고성능 전기차 감속기 설계

2016033690 이상진
2017037156 윤준상

1 아이오닉 N

2 기어비 도출

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HYUNDAI
HELIX ULTRA
HELIX
7
WRC
i20

1 아이오닉 Electric Specs

무게	**1430 kg**
타이어	**205/55/16**
모터 타입	**PMSM**
출력	**88 kW**
최대토크	**292 Nm**
최대각속도	**10500 RPM**
감속비	**7.4**

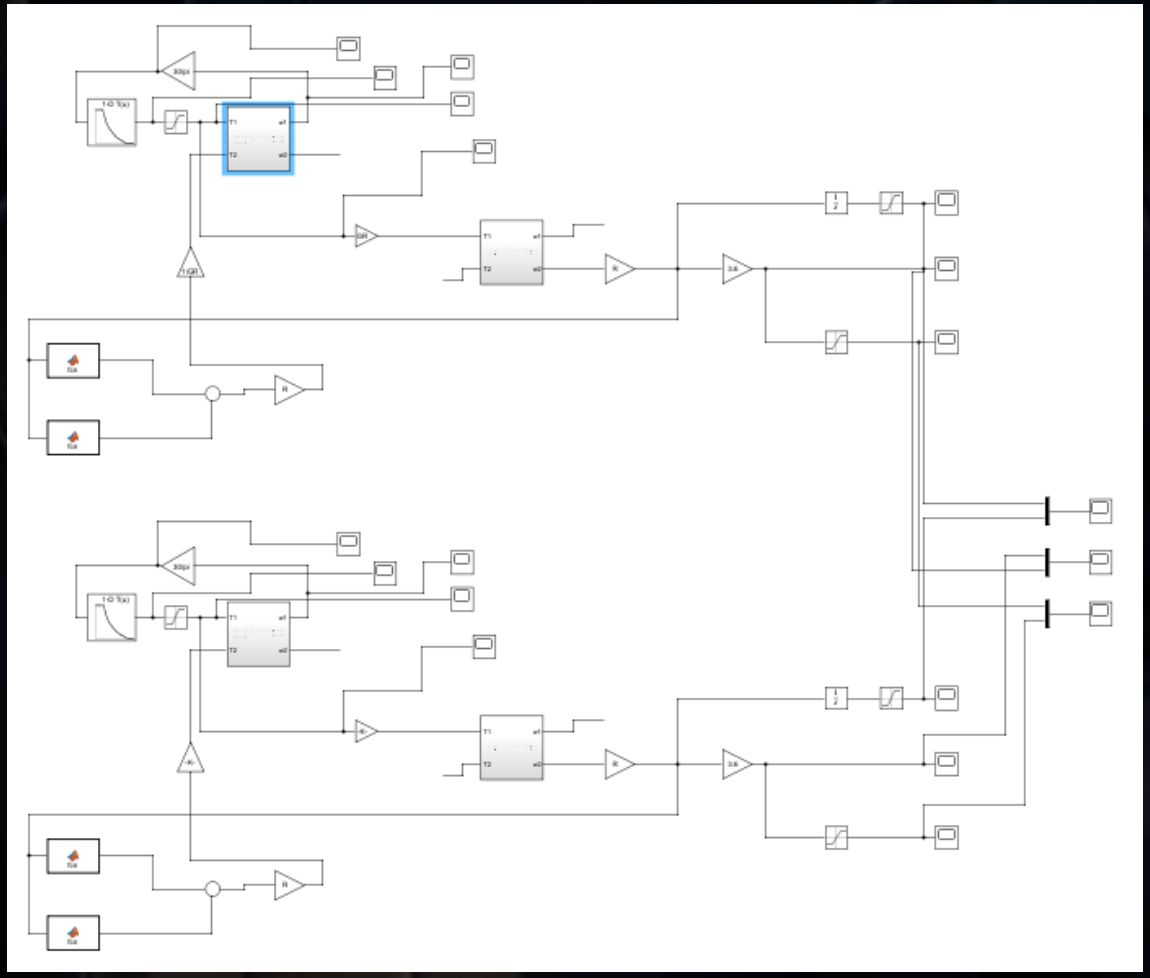
최대속도	**169.01 km/h**
0-100 km/h	**10 s**
0-1/4 miles	**17.1 s**
0-1 km	**31.3 s**
전명투명면적	**2.22 m^2**
드래그 계수	**0.24**

1 아이오닉 N Specs

무게	**1330 kg**
타이어	**245/40/19**
모터 타입	**PMSM**
출력	**88 kW**
최대토크	**292 Nm**
최대각속도	**10500 RPM**
감속비	**5.48**

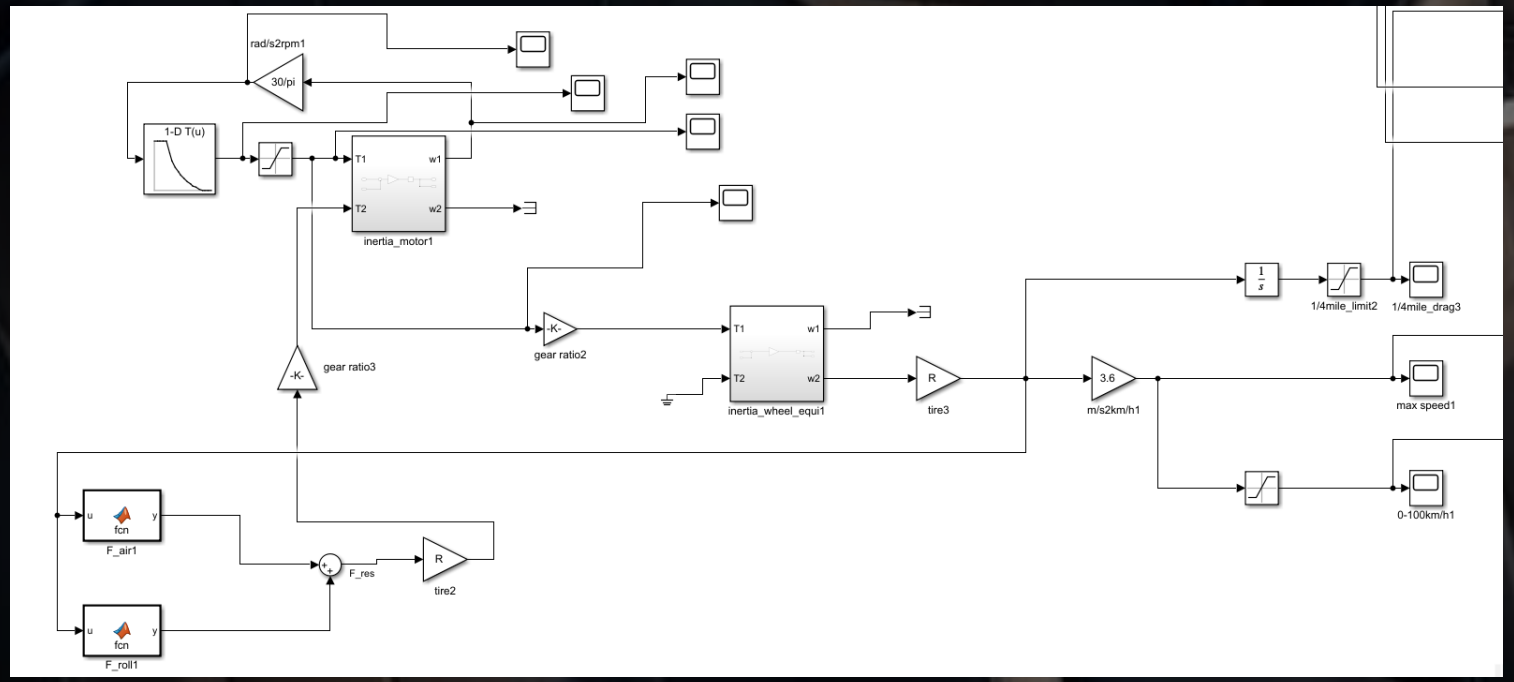
최대속도	**253.94 km/h**
0-100 km/h	**7.48 s**
0-1/4 miles	**15.42 s**
0-1 km	**26.3 s**
전명투명면적	**2.22 m^2**
드래그 계수	**0.24**

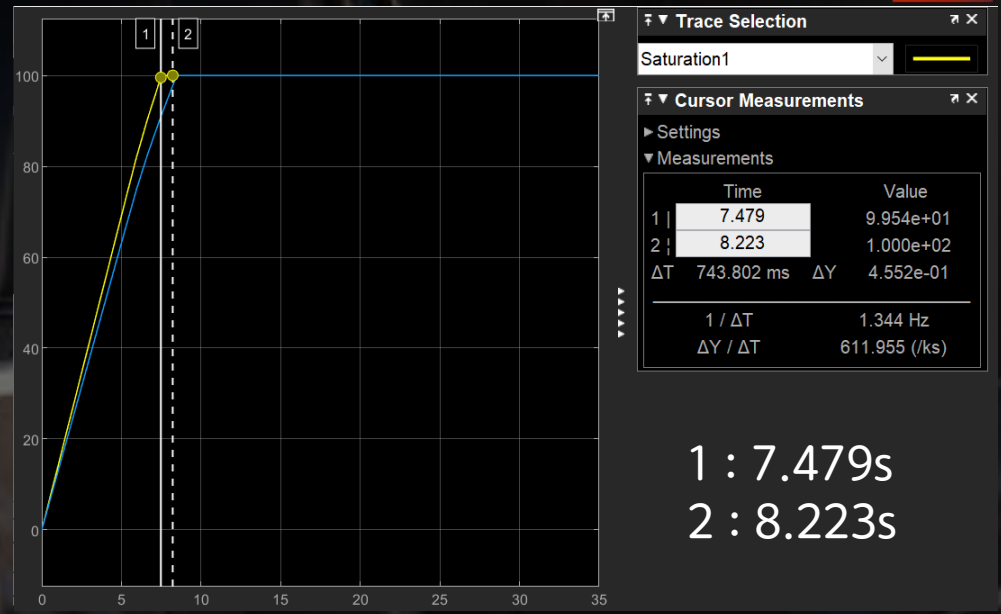
2 기어비 도출



```
%% Constants
g=9.81;
m = 1330; %[kg]
m_wheel=15; %[kg]
u_roll=0.01;
u_tire=1.0;
A=2.22; %[m^2]
Cd=0.24; %[
GR=6;
GR2=5.48;
mu=1;
%tire=245/40/19
aspect_ratio=0.4; tread_width=245; wheel_inch=19;
%% Car Parameters

R=wheel_inch*25.4*0.001*0.5+tread_width*aspect_ratio*0.001; %tire outter diameter[m]
R
J_wheel = m_wheel*R^2
J_motor=0.05;%[kg*m^2]
J_wheel_equi=J_wheel+m*R^2
```

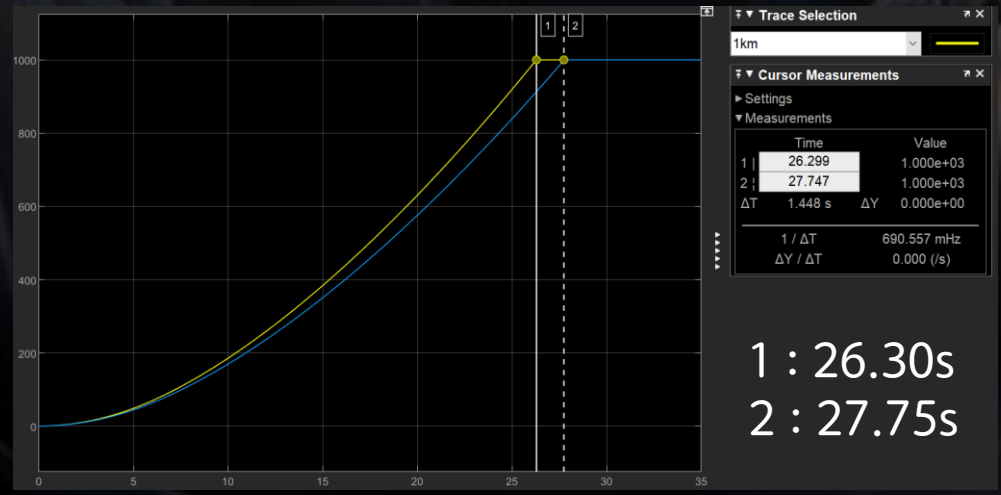
2 기어비 도출





1 : 7.479s
2 : 8.223s

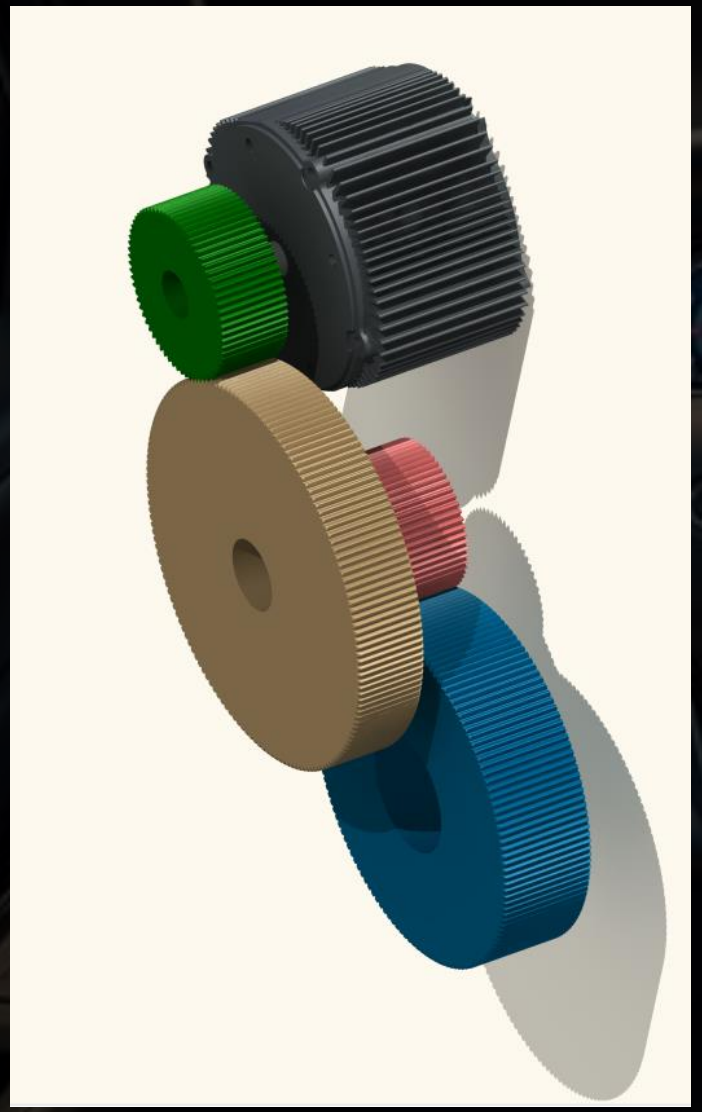
△ 0-100 km/h



1 : 26.30s
2 : 27.75s

△ 1 km time

3 기어 강도계산



target gear ratio	5.5
motor max torque[Nm]	292
presuure angle[deg]	20
rated rpm[rpm]	2750
final gear ratio	5.485714
pinion1 teeth	70
gear1 teeth	160
gear ratio1	2.285714
pinion2 teeth	60
gear2 teeth	144
gear ratio2	2.4

AISI4320 Material properties	
young's modulus[Gpa]	205
poisson's ratio	0.29

gear speciation				
	pinion1	gear1	pinion2	gear2
teeth	70	160	60	144
module[mm]	2	2	2	2
pcd[mm]	140	320	120	288
base diameter[mm]	131.557	300.7016	112.7631	270.6315
addendum[mm]	2	2	2	2
deddendum[mm]	2.5	2.5	2.5	2.5
circular pitch[mm]	6.283185	6.283185	6.283185	6.283185
thickness[mm]	3.141593	3.141593	3.141593	3.141593
face width[mm]	60	60	80	80

Material : AISI 4320 (SNCM420)

- Allowable Bending Strength : 510MPa
- Allowable Hertzian Strength : 1628MPa
- Heat Treatment : Carburized and quenched 로 가정

3 기어 강도계산

$$\sigma_F = F_t \frac{Y_F Y_\varepsilon Y_\beta}{m_n b}\left(\frac{K_V K_O}{K_L K_{FX}}\right) S_F$$

JGMA Bending Strength Equation

$$\sigma_H = \sqrt{\frac{F_t}{d_{01} b_H}\frac{i \pm 1}{i}} \frac{Z_H Z_M Z_\varepsilon Z_\beta}{K_{HL} Z_L Z_R Z_V Z_W K_{HX}} \sqrt{K_{H\beta} K_V K_O}\, S_H$$

JGMA Hertz Strength Equation

```
if 0< b <=50.8
    Ye = 1.3;
elseif 50.8 < b <190.5
    Ye = 1.4;
elseif 190.5<= b < 317.5
    Ye = 1.5;
elseif 317.5 <= b
    Ye = 1.8;
end
B = 0.25*(12-Q)^(2/3);
A = 50 + 56*(1-B) ;
Vt = (A + (Q - 3))^2/(200);
Kv = ((A+sqrt(200*Vt))/A)^B;
Ko = 1.25;
Kl = 1.0;
Kfx = 0.904*(b*m*sqrt(Yf))^0.0535;

Ft = 2000*t/d ; %[N]
Fr=Ft*tan(20*pi/180); %[N]
bstress = (Ft*Yf*Ye*Yb*Kv*Ko*Sf)/(m*b*Kl*Kfx);
bstress_lewis = (Ft)/(m*b*Yf);
```

```
disp("strength(Facewidth,Module,Diameter,Power,RPM,Quality,Safety factor
b=input('face width[mm]:');
m=input('module[mm]:');
d=input('pitch diameter[mm]:');
T=input('max Torque[Nm]:');
Q=input('gear quality:');
Sf=input('safety factor:');
stress_torque(b,m,d,T,Q,Sf)
```

3 기어 강도계산

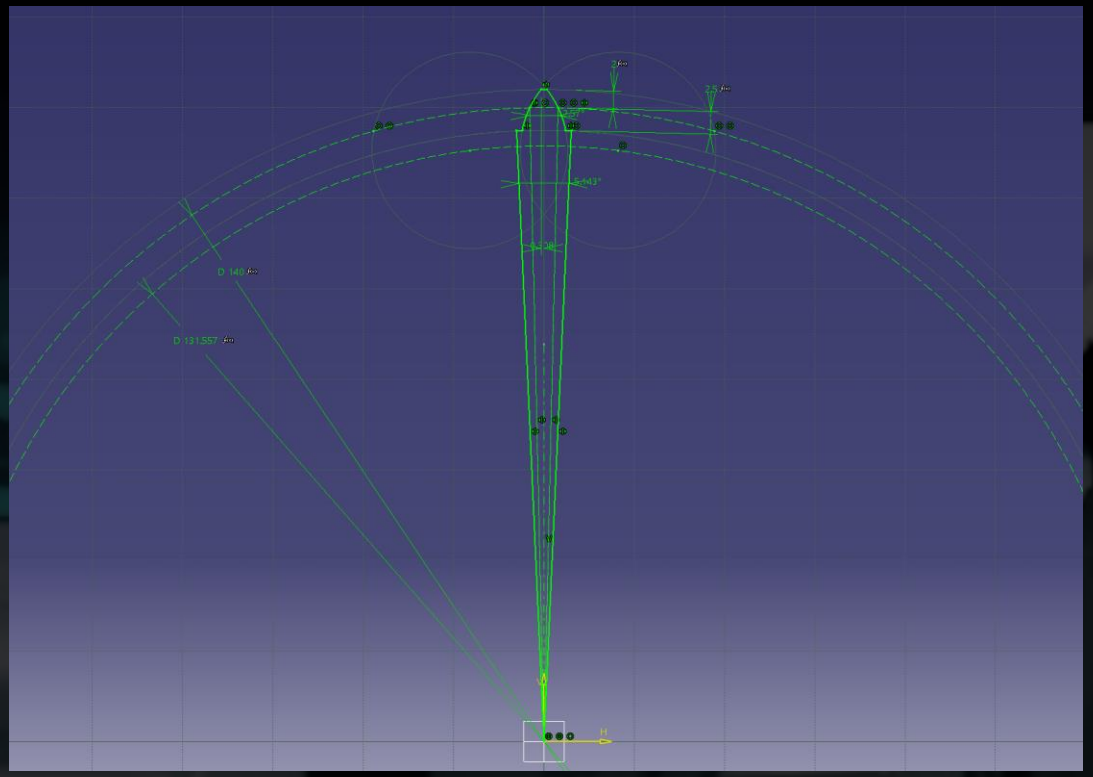
```
Command Window
strength(Facewidth,Module,Diameter,Power,RPM,Quality,Safety factor)
face width[mm]:60
module[mm]:2
pitch diameter[mm]:80
max Torque[Nm]:393
gear quality:10
safety factor:1.5
this is not possible
modify a gear speciation
```

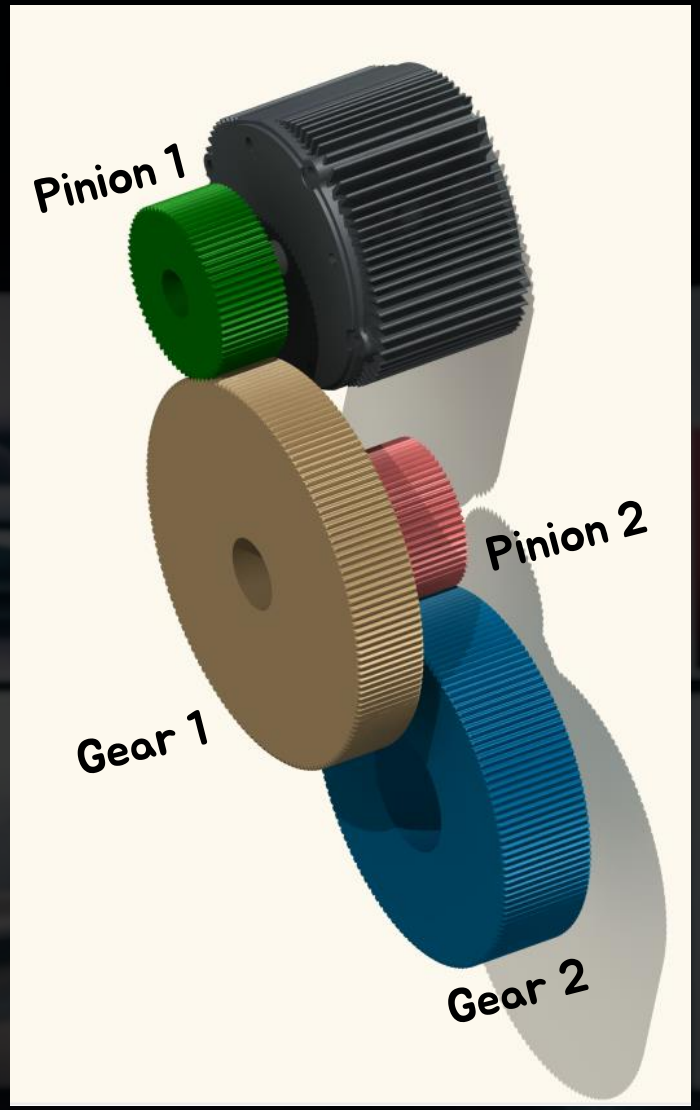
"This is Not Possible."

```
Command Window
strength(Facewidth,Module,Diameter,Power,RPM,Quality,Safety factor)
face width[mm]:60
module[mm]:2
pitch diameter[mm]:140
max Torque[Nm]:292
gear quality:10
safety factor:1.2

this is possible
재료굽힘허용강도:510Mpa

bstress =

   34.0832

재료치면허용강도:1628Mpa

hstress =

  978.6857

tangential load[N]

Ft =

   4.1714e+03

radial load[N]

Fr =

   1.5183e+03
```

"This is Possible."

4 기어 응력해석

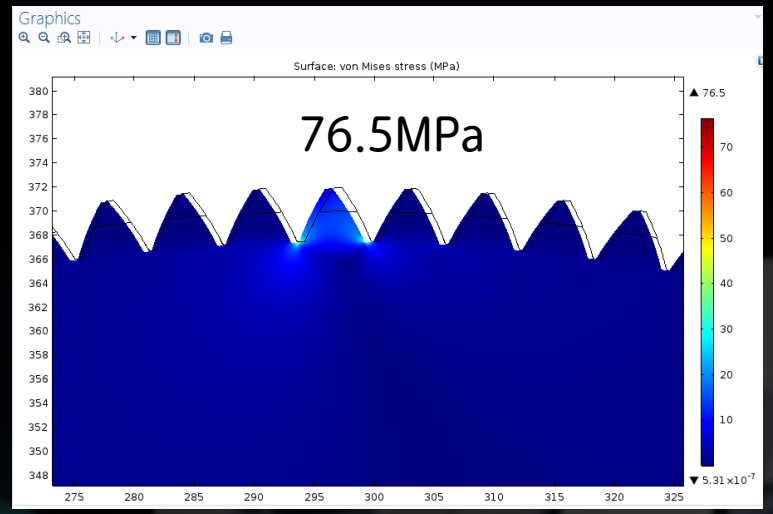


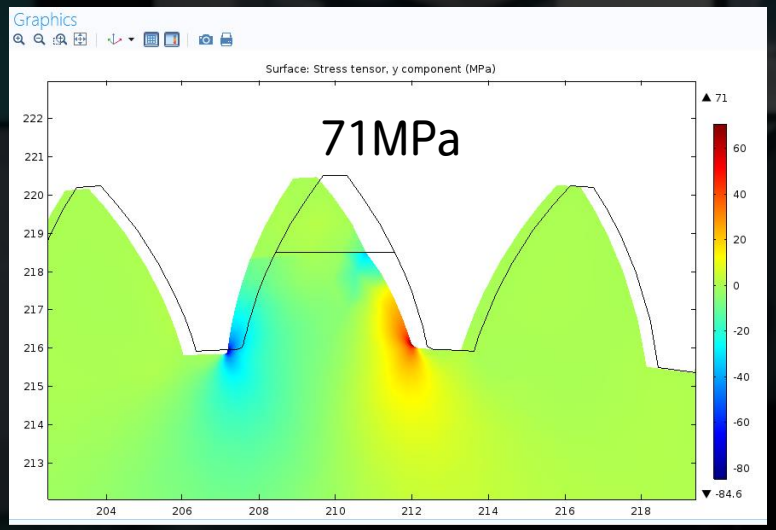


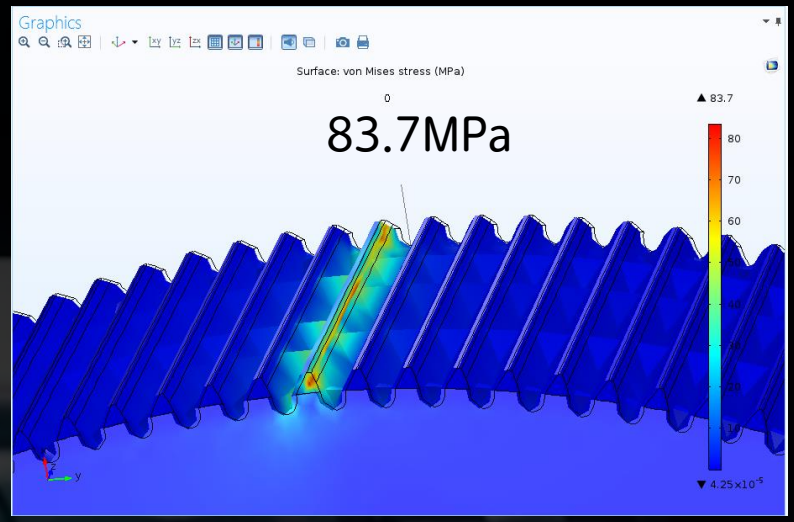
4 기어 응력해석 Stage 1st

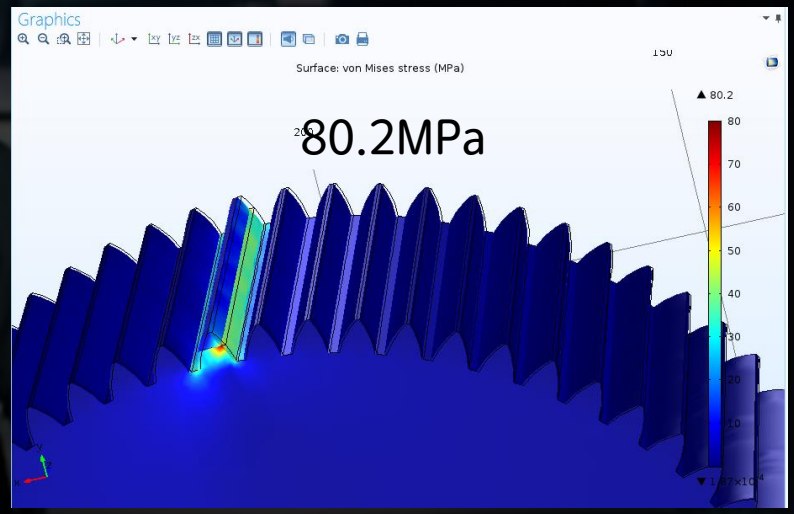
Gear 1

Pinion 1









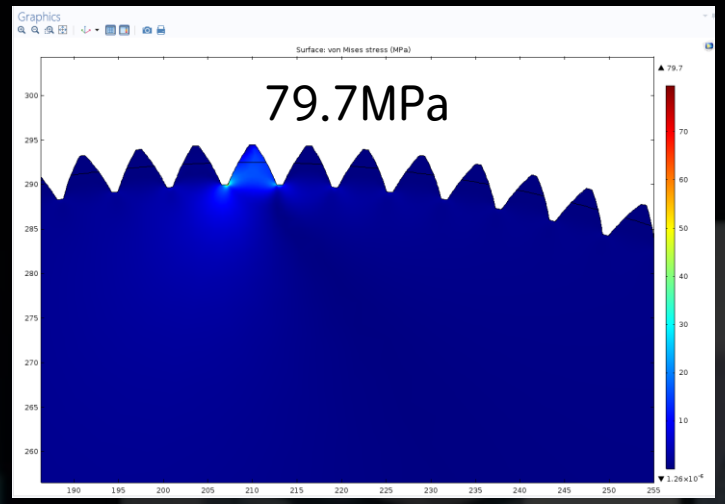
2D

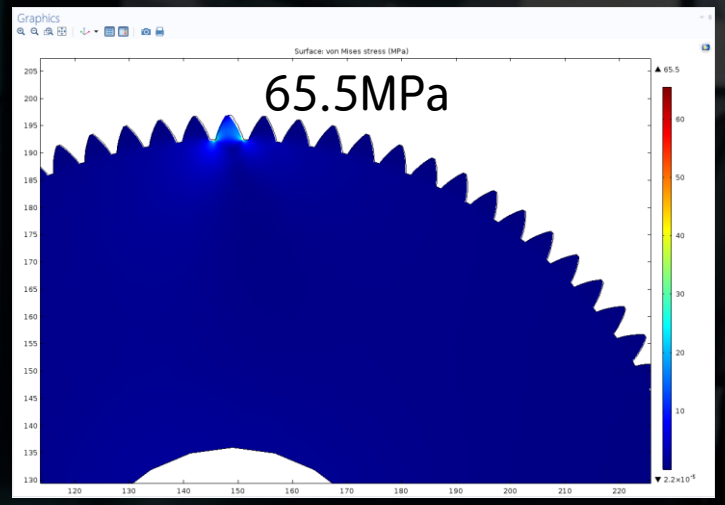
3D

4 기어 응력해석 Stage 2nd

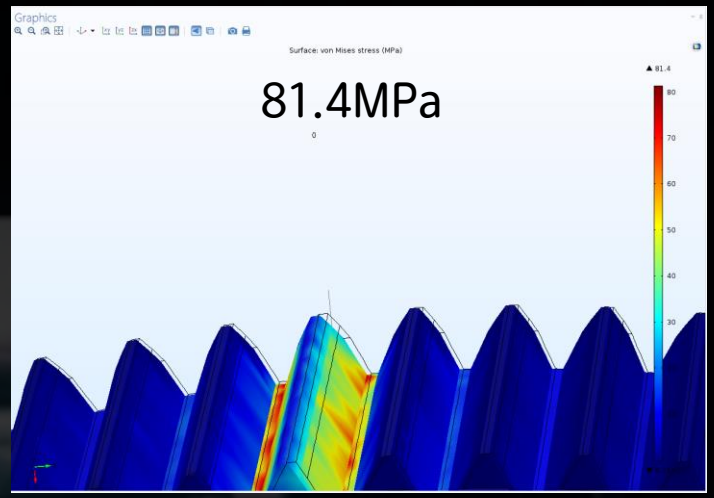
Gear 2

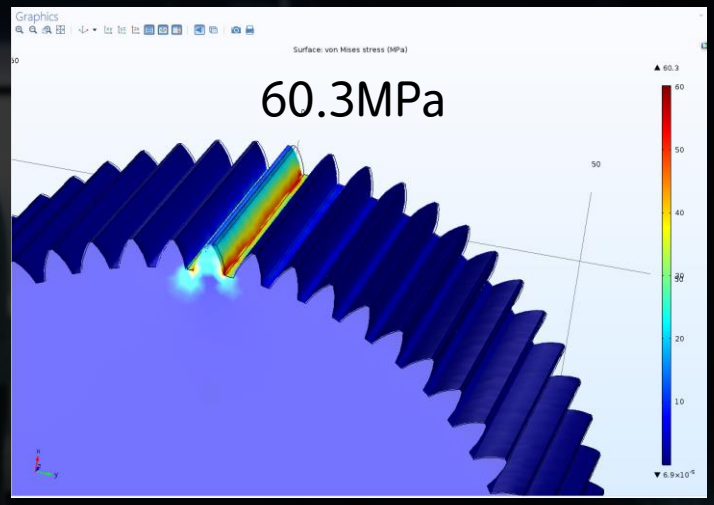
Pinion 2





2D



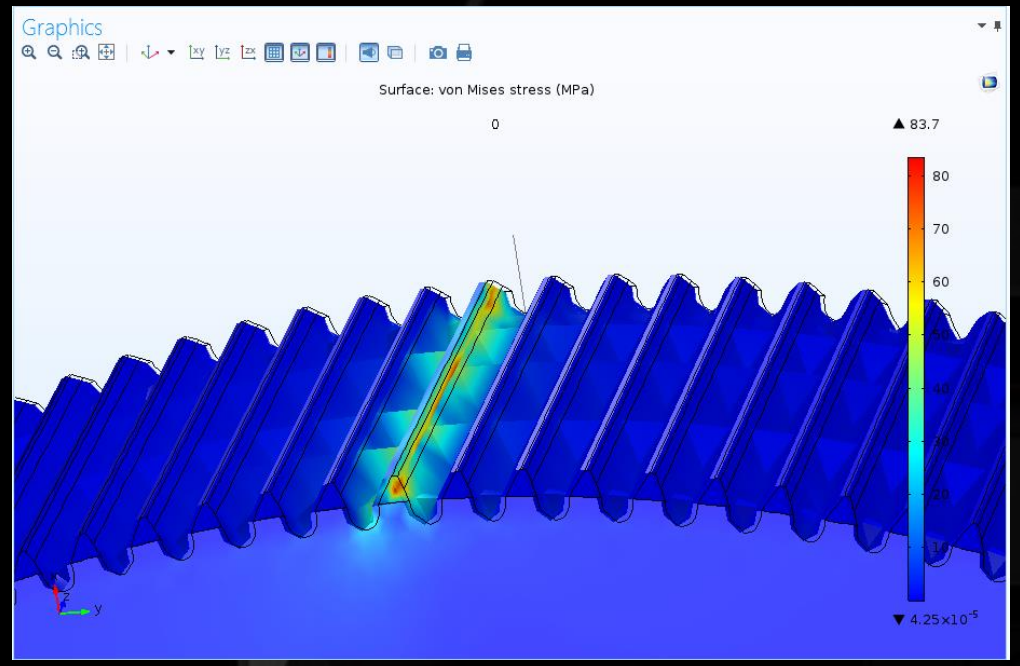


3D

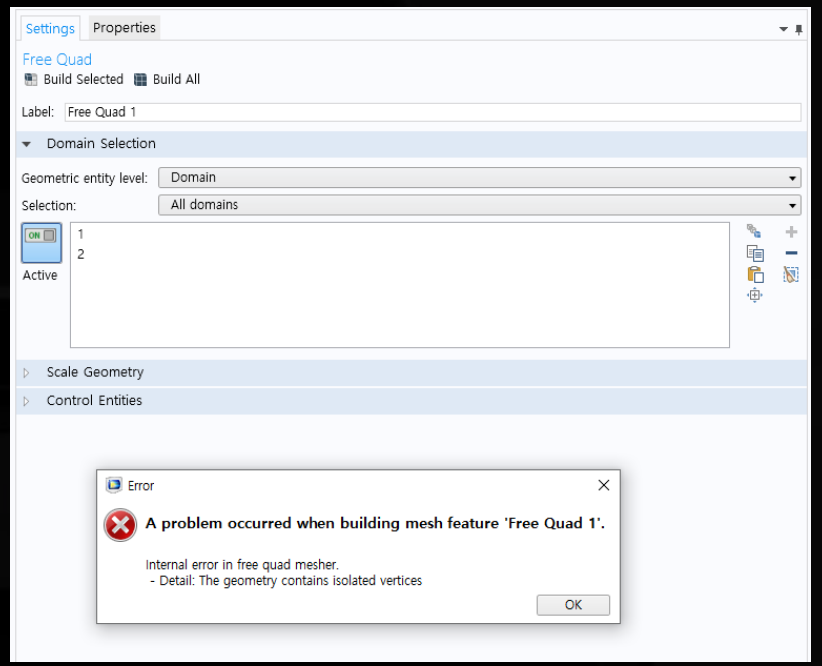
5 결과

Bending Stress Analysis Result				
	Pinion1	Gear1	Pinion2	Gear2
Analytic [MPa]	81.03	75.85	65.86	71.55
	FEA [MPa]			
FEA (2D)	71	76.5	65.5	79.7
FEA (3D)	80.2	83.7	60.3	81.4

5 오차 원인



Import Error

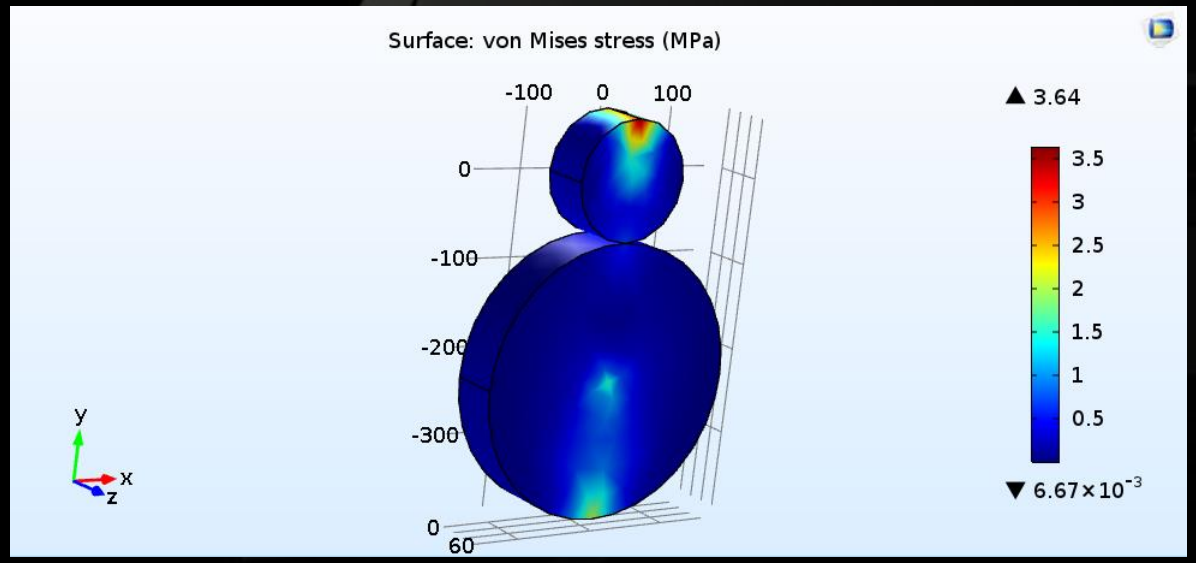


Quad Mesh Error

$$\sigma_F = F_t \frac{Y_F Y_\varepsilon Y_\beta}{m_n b} \left(\frac{K_V K_O}{K_L K_{FX}} \right) S_F$$

Factors of strength formula

5 Development



Hertzian Stress Analysis

Optimization

Reference

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2. Dr. Majid Rashidi(2012), FINITE ELEMENT ANALYSIS OF SPUR GEAR SET,『MSL academic endeavors』, p11-16

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Q & A