# Omni Directional Wheel Optic design


- 2019041076 정찬민
- 2019087856 한상원

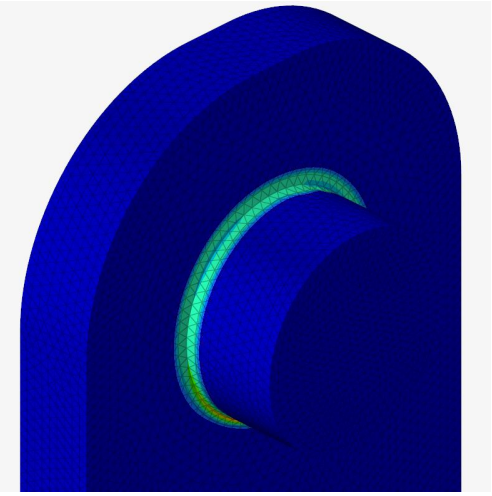
# * 목차

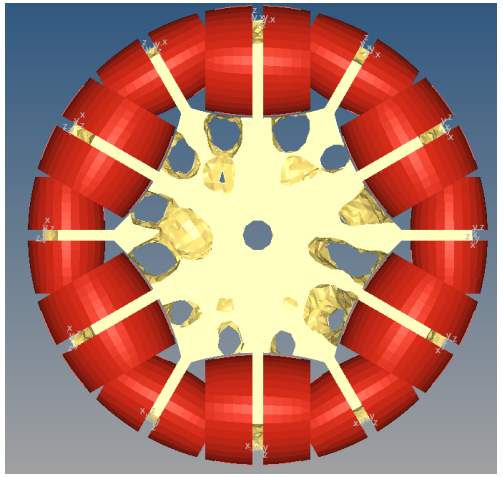
# * Abstruct



**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

## 새로운 형태의 전동 휠체어

카이로보틱스(Korea)


WHILL(Japan)

ROBOOTER(China)

# #1. Info – What is Omni wheel

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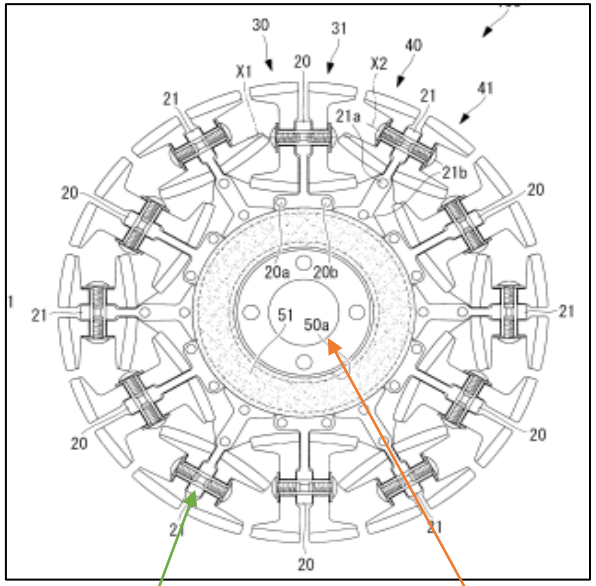
**# 핵심 부품**

- 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)



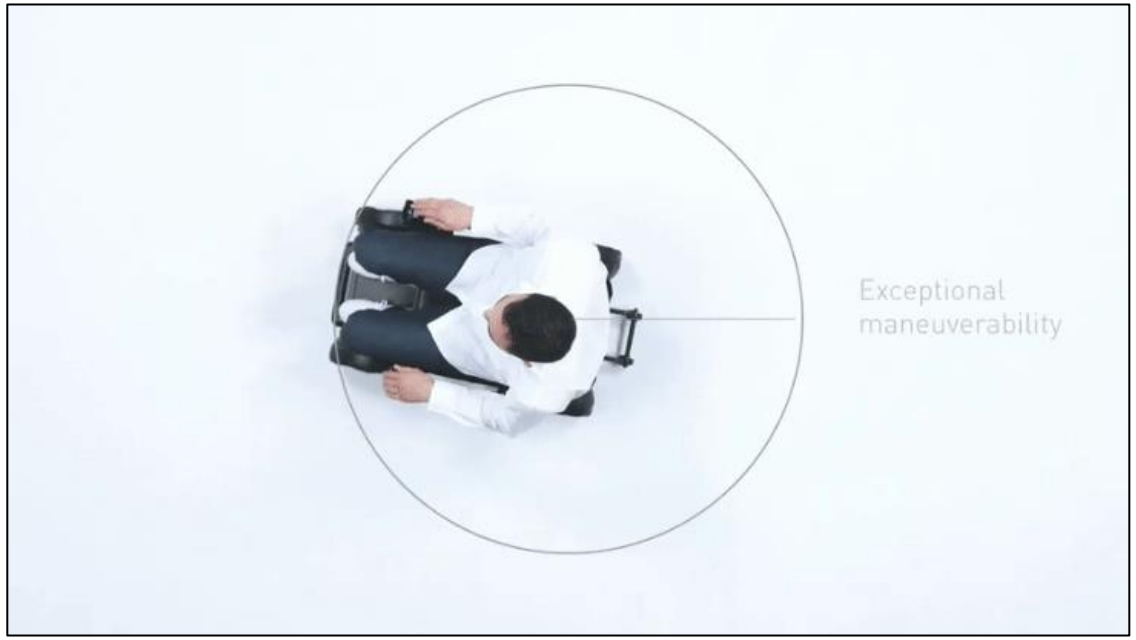

(1) Bando, K., & Naito, J. (2015). Omni-directional wheel and omni-directional vehicle including the same. (Japan, JP5687352 B1)

# #1. Info – Omni wheel movement



*(2) https://youtu.be/_ubcktAK0Cw?feature=shared*


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



# #1. 연구 방향 선정

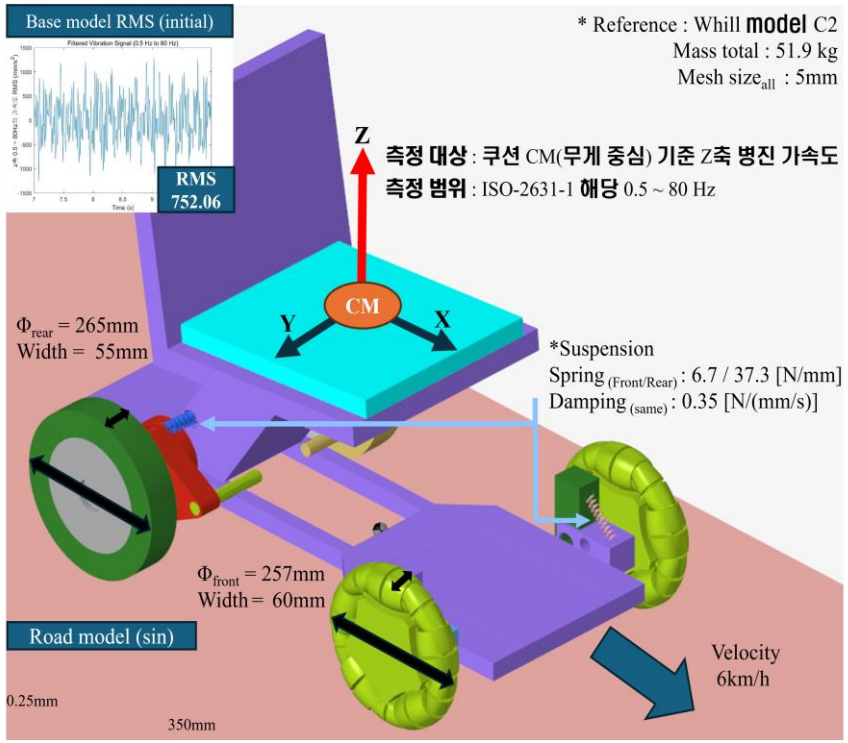


## # 진동 해석 진행 및 각종 문제점

- 차체, 방석, 스프링 등 다양한 요소로 인한 복잡성
→ 가정 등 고려할 부분이 많음

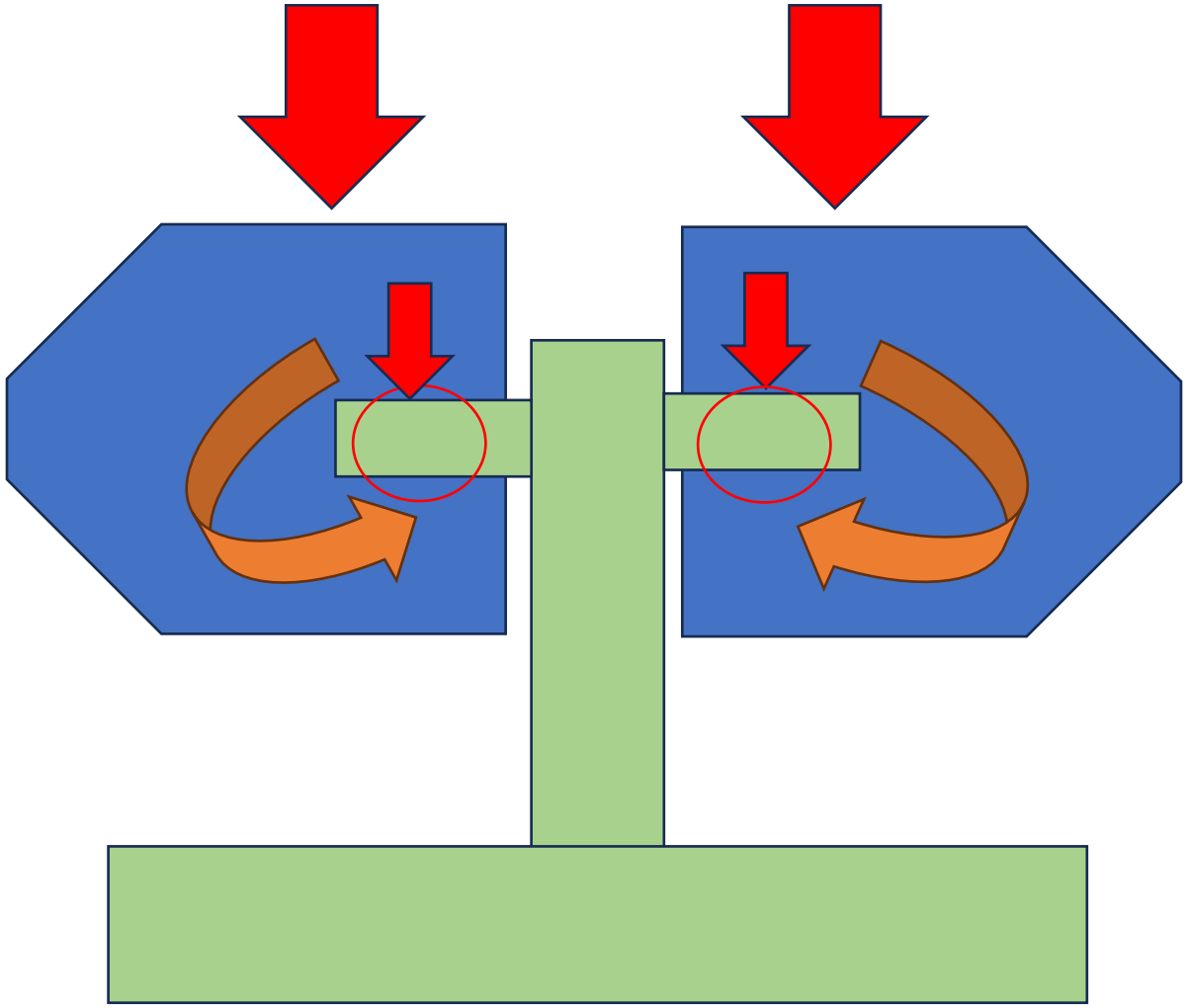
- 모델 규모에 비례한 mesh 생성 및 해석 진행 시간
→ Case study로 인한 요구 해석 시간 증가

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

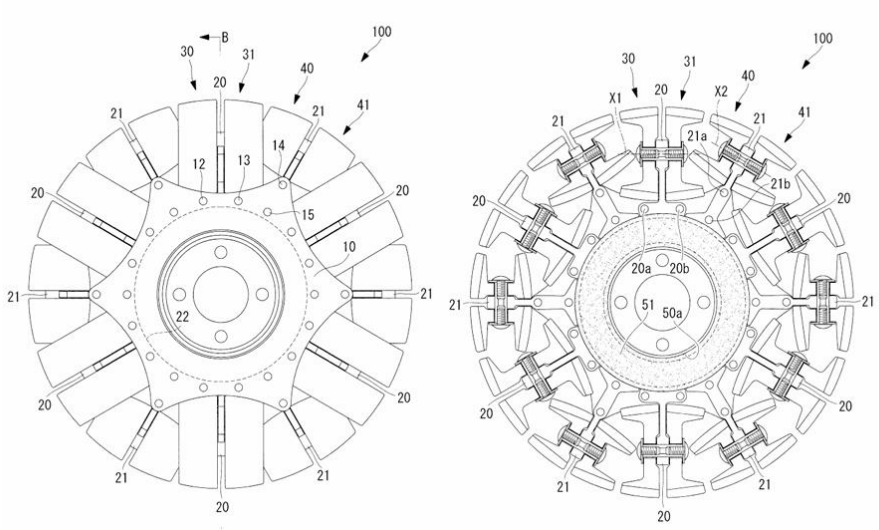
Z축 방향으로의 정적 하중에 대한 해석 필요성

# #1. The base idea



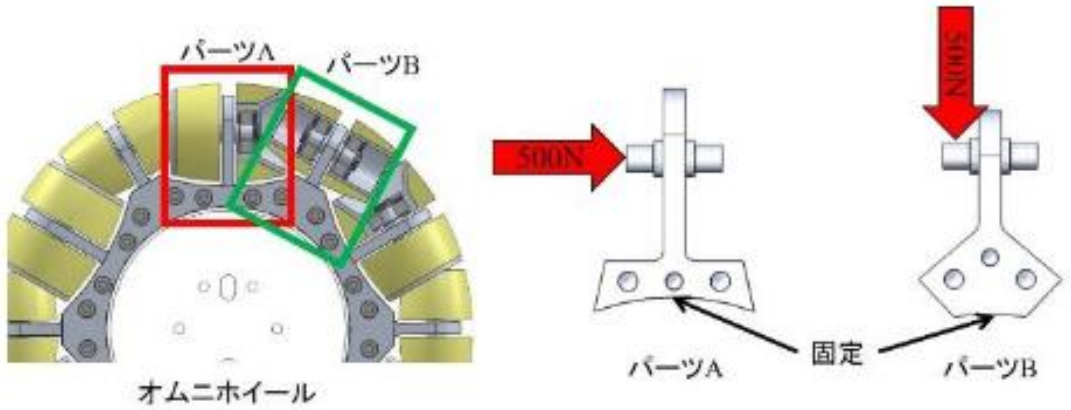
(1)

【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

특허 형상을 바탕으로
롤러 지지대 모델 제작

참고 논문[4]에서 강도 해석
횡, 종 방향으로 하중 부여

# #1. Feasibility for anlysis – Static load

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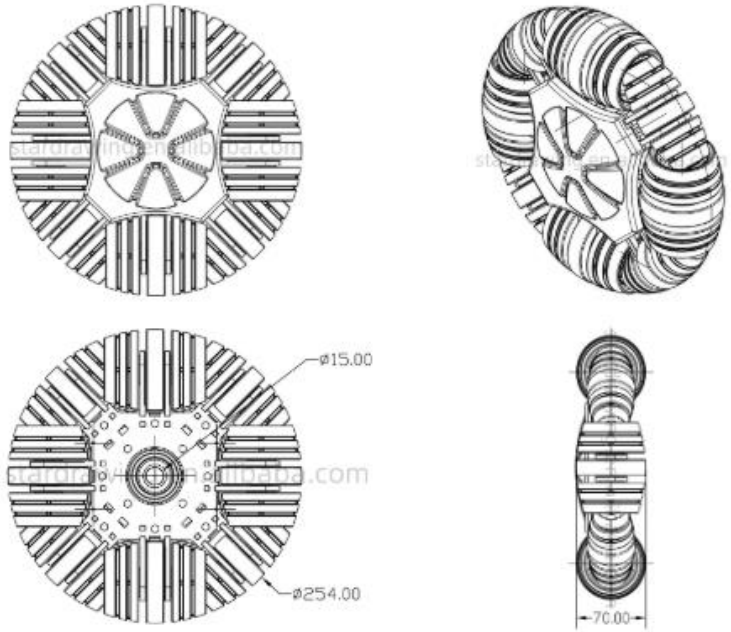
| Omni wheel type | Wheel diameter (mm) | Roller Diameter$_{max}$ (mm) | Dynamic load (kg) | Static load (kg) |
|---|---|---|---|---|
| Reference | 254 | 70 | 100 | 120 |
| Whill C2 | 257 | 62 | - | - |

- 제작 모델과 비슷한 치수[5]를 모델 탐색
  정적 하중 제한 : 120kg
- Whill C2 catalog[6]에서는 하중 제한이 115kg
- 신뢰성을 높이기 위해 하중 제한을 200kg로 설정

→ 2000N의 힘을 가하여 해석을 진행

(5)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



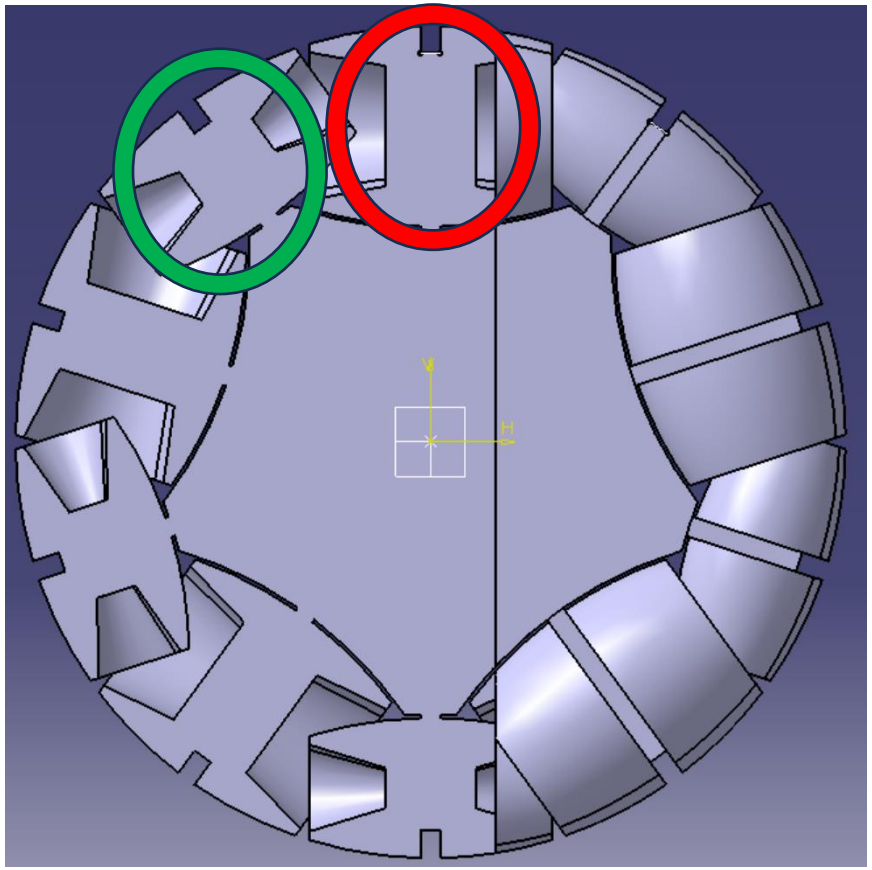

| Wheel Diameter (MM) | Roller Diameter (MM) | Dynamic Load (KG) | Static Load (KG) |
|---|---|---|---|
| 254 | 70 | 100 | 120 |

| | |
|---|---|
| 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℃～40℃ |

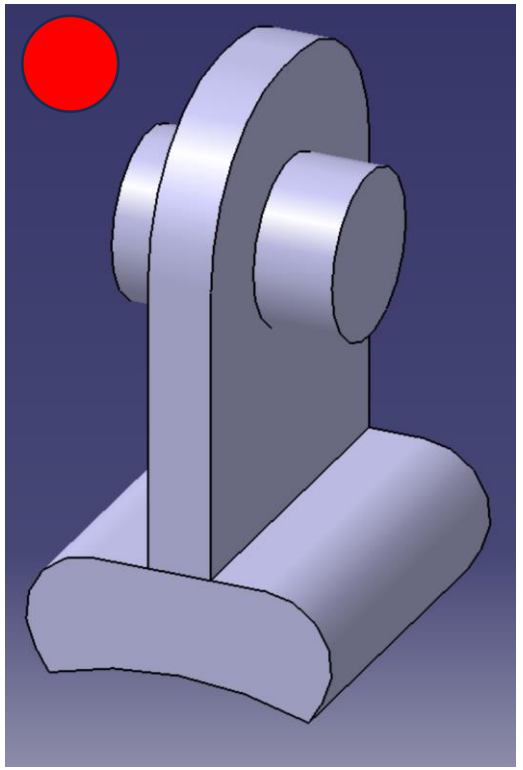
# Free Shape Optimize

# #2-1 shape optimization – cad model

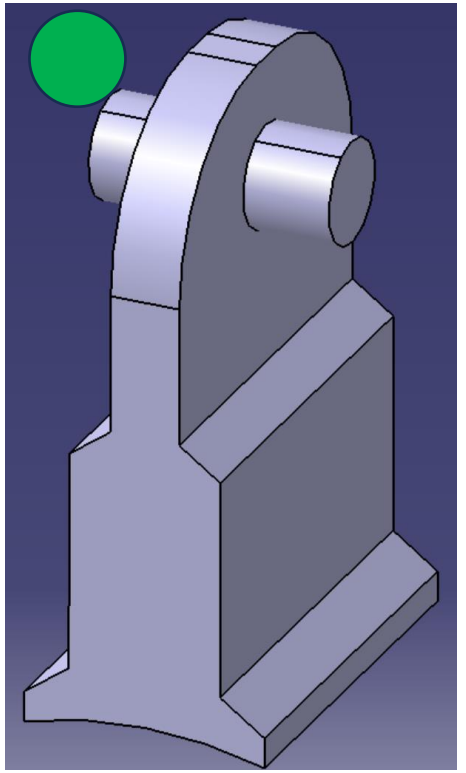




Section cut for
Omni wheel



Support for
Big roller



Support for
small roller

# #2-1 Force analyze method

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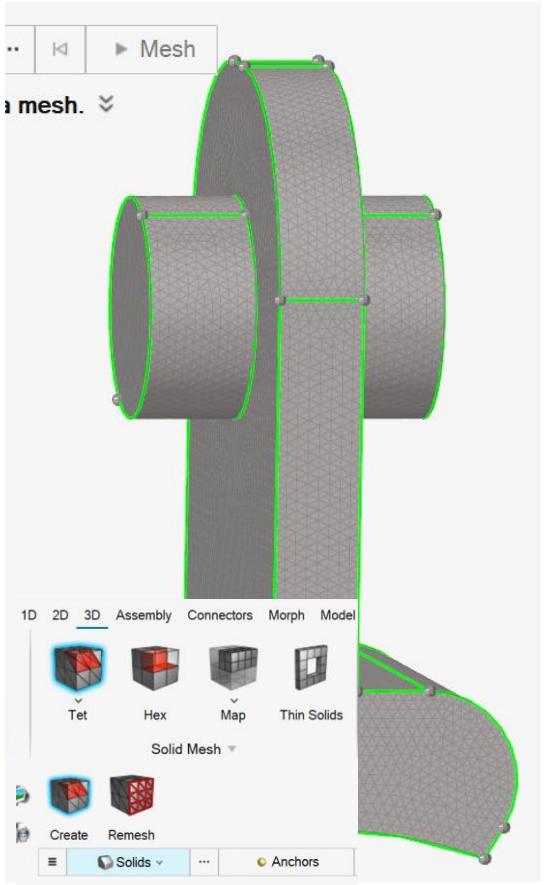
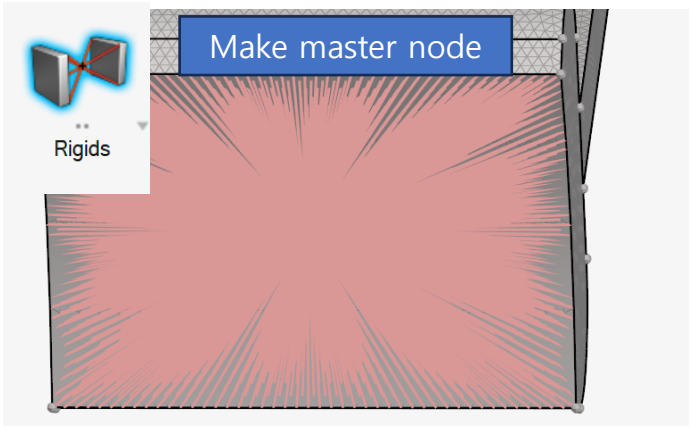
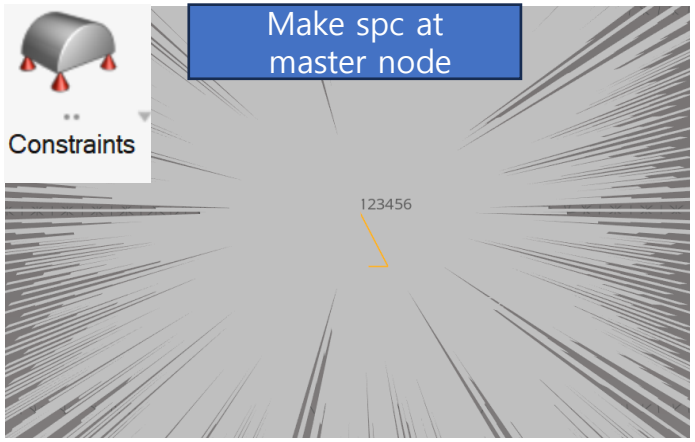
## #1 Mesh generate (1mm)

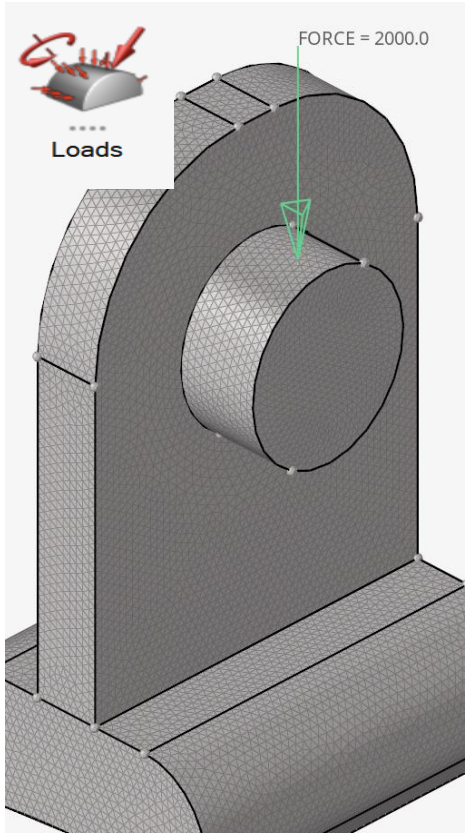



## #2 Create SPC



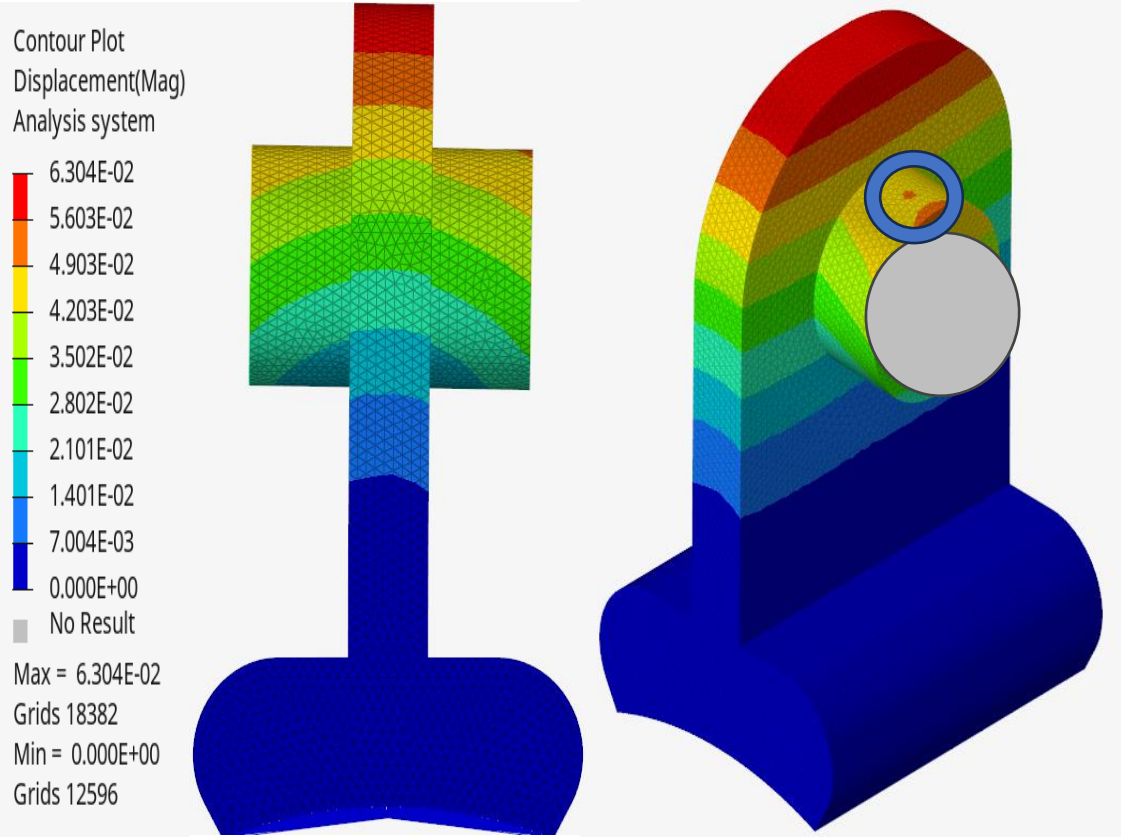




## #3 Create Z force



# #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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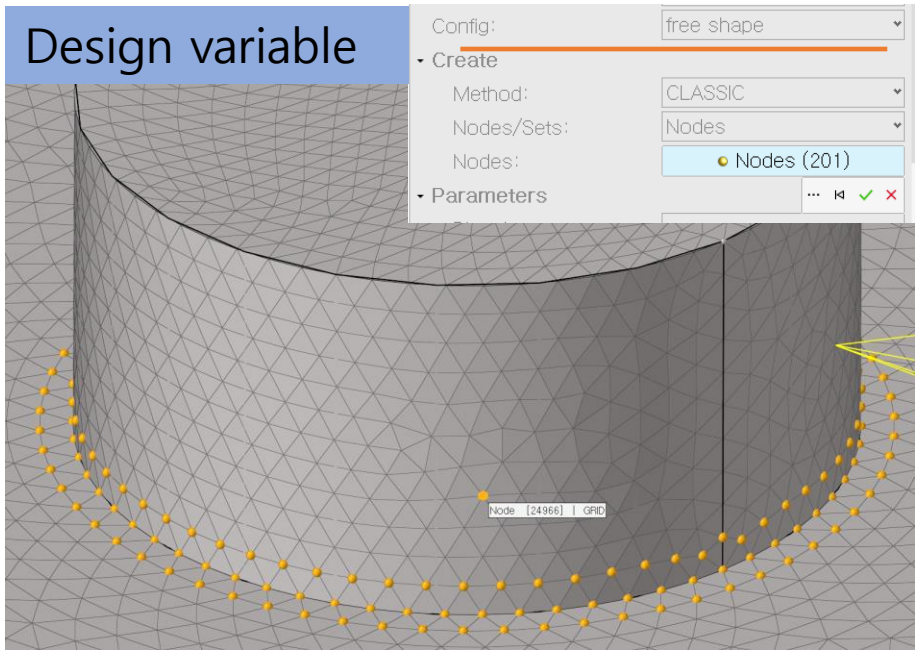
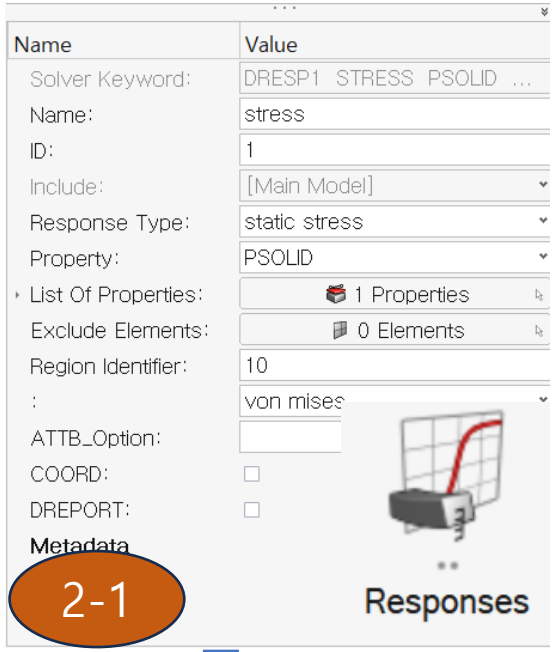
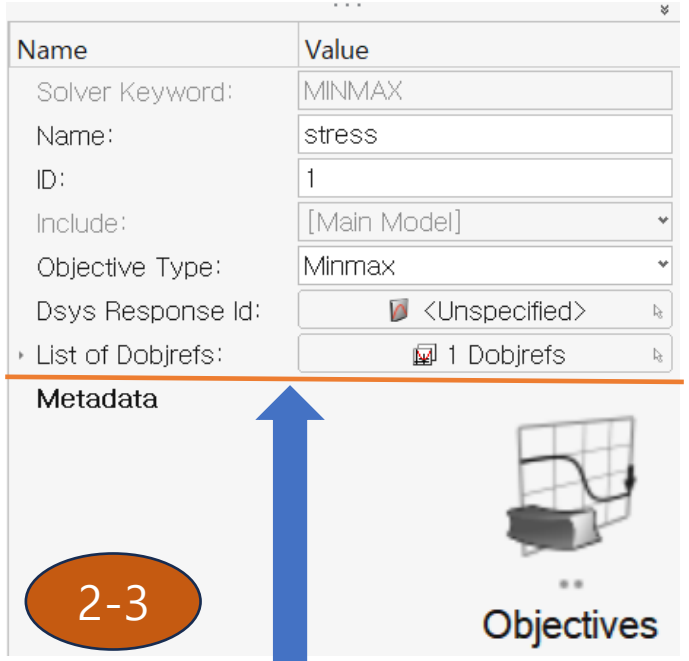
1

Design variable

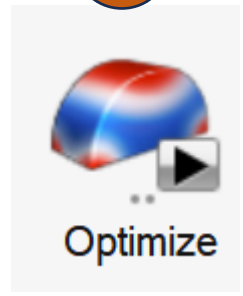




3




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

# #2-2 Methods to see Optimize summary

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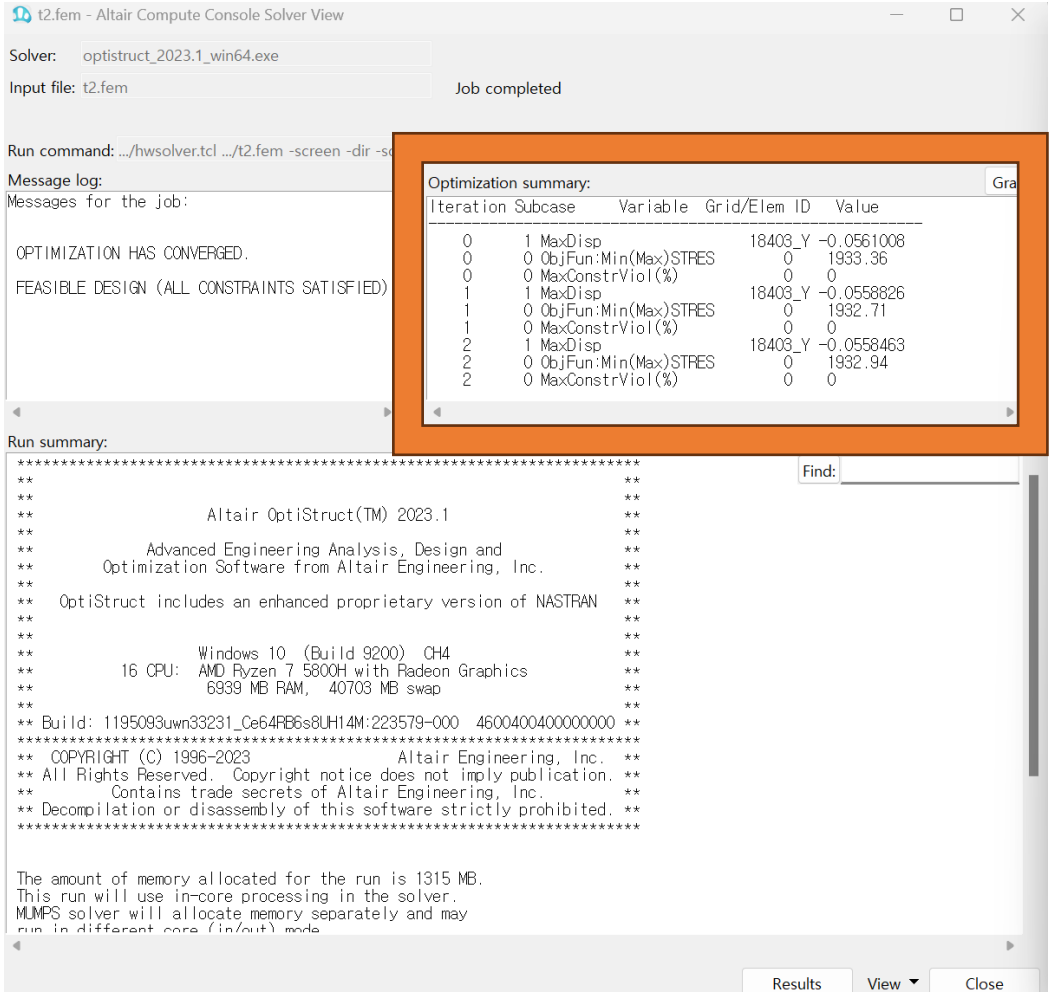
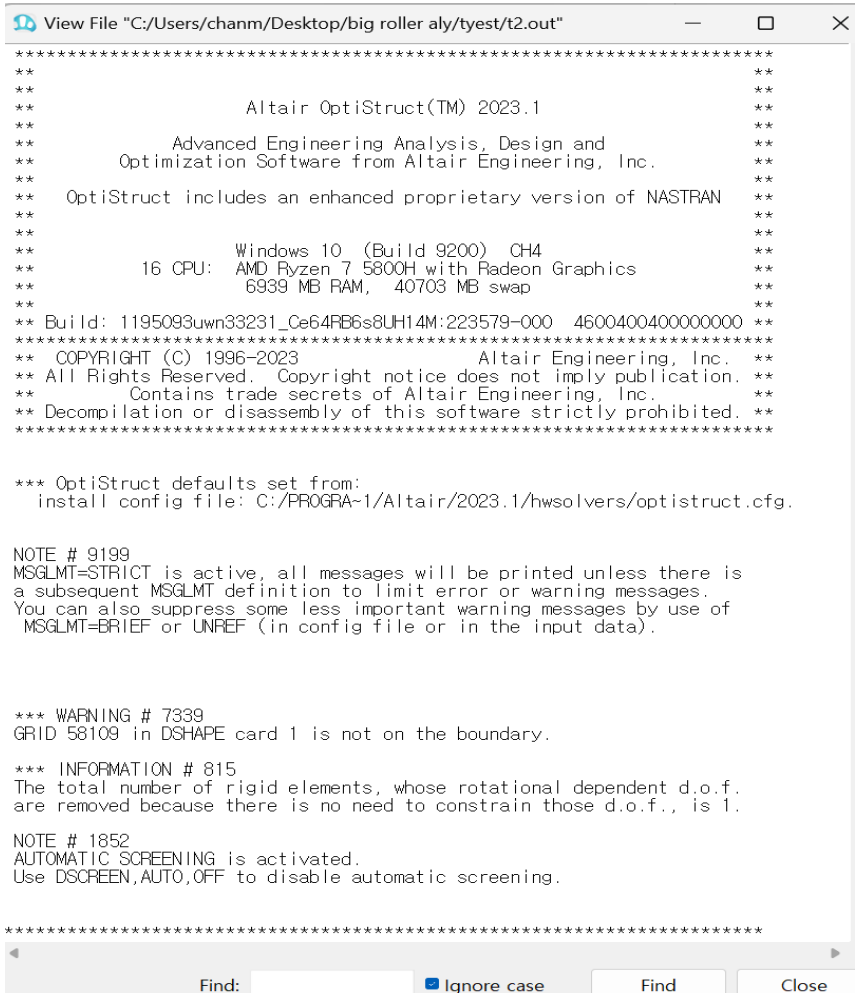
## #1 Optistruct solver view




## #2 Solver output file



# #2-2 Select for the best Iteration case

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```
ITERATION   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.
```

(1) (2) (3)

**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 복원이 빠름, 영구 변형 가능성 낮음

# #2-2 Select for the best Iteration case

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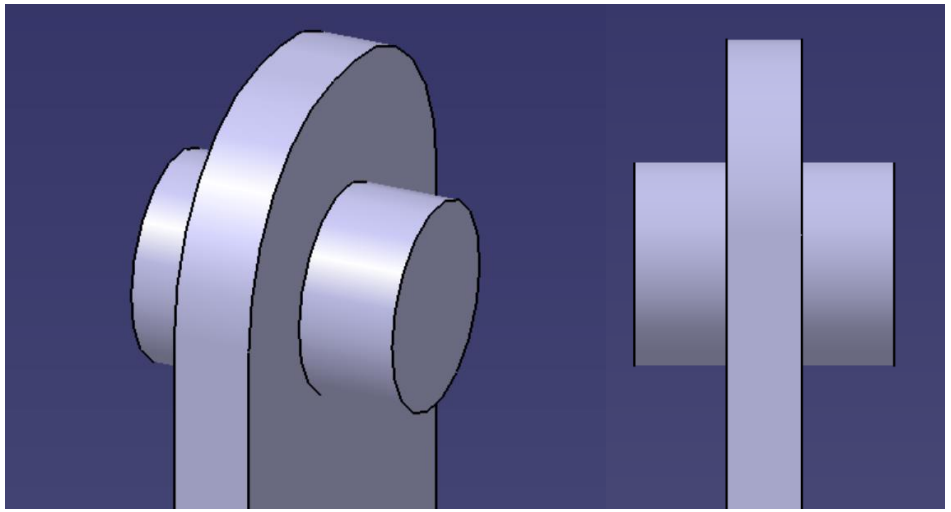
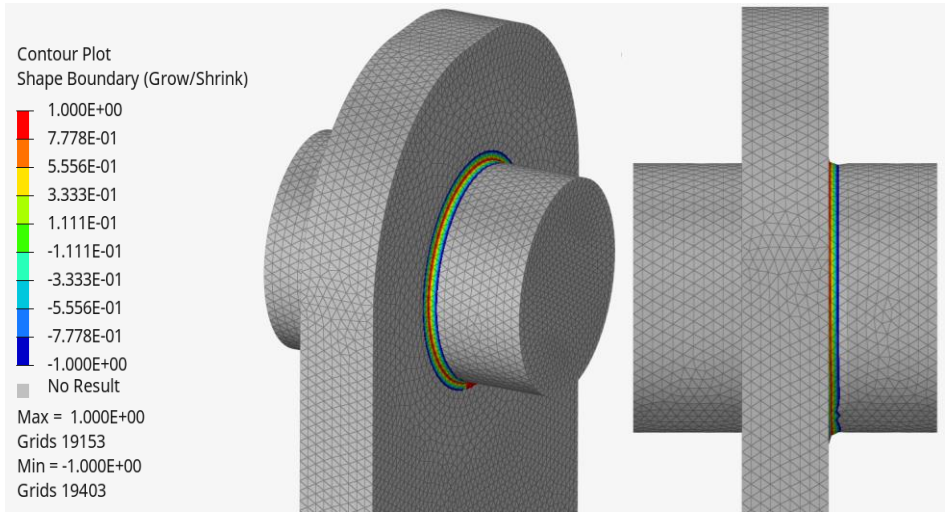


Base model view (isometric/front)

| | 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% |

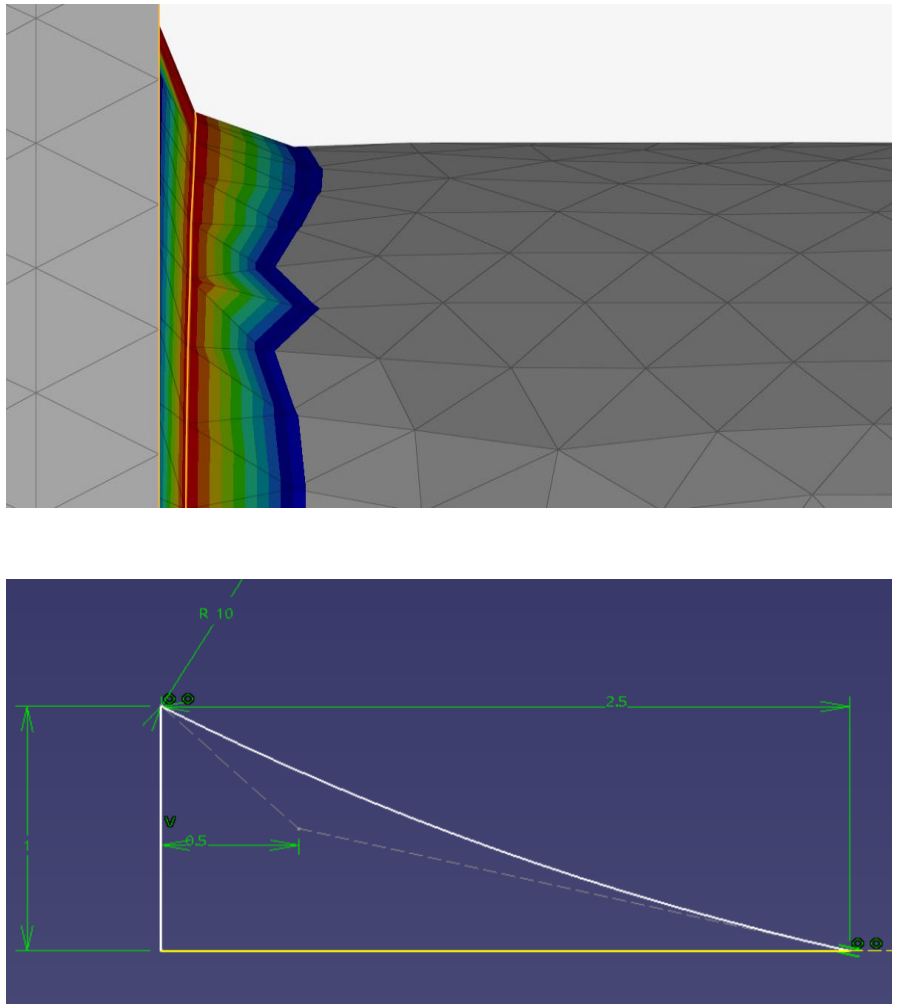



Optimum model view (isometric/front)

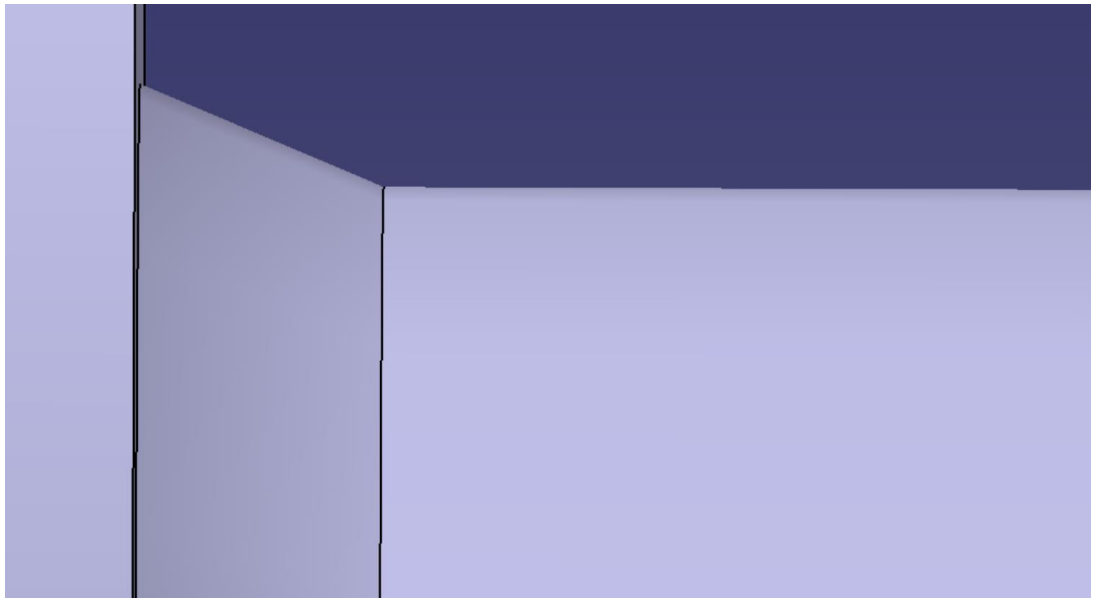
- 전반적으로 Base 대비 감소 추세를 보임
- 특히 Epsilon부분 변화를 보니 내구성이 증가로 이어질 수 있다고 추측 가능
- Contour를 참고하니 fillet 형태와 유사함

# #2-2 Remodeling






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



Refine model

# #2-3 Compare Base vs Optimum

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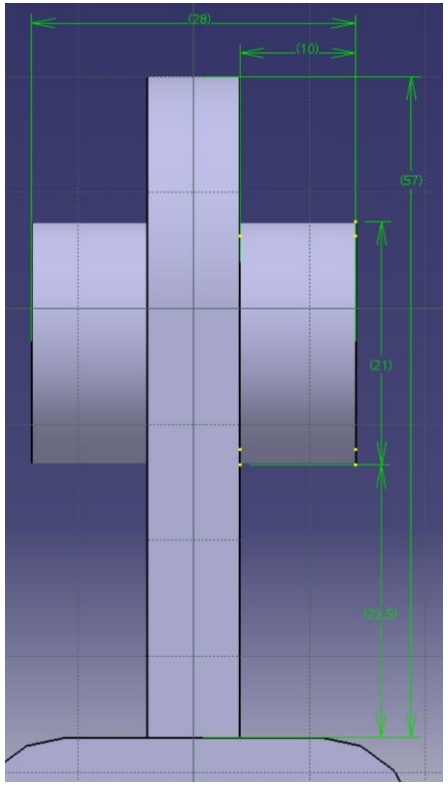
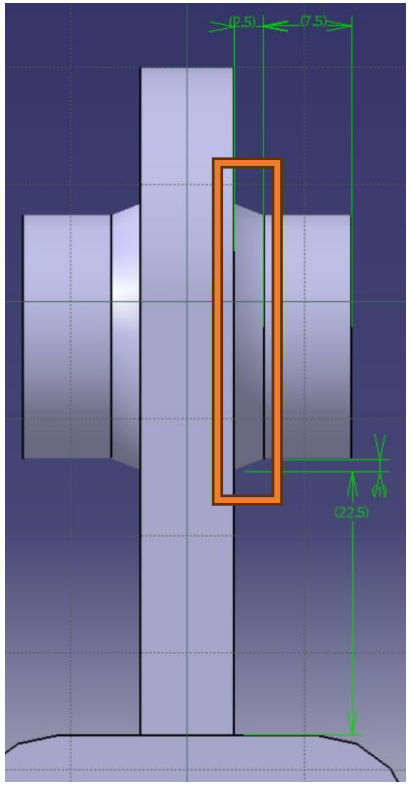



Base model

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



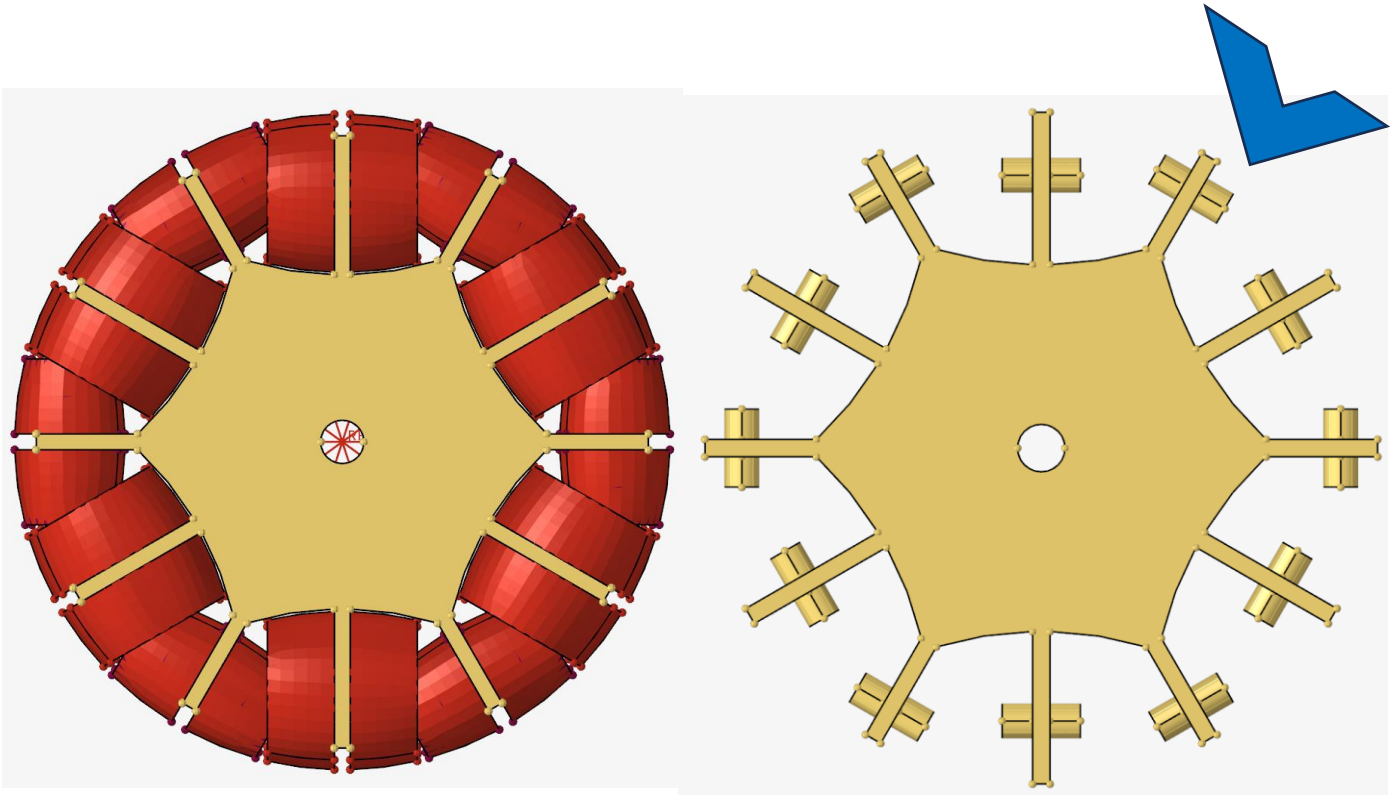

Refine model

→미약하지만 Base 모델 대비 변위, $stress_{max}$를 감소할 수 있었다.

# Mass Optimize

# #3-1 Mass optimize – body select



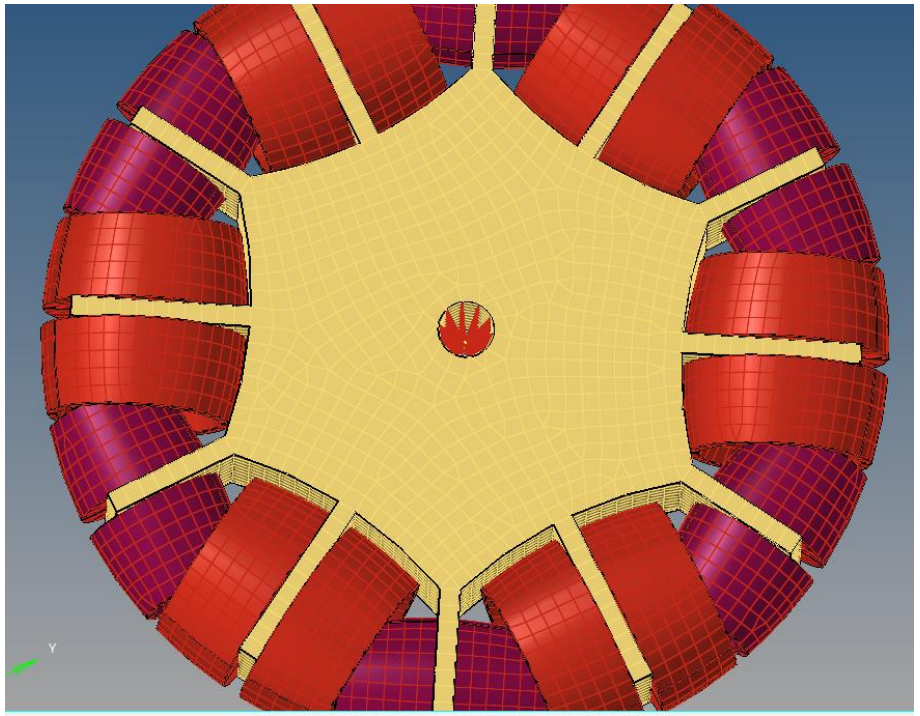


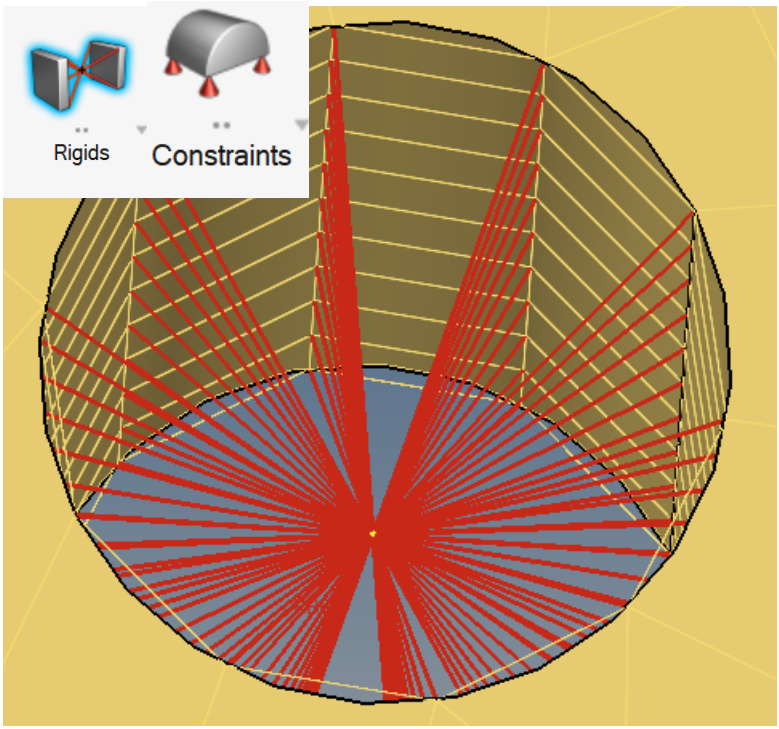
**Omni wheel model overall (left)**
**Model except rollers (right)**

- 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

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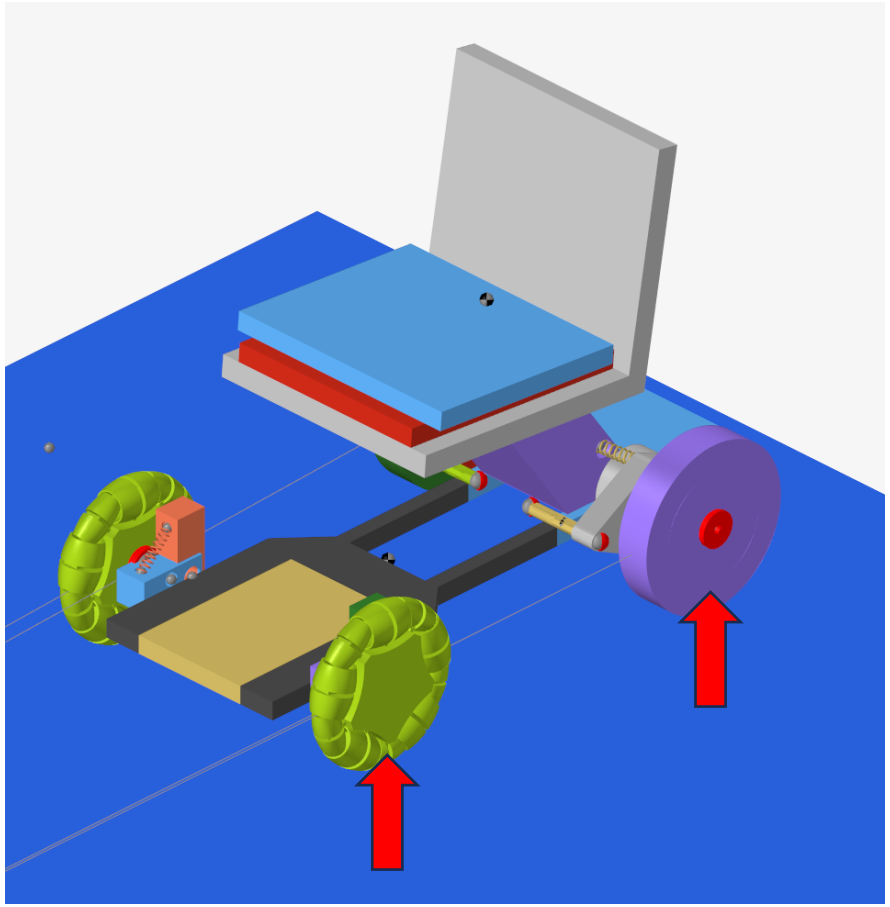
(7) 식품의약품안전처



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

- 전세계 평균 체중 = 62kg [7)]

- 휠체어의 62kg의 무게를 올려두고 정적상태에서 바퀴의 수직력 측정

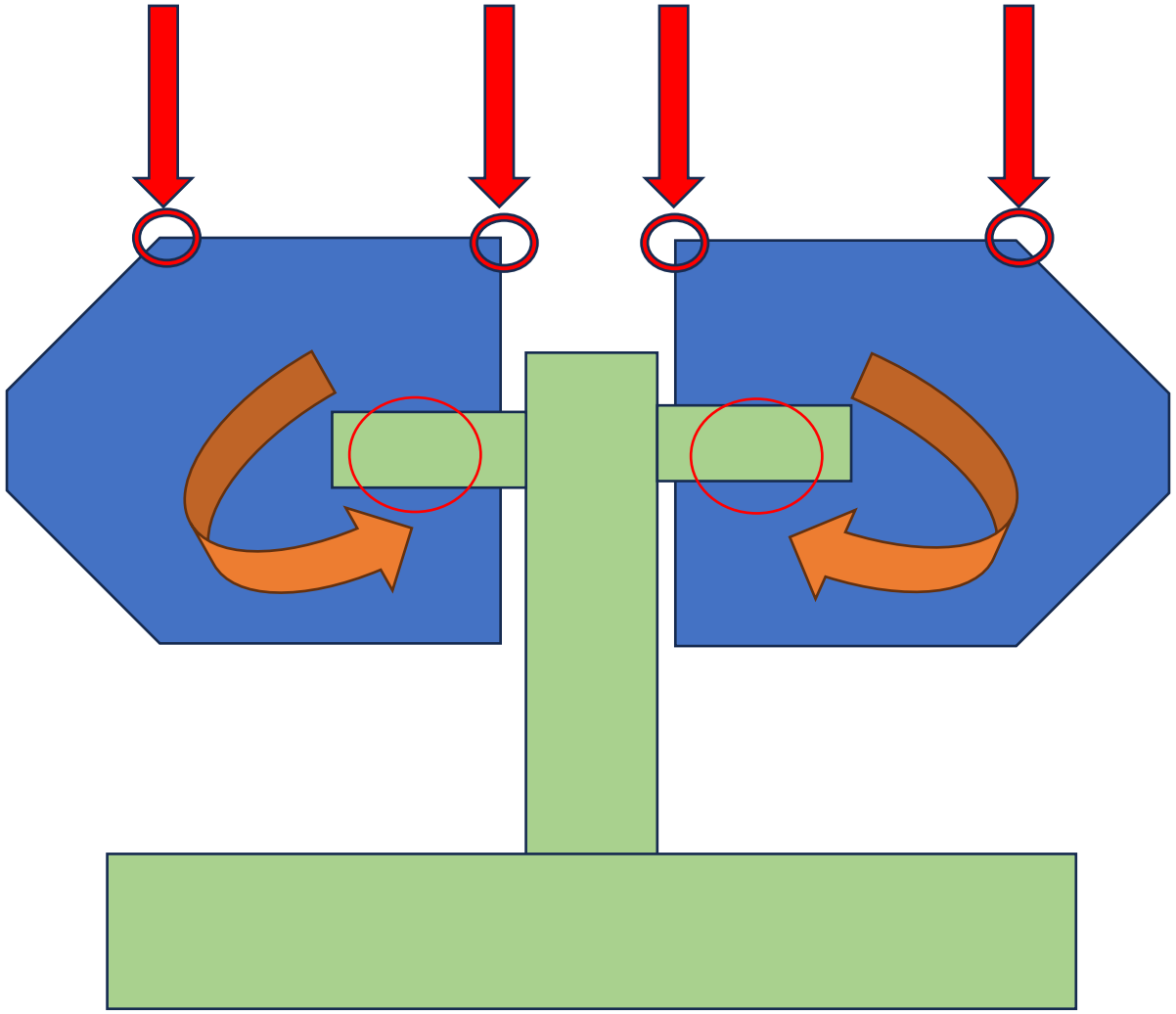
| Normal force (N) | |
|---|---|
| Front Wheel | Rear wheel |
| 259.3 | 279.8 |

- 전반적으로 2000N 미만

→ 2000N을 버티면 실사용에 문제가 없을 것이라 판단

# #3-2 Force apply node select



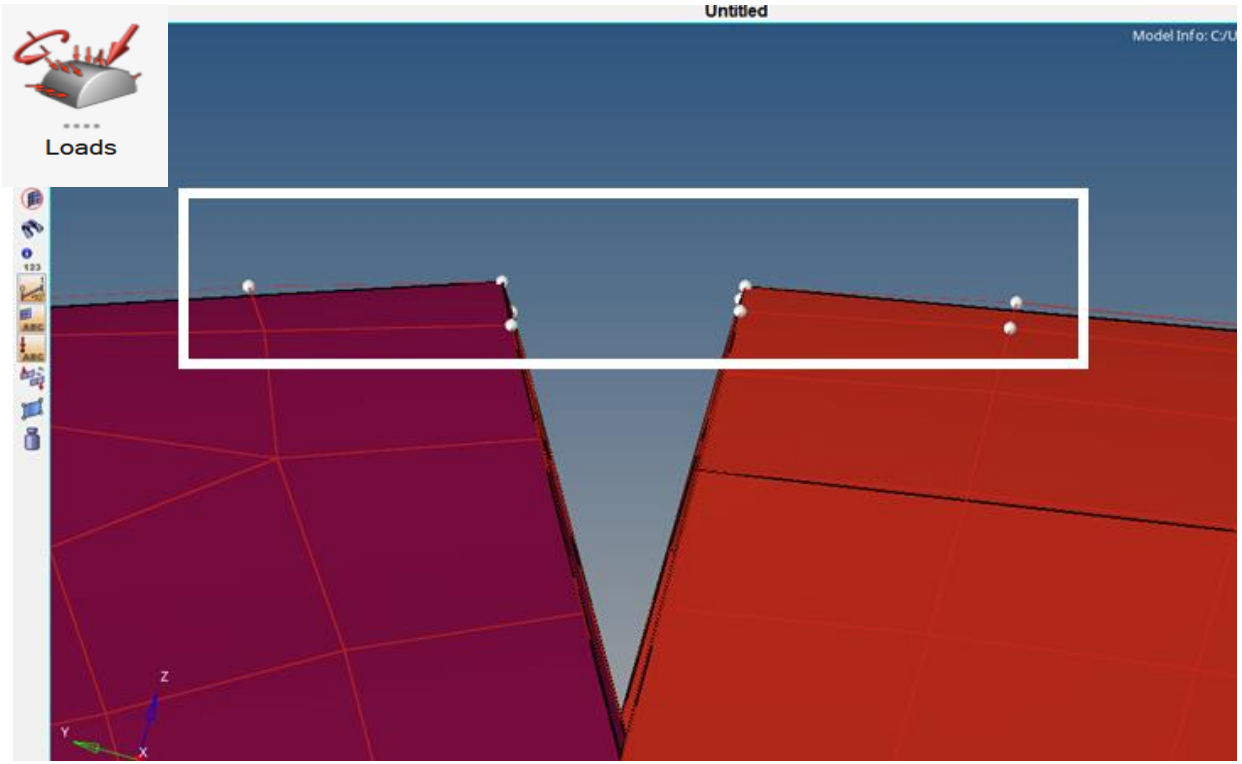


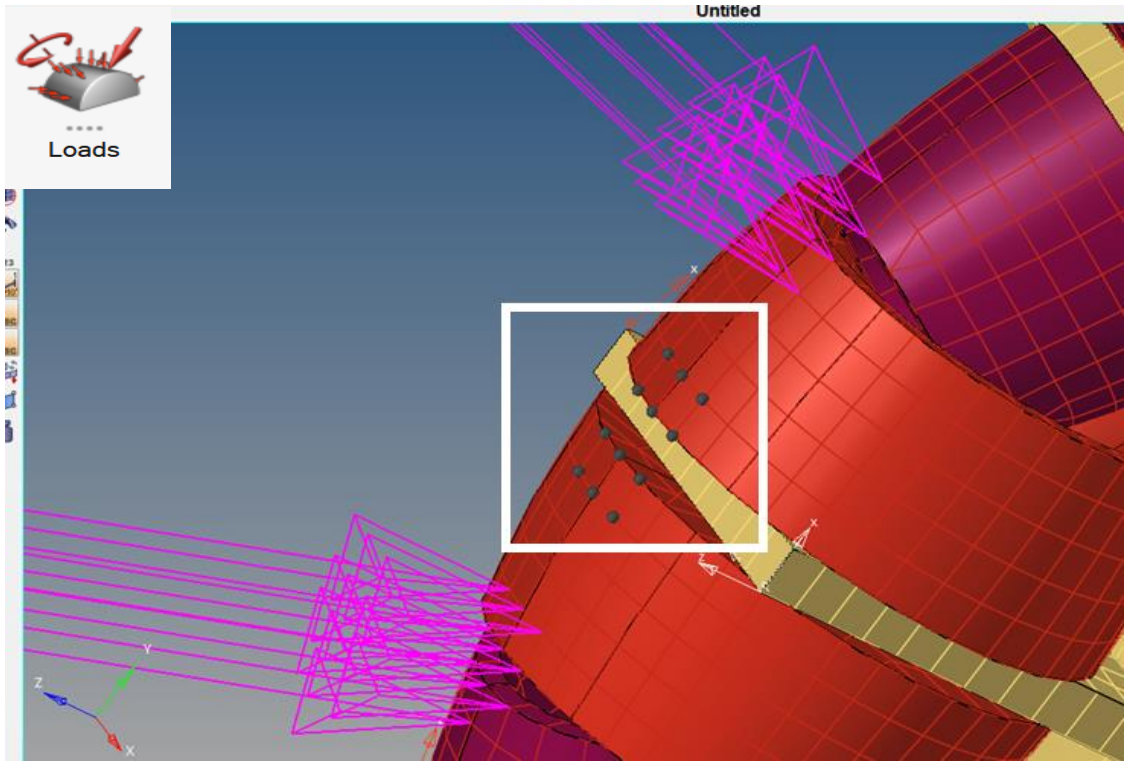
The sample illust of predictable effect
by stress at roller support

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

# #3-2 Force apply






**Force apply to node (gap part)**

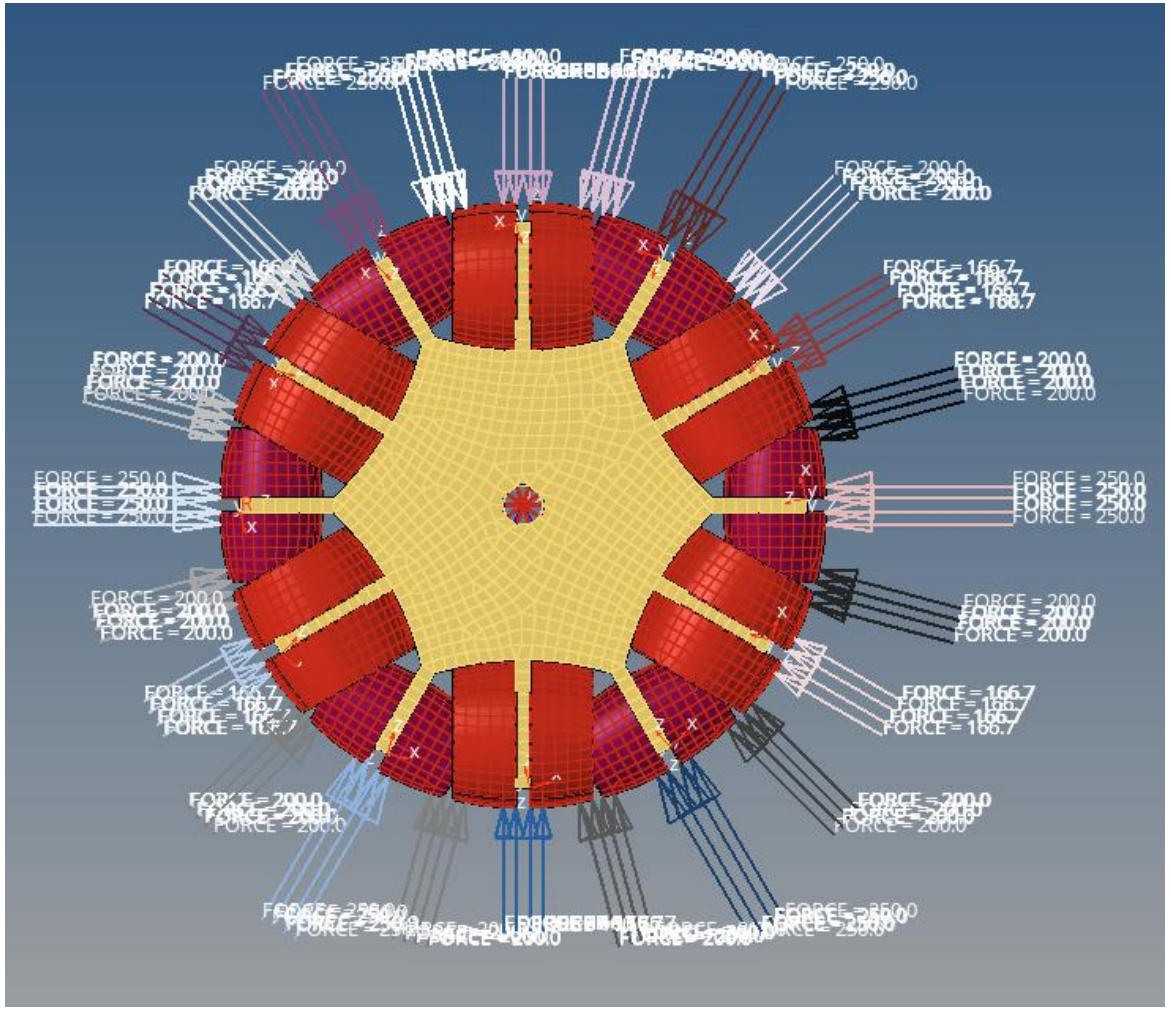
흰색 Box 범위에
총 2000N의 힘을 분배해서 입력

# #3-2 Force apply to all roller



- 앞서 진행한 작업을 전 Roller에 적용

- 각 롤러마다 다른 load collectors로 배치




**Visualize load collectors apply to model**

# #3-3 Process of Optimizing

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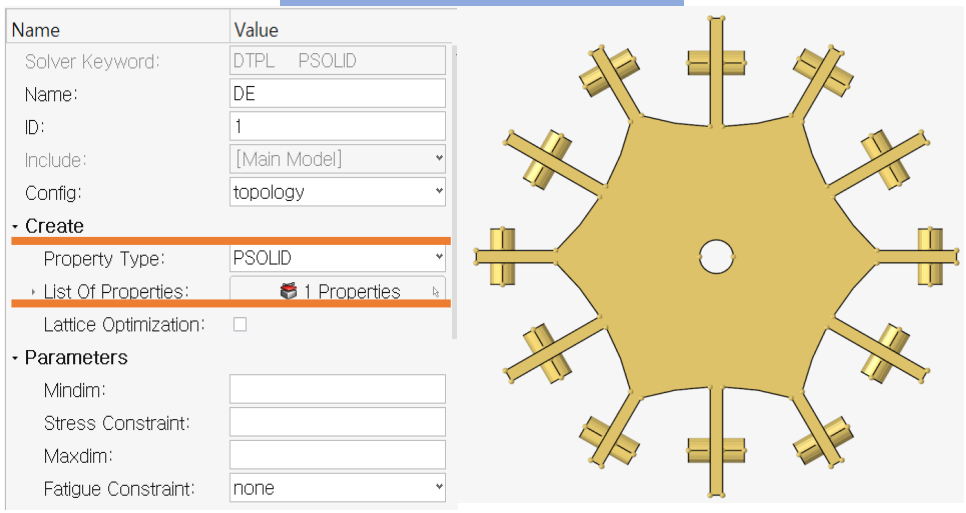
1

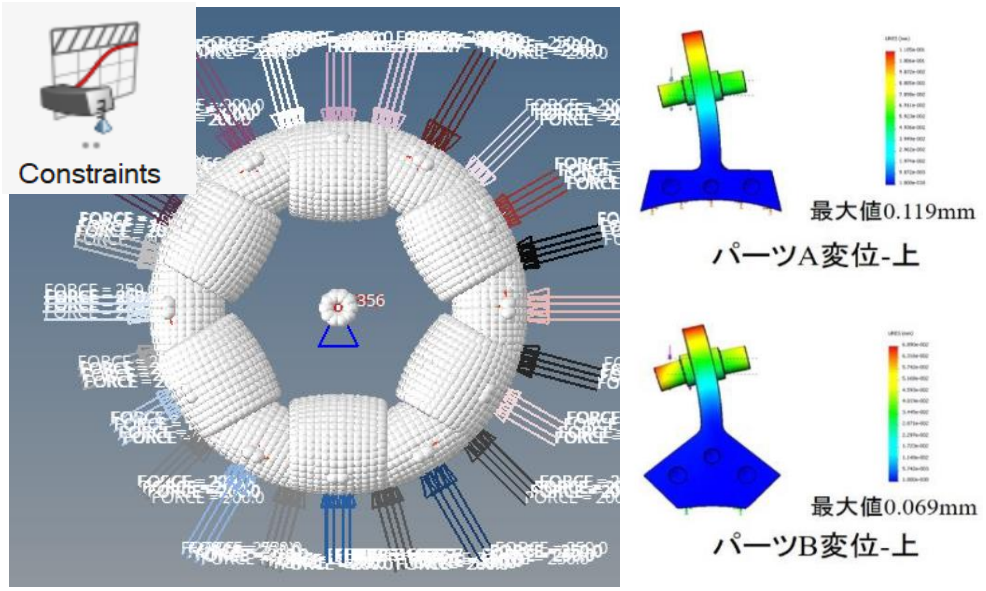
Design variable




**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[4]의 해석 결과를 바탕으로
롤러의 모든 노드에 대해
±**0.1mm** 변위를 구속 조건으로 설정

# #3-3 Process of Optimizing

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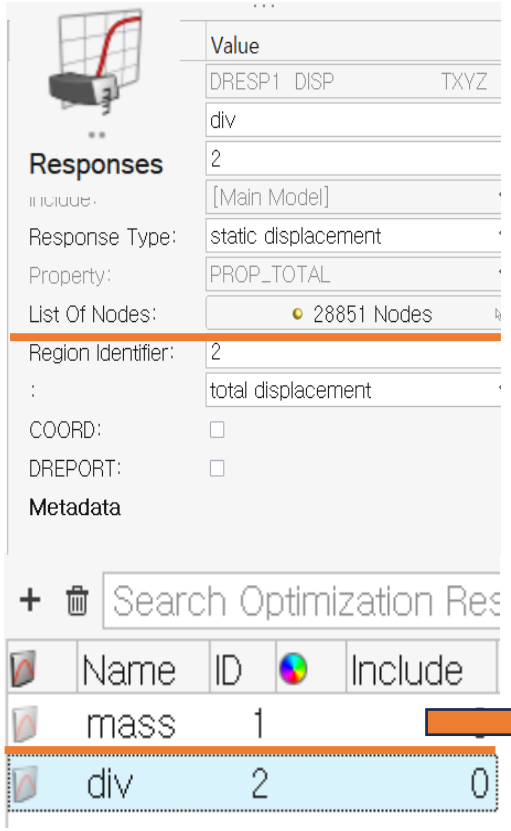
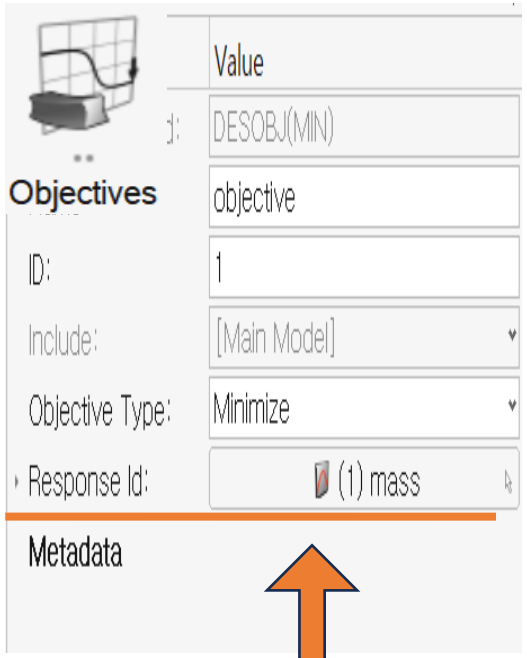
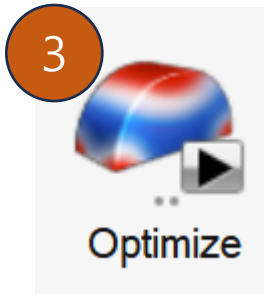
2-2




2-3




3




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

[2-2]중 총질량에 대해
질량 최소화 (최적화 목적) 설정

# #3-4 Optistruct solver view

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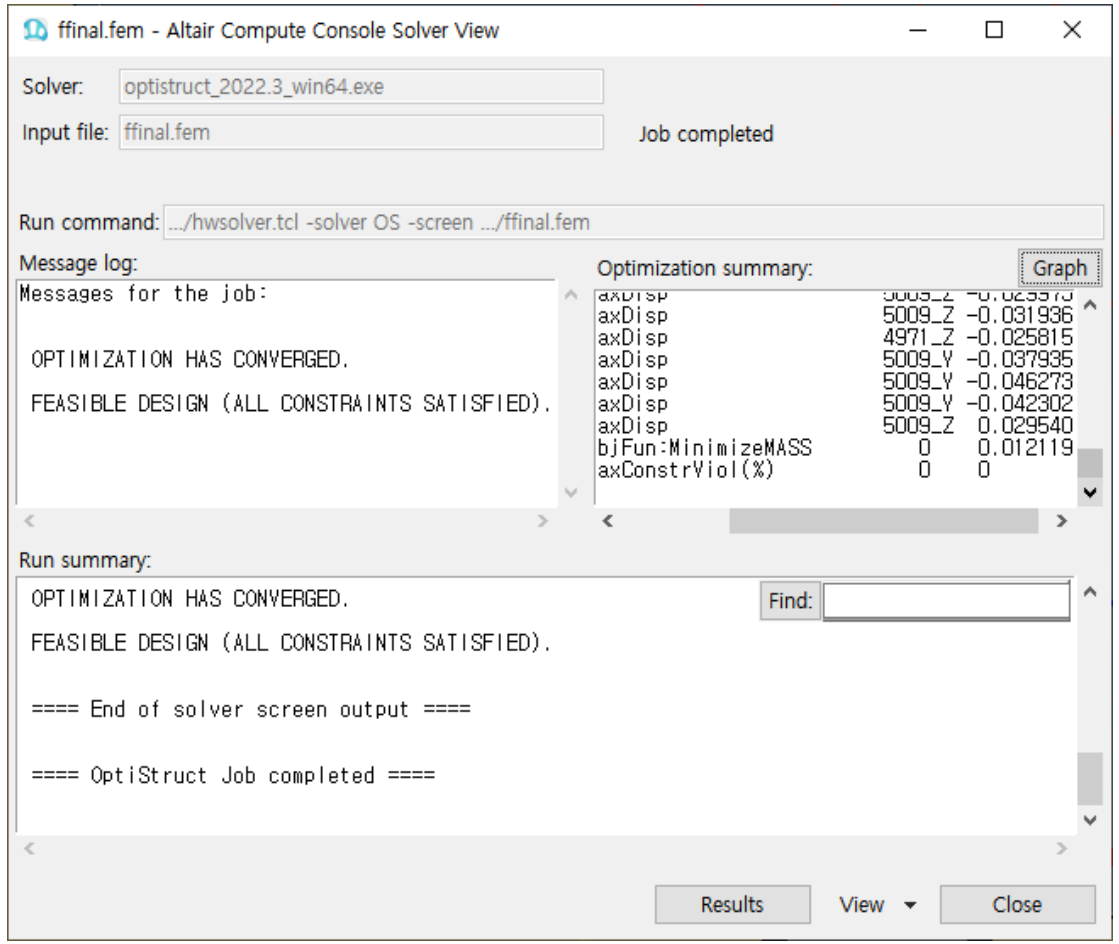
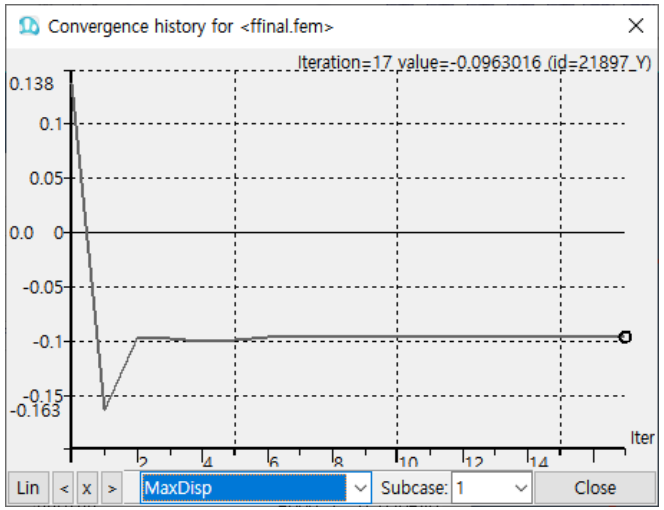
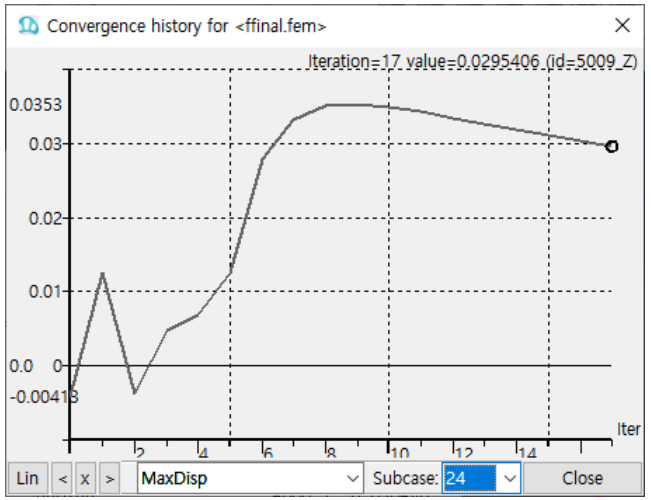
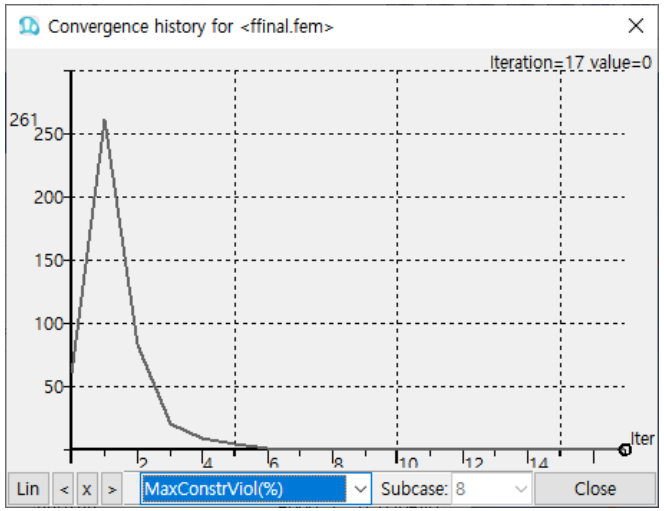
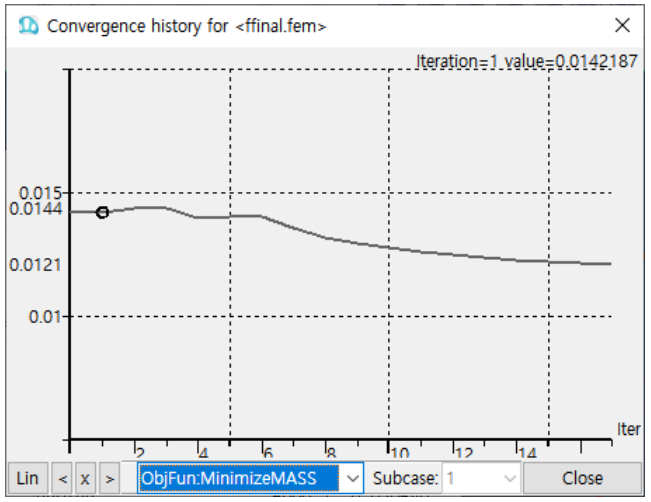


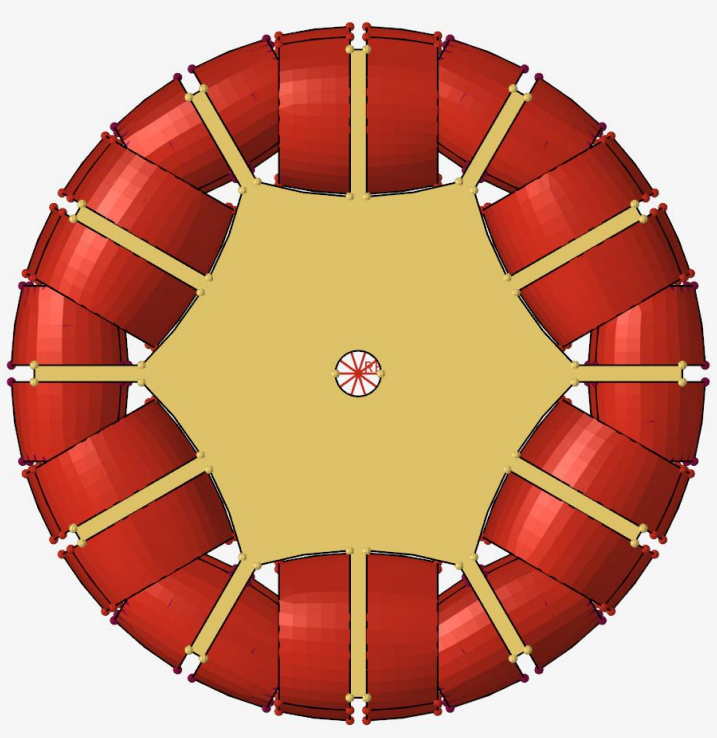



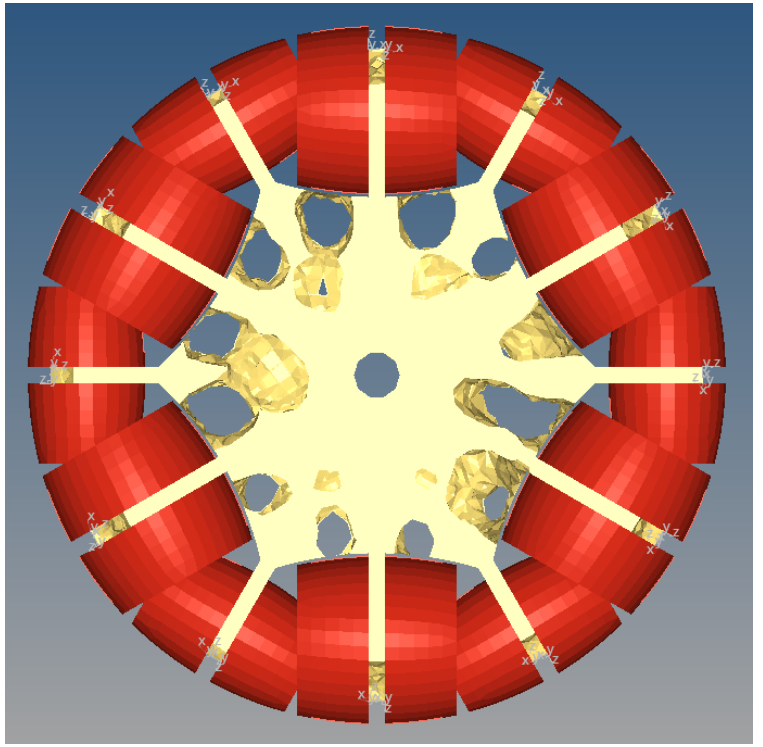
# #3-4 Optimization result





Base model

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



Optimum model

→약 2kg 의 중량 감소가 이루어짐

# #3-4 Optimum model section review

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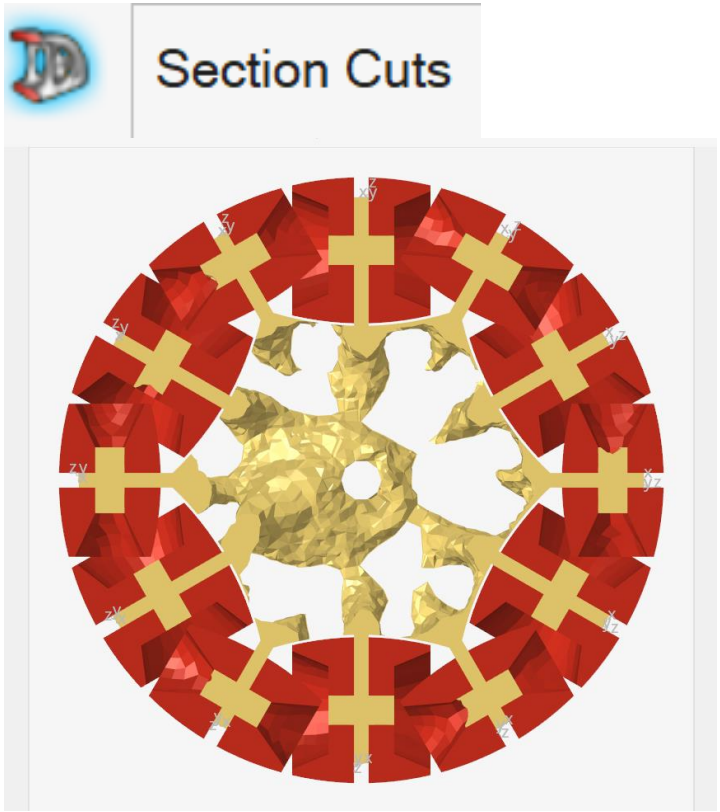
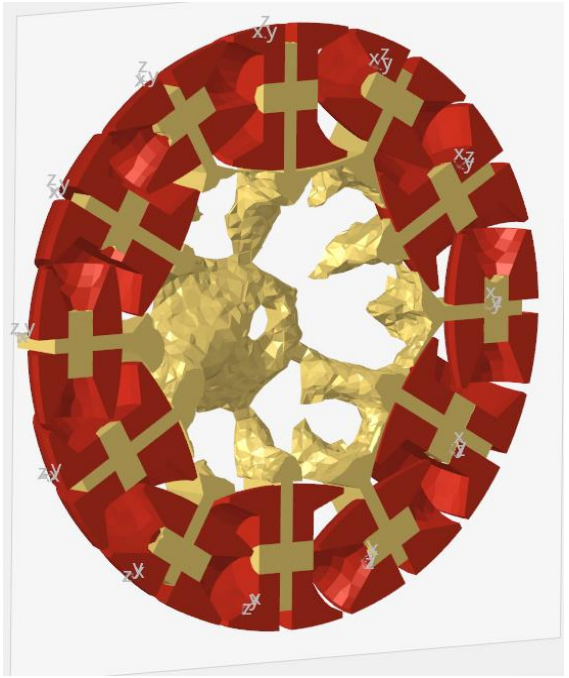



Front view



Isometric view

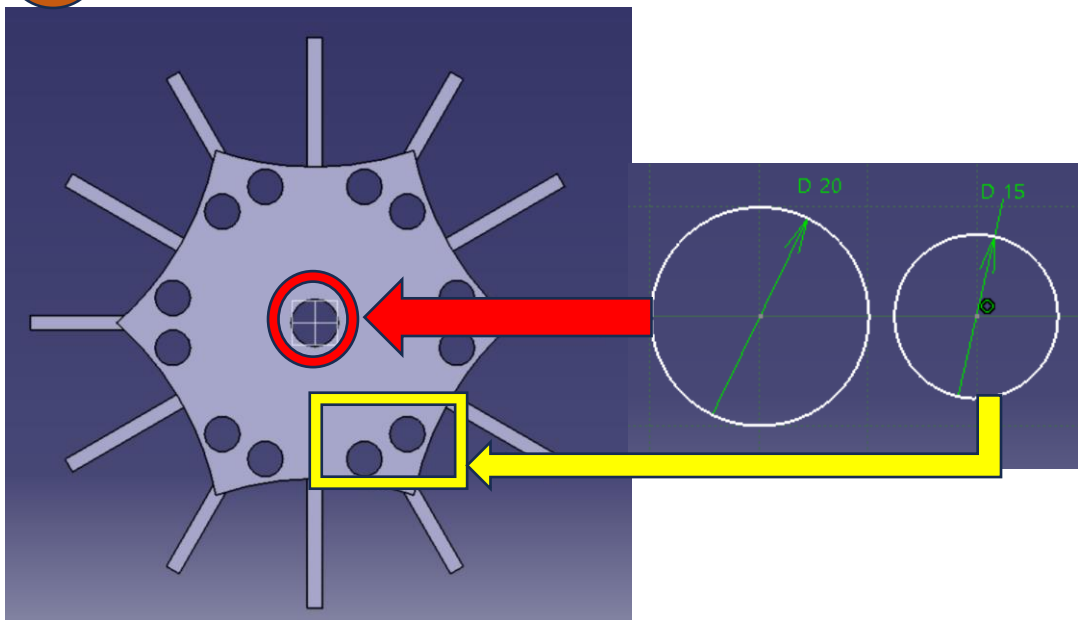
Side view

→ Roller support 부분 외 pocketing이 이루어짐

# #3-5 Model refining



1

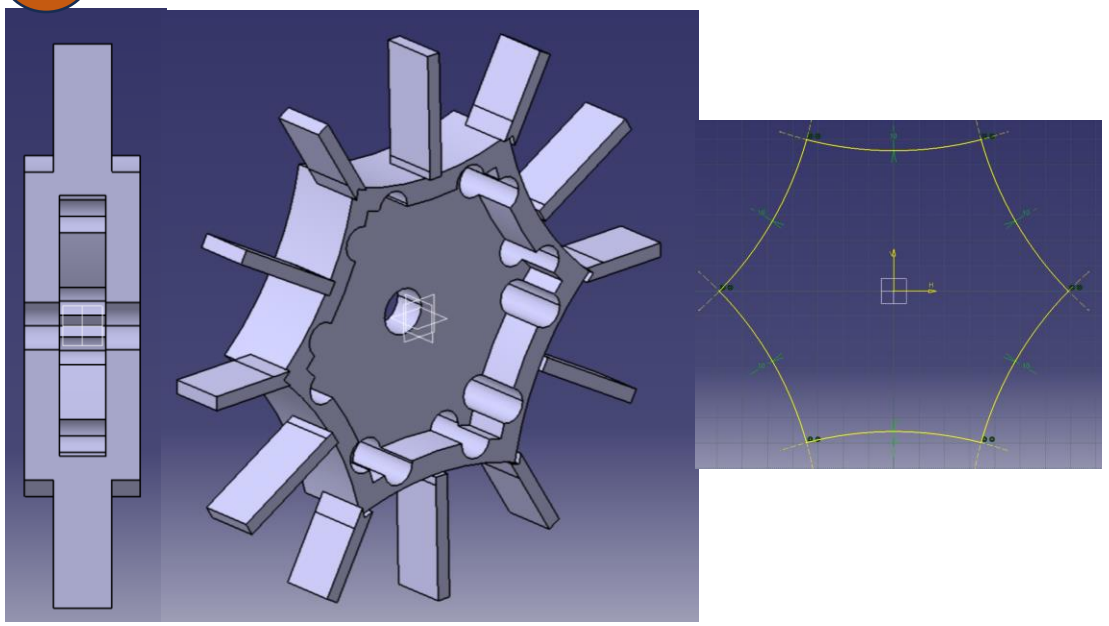



**Front view of model**

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

위 기준으로 Pocketing 진행

2

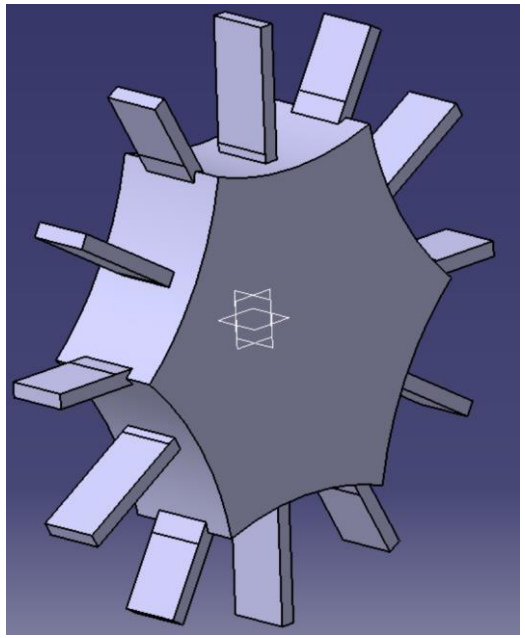


**Section view from side view (left)**
**Isometric view od model (middle)**

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

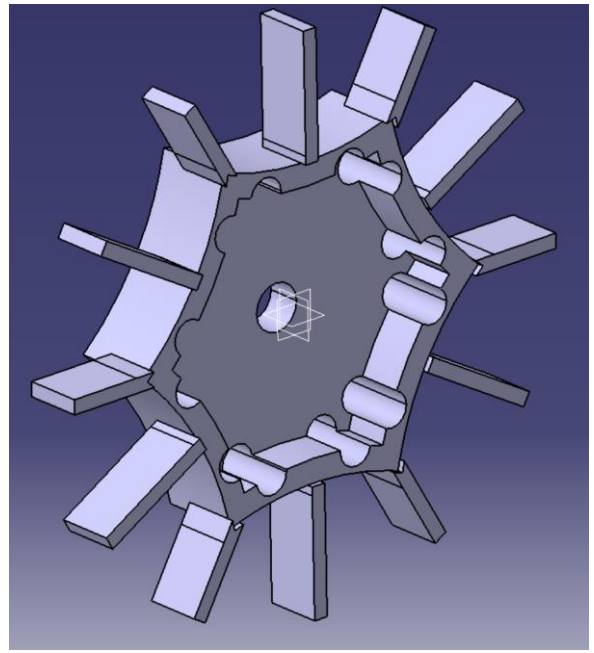
# #3-5 Check for weight decrease





Base model

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



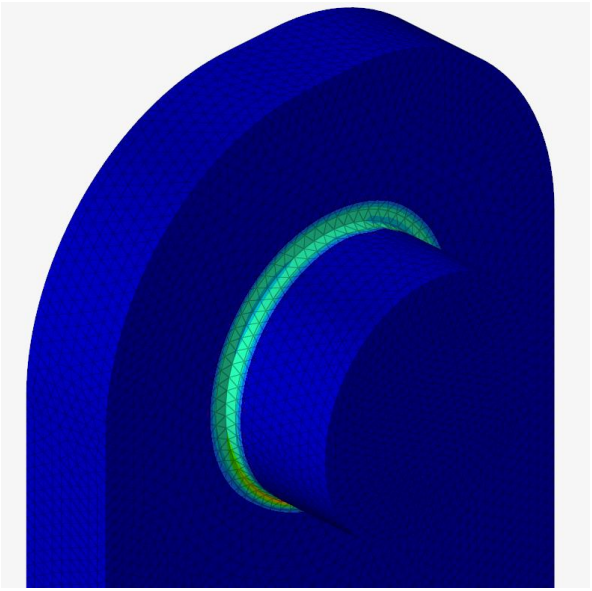
Refine model

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

# * Summary

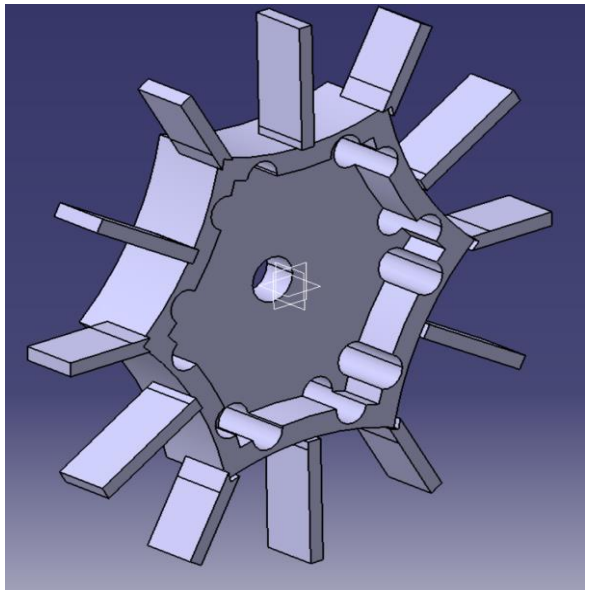


## #1 Free shape Optimization for big roller support



- Obj (reduce stress)
- Result: making fillet

## #2 Mass optimization Except rollers



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