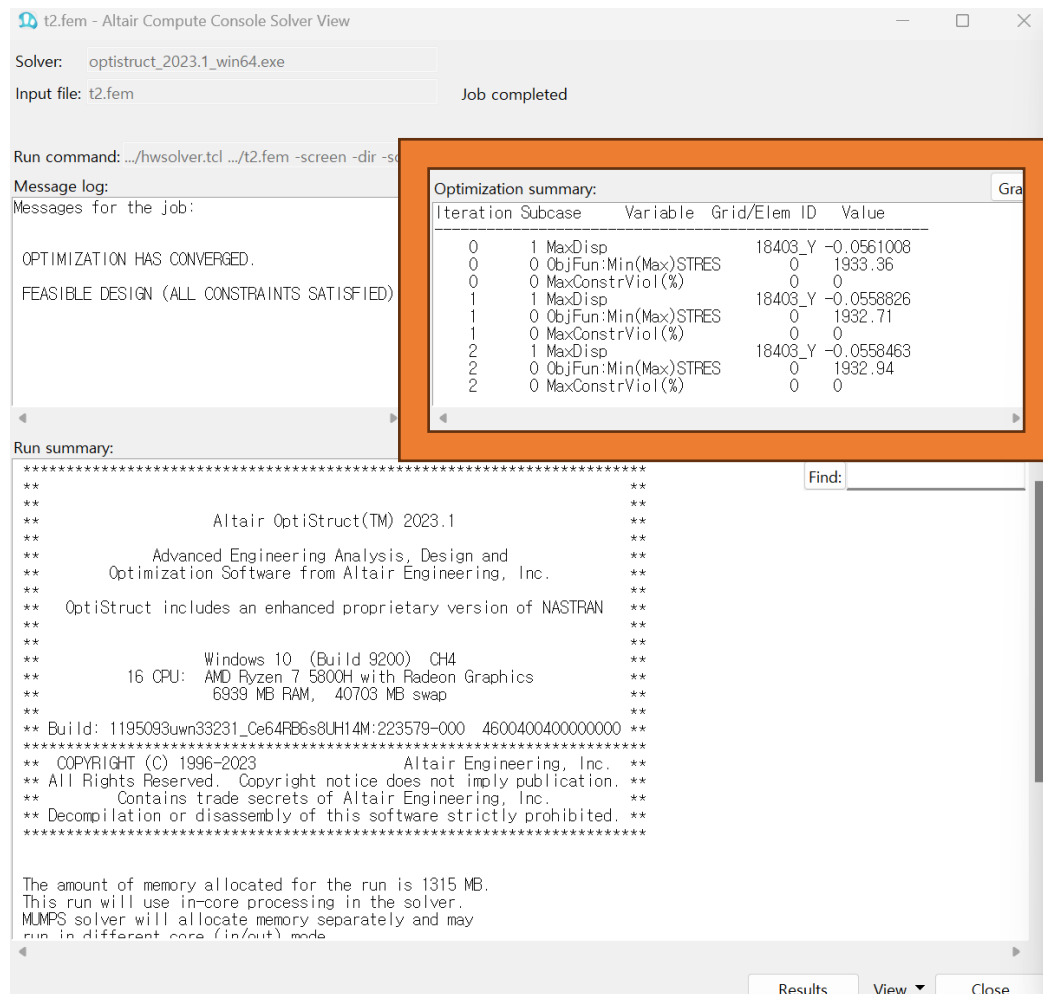
2-2

3



# #2-2 Methods to see Optimize summary HANYANG UNIVERSITY

## #1 Optistruct solver view



The screenshot shows the Altair Compute Console Solver View window. The 'Solver' is 'optistruct\_2023.1\_win64.exe' and the 'Input file' is 't2.fem'. The 'Run command' is '.../hwsolver.tcl .../t2.fem -screen -dir -s'. The 'Message log' shows 'OPTIMIZATION HAS CONVERGED.' and 'FEASIBLE DESIGN (ALL CONSTRAINTS SATISFIED)'. The 'Run summary' section is highlighted with an orange box, showing the following optimization summary:

Iteration	Subcase	Variable	Grid/Elem ID	Value
0	1	MaxDisp	18403_Y	-0.0561008
0	0	ObjFun:Min(Max)STRES	0	1933.36
0	0	MaxConstrViol(%)	0	0
1	1	MaxDisp	18403_Y	-0.0558826
1	0	ObjFun:Min(Max)STRES	0	1932.71
1	0	MaxConstrViol(%)	0	0
2	1	MaxDisp	18403_Y	-0.0558463
2	0	ObjFun:Min(Max)STRES	0	1932.94
2	0	MaxConstrViol(%)	0	0

The 'Run summary' section also displays the following information:

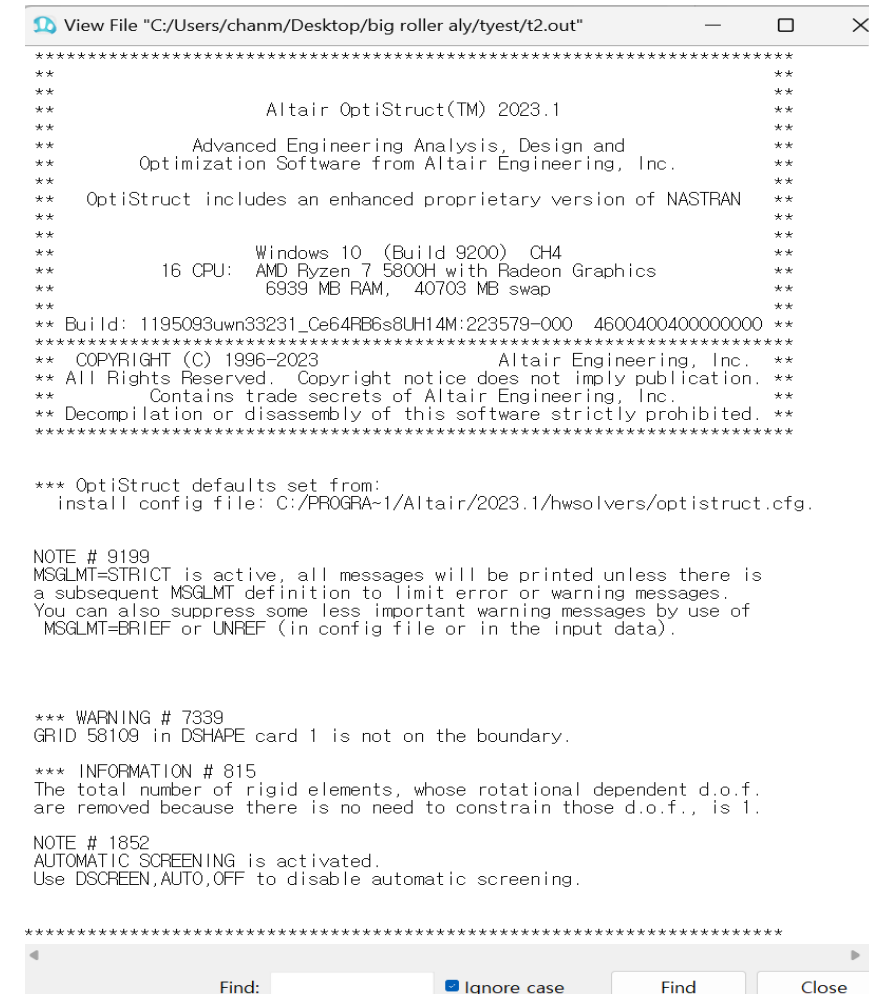
```
Altair OptiStruct(TM) 2023.1
Advanced Engineering Analysis, Design and
Optimization Software from Altair Engineering, Inc.
OptiStruct includes an enhanced proprietary version of NASTRAN

Windows 10 (Build 9200) CH4
16 CPU: AMD Ryzen 7 5800H with Radeon Graphics
6939 MB RAM, 40703 MB swap

Build: 1195093uwn33231_Ce64PB6s8UH14M:223579-000 4600400400000000
COPYRIGHT (C) 1996-2023 Altair Engineering, Inc.
All Rights Reserved. Copyright notice does not imply publication.
Contains trade secrets of Altair Engineering, Inc.
Decompilation or disassembly of this software strictly prohibited.
```

The amount of memory allocated for the run is 1315 MB. This run will use in-core processing in the solver. MUMPS solver will allocate memory separately and may run in different core (in/out) mode.

## #2 Solver output file



The screenshot shows the 'View File' window for the file 'C:/Users/chanm/Desktop/big roller aly/tyest/t2.out'. The content of the file is as follows:

```
Altair OptiStruct(TM) 2023.1
Advanced Engineering Analysis, Design and
Optimization Software from Altair Engineering, Inc.
OptiStruct includes an enhanced proprietary version of NASTRAN

Windows 10 (Build 9200) CH4
16 CPU: AMD Ryzen 7 5800H with Radeon Graphics
6939 MB RAM, 40703 MB swap

Build: 1195093uwn33231_Ce64PB6s8UH14M:223579-000 4600400400000000
COPYRIGHT (C) 1996-2023 Altair Engineering, Inc.
All Rights Reserved. Copyright notice does not imply publication.
Contains trade secrets of Altair Engineering, Inc.
Decompilation or disassembly of this software strictly prohibited.
```

\*\*\* OptiStruct defaults set from:  
install config file: C:/PROGRA~1/Altair/2023.1/hwsolvers/optistruct.cfg.

NOTE # 9199  
MSGLMT=STRICT is active, all messages will be printed unless there is a subsequent MSGLMT definition to limit error or warning messages. You can also suppress some less important warning messages by use of MSGLMT=BRIEF or UNREF (in config file or in the input data).

\*\*\* WARNING # 7339  
GRID 58109 in DSHAPE card 1 is not on the boundary.

\*\*\* INFORMATION # 815  
The total number of rigid elements, whose rotational dependent d.o.f. are removed because there is no need to constrain those d.o.f., is 1.

NOTE # 1852  
AUTOMATIC SCREENING is activated.  
Use DSCREEN,AUTO,OFF to disable automatic screening.

# #2-2 Select for the best Iteration case

ITERATION 1 **1**  
the 1st satisfied convergence ratio = 3.3767E-04

Objective Function (Min(Max) STRES) = 1.93271E+03 % change = -0.03  
Maximum Constraint Violation % = 0.00000E+00  
Volume = 4.88285E+04 Mass = 3.83303E-04

	<b>2</b>	<b>3</b>
Subcase	<u>Compliance</u>	Epsilon
1	2.318476E+01	7.462539E-13

Note : Epsilon = Residual Strain Energy Ratio.

**Example of each value  
from output file**

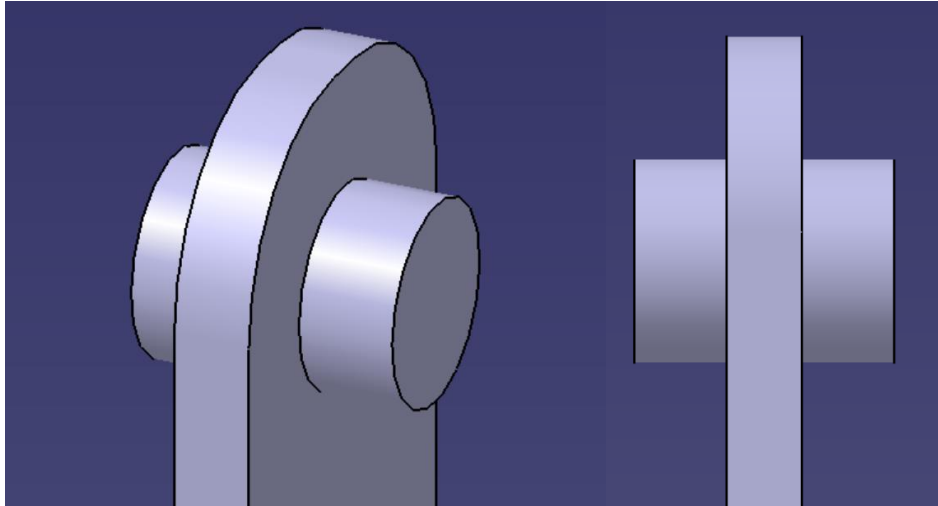
## # 각 중요 수치 (ALL: lower is better)

**#1. Convergence ratio** : 최적해 수렴도 및 해의 안정도  
일반적으로 1 이하의 경우 **수렴 속도**가 빠르다

**#2. compliance** : 변위 민감도 (변위 비율)  
작을수록 변형이 적다 = **높은 강성**

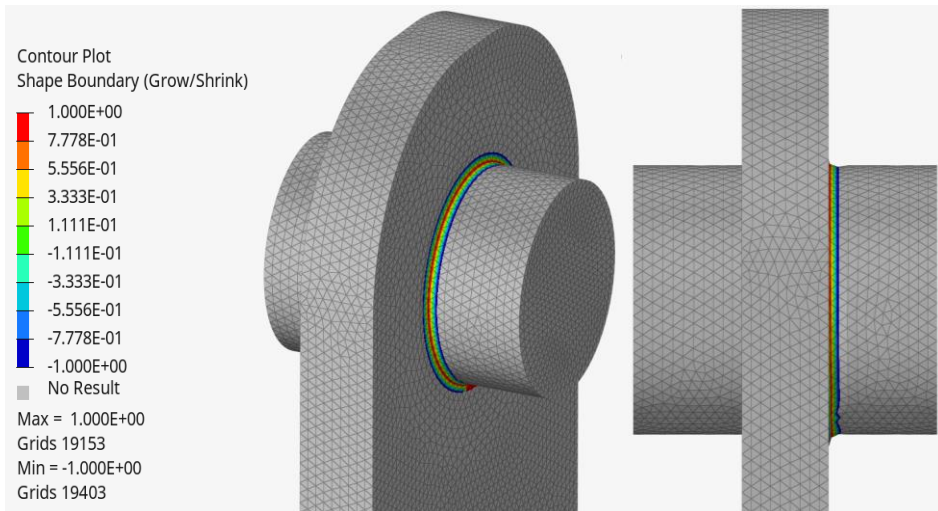
**#3. Epsilon** → 잔여 응력 비율  
작을수록 **복원**이 빠름, 영구 변형 가능성 **낮음**

# #2-2 Select for the best Iteration case



Base model view (isometric/front)

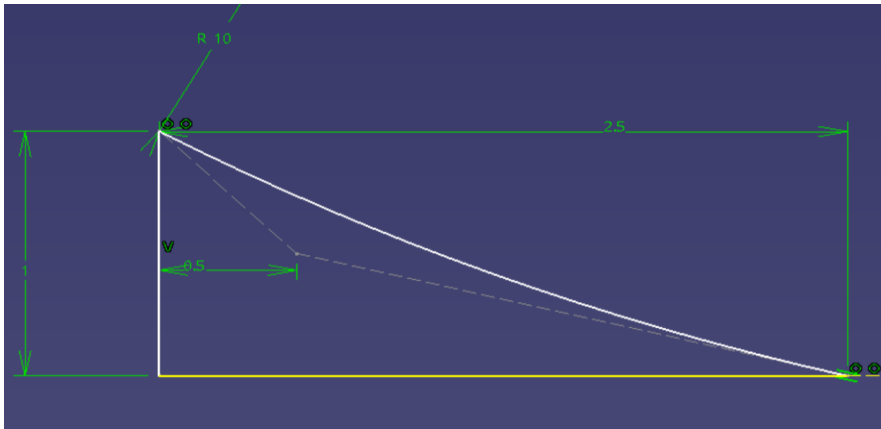
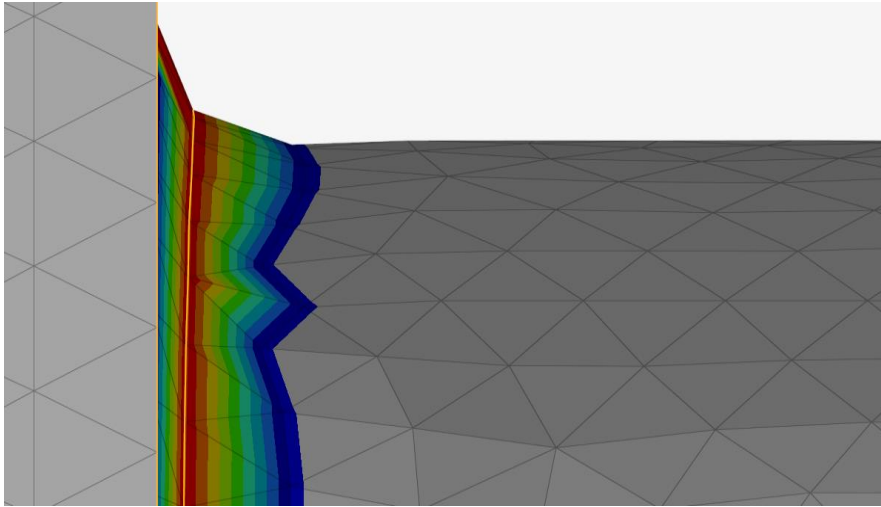
	Stress (Mpa)	Displacement (mm)	Compliance	Epsilon
Base case	1933.36	-0.0561	2.326E+01	2.462E-12
Optimum case	1932.71	-0.0558	2.318E+01	7.462E-13
%오차	-0.03%	-0.5%	-0.35%	-69.69%



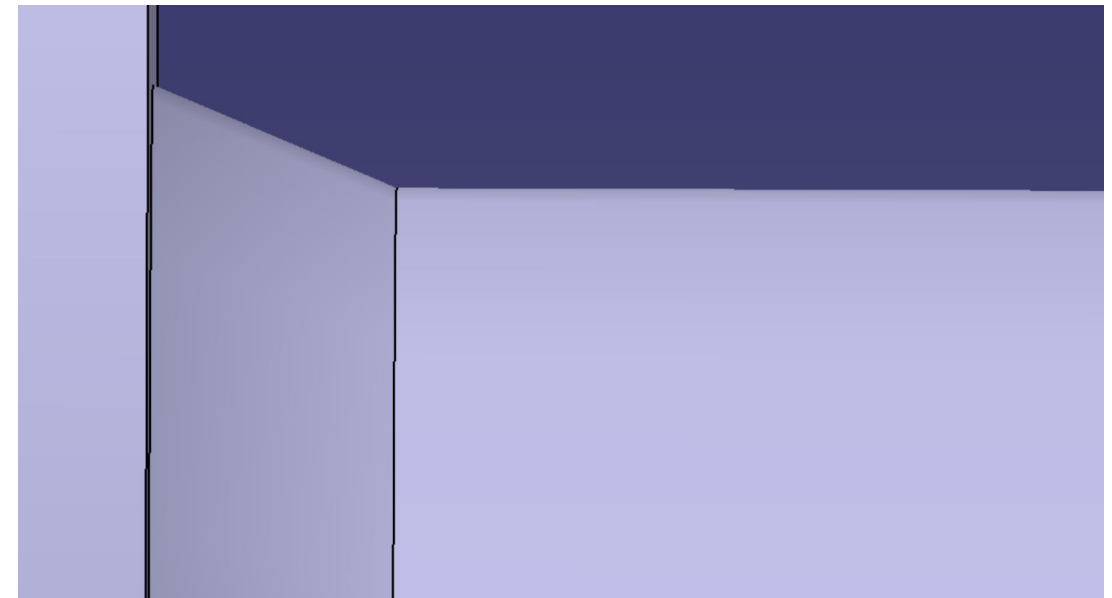
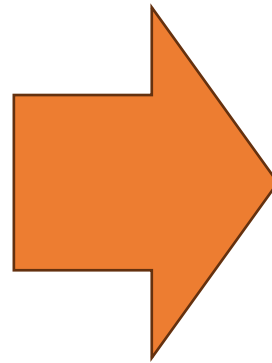
Optimum model view (isometric/front)

- 전반적으로 Base 대비 감소 추세를 보임
- 특히 Epsilon부분 변화를 보니 내구성이 증가로 이어질 수 있다고 추측 가능
- Contour를 참고하니 fillet 형태와 유사함

# #2-2 Remodeling

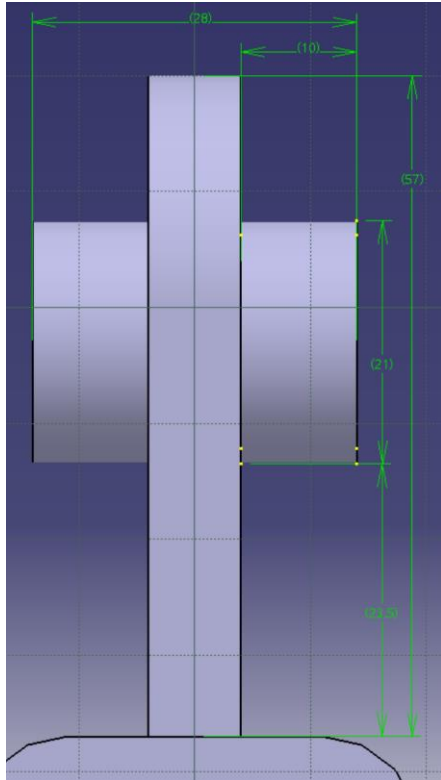


Shape Optimize contour (Top)  
Fillet making from contour result (bottom)



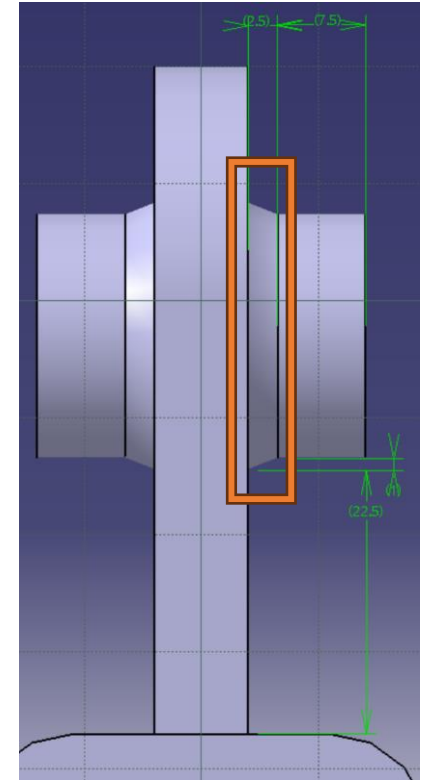
Refine model

# #2-3 Compare Base vs Optimum



Base model

Max Displacement (mm)	
Base model	Refined model
-0.0626	-0.0615
% 오차	
-1.87%	



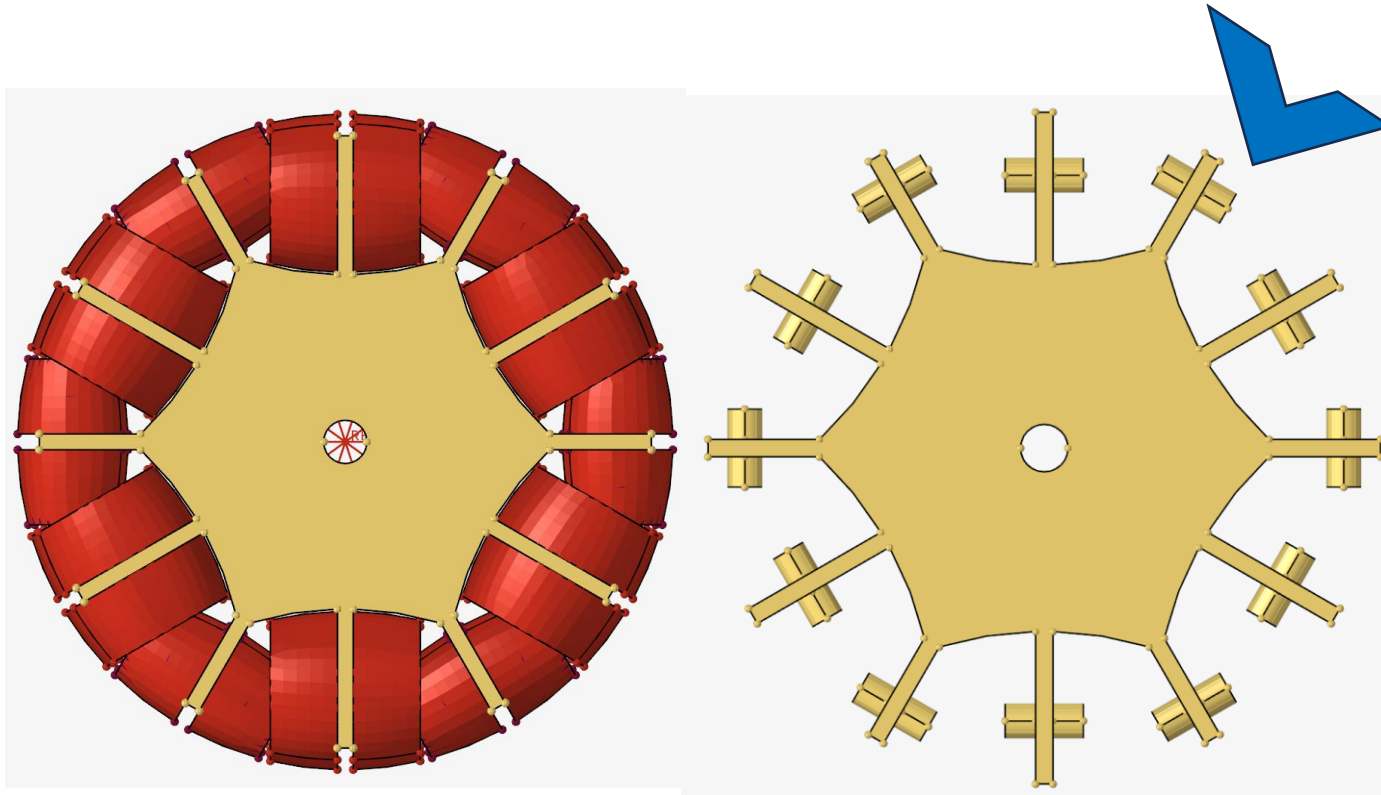
Refine model

→미약하지만 Base 모델 대비 변위,  $\text{stress}_{\max}$ 를 감소할 수 있었다.



Mass Optimize

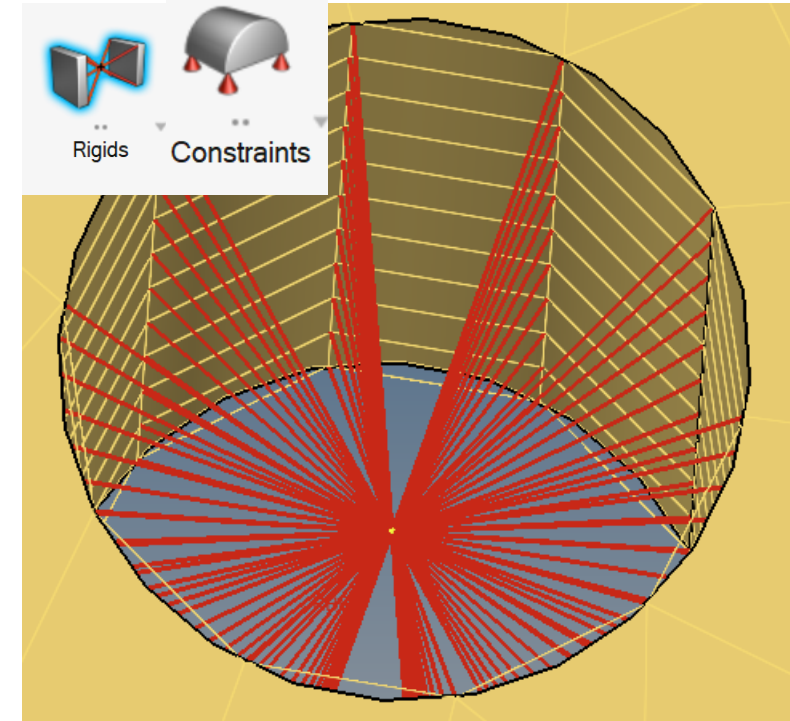
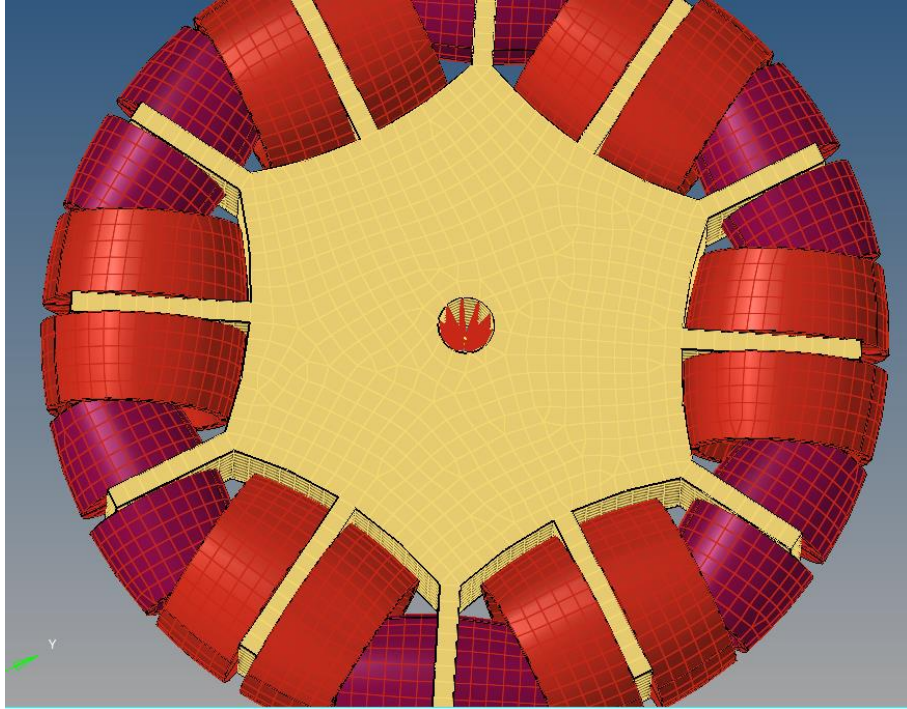
# #3-1 Mass optimize – body select



Omni wheel model overall (left)  
Model except rollers (right)

- 5mm 로 mesh generate
- Roller 제외 Wheel hub, support 부분에 대해 Mass Optimize 실행

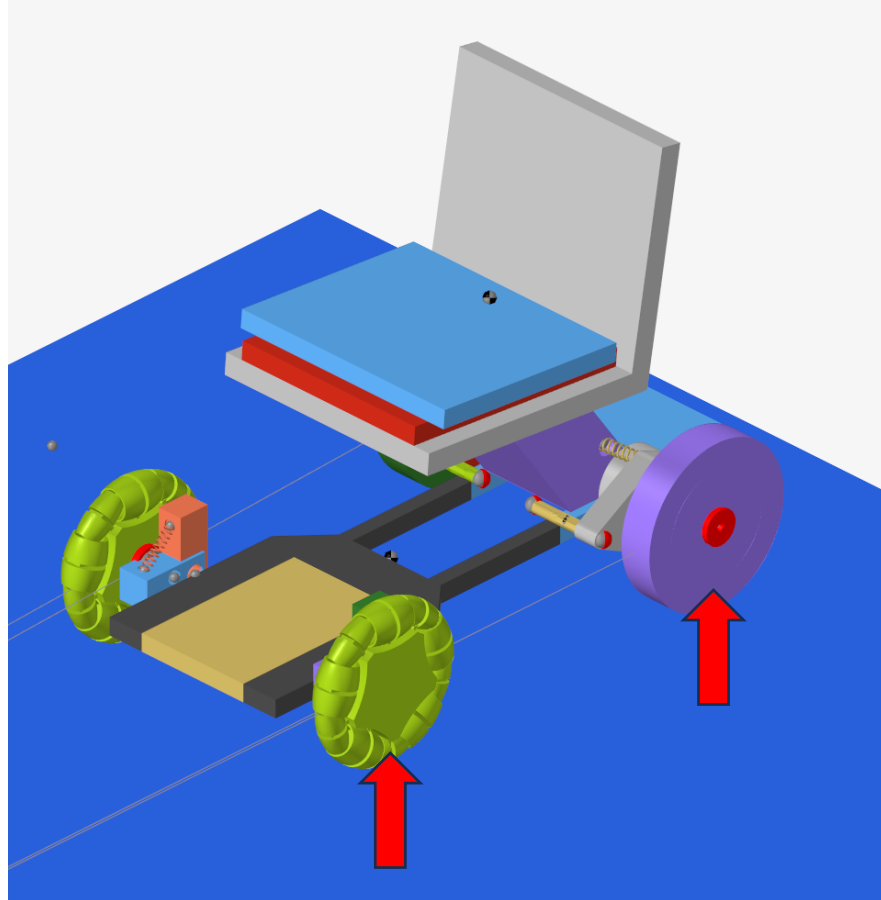
# #3-1 Making Spc



rbe3을 이용해 가운데 구멍의 노드를  
묶은 후 6자유도 모두 구속

# #3-1 Measurement of normal force

(7) 식품의약품안전처



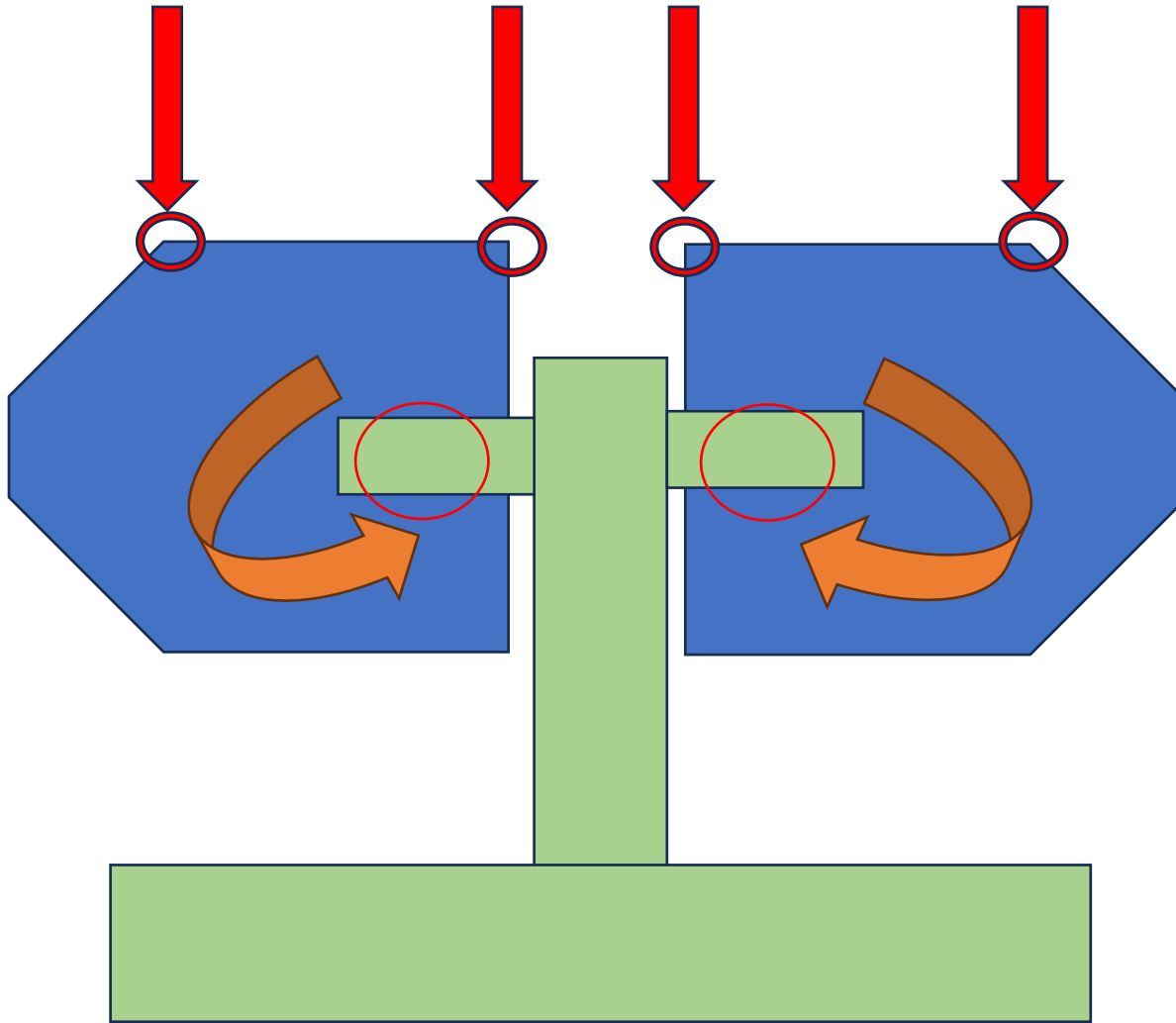
Measurement to earn  
Normal force at each wheel

- 전세계 평균 체중 = 62kg <sup>7)</sup>
- 휠체어의 62kg의 무게를 올려두고 정적상태에서 바퀴의 수직력 측정

Normal force (N)	
Front Wheel	Rear wheel
259.3	279.8

- 전반적으로 2000N 미만
- 2000N을 버티면 실사용에 문제가 없을 것이라 판단

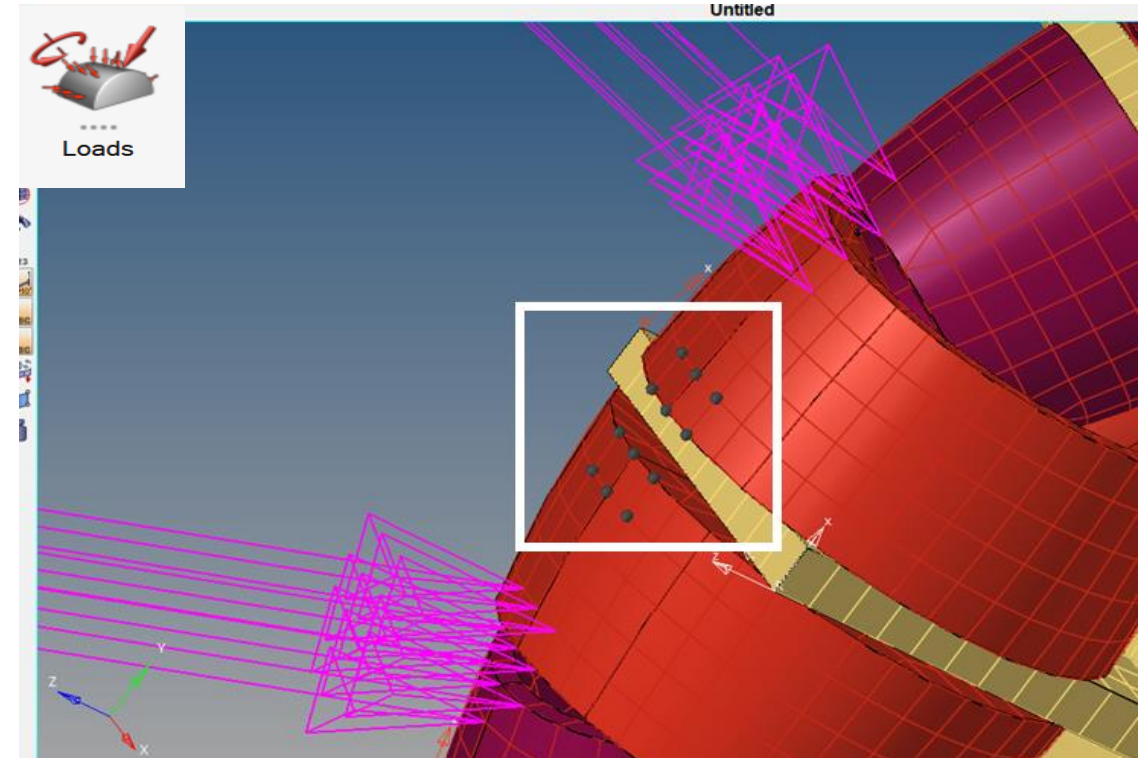
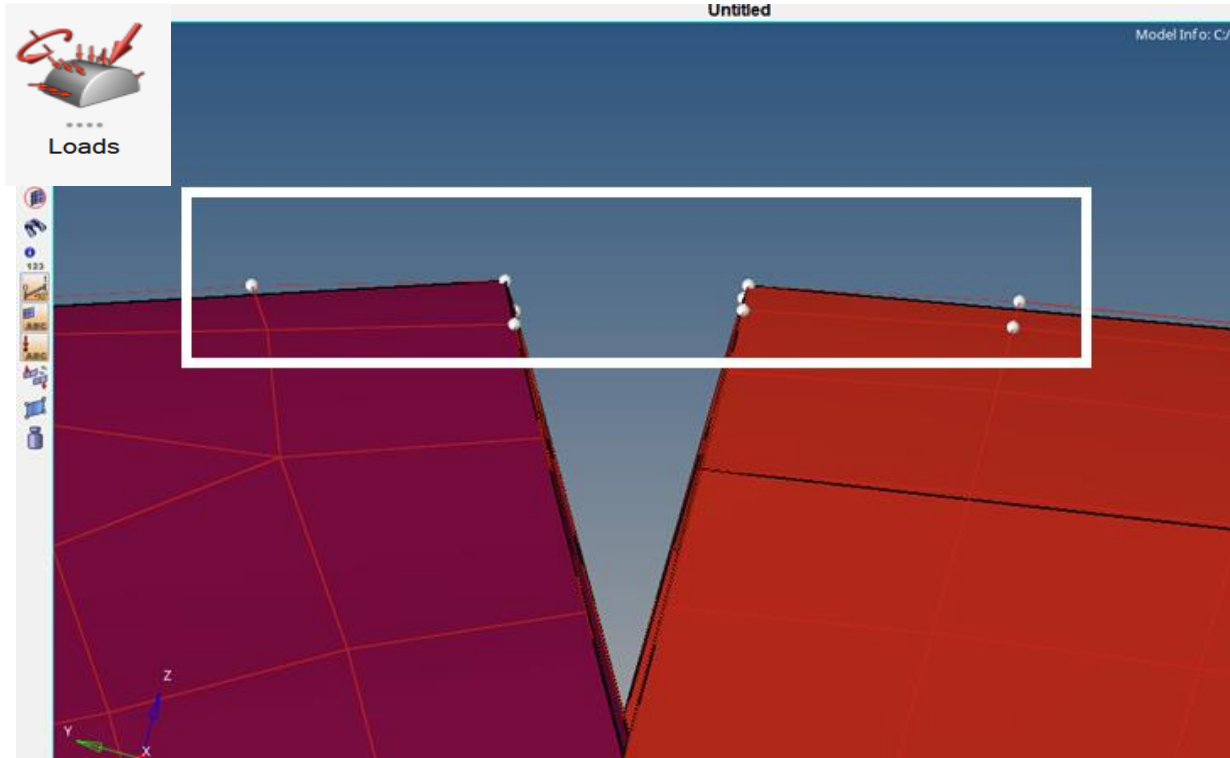
## #3-2 Force apply node select



↓ 화살표 부분(gap)에  
힘이 작용하는 점이 가장  
큰 변화를 일으킬 것이라 추측

The sample illust of predictable effect  
by stress at roller support

# #3-2 Force apply



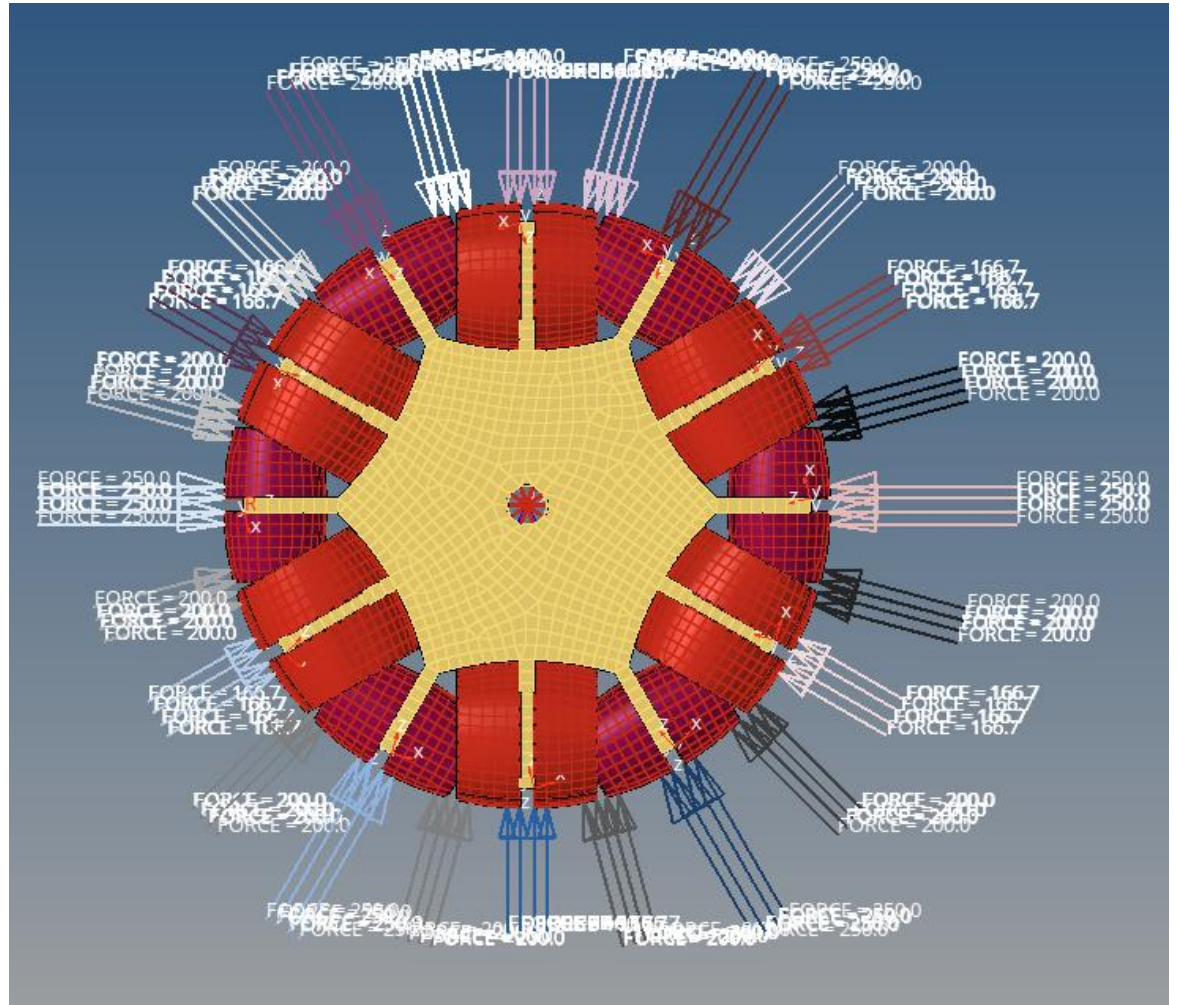
Force apply to node (gap part)

흰색 Box 범위에  
총 2000N의 힘을 분배해서 입력



## #3-2 Force apply to all roller

- 앞서 진행한 작업을  
전 Roller에 적용
- 각 롤러마다 다른  
load collectors로 배치



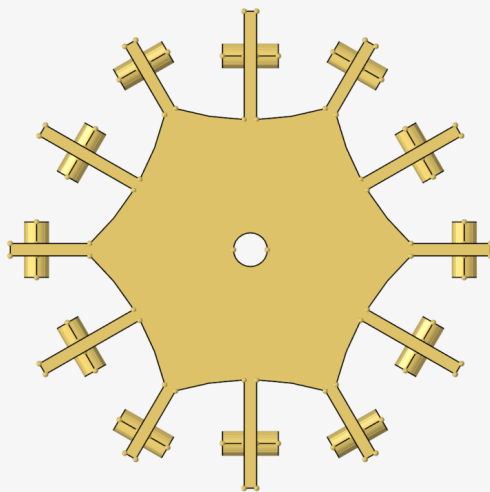
Visualize load collectors apply to model

# #3-3 Process of Optimizing

1

Design variable

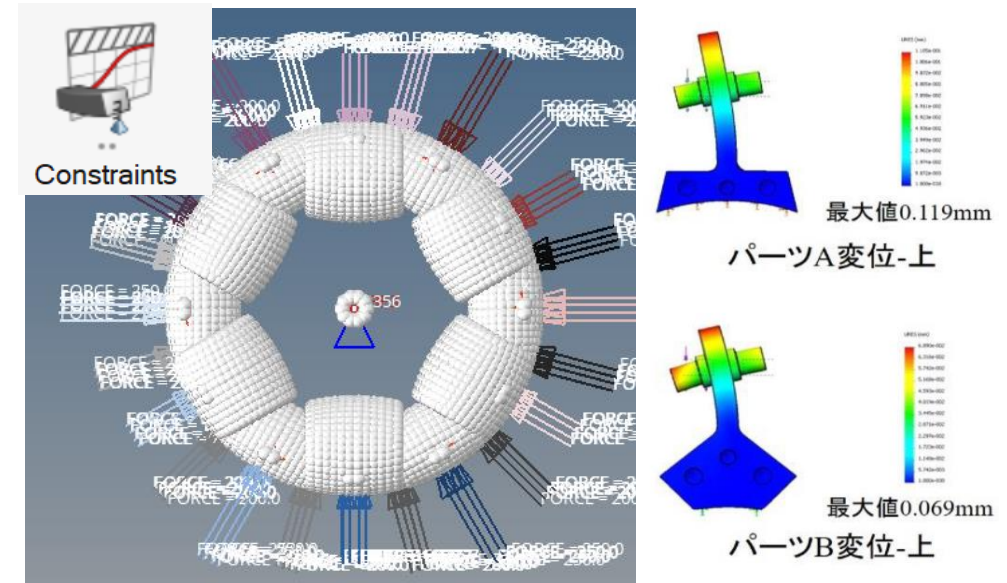
Name	Value
Solver Keyword:	DTPL PSOLID
Name:	DE
ID:	1
Include:	[Main Model]
Config:	topology
• Create	
Property Type:	PSOLID
List Of Properties:	1 Properties
Lattice Optimization:	<input type="checkbox"/>
• Parameters	
Mindim:	
Stress Constraint:	
Maxdim:	
Fatigue Constraint:	none



Task bar for design variable (left)  
Target model (right)

최적화 방법 : Topology  
대상 : Hub + support

2-1

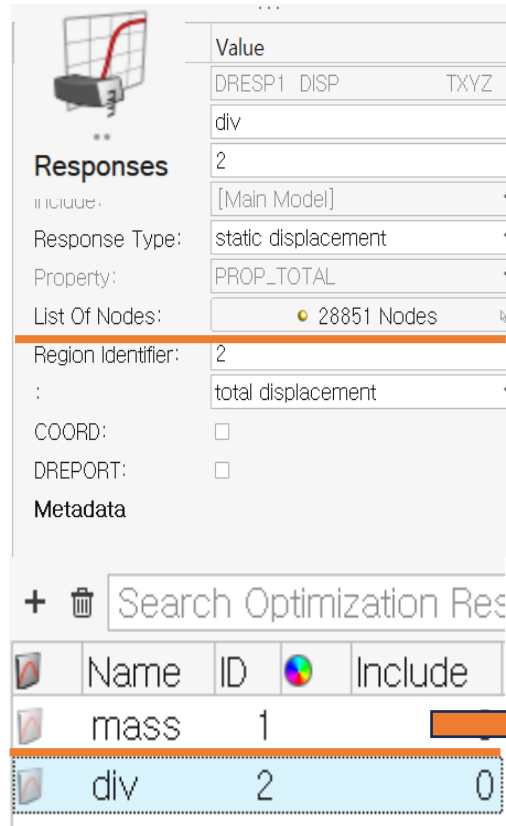


Constraint target node (left)  
Displacement in ref article (right)

참고 논문<sup>4)</sup>의 해석 결과를 바탕으로  
롤러의 모든 노드에 대해  
 $\pm 0.1\text{mm}$  변위를 구속 조건으로 설정

# #3-3 Process of Optimizing

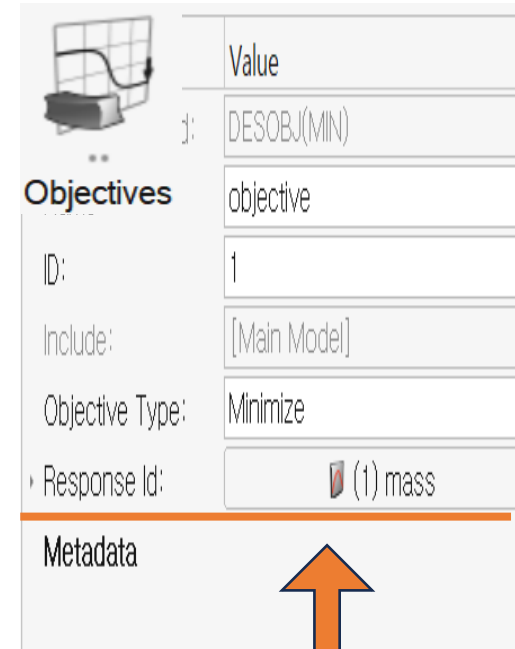
2-2



Value		
DRESP1	DISP	XYZ
div		
2		
[Main Model]		
Response Type:	static displacement	
Property:	PROP_TOTAL	
List Of Nodes:	28851 Nodes	
Region Identifier:	2	
:	total displacement	
COORD:	<input type="checkbox"/>	
DREPORT:	<input type="checkbox"/>	
Metadata		
+ - Search Optimization Res		
Name	ID	Include
mass	1	
div	2	0

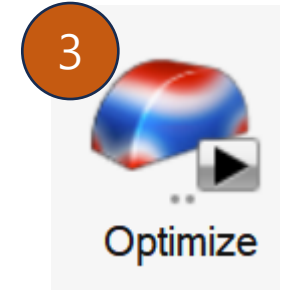
[2-1]에서 정한 구속 조건에 대해  
정적 변위 및 총질량을 반응으로 선정

2-3



Value	
DESOBJ(MIN)	
objective	
ID:	1
Include:	[Main Model]
Objective Type:	Minimize
Response Id:	(1) mass
Metadata	

[2-2]중 총질량에 대해  
질량 최소화 (최적화 목적) 설정



# #3-4 Optistruct solver view

ffinal.fem - Altair Compute Console Solver View

Solver:

Input file:  Job completed

Run command:

Message log:

Messages for the job:

OPTIMIZATION HAS CONVERGED.  
FEASIBLE DESIGN (ALL CONSTRAINTS SATISFIED).

Optimization summary:

axDisp	5009_Z	-0.023373
axDisp	5009_Z	-0.031936
axDisp	4971_Z	-0.025815
axDisp	5009_Y	-0.037935
axDisp	5009_Y	-0.046273
axDisp	5009_Y	-0.042302
axDisp	5009_Z	0.029540
bjFun:MinimizeMASS	0	0.012119
axConstrViol(%)	0	0

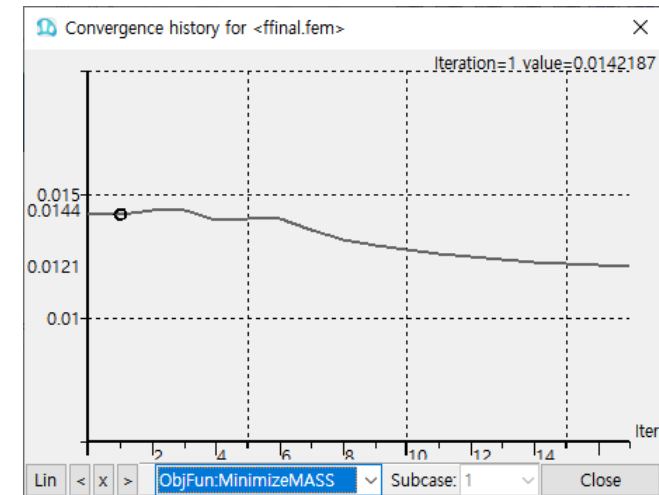
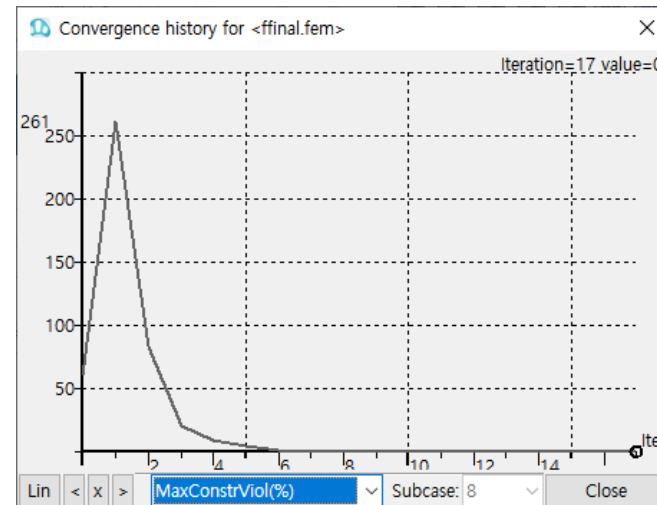
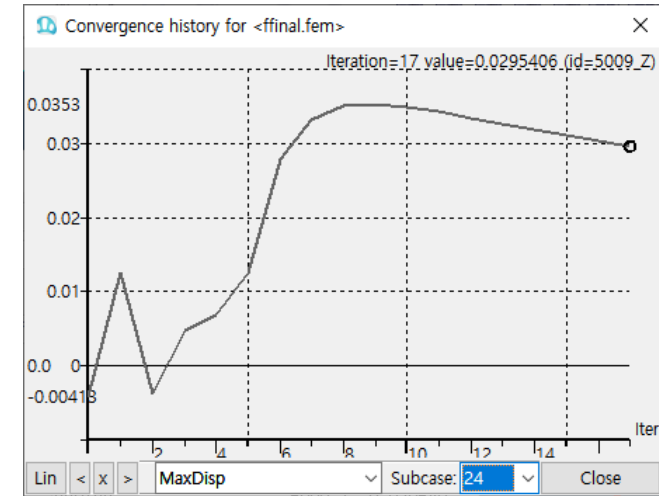
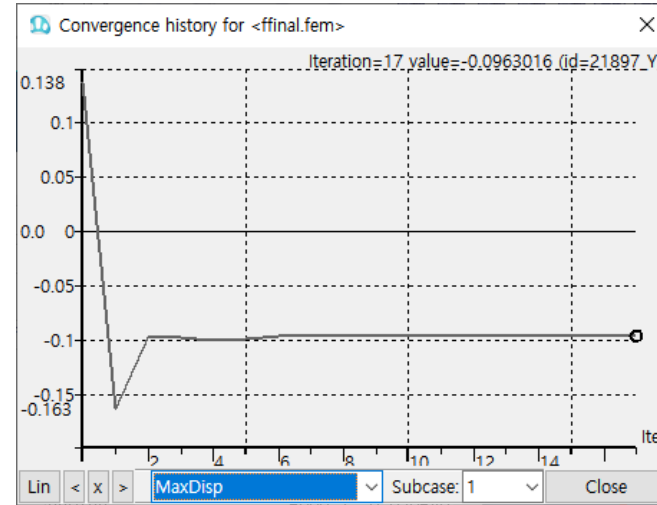
Run summary:

OPTIMIZATION HAS CONVERGED.  
FEASIBLE DESIGN (ALL CONSTRAINTS SATISFIED).

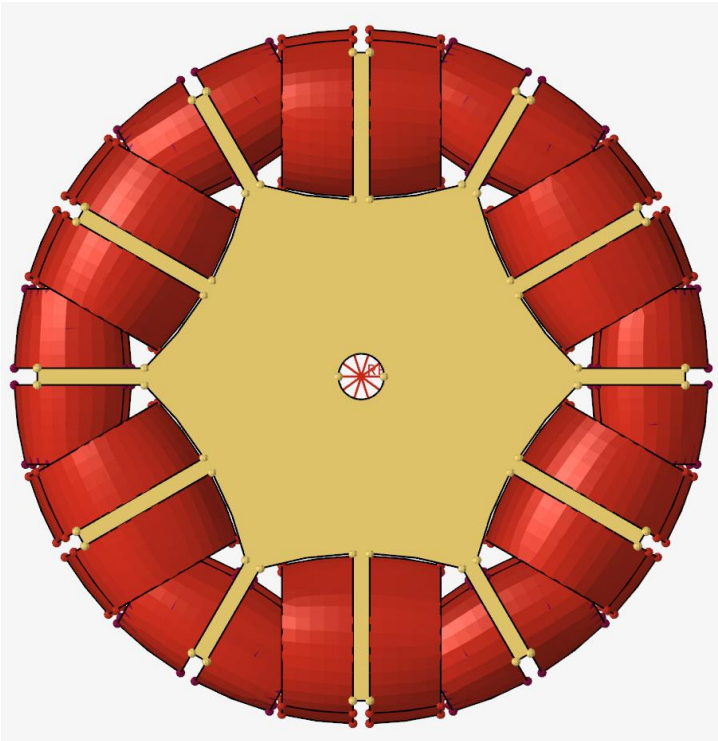
==== End of solver screen output ====

==== OptiStruct Job completed ====

Results View Close

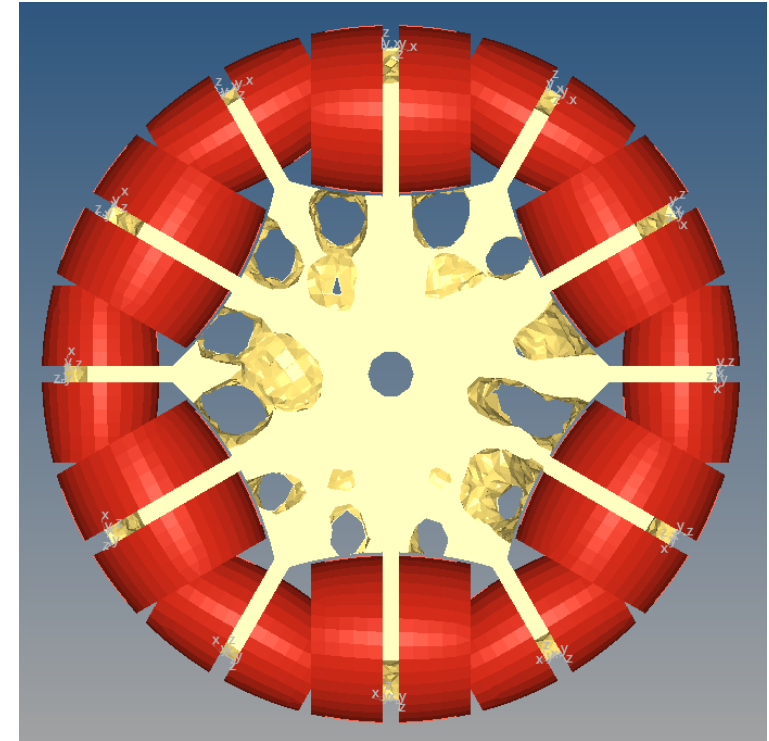


# #3-4 Optimization result



Base model

Total Mass (kg)	
Base model	Optimum model
14.211	12.119
% 오차	
-14.72%	

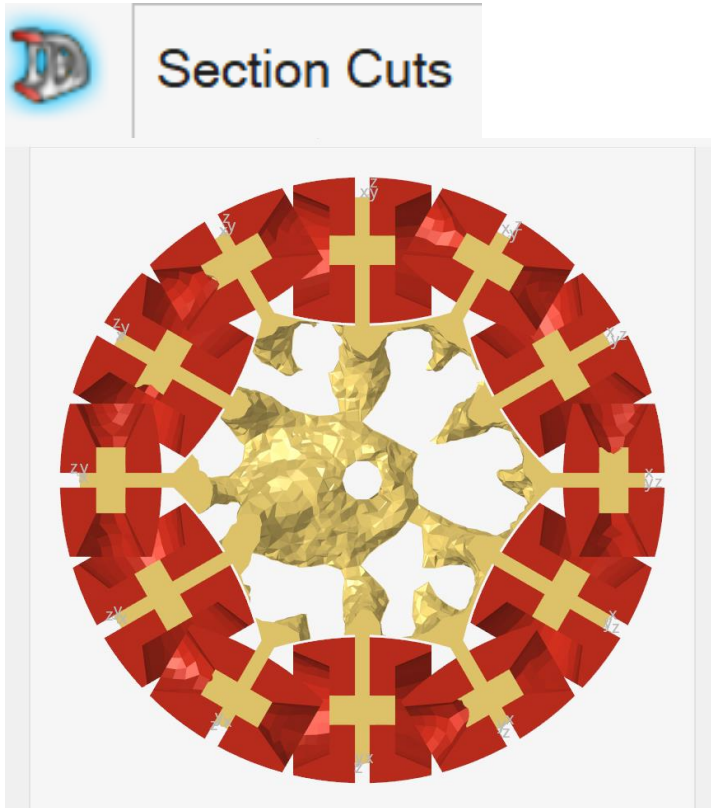


Optimum model

→약 2kg 의 중량 감소가 이루어짐



# #3-4 Optimum model section review



Front view



Isometric view

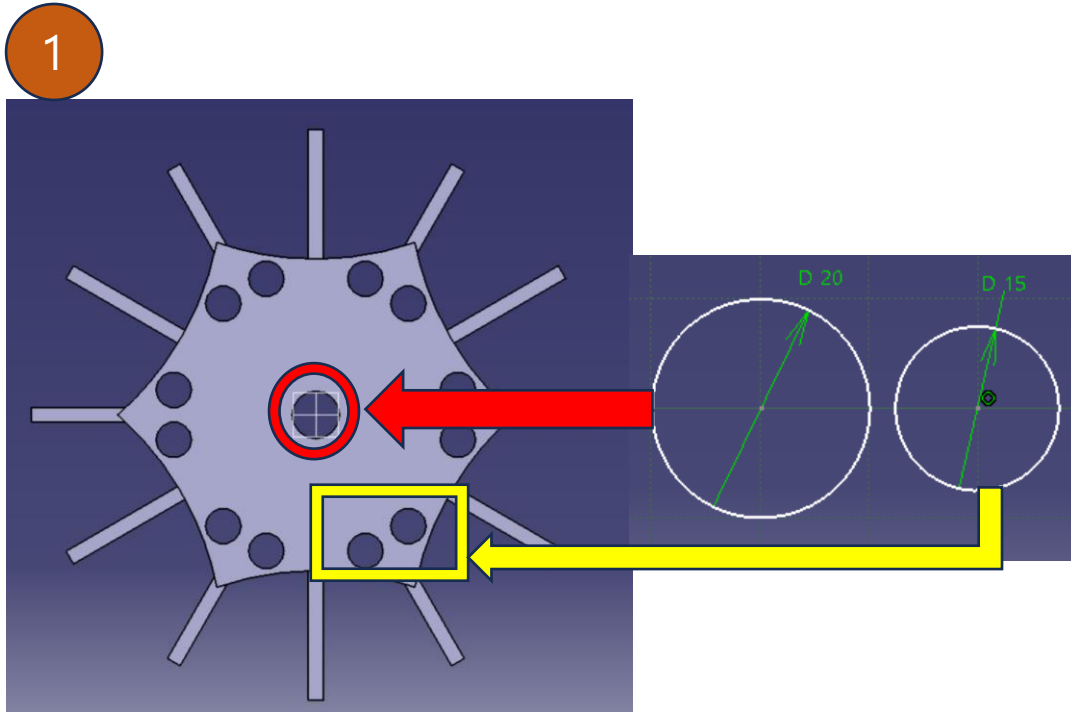


Side view

→ Roller support 부분 외 pocketing이 이루어짐



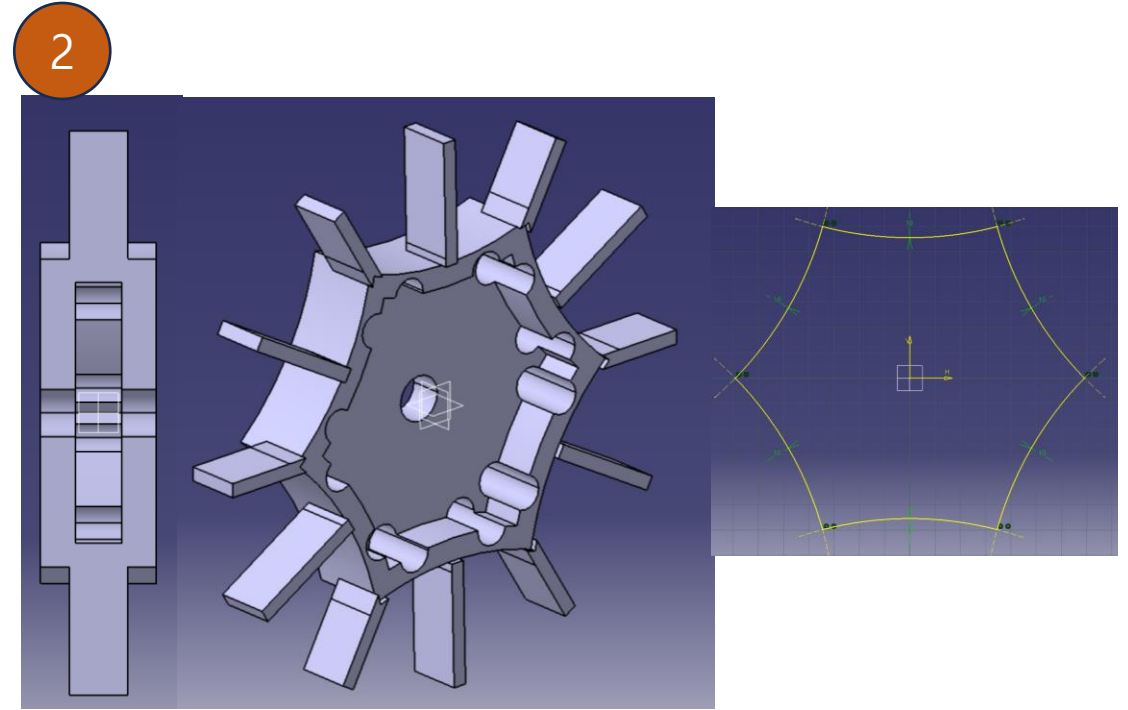
# #3-5 Model refining



Front view of model

Wheel hub hole →  $R = 10$   
Hole nearby support →  $R = 7.5$

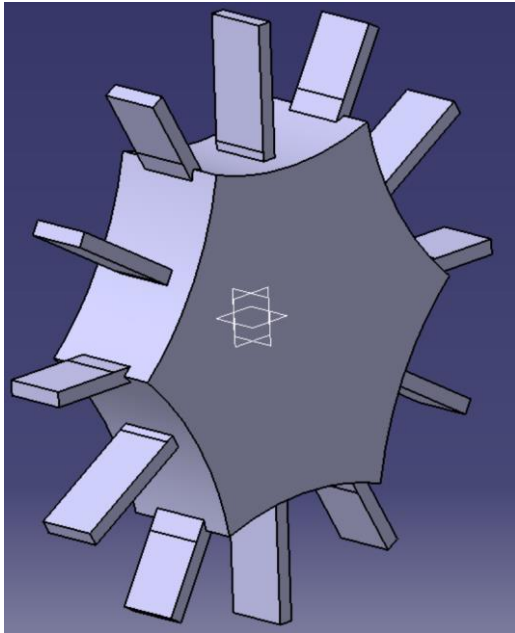
위 기준으로 Pocketing 진행



Section view from side view (left)  
Isometric view of model (middle)

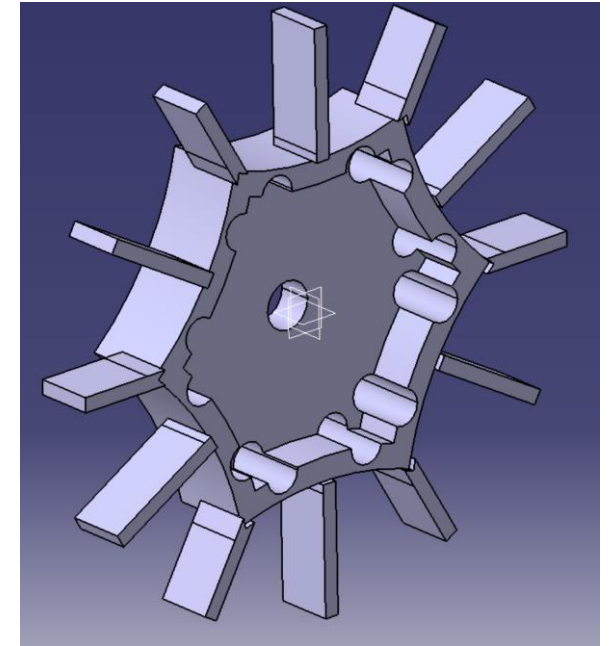
Offset → 10mm 를 부여하여  
좌우 10mm 총 **20mm**  
Pocketing 진행

# #3-5 Check for weight decrease



Base model

Mass (kg)	
Base model	Refined model
6.827	4.375
% 오차	
-35.91%	

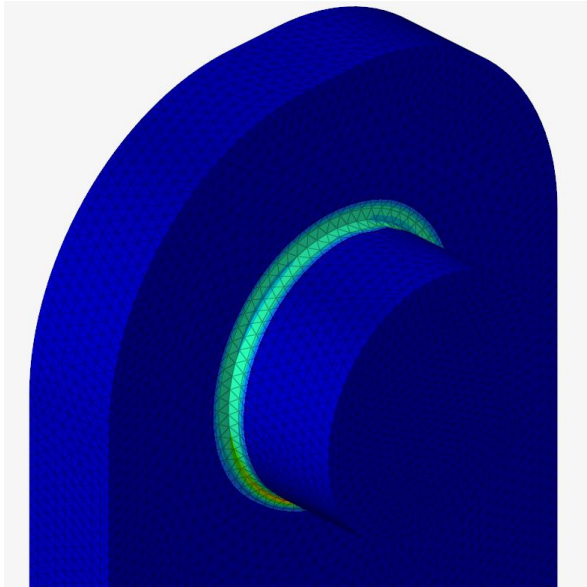


Refine model

→ Optistruct solver file와 같이 2kg  
질량 차이를 확인할 수 있었다

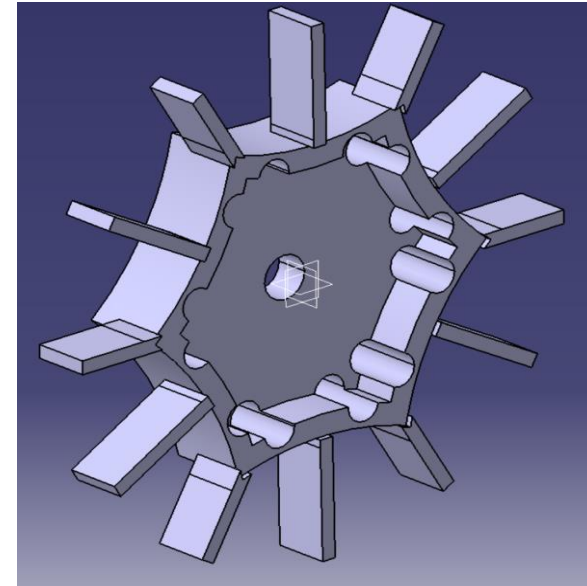
# \* Summary

## #1 Free shape Optimization for big roller support



- Obj (reduce stress)
- Result: making fillet

## #2 Mass optimization Except rollers



- Obj (reduce mass)
- Result: pocket middle part