

# Omni Directional Wheel Optic design



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1

연구배경

2

Roller support free shape design

3

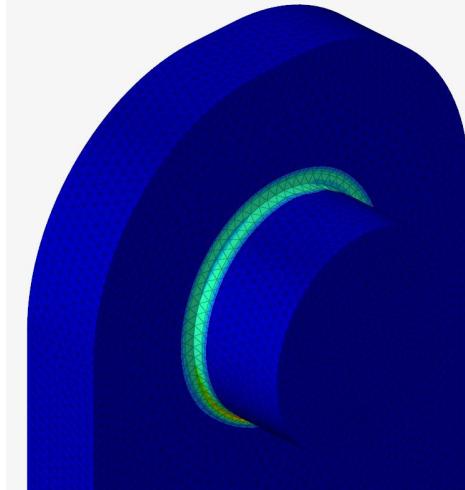
Wheel overall mass optimize

# \* Abstract

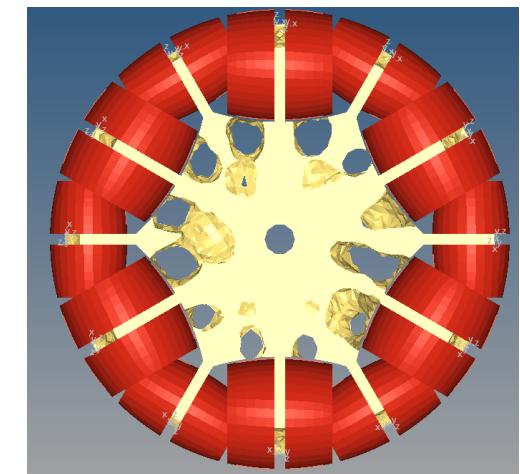
Omni Wheel



#1 롤러 지지대  
형상 최적화



#2 롤러 제외  
중량 최소화



# #1. Info – What is Omni wheel

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드라마 '선재를 업고 튀어' 등장 장면



카이로보틱스(Korea)

새로운 형태의 전동 휠체어



WHILL(Japan)



ROBOOTER(China)

# #1. Info – What is Omni wheel

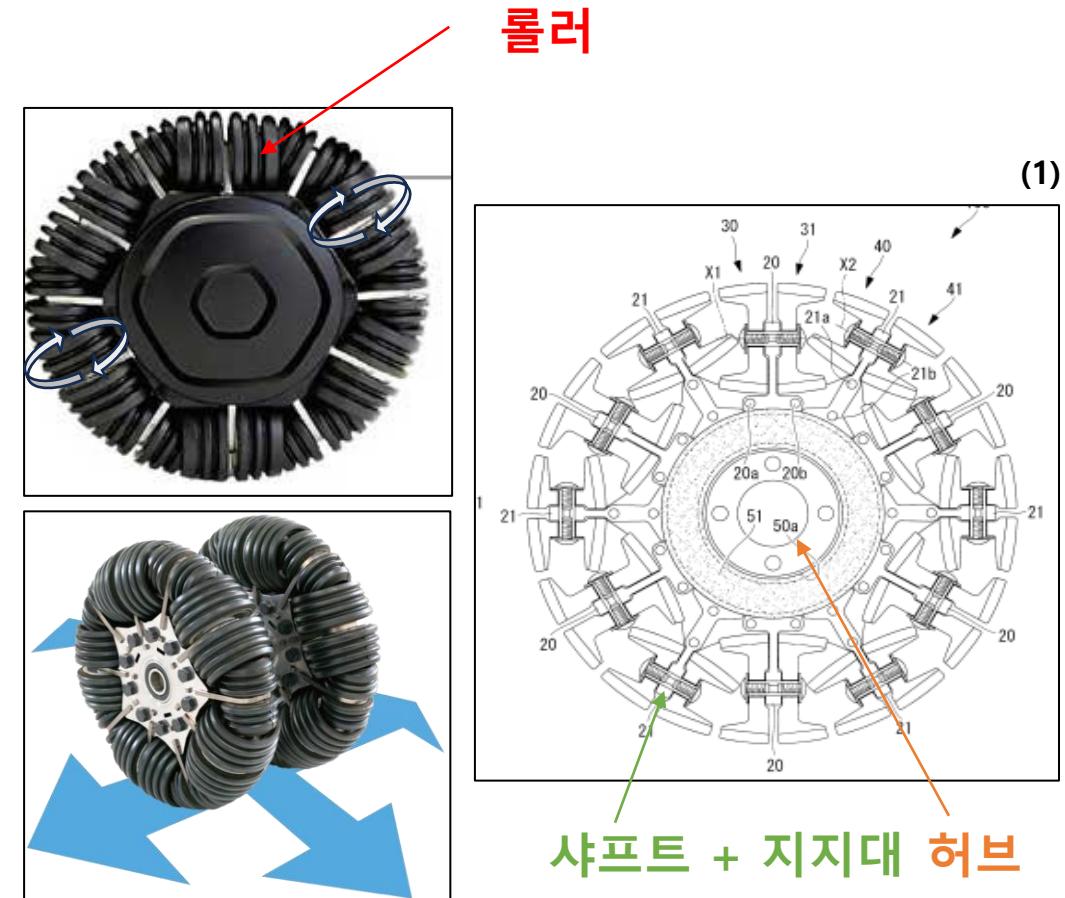
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## # 핵심 부품

- 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



(1) Bando, K., & Naito, J. (2015). Omni-directional wheel and omni-directional vehicle including the same. (Japan, JP5687352 B1)

# #1. Info – Omni wheel movement

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



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



# #1. 연구 방향 선정

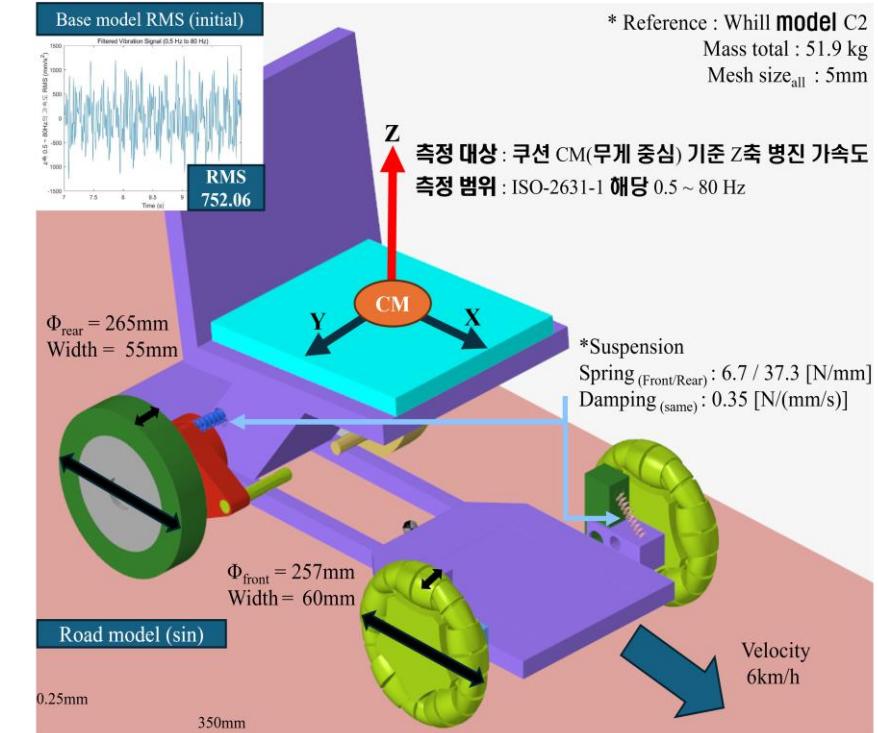
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## # 진동 해석 진행 및 각종 문제점

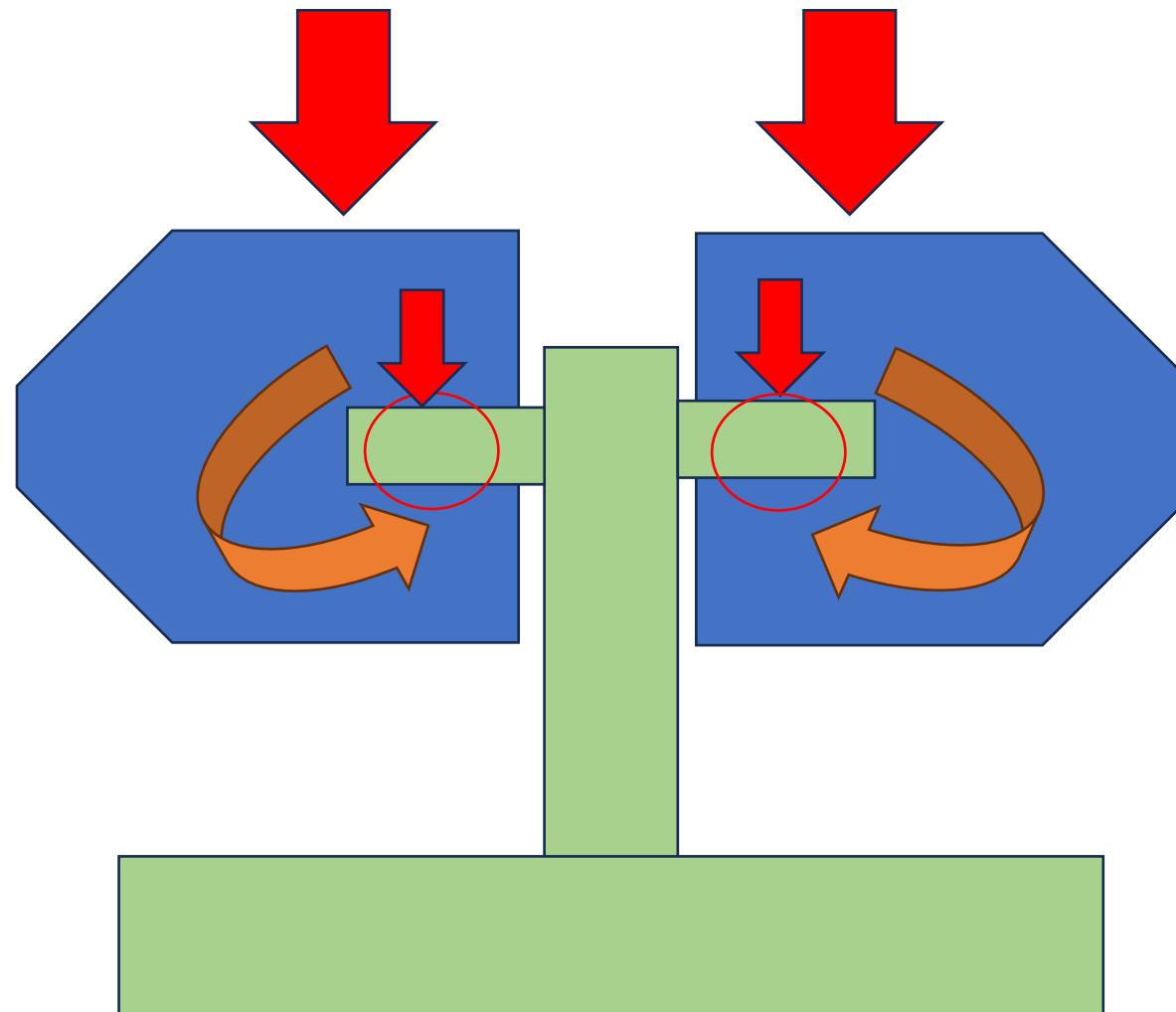
- 차체, 방석, 스프링 등 다양한 요소로 인한 복잡성  
→ 가정 등 고려할 부분이 많음
- 모델 규모에 비례한 mesh 생성 및 해석 진행 시간  
→ Case study로 인한 요구 해석 시간 증가



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

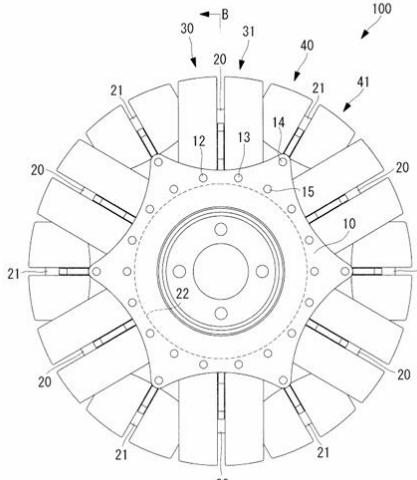
- 지면으로 부터 받는 수직 항력
  - 하중으로 인한 힘
- 롤러 지지 부분에 힘 작용으로  
Bending 등의 변형 가능성

Z축 방향으로의 정적 하중에  
대한 해석 필요성

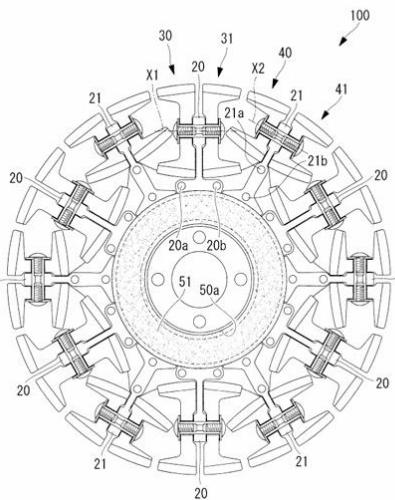
# #1. The base idea

(1)

【図 1】

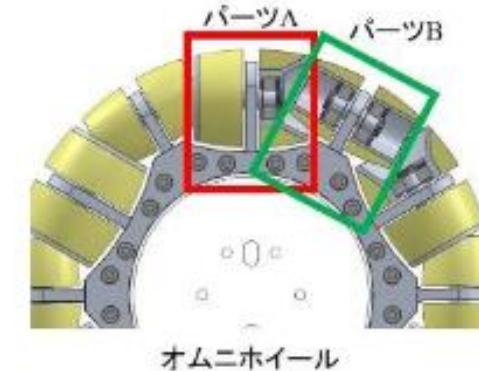


【図 2】

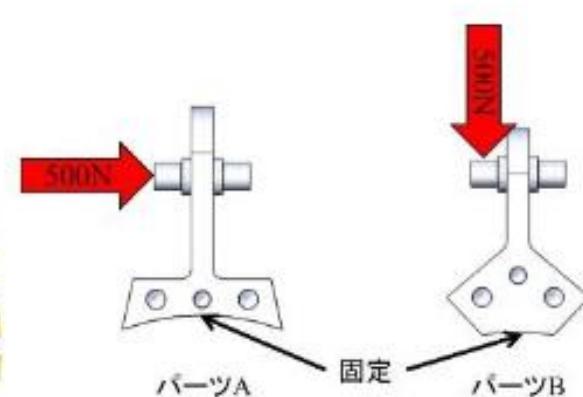


(a) Structural blueprint for  
Omni wheel

(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・ファジー・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・ファジー・システム学会.



(b) Roller support method  
In pre study



특히 형상을 바탕으로  
롤러 지지대 모델 제작

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

# #1. Feasibility for analysis – Static load

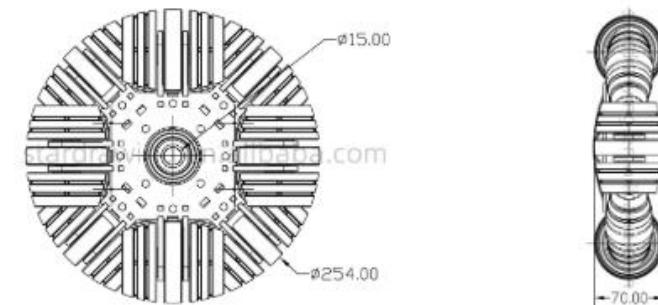
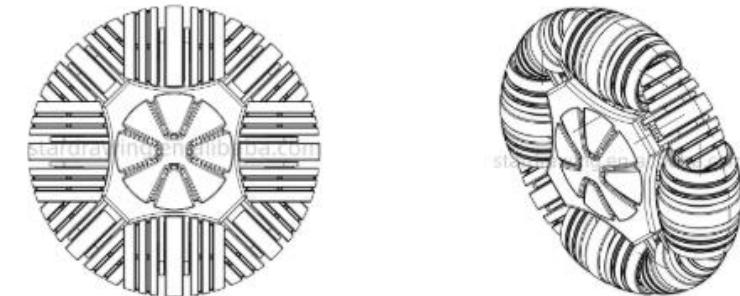
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(5)[https://www.alibaba.com/product-detail/S-S-254mm-omni-robot-directional\\_1600879114202.html?spm=a2700.7724857.0.0.13761270tCjYnN](https://www.alibaba.com/product-detail/S-S-254mm-omni-robot-directional_1600879114202.html?spm=a2700.7724857.0.0.13761270tCjYnN)

(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	-	-

- 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 **200kg**로 설정  
→ **2000N**의 힘을 가하여 해석을 진행



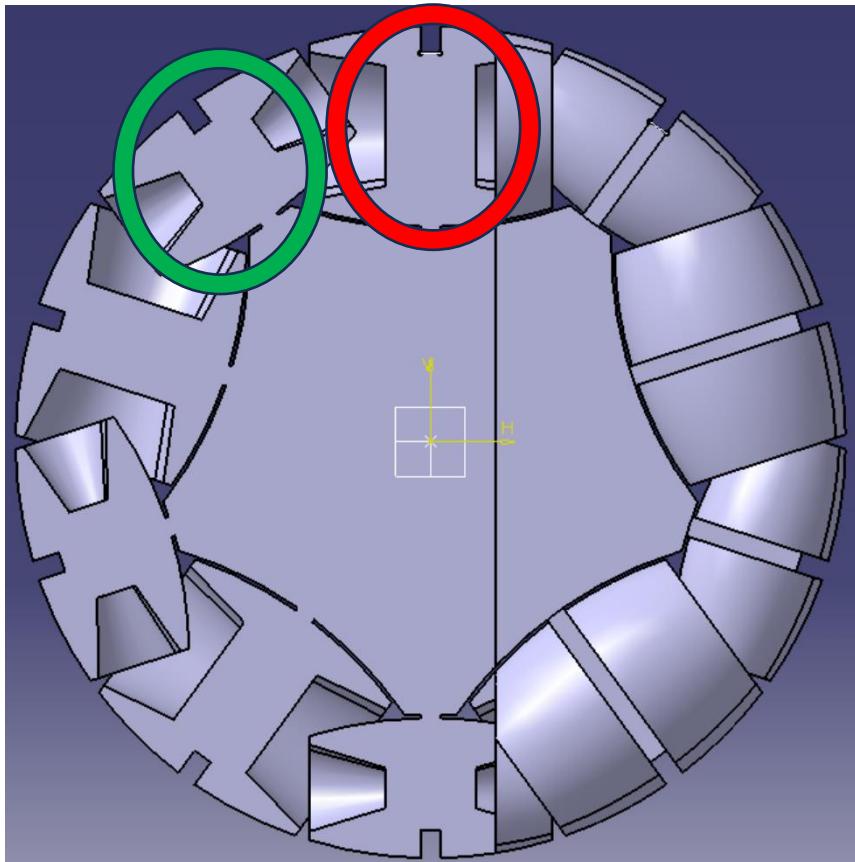
Wheel Diameter (MM)	Roller Diameter (MM)	Dynamic Load (KG)	Static Load (KG)
254	70	100	<b>120</b>

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

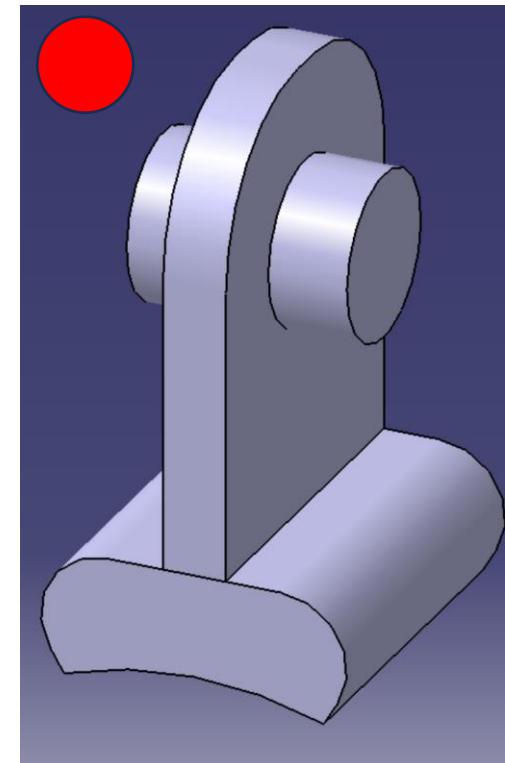
Free Shape Optimize

# #2-1 shape optimization – cad model

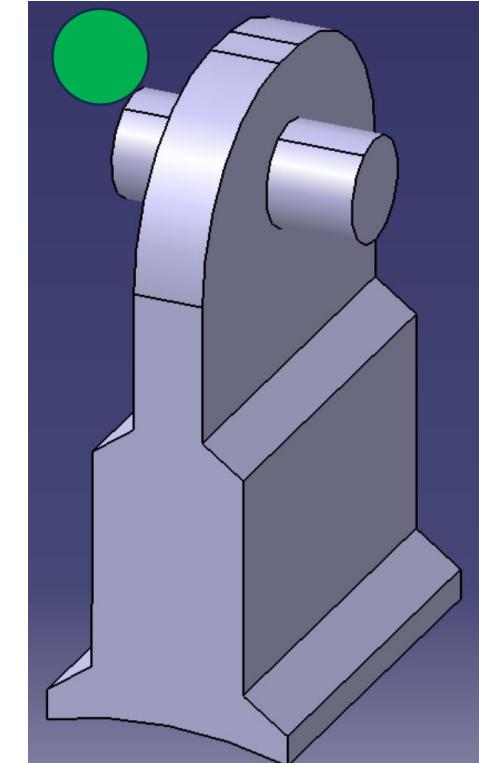
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Section cut for  
Omni wheel



Support for  
Big roller

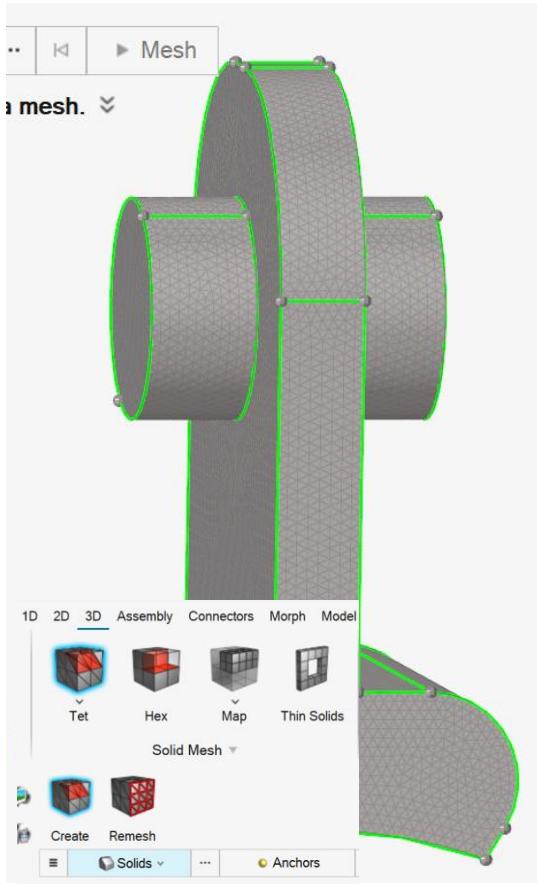


Support for  
small roller

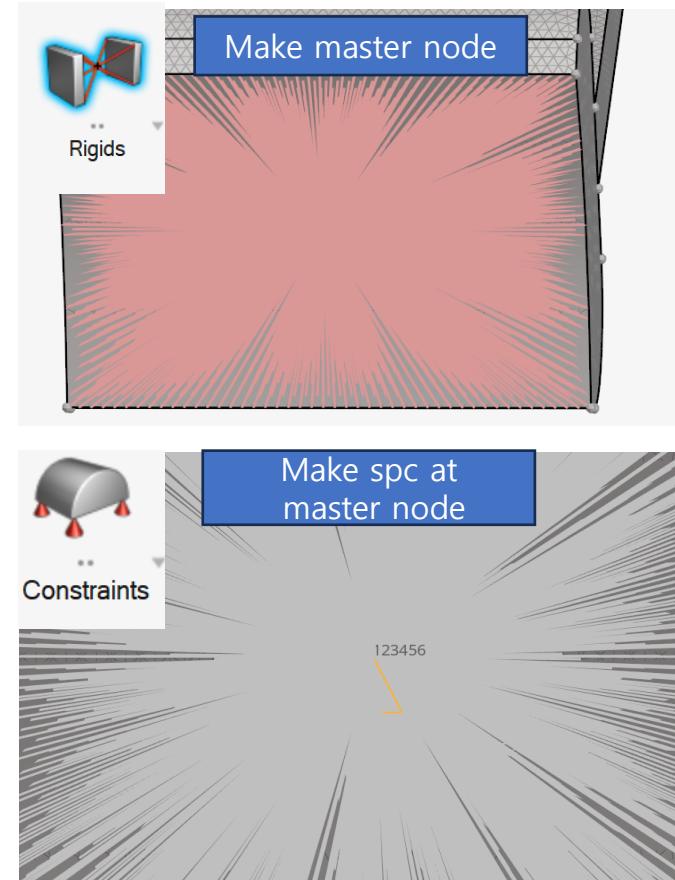
# #2-1 Force analyze method

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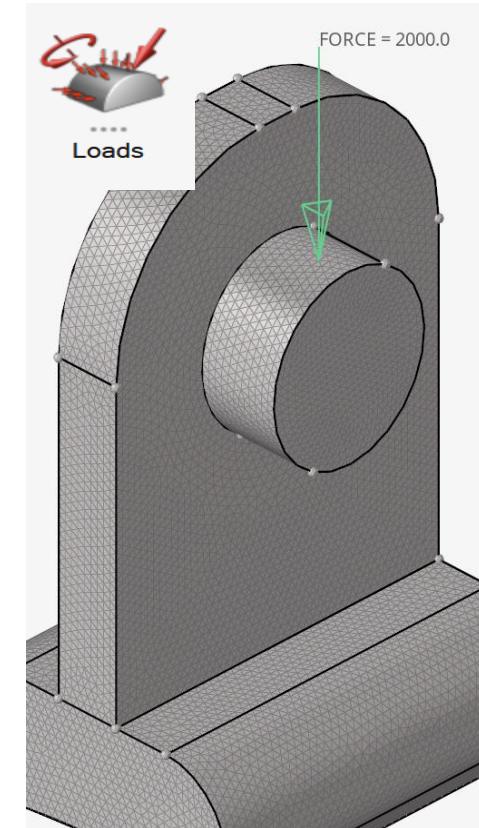
#1 Mesh generate (1mm)



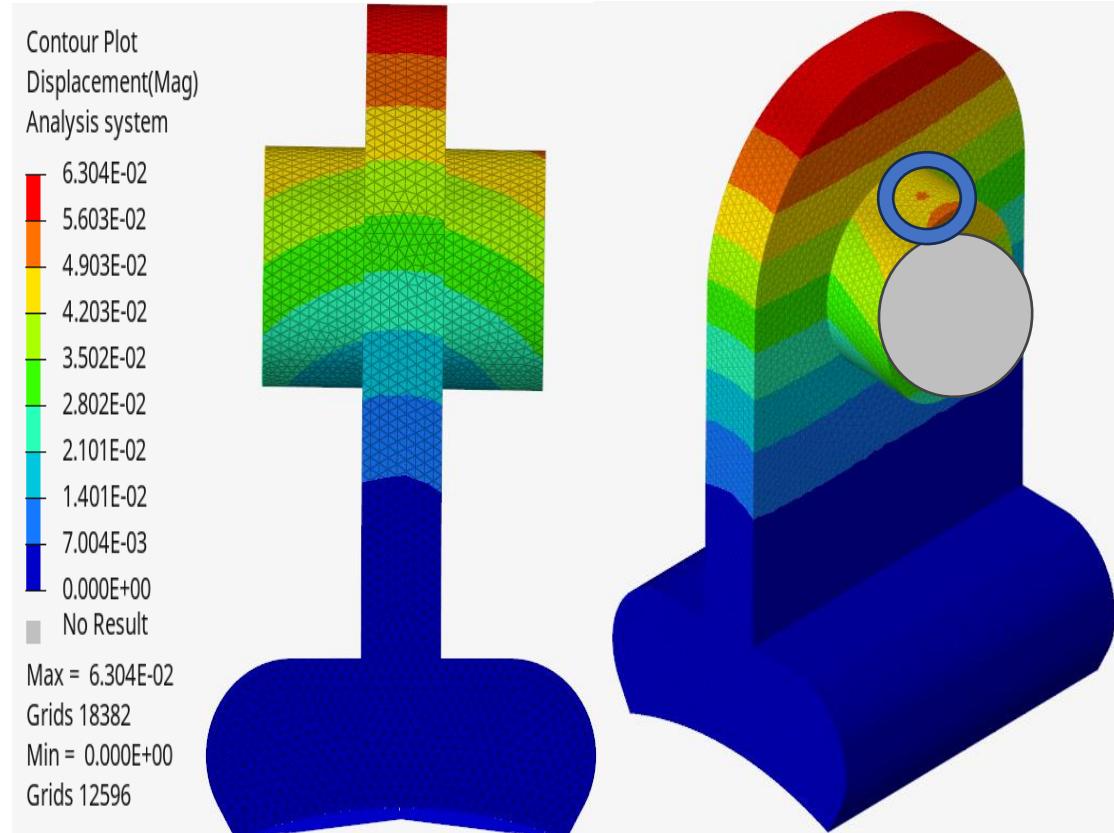
#2 Create SPC



#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



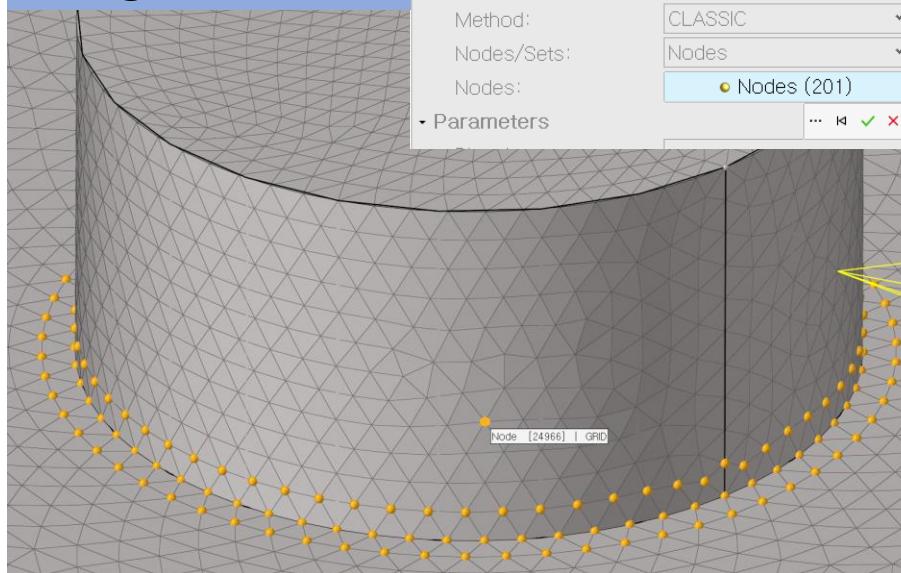
Cylinder와 지지대 체결 부분에  
대한 형상 최적화 진행

# #2-2 Free shape optimization method

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1

## Design variable



Name	Value
Solver Keyword:	DRESP1 STRESS PSOLID ...
Name:	stress
ID:	1
Include:	[Main Model]
Response Type:	static stress
Property:	PSOLID
List Of Properties:	1 Properties
Exclude Elements:	0 Elements
Region Identifier:	10
:	von mises
ATTB_Option:	
COORD:	
DREPORT:	
Metadata	

2-1

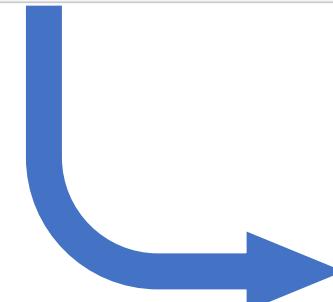
Responses

Name	Value
Solver Keyword:	MINMAX
Name:	stress
ID:	1
Include:	[Main Model]
Objective Type:	Minmax
Dsys Response Id:	<Unspecified>
List of Dobjrefs:	1 Dobjrefs

2-3

Objectives

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



Design object references	
ID:	1
Include:	[Main Model]
Response:	(1) stress
All Loadsteps:	<input type="checkbox"/>
List of Loadsteps:	1 Loadsteps
Negative Reference Op...:	<OFF>
Upper Options	
Positive Reference O...:	POSREF
Positive Reference:	1.0
Metadata	

2-2

3

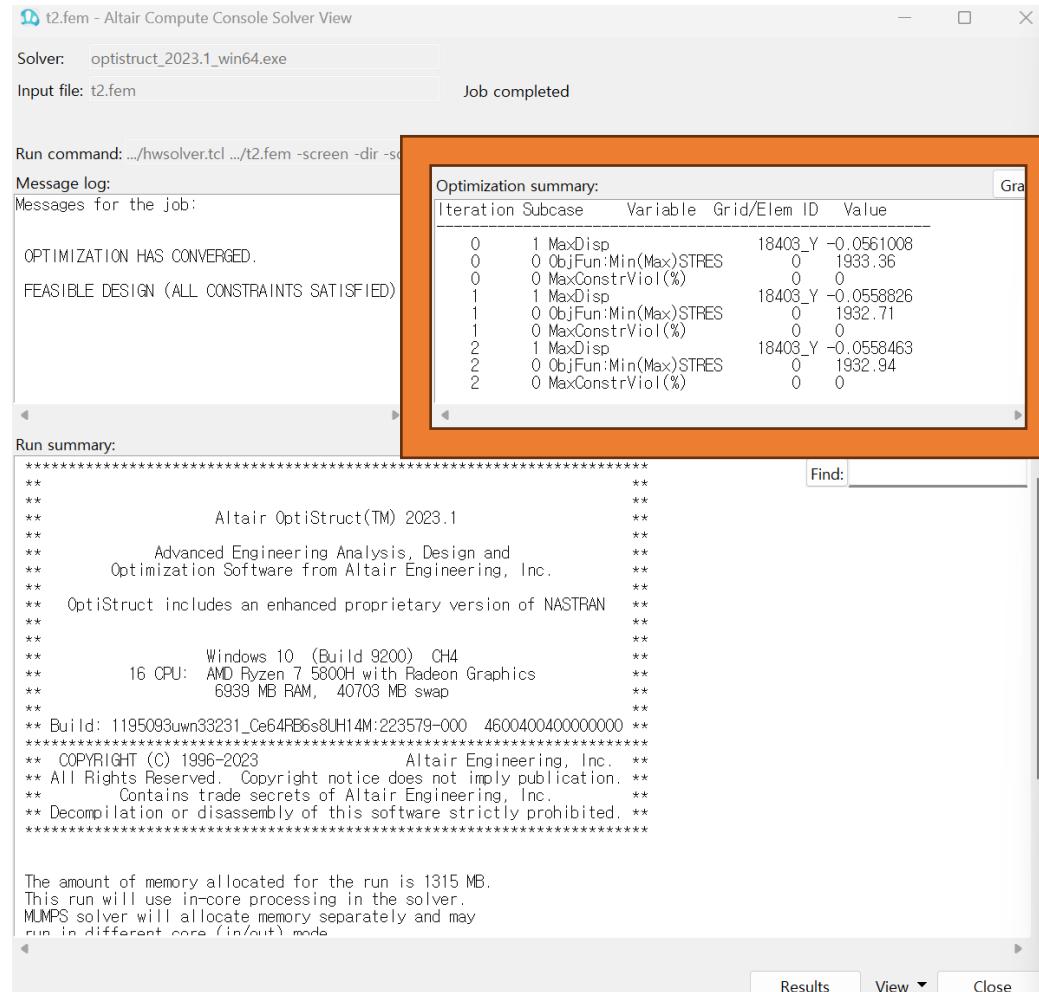


Optimize

# #2-2 Methods to see Optimize summary

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## #1 Optistruct solver view



## #2 Solver output file

The screenshot shows the content of a solver output file (t2.out) with the following details:

- Header:

```
*****  
**  
** 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_Ce64RB6s8UH14M: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. **  
*****
```
- Defaults:

```
*** OptiStruct defaults set from:  
install config file: C:/PROGRAM/1/Altair/2023.1/hwsolvers/optistruct.cfg.
```
- Notes:

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

```
*** WARNING # 7339  
GRID 58109 in DSHAPE card 1 is not on the boundary.
```
- Information:

```
*** 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.
```
- Notes:

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

# #2-2 Select for the best Iteration case

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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
Subcase	Compliance	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)

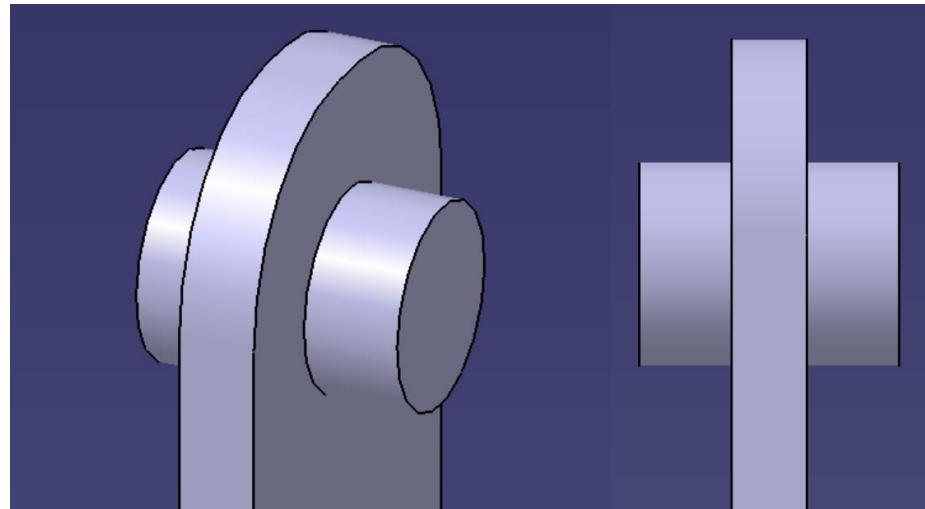
#1. **Convergence ratio** : 최적해 수렴도 및 해의 안정도  
일반적으로 1 이하의 경우 수렴 속도가 빠르다

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

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

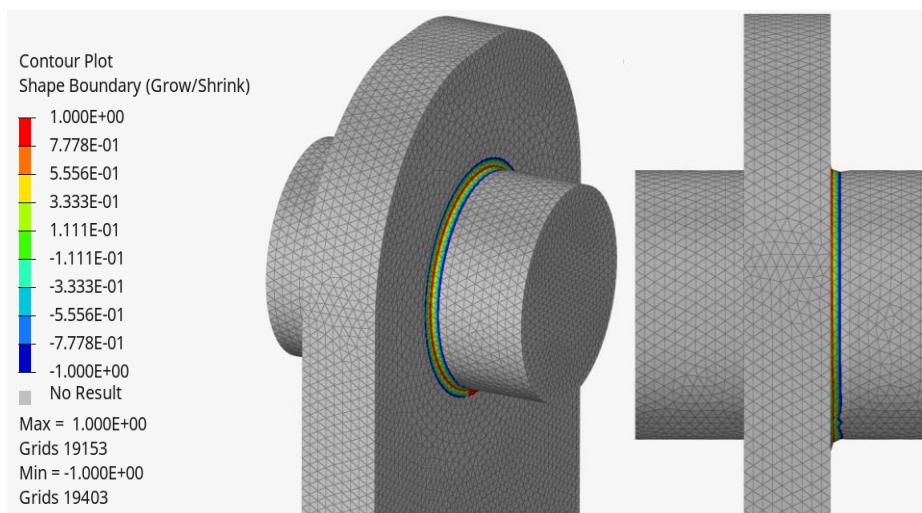
# #2-2 Select for the best Iteration case

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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%

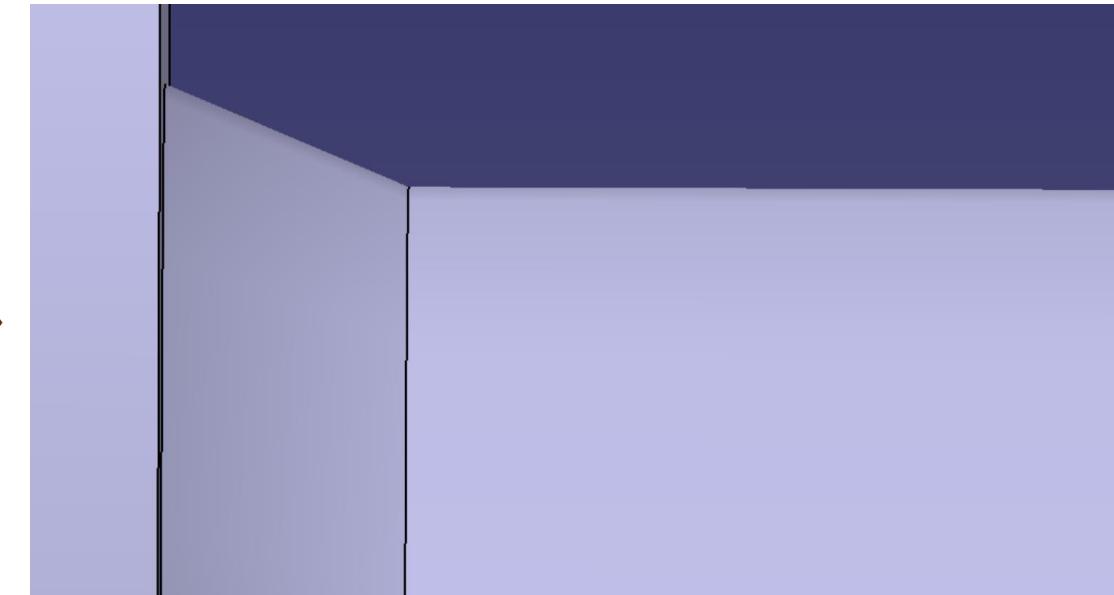
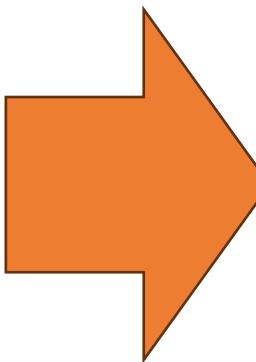
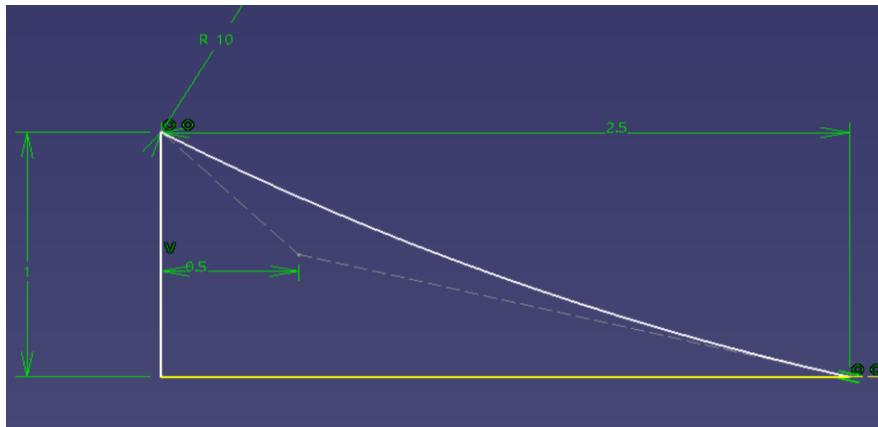
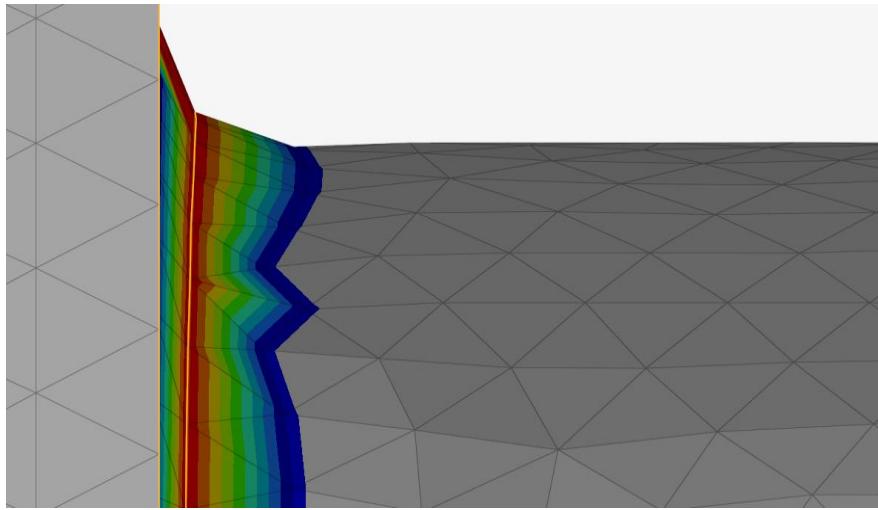


Optimum model view (isometric/front)

- 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

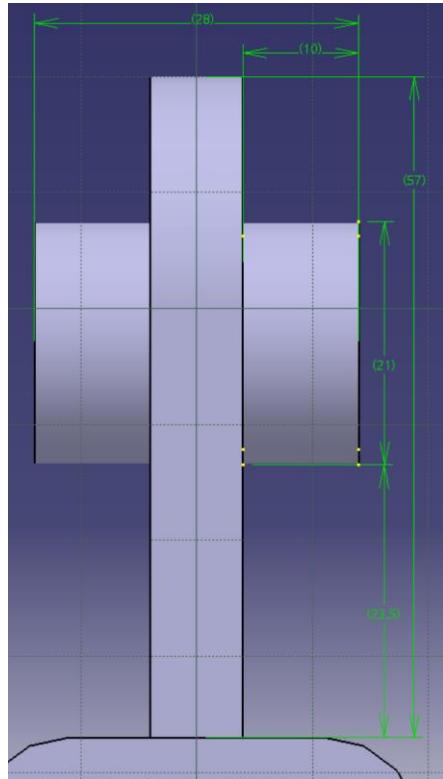
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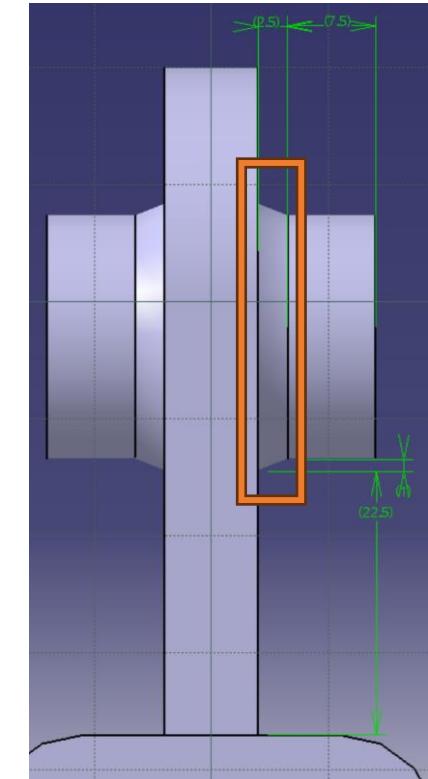
Refine model

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

# #2-3 Compare Base vs Optimum



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

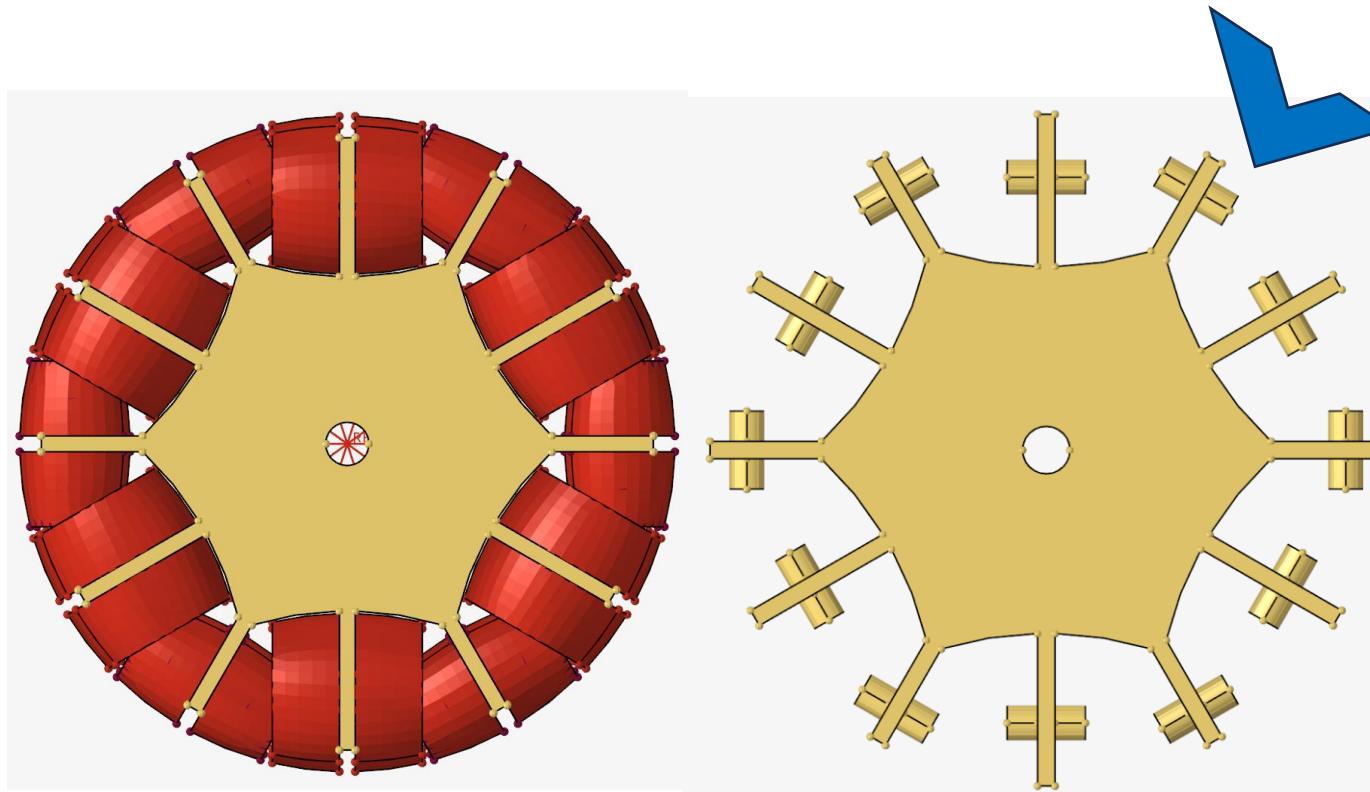


→미약하지만 Base 모델 대비 변위,  $\text{stress}_{\max}$ 를 감소할 수 있었다.

# Mass Optimize

# #3-1 Mass optimize – body select

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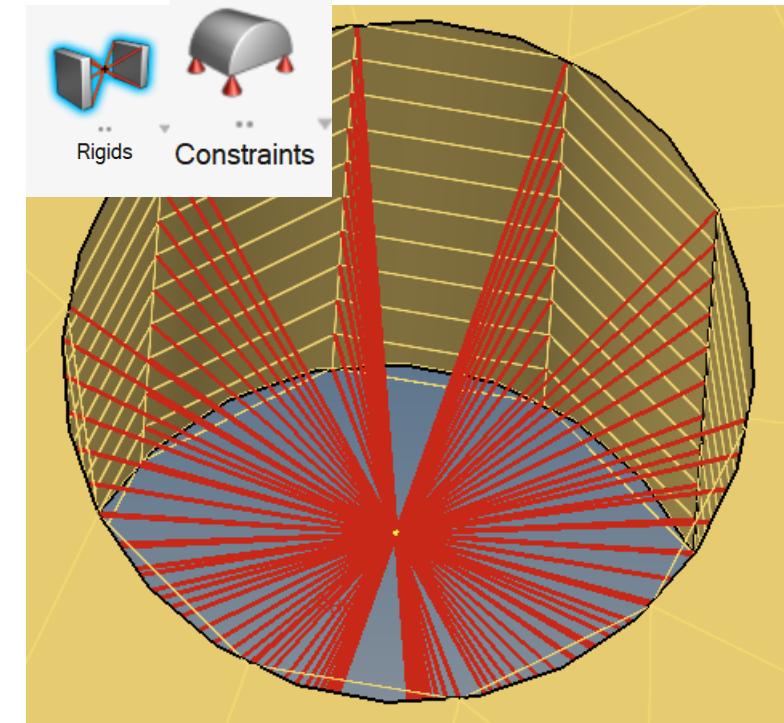
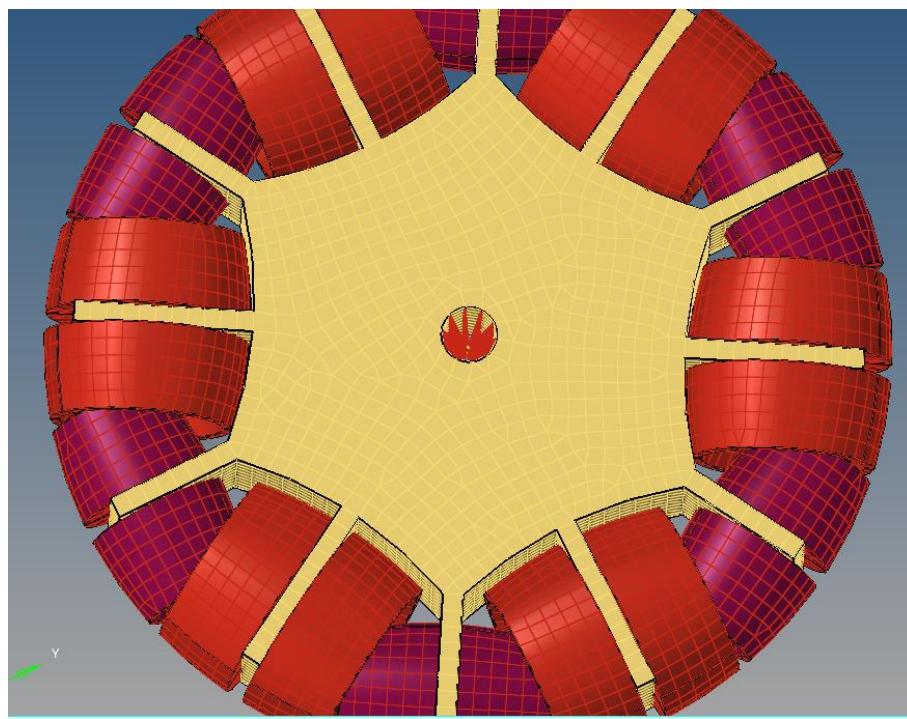


Omni wheel model overall (left)  
Model except rollers (right)

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

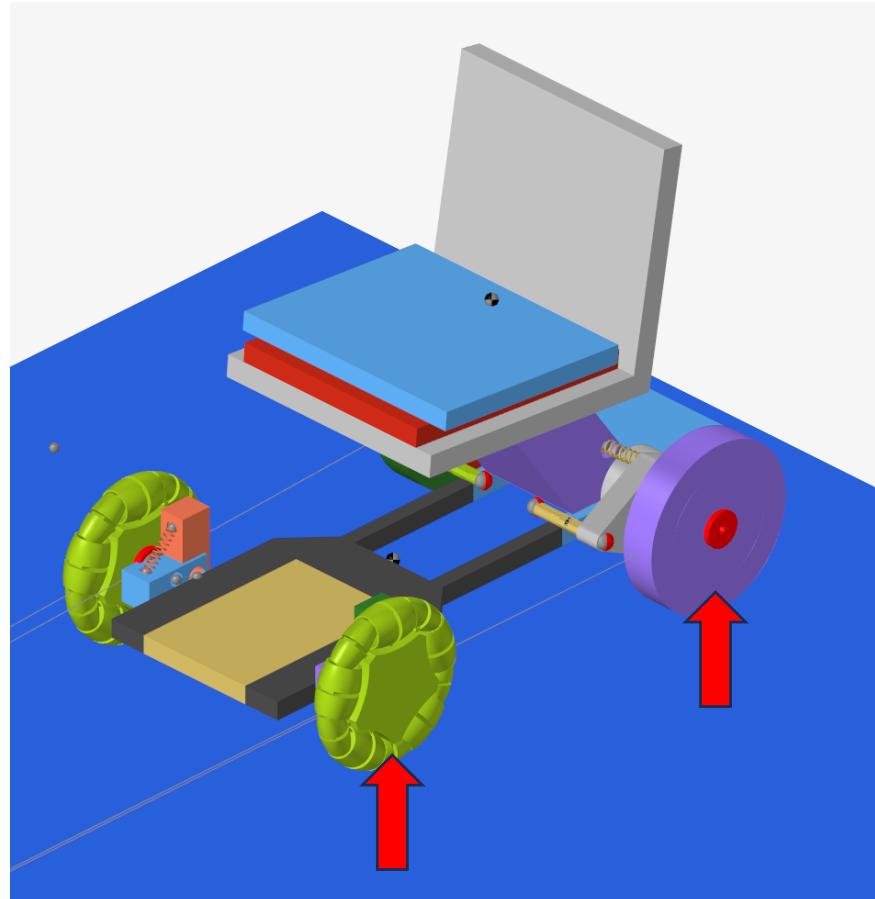
# #3-1 Making Spc

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rbe3을 이용해 가운데 구멍의 노드를  
묶은 후 6자유도 모두 구속

# #3-1 Measurement of normal force



**Measurement to earn  
Normal force at each wheel**

- 전세계 평균 체중 = 62kg <sup>7)</sup>

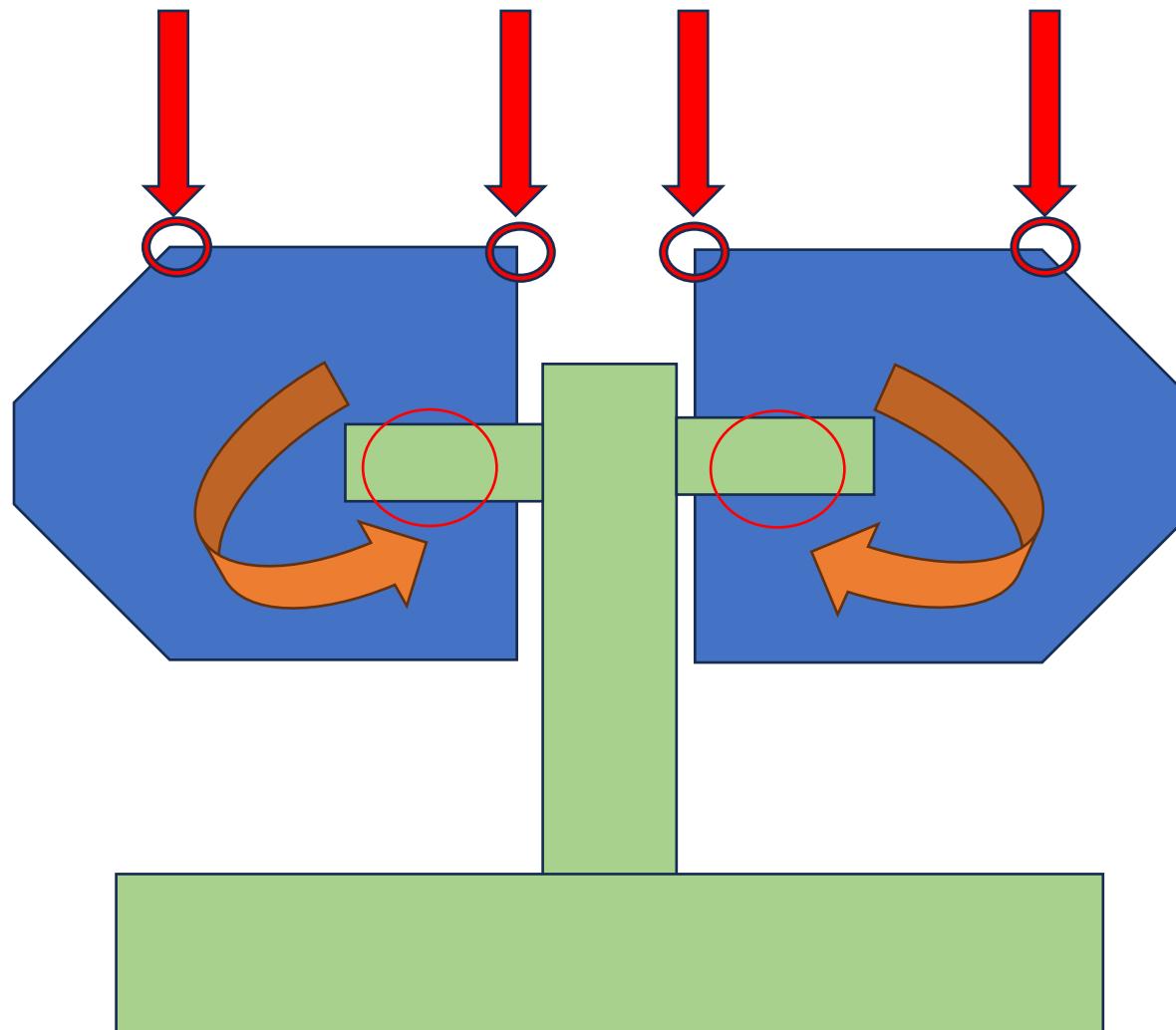
- 훨체어의 62kg의 무게를 올려두고 정적상태에서 바퀴의 수직력 측정

Normal force (N)	
Front Wheel	Rear wheel
259.3	279.8

- 전반적으로 2000N 미만

→ 2000N을 버티면 실사용에 문제가 없을 것이라 판단

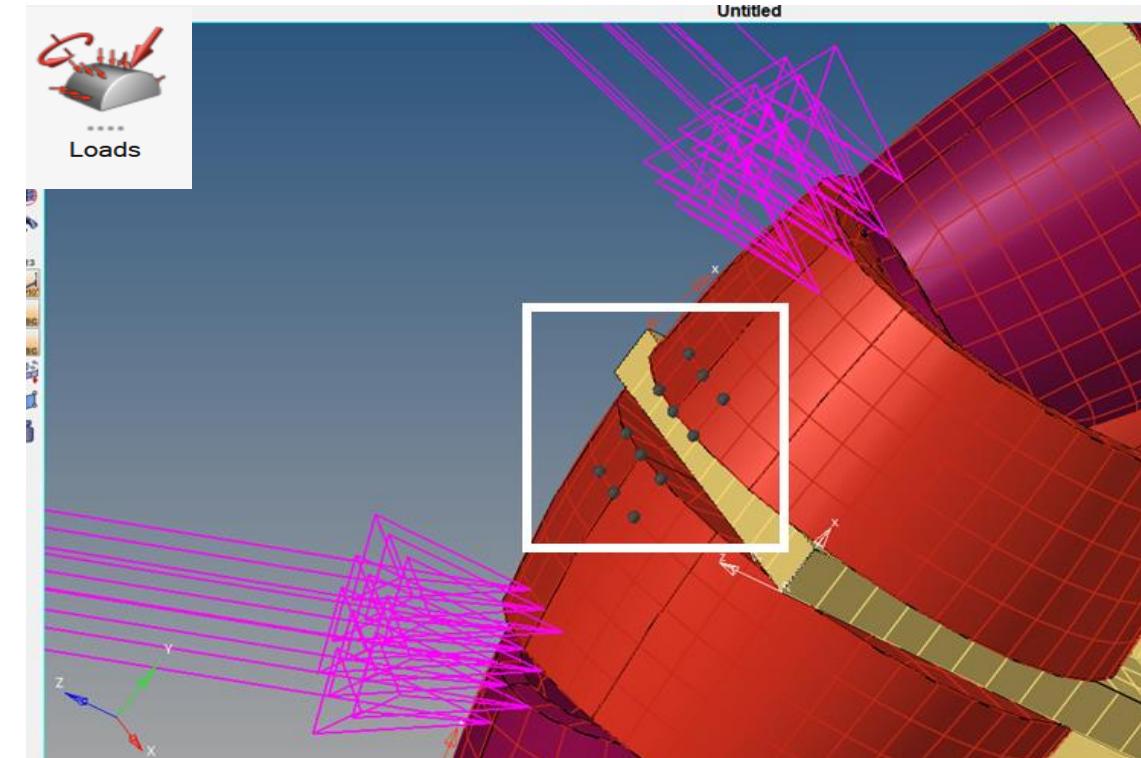
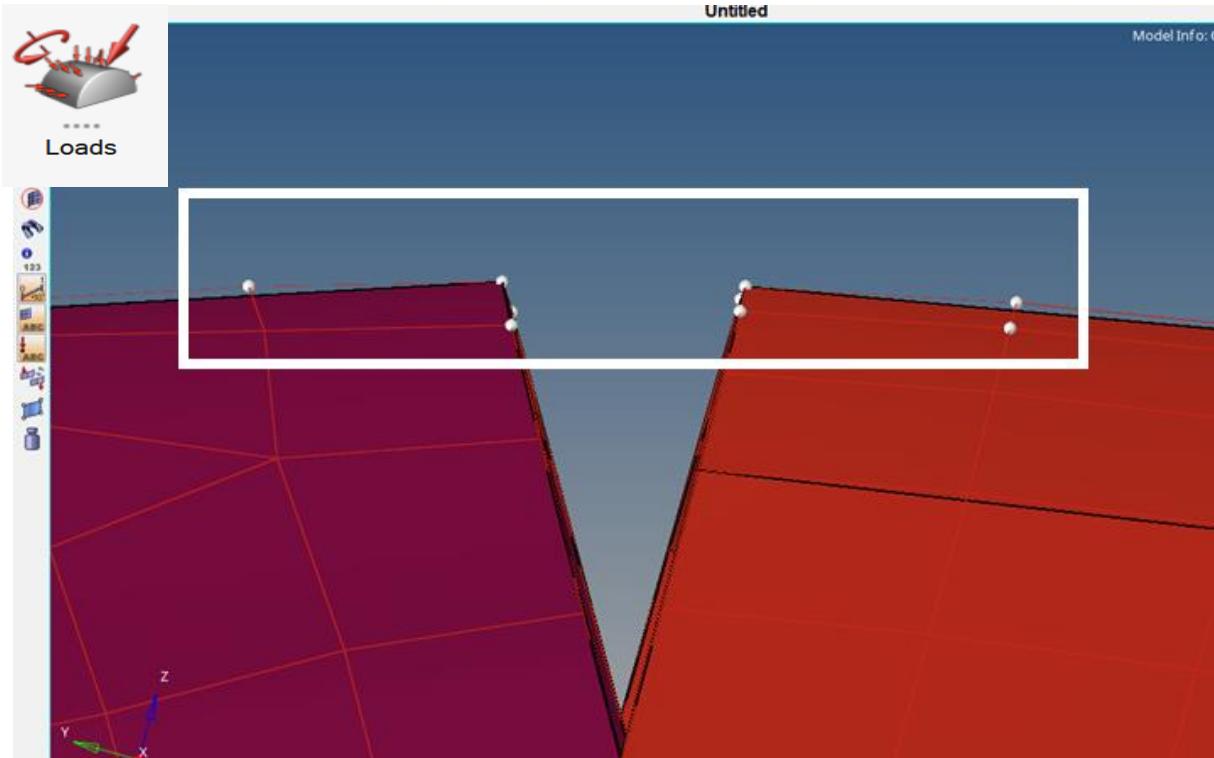
# #3-2 Force apply node select



The sample illust of predictable effect  
by stress at roller support

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

# #3-2 Force apply



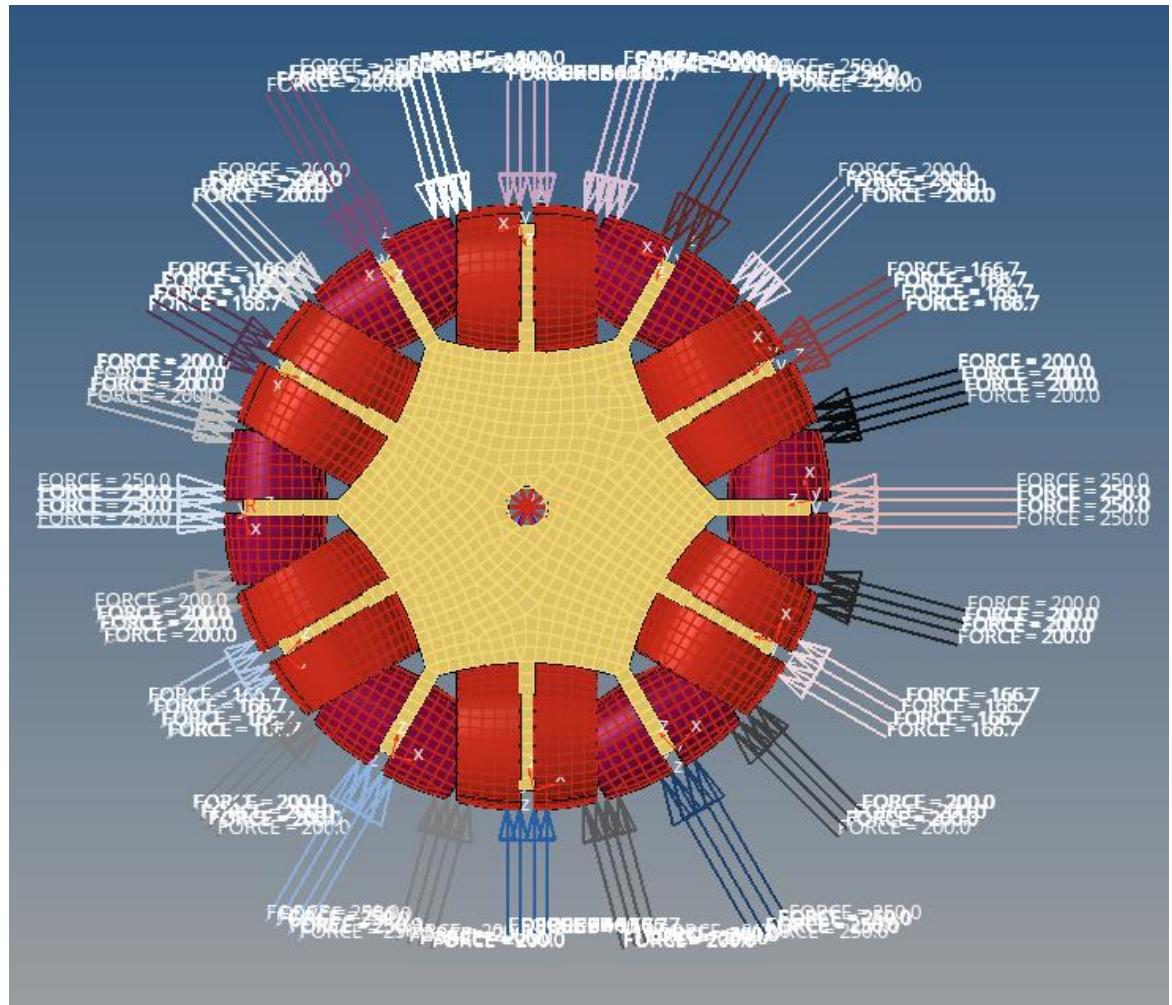
Force apply to node (gap part)

흰색 Box 범위에  
총 2000N의 힘을 분배해서 입력

# #3-2 Force apply to all roller

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

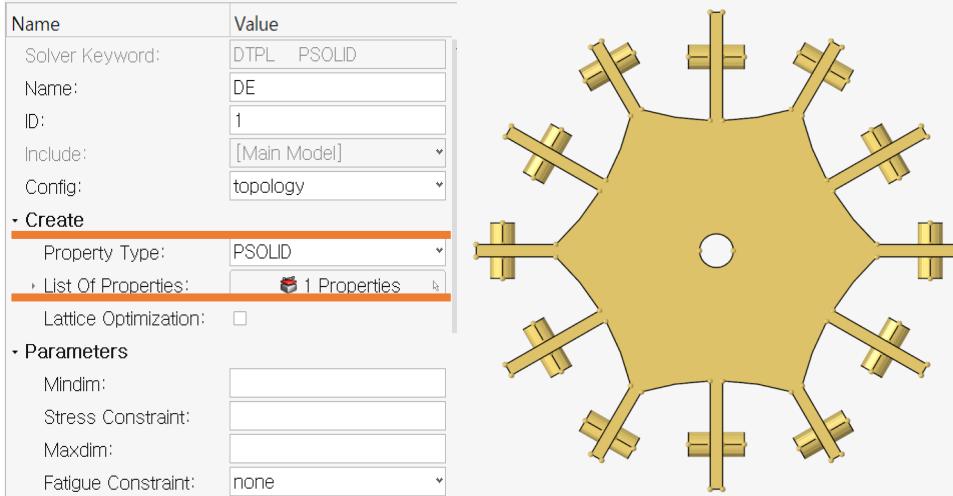


Visualize load collectors apply to model

# #3-3 Process of Optimizing

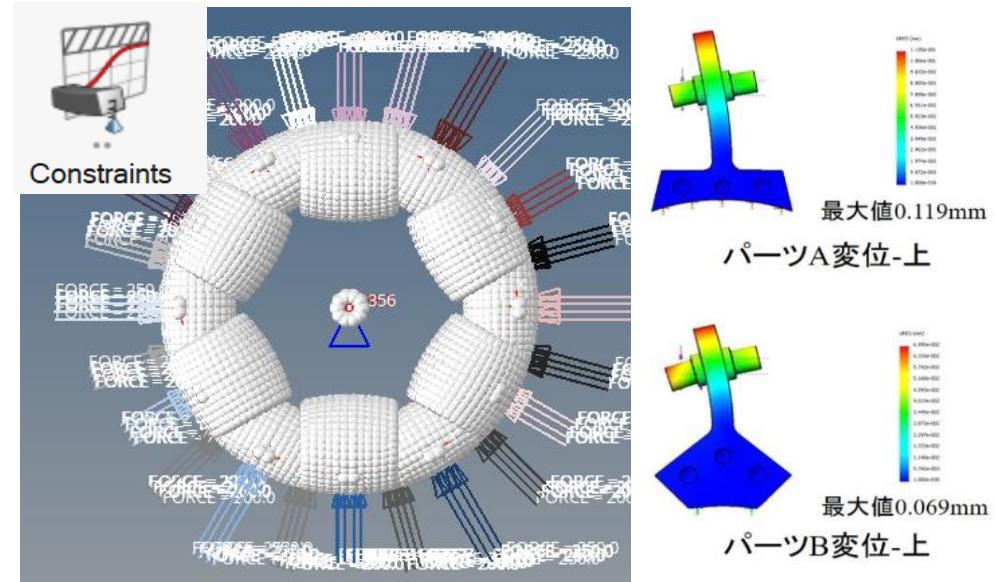
1

Design variable



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

2-1



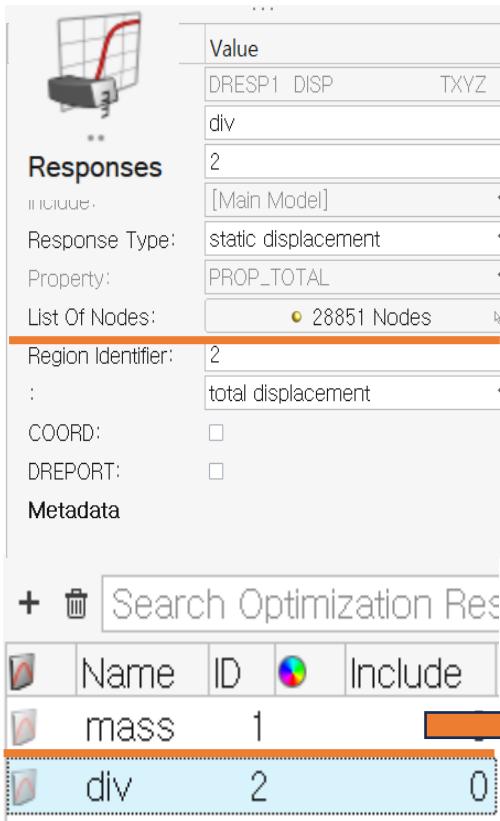
Constraint target node (left)  
Displacement in ref article (right)

최적화 방법 : Topology  
대상 : Hub + support

참고 논문<sup>4)</sup>의 해석 결과를 바탕으로  
롤러의 모든 노드에 대해  
±0.1mm 변위를 구속 조건으로 설정

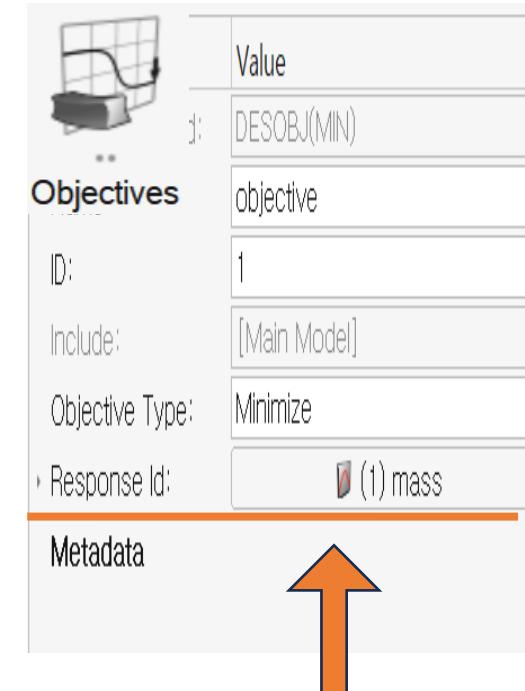
# #3-3 Process of Optimizing

2-2



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

2-3



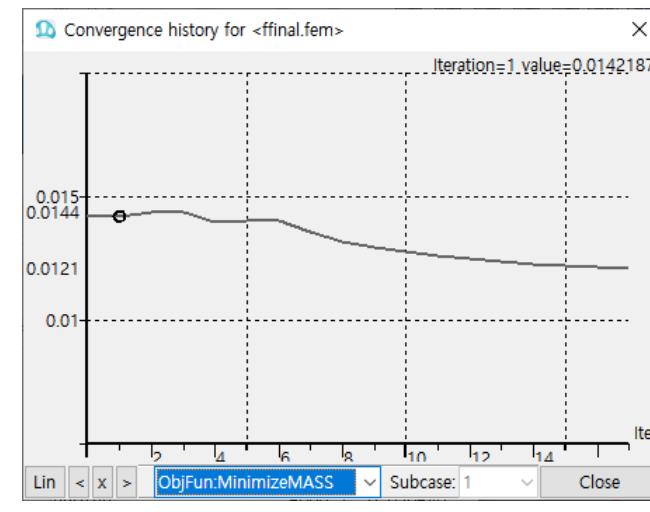
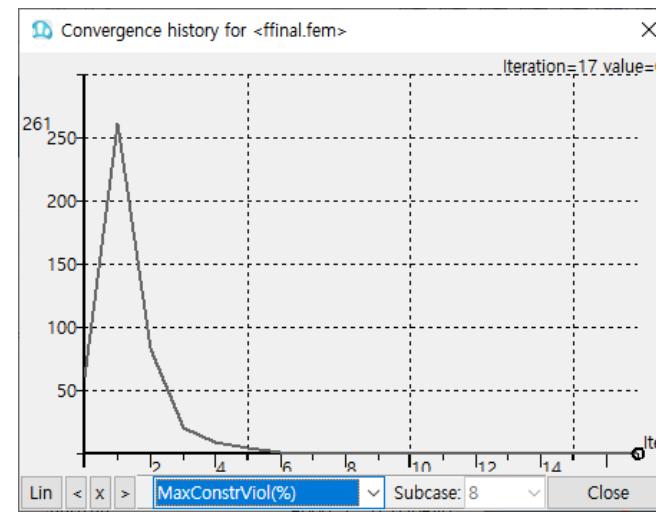
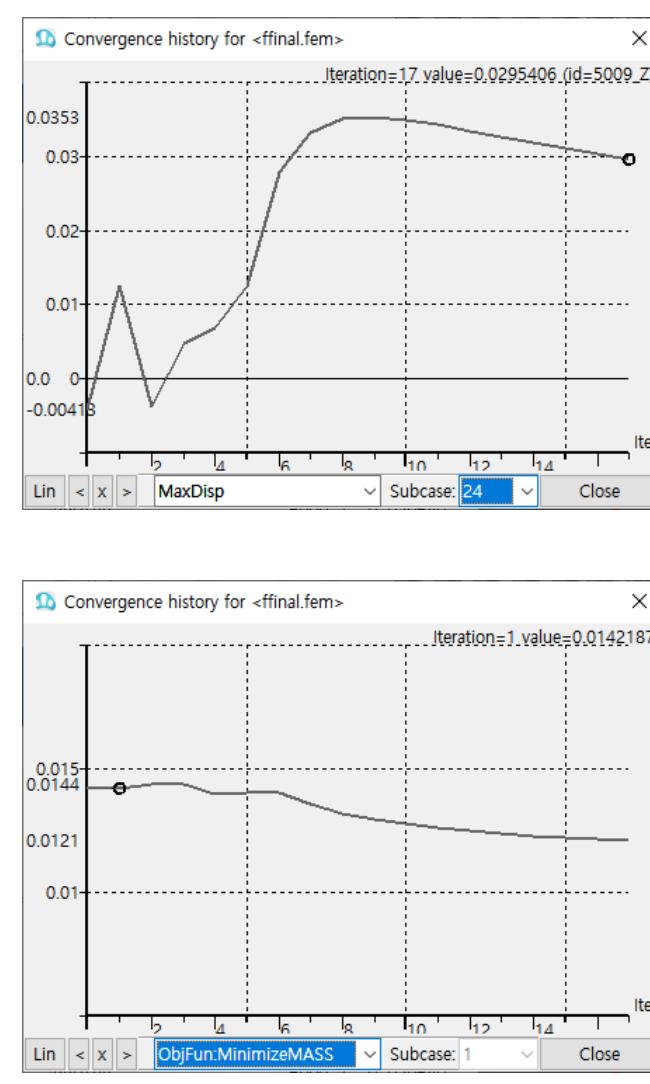
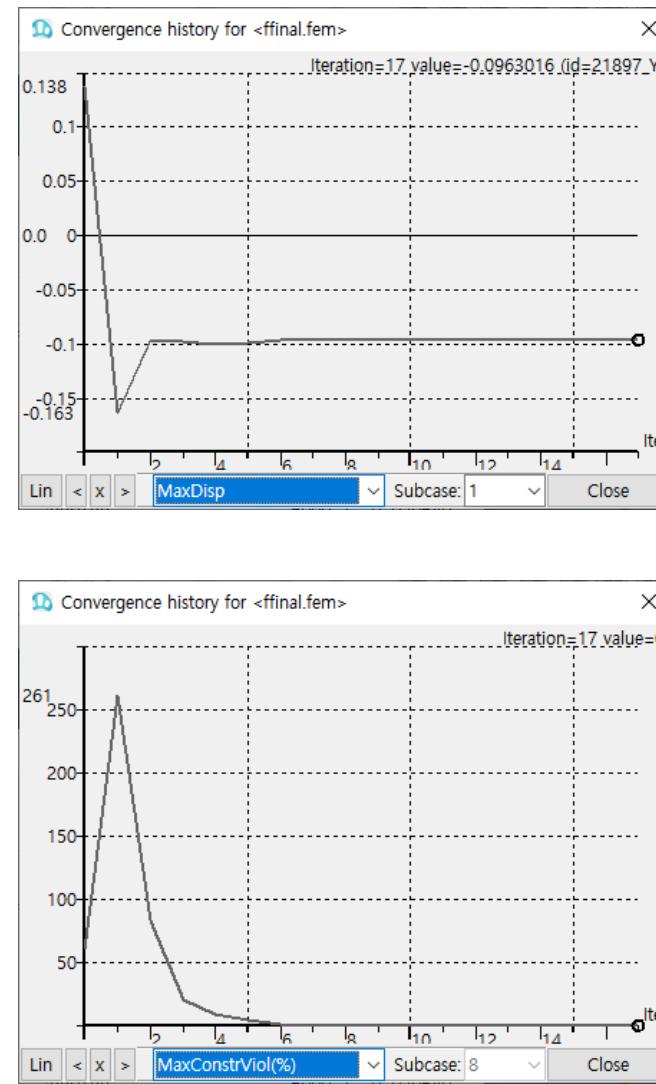
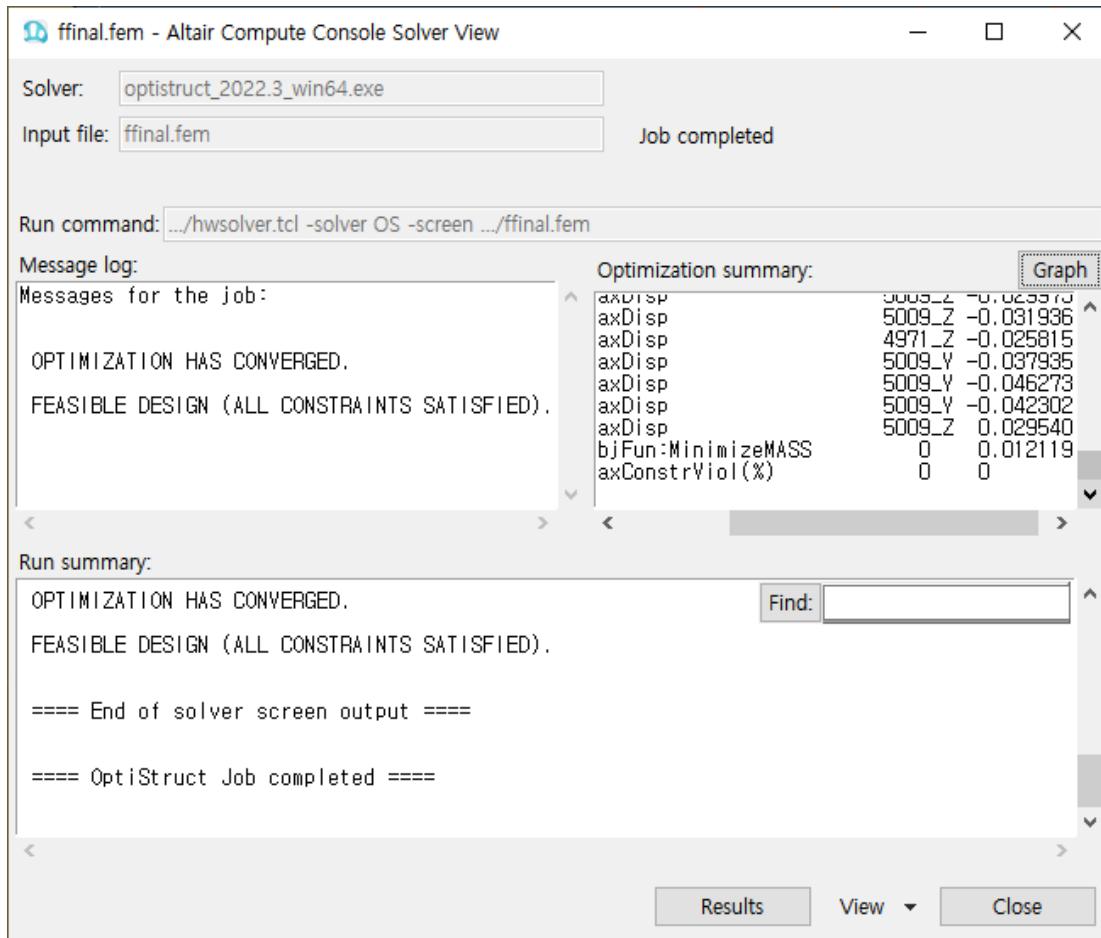
[2-2]중 총질량에 대해  
질량 최소화 (최적화 목적) 설정

3

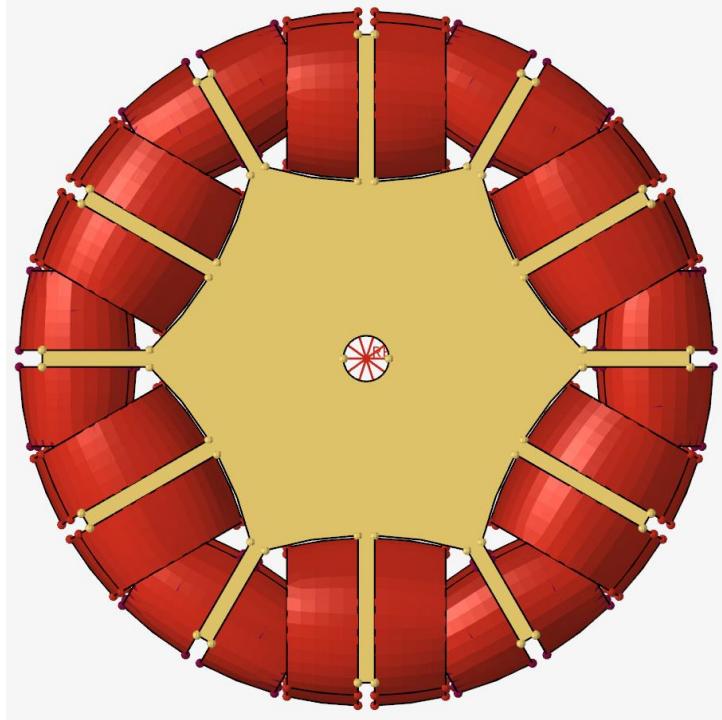


# #3-4 Optistruct solver view

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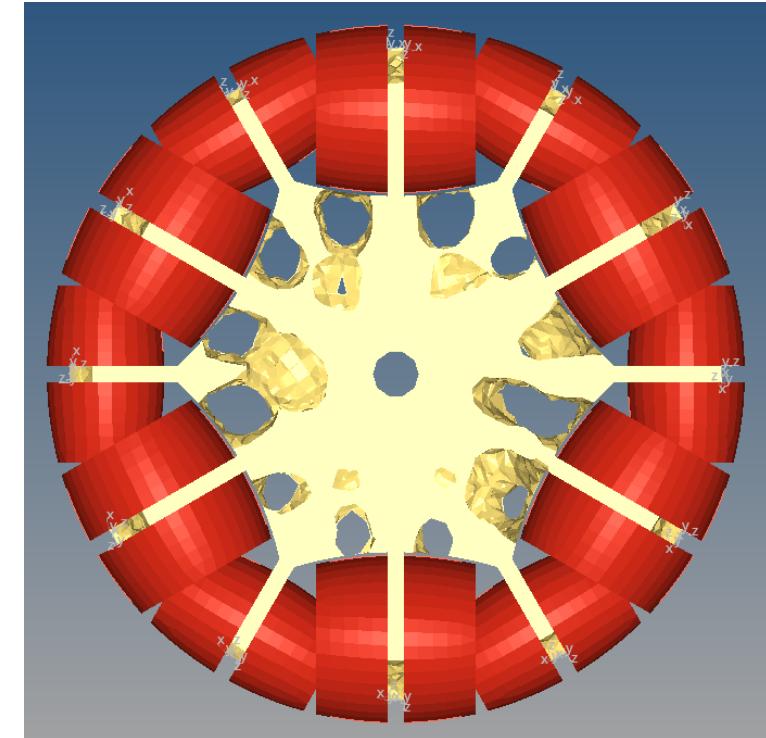
# #3-4 Optimization result



Base model

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

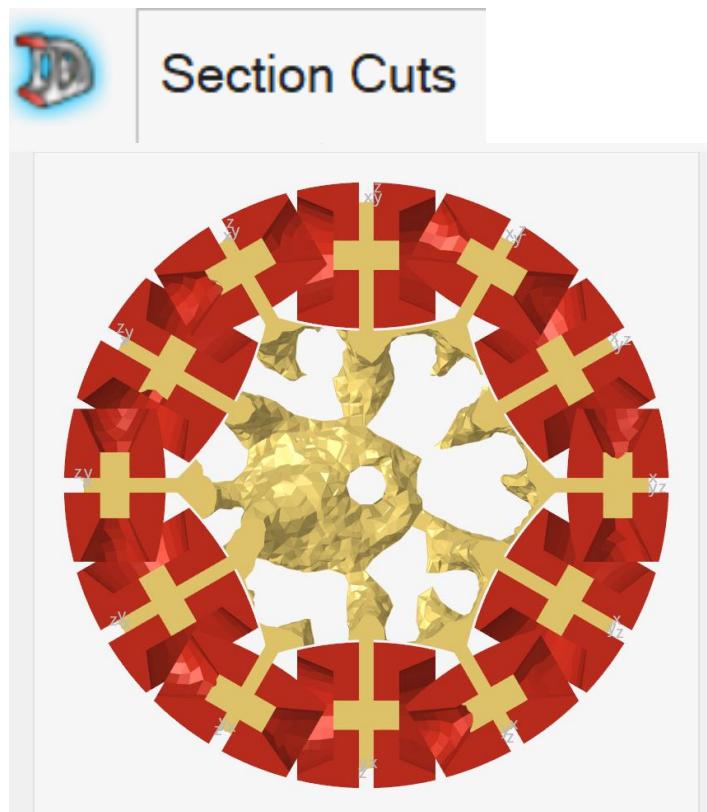
→약 2kg 의 중량 감소가 이루어짐



Optimum model

# #3-4 Optimum model section review

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Front view



Isometric view

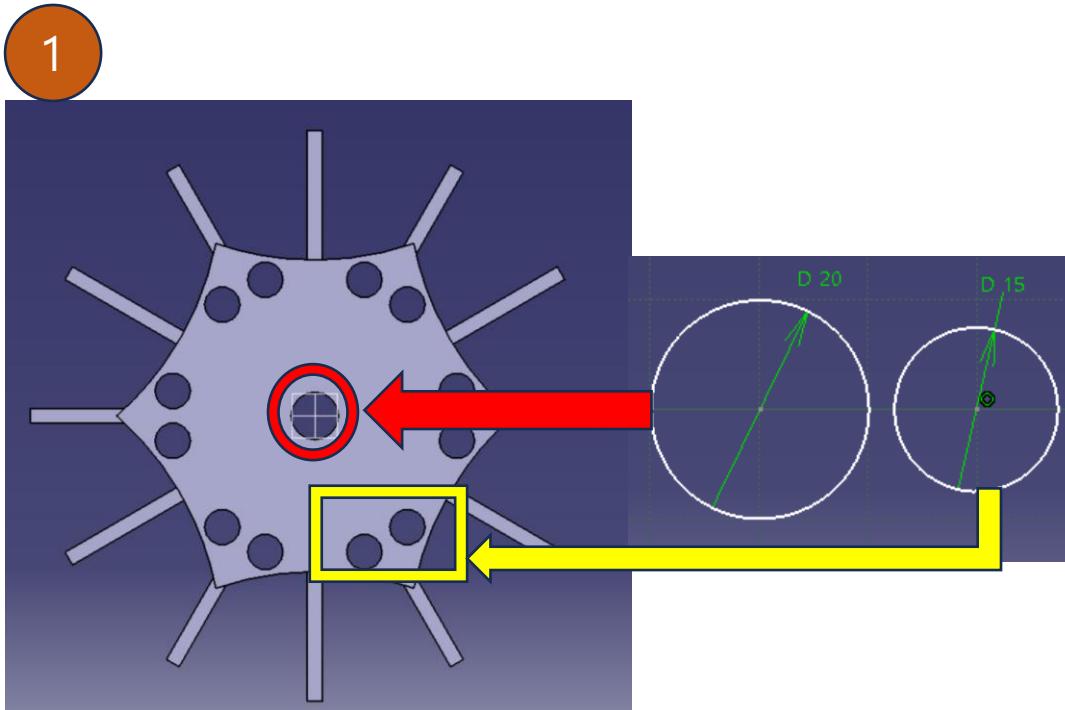


Side view

→ Roller support 부분 외 pocketing이 이루어짐

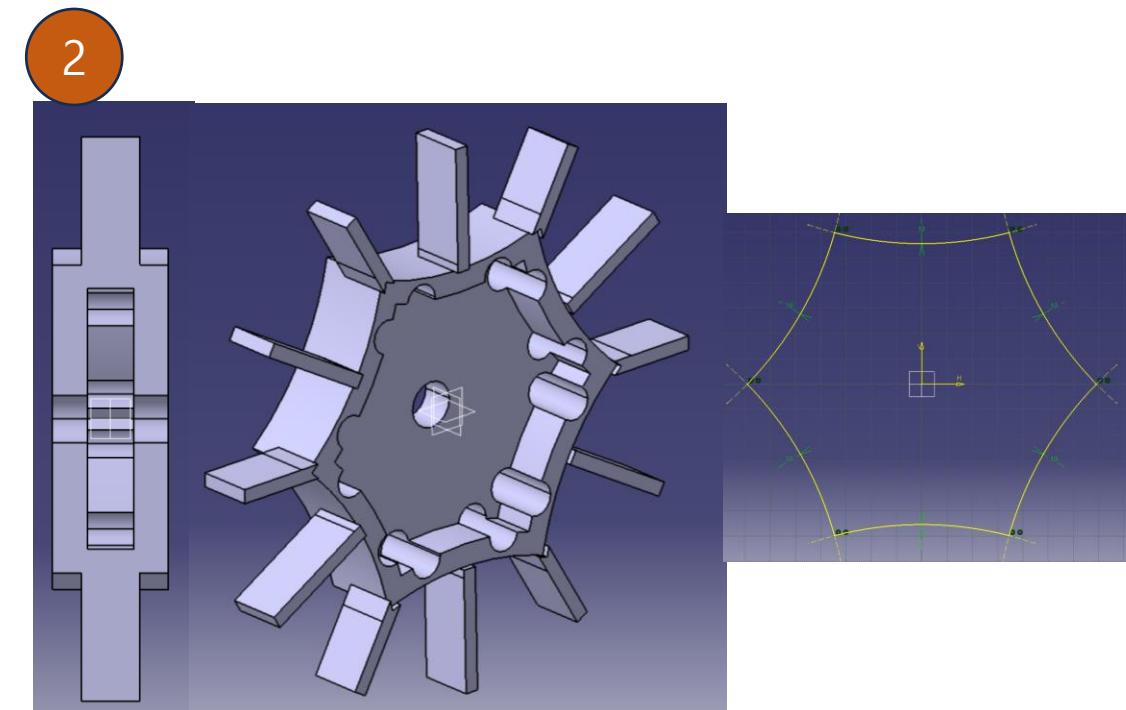
# #3-5 Model refining

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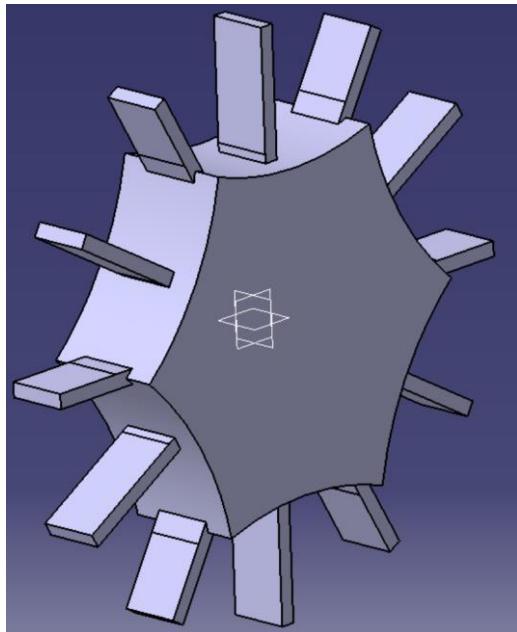
Wheel hub hole →  $R = 10$   
Hole nearby support →  $R = 7.5$

위 기준으로 Pocketing 진행



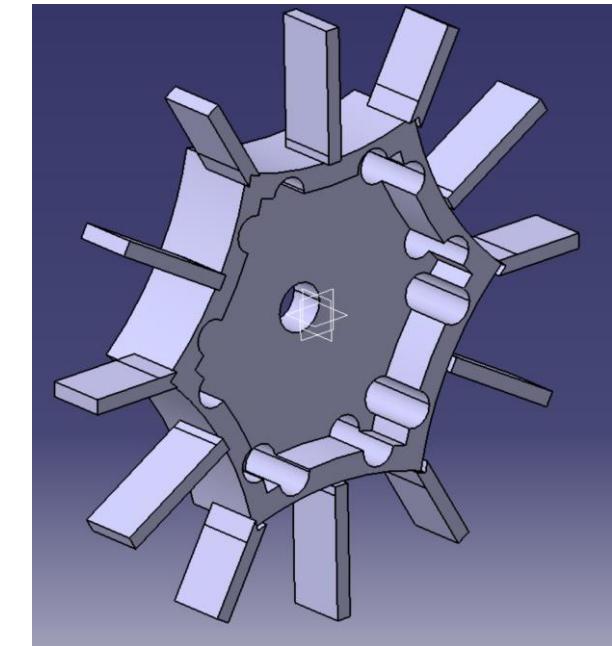
Offset → 10mm 를 부여하여  
좌우 10mm 총 20mm  
Pocketing 진행

# #3-5 Check for weight decrease



Base model

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

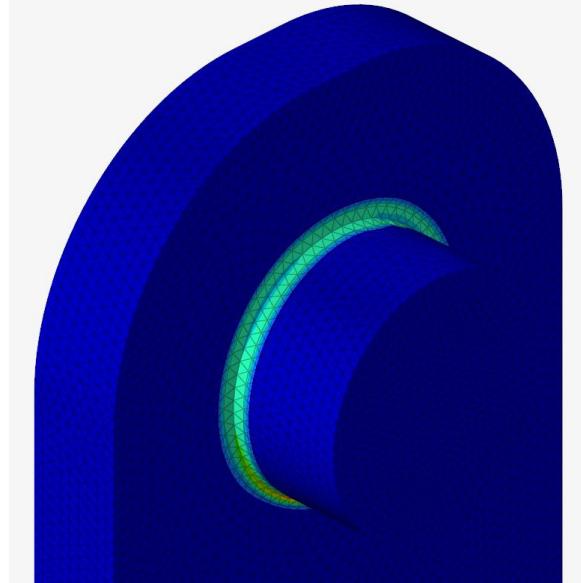


Refine model

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

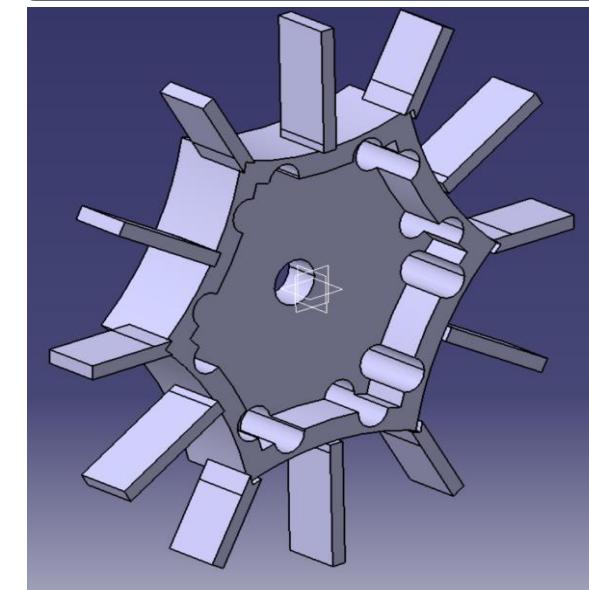
# \* Summary

#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