CAE Team Project

Sliding Friction을 고려한 Gear Tooth Root에서의 Stress Analysis

Gear Second
기어 세컨드

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2016033781 장영석
2016033609 박두하

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Analysis

1

PART 1

[Introduction]

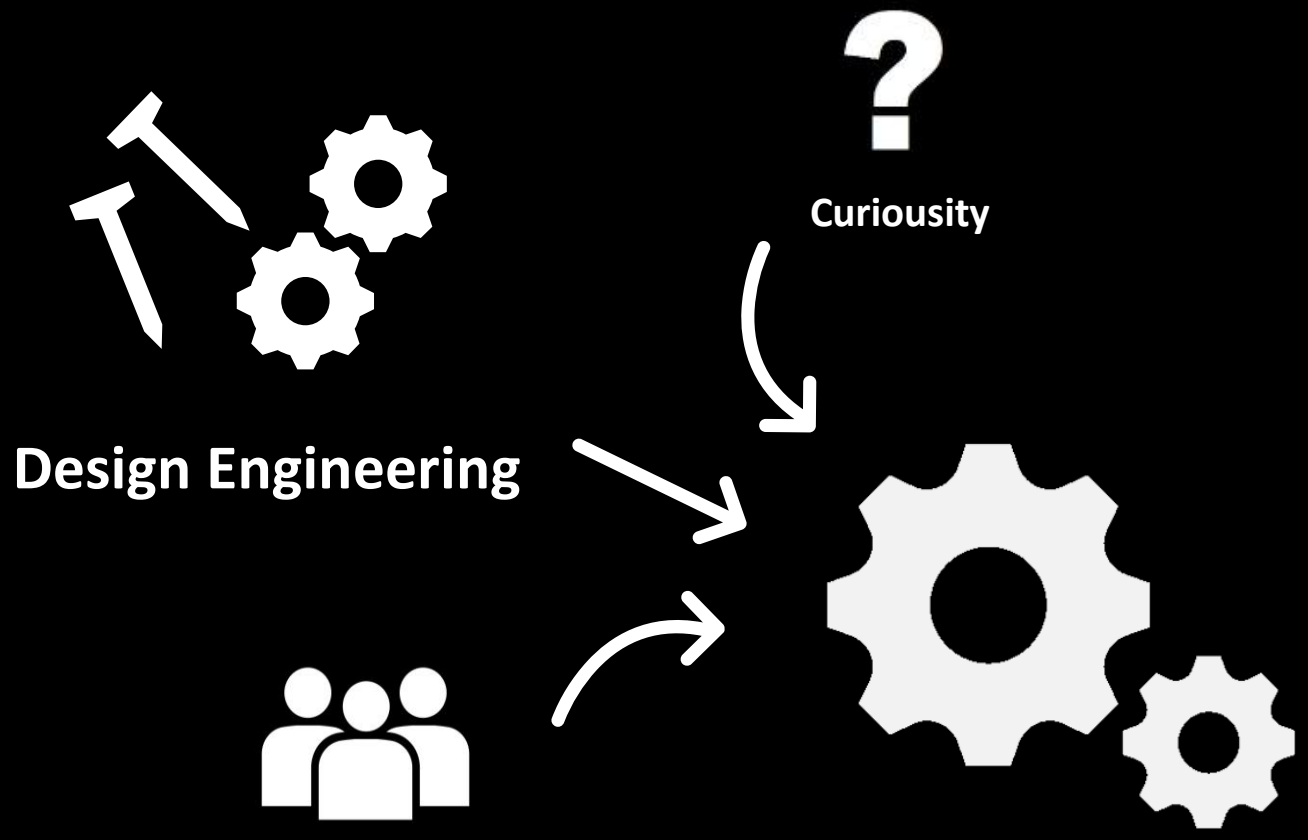
Du-Ha Park

INTRODUCTION

Team Name?

INTRODUCTION

Topic



INTRODUCTION

Research direction

1. MathWorks MATLAB
   회전 각도에 따라 기어에 작용하는 Frictional & Normal Force 계산

2. 

(modeling)
   2D/3D modeling & Location 찾기

3. COMSOL (3D -> 2D)
   기어의 Tooth Root에 작용하는 응력을 3D, 2D(plane stress, plane strain) 요소로 해석,
   3D 모델과의 비교를 통해 2D 해석의 적합성 근거 마련

4. COMSOL (2D Component)
   계산된 Data를 조건별로 비교, 미끄럼 마찰을 고려한 응력 분석

2

PART 2

[MATLAB - Force]

Seung-Hun Lee

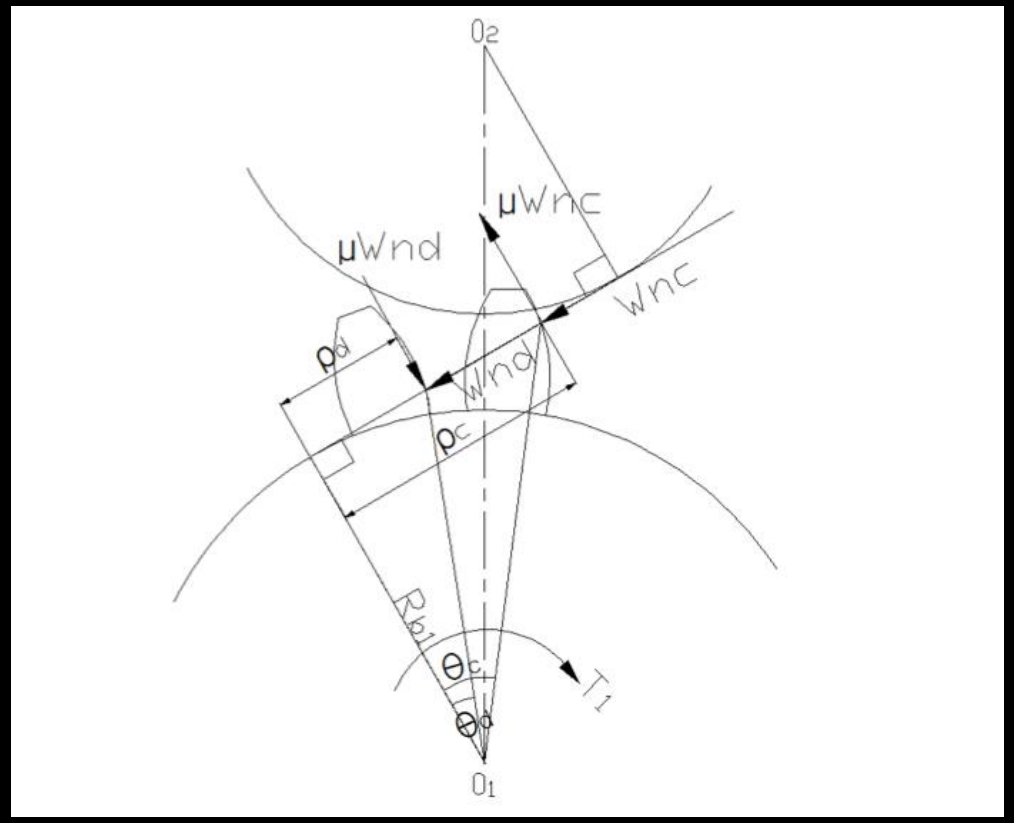
MATLAB & COMSOL

Parameter

	Driving	Driven
Normal module (mm)	2	
Normal pressure angle	20 [deg]	
Center distance (mm)	58	
Whole depth (mm)	4.26	
Number of teeth	30	26
Face width (mm)	16	13
Outside radius (mm)	32.9	28.86
Pitch radius (mm)	30	26
Root radius (mm)	28.64	24.6
Addendum mo. Co.	0.57	0.55

MATLAB

Governing Equation



E_c, E_d : c, d치의 오차

W_{nd}, W_{nc} : c, d치의 수직력

R_{b1} : 구동기어의 base circle radius

T_1 : 구동기어의 토크

ρ_d, ρ_c : c, d치의 곡률반경

Q_c, Q_d : c, d치의 컴플라이언스

MATLAB

Governing equation

$$E_c = W_{nc} Q_c$$

$$E_d = W_{nd} Q_d$$

$$T_1 = W_{nd} R_{b1} + W_{nc} R_{b1} - \mu W_{nd} \rho_d + \mu W_{nc} \rho_c$$

$$\begin{pmatrix} W_{nc} & W_{nd} \end{pmatrix} \begin{pmatrix} Q_c & 0 & R_{b1} + \mu^* \rho_c \\ 0 & Q_d & R_{b1} - \mu^* \rho_d \end{pmatrix} = \begin{pmatrix} E_c & E_d & T_1 \end{pmatrix}$$

MATLAB

Normal Force

C:₩Users₩taeji₩OneDrive₩바탕 화면₩2020-2₩CAE₩Project₩GearSecond₩Gear_fricition_force.m

편집기 | 퍼블리시 | 보기

새로 만들기 | 열기 | 저장 | 파일 찾기 | 비교 | 인쇄 | 이동 | 찾기 | 삽입 | 주석 | 들여쓰기 | 중단점 | 실행

파일 | 탐색 | 편집 | 중단점

```
68
69      %% Normal force
70
71 -    for i=1:n
72 -        if (theta(i) >= 28 && theta(i) < 34)
73 -            Wn10(i) = Tp*1000/(Rbp-mu0*rho1(i));
74 -            Wn11(i) = Tp*1000/(Rbp-mu1*rho1(i));
75 -            Wn12(i) = Tp*1000/(Rbp-mu2*rho1(i));
76 -            Wn120(i,:) = [Wn10(i) Wn20(i)];
77 -            Wn121(i,:) = [Wn11(i) Wn21(i)];
78 -            Wn122(i,:) = [Wn12(i) Wn22(i)];
79 -            Wf0(i,:) = -(Wn120(i,1)+Wn120(i,2))*mu0;
80 -            Wf1(i,:) = -(Wn121(i,1)+Wn121(i,2))*mu1;
81 -            Wf2(i,:) = -(Wn122(i,1)+Wn122(i,2))*mu2;
82 -        end
83 -    end
84
85 -    for i=1:n
86 -        if (theta(i) >= 34 && theta(i) < 40)
87 -            Wn20(i) = Tp*1000/(Rbp+mu0*rho2(i));
88 -            Wn21(i) = Tp*1000/(Rbp+mu1*rho2(i));
89 -            Wn22(i) = Tp*1000/(Rbp+mu2*rho2(i));
90 -            Wn120(i,:) = [Wn10(i) Wn20(i)];
91 -            Wn121(i,:) = [Wn11(i) Wn21(i)];
92 -            Wn122(i,:) = [Wn12(i) Wn22(i)];
93 -            Wf0(i,:) = (Wn120(i,1)+Wn120(i,2))*mu0;
94 -            Wf1(i,:) = (Wn121(i,1)+Wn121(i,2))*mu1;
95 -            Wf2(i,:) = (Wn122(i,1)+Wn122(i,2))*mu2;
96 -        end
97 -    end
98
99 -    for i=1:n
```

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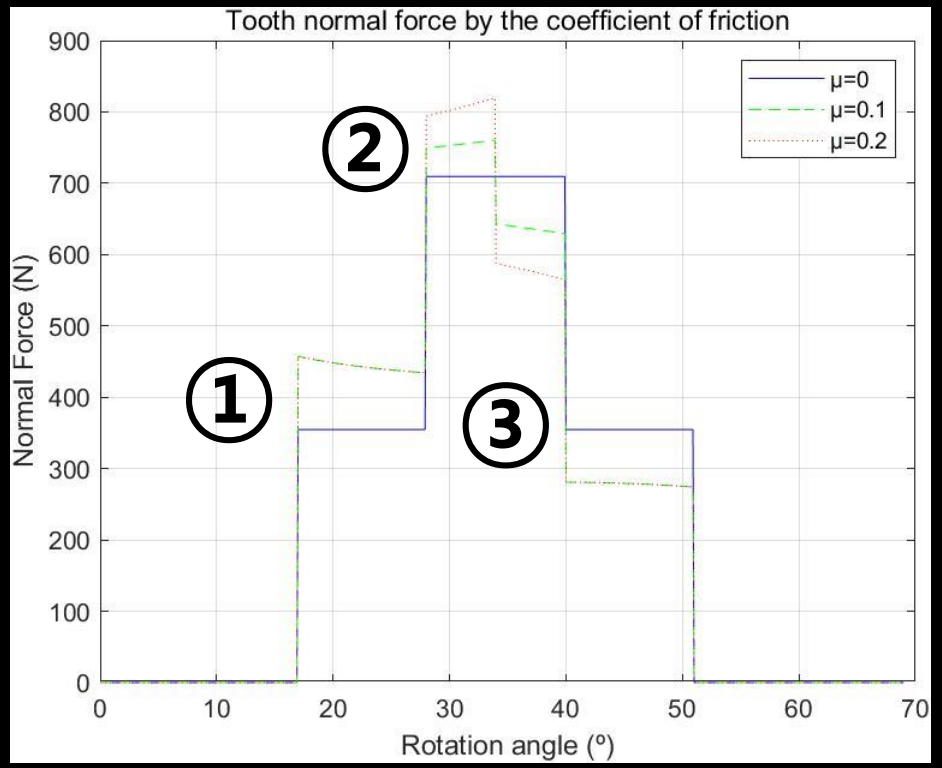
파일 | 탐색 | 편집 | 중단점

```
98
99 -    for i=1:n
100 -       T=[Tp*1000 max(Wn120(:,1))];
101 -       if (theta(i) >= 17 && theta(i) < 28)
102 -         A1 = [Rbp-mu1*rho1(i) 1; Rbp+mu1*rho2(i) 1];
103 -         A2 = [Rbp-mu2*rho1(i) 1; Rbp+mu2*rho2(i) 1];
104 -         Wn120(i,:) = max(Wn120(:,1))/2;
105 -         Wn121(i,:) = T*inv(A1);
106 -         Wn122(i,:) = T*inv(A2);
107 -         Wf0(i,:) = -Wn120(i,1)*mu0;
108 -         Wf1(i,:) = -Wn121(i,1)*mu1;
109 -         Wf2(i,:) = -Wn122(i,1)*mu2;
110 -       end
111 -   end
112
113 -    for i=1:n
114 -        T=[Tp*1000 max(Wn120(:,1))];
115 -       if (theta(i) >= 40 && theta(i) < 51)
116 -         A1 = [Rbp-mu1*rho1(i) 1; Rbp+mu1*rho2(i) 1];
117 -         A2 = [Rbp-mu2*rho1(i) 1; Rbp+mu2*rho2(i) 1];
118 -         Wn120(i,:) = max(Wn120(:,1))/2;
119 -         Wn121(i,:) = T*inv(A1);
120 -         Wn122(i,:) = T*inv(A2);
121 -         Wf0(i,:) = Wn120(i,2)*mu0;
122 -         Wf1(i,:) = Wn121(i,2)*mu1;
123 -         Wf2(i,:) = Wn122(i,2)*mu2;
124 -       end
125 -   end
126     %% Plot
127 -       plot(theta,Wf1(:,1),'blue',theta,Wf2(:,1),'green--');
128 -       title("Friction force by the coefficient of friction")
129 -       xlabel("Rotatio     n angle (°)")
```

MATLAB

Normal Force



		μ = 0	μ = 0.1	μ = 0.2
①	두 개의 치가 맞물림 (rotation angle = 20°)	354.7259 N	448.3181 N	448.3181 N
②	한 개의 치가 맞물림 (rotation angle = 30°)	709.4518 N	752.9218 N	802.0665 N
③	두 개의 치가 맞물림 (rotation angle = 42°)	354.7259 N	280.5680 N	280.5680 N

MATLAB

Frictional Force

C:₩Users₩taeji₩OneDrive₩바탕 화면₩2020-2₩CAE₩Project₩GearSecond₩Gear_fricition_force.m

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```
68
69      %% Frictional force
70
71 —    for i=1:n
72 —        if (theta(i) >= 28 && theta(i) < 34)
73 —            Wn10(i) = Tp*1000/(Rbp-mu0*rho1(i));
74 —            Wn11(i) = Tp*1000/(Rbp-mu1*rho1(i));
75 —            Wn12(i) = Tp*1000/(Rbp-mu2*rho1(i));
76 —            Wn120(i,:) = [Wn10(i) Wn20(i)];
77 —            Wn121(i,:) = [Wn11(i) Wn21(i)];
78 —            Wn122(i,:) = [Wn12(i) Wn22(i)];
79 —            Wf0(i,:) = -(Wn120(i,1)+Wn120(i,2))*mu0;
80 —            Wf1(i,:) = -(Wn121(i,1)+Wn121(i,2))*mu1;
81 —            Wf2(i,:) = -(Wn122(i,1)+Wn122(i,2))*mu2;
82 —        end
83 —    end
84
85 —    for i=1:n
86 —        if (theta(i) >= 34 && theta(i) < 40)
87 —            Wn20(i) = Tp*1000/(Rbp+mu0*rho2(i));
88 —            Wn21(i) = Tp*1000/(Rbp+mu1*rho2(i));
89 —            Wn22(i) = Tp*1000/(Rbp+mu2*rho2(i));
90 —            Wn120(i,:) = [Wn10(i) Wn20(i)];
91 —            Wn121(i,:) = [Wn11(i) Wn21(i)];
92 —            Wn122(i,:) = [Wn12(i) Wn22(i)];
93 —            Wf0(i,:) = (Wn120(i,1)+Wn120(i,2))*mu0;
94 —            Wf1(i,:) = (Wn121(i,1)+Wn121(i,2))*mu1;
95 —            Wf2(i,:) = (Wn122(i,1)+Wn122(i,2))*mu2;
96 —        end
97 —    end
98
99 —    for i=1:n
```

C:₩Users₩taeji₩OneDrive₩바탕 화면₩2020-2₩CAE₩Project₩GearSecond₩Gear_fricition_force.m

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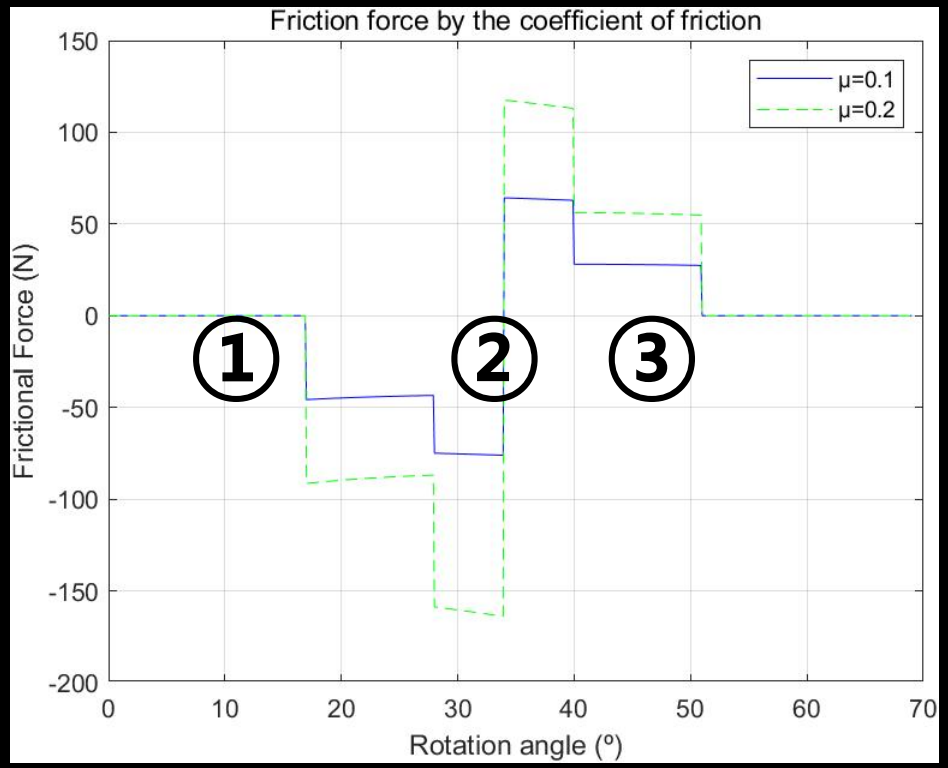
```
98
99 —    for i=1:n
100 —       T=[Tp*1000 max(Wn120(:,1))];
101 —       if (theta(i) >= 17 && theta(i) < 28)
102 —         A1 = [Rbp-mu1*rho1(i) 1; Rbp+mu1*rho2(i) 1];
103 —         A2 = [Rbp-mu2*rho1(i) 1; Rbp+mu2*rho2(i) 1];
104 —         Wn120(i,:) = max(Wn120(:,1))/2;
105 —         Wn121(i,:) = T*inv(A1);
106 —         Wn122(i,:) = T*inv(A2);
107 —         Wf0(i,:) = -Wn120(i,1)*mu0;
108 —         Wf1(i,:) = -Wn121(i,1)*mu1;
109 —         Wf2(i,:) = -Wn122(i,1)*mu2;
110 —       end
111 —   end
112
113 —   for i=1:n
114 —       T=[Tp*1000 max(Wn120(:,1))];
115 —       if (theta(i) >= 40 && theta(i) < 51)
116 —         A1 = [Rbp-mu1*rho1(i) 1; Rbp+mu1*rho2(i) 1];
117 —         A2 = [Rbp-mu2*rho1(i) 1; Rbp+mu2*rho2(i) 1];
118 —         Wn120(i,:) = max(Wn120(:,1))/2;
119 —         Wn121(i,:) = T*inv(A1);
120 —         Wn122(i,:) = T*inv(A2);
121 —         Wf0(i,:) = Wn120(i,2)*mu0;
122 —         Wf1(i,:) = Wn121(i,2)*mu1;
123 —         Wf2(i,:) = Wn122(i,2)*mu2;
124 —       end
125 —   end
126     %% Plot
127 —       plot(theta,Wf1(:,1),'blue',theta,Wf2(:,1),'green--');
128 —       title("Friction force by the coefficient of friction")
129 —       xlabel("Rotatio     n angle (º)")
```

MATLAB

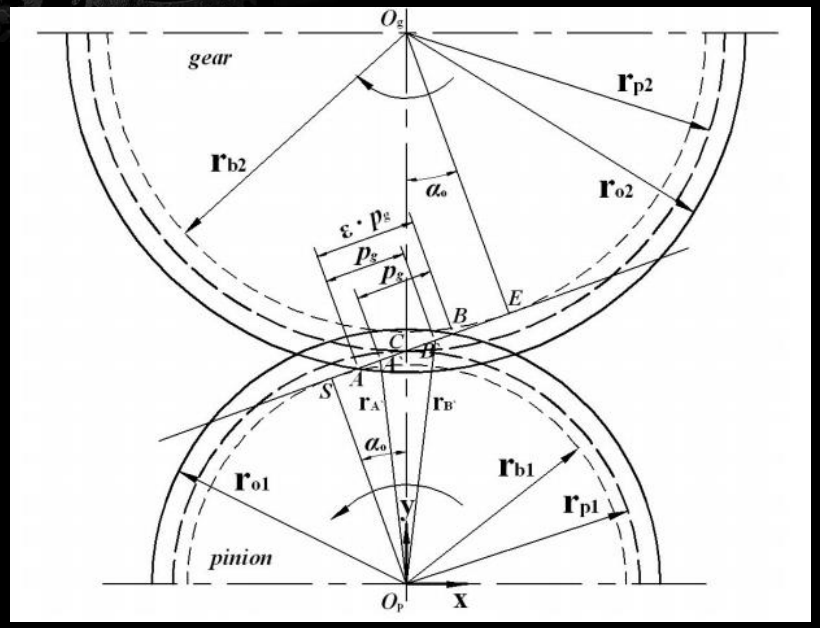
Frictional Force



		μ = 0.1	μ = 0.2
①	두 개의 치가 맞물림 (rotation angle = 20°)	-44.8318 N	-89.6636 N
②	한 개의 치가 맞물림 (rotation angle = 30°)	-75.2922 N	-160.4133 N
③	두 개의 치가 맞물림 (rotation angle = 42°)	28.0568 N	56.1136 N

MATLAB

Governing equation



$$r_{B'} = \sqrt{{r_{p1}}^2 + (CB')^2 - 2 \times r_{p1} \times CB' \times \cos(a_0 + 90)}$$

$$\boldsymbol{E}(\text{물림율}) = \frac{\sqrt{(2\mathbf{R_{op}})^2 - (2\mathbf{R_{bp}})^2} + \sqrt{(2\mathbf{R_{og}})^2 - (2\mathbf{R_{bg}})^2} - \sqrt{(2\mathbf{C})^2 - (2\mathbf{R_{bp}} + 2\mathbf{R_{bg}})^2}}{2 \times \boldsymbol{\pi} \times \mathbf{m} \times \mathbf{cos}(\mathbf{angle})}$$

MATLAB

Location

C:₩Users₩taeji₩OneDrive₩바탕 화면₩2020-2₩CAE₩Project₩GearSecond₩Gear_location.m

편집기 퍼블리시 보기

새로 만들기 열기 저장 파일 찾기 비교 인쇄 (파일) | 이동 찾기 (탐색) | 삽입 주석 들여쓰기 (편집) | 중단점 (중단점) | 실행 실행 및 진행 섹션 실행 진행 실행 시간 측정 (실행)

```
26 —    Rpg = 26; % Pitch radius [mm]
27 —    Rrg = 24.6; % Root radius [mm]
28 —    Rbg = Rpg*cos(angle); % Base radius [mm]
29
30      %% using data
31 —    lp = sqrt(Rog^2-(Rpg*cos(angle)^2))-Rpg*sin(angle); % Line of approach
32 —    lg = sqrt(Rop^2-(Rpp*cos(angle))^2)-Rpp*sin(angle); % Line of recess
33 —    L = lp+lg; % Length of line action
34
35      %% Analysis
36
37 —    mu0 = 0;
38 —    mu1 = 0.1;
39 —    mu2 = 0.2;
40
41 —    thetai = atan((Rpp*cos(angle)-lp)/Rbp);
42 —    thetaf = atan((Rpp*cos(angle)+lg)/Rbp);
43
44 —    e=(sqrt((2*Rop)^2-(2*Rbp)^2)+sqrt((2*Rog)^2-(2*Rbg)^2)-sqrt((2*C)^2-(2*Rbp+2*Rbg)^2))/(2*pi*m*cos(angle));
45
46      %% ready to plot
47 —    theta = (0:0.1:thetaf*180/pi+18)';
48 —    n=length(theta);
49 —    rho1 = Rbp*tan(theta/180*pi);
50 —    rho2 = Rbp*tan((theta+2*180/Np)/180*pi);
51
52 —    LG = sqrt(Rbp^2+rho1(310)^2);
53 —    HP = sqrt(Rbp^2+rho1(210)^2);
54 —    LP = sqrt(Rbp^2+rho2(210)^2);
55 —    fprintf("Single teeth(rotation angle = 30° at pinion) loaction = %.2fmm ₩n",LG)
56 —    fprintf("Double tooth(rotation angle = 20° at pinion) HP location = %.2fmm ₩n",HP)
57 —    fprintf("Double tooth(rotation angle = 20° at pinion) LP location = %.2fmm ₩n",LP)
```

MATLAB

Location

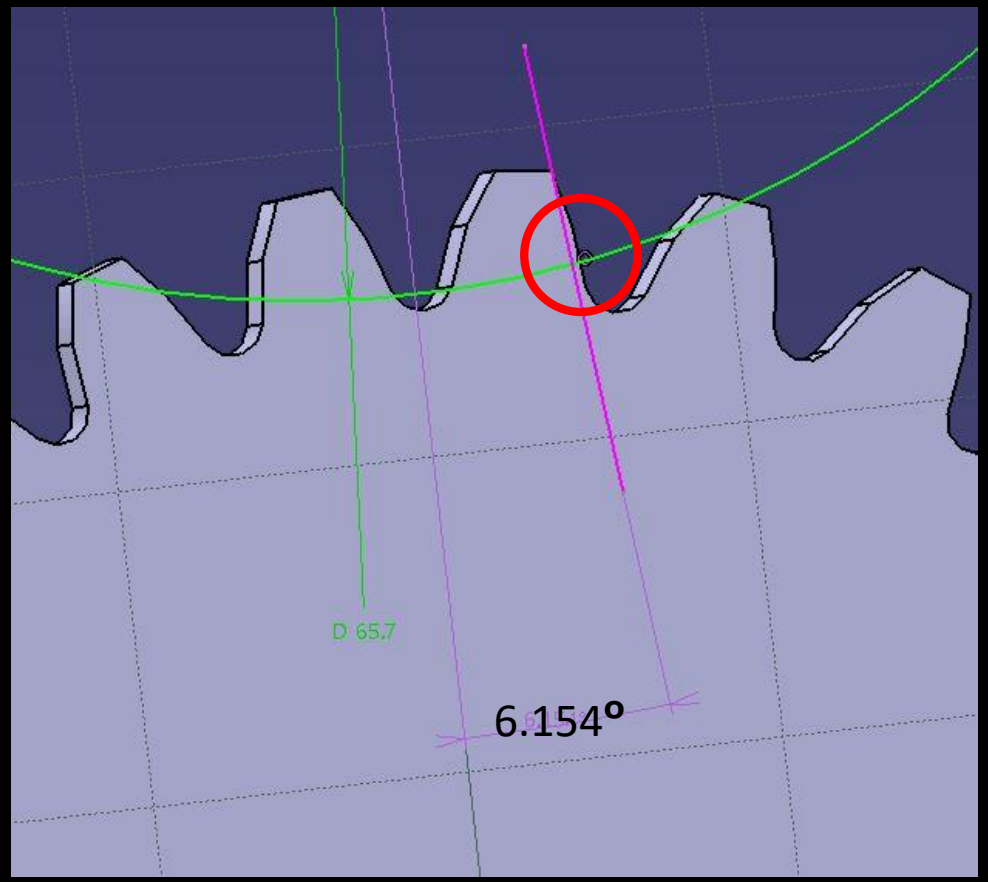
```
Single teeth(rotation angle = 30º at pinion) loaction = 32.85mm
Double tooth(rotation angle = 20º at pinion) HP location = 30.18mm
Double tooth(rotation angle = 20º at pinion) LP location = 33.58mm
```

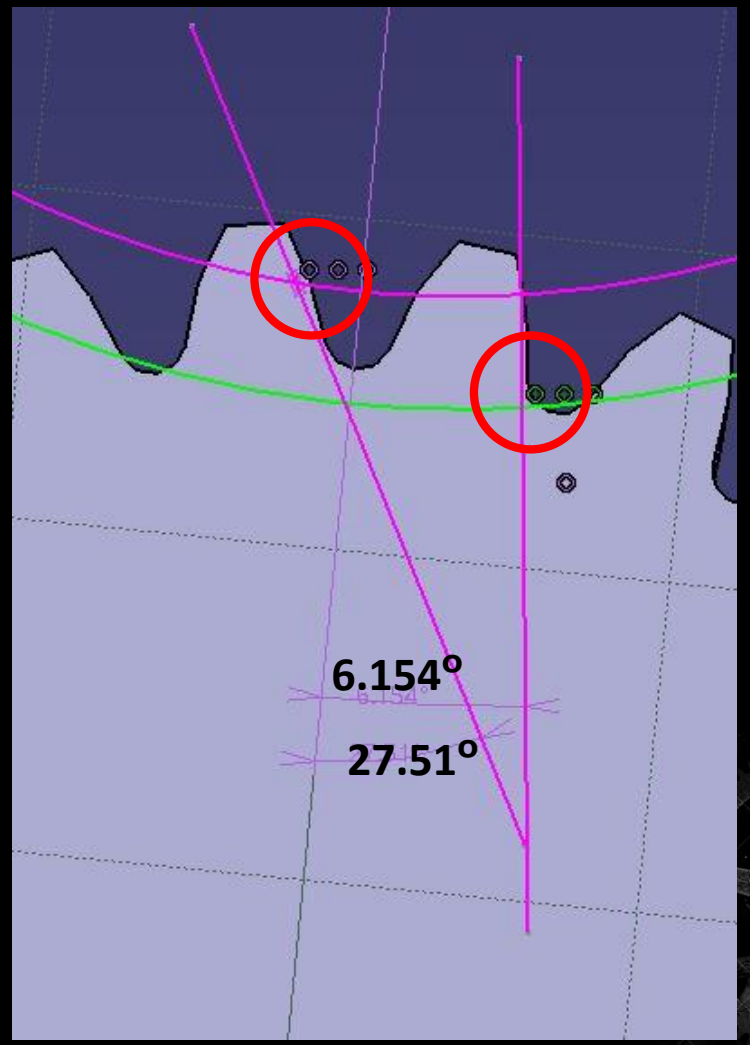
Pinion이 20º 회전하면 두 개의 치가 맞물리며
[higher-point] Pinion 중점에서 r = 30.18mm 원과 교점
[lower-point] Pinion 중점에서 r = 33.58mm 원과 교점.

Pinion이 30º 회전하면 한 개의 치가 맞물리며,
[Point] Pinion에서 r = 32.85mm 원과 교점.

MATLAB

Location





3

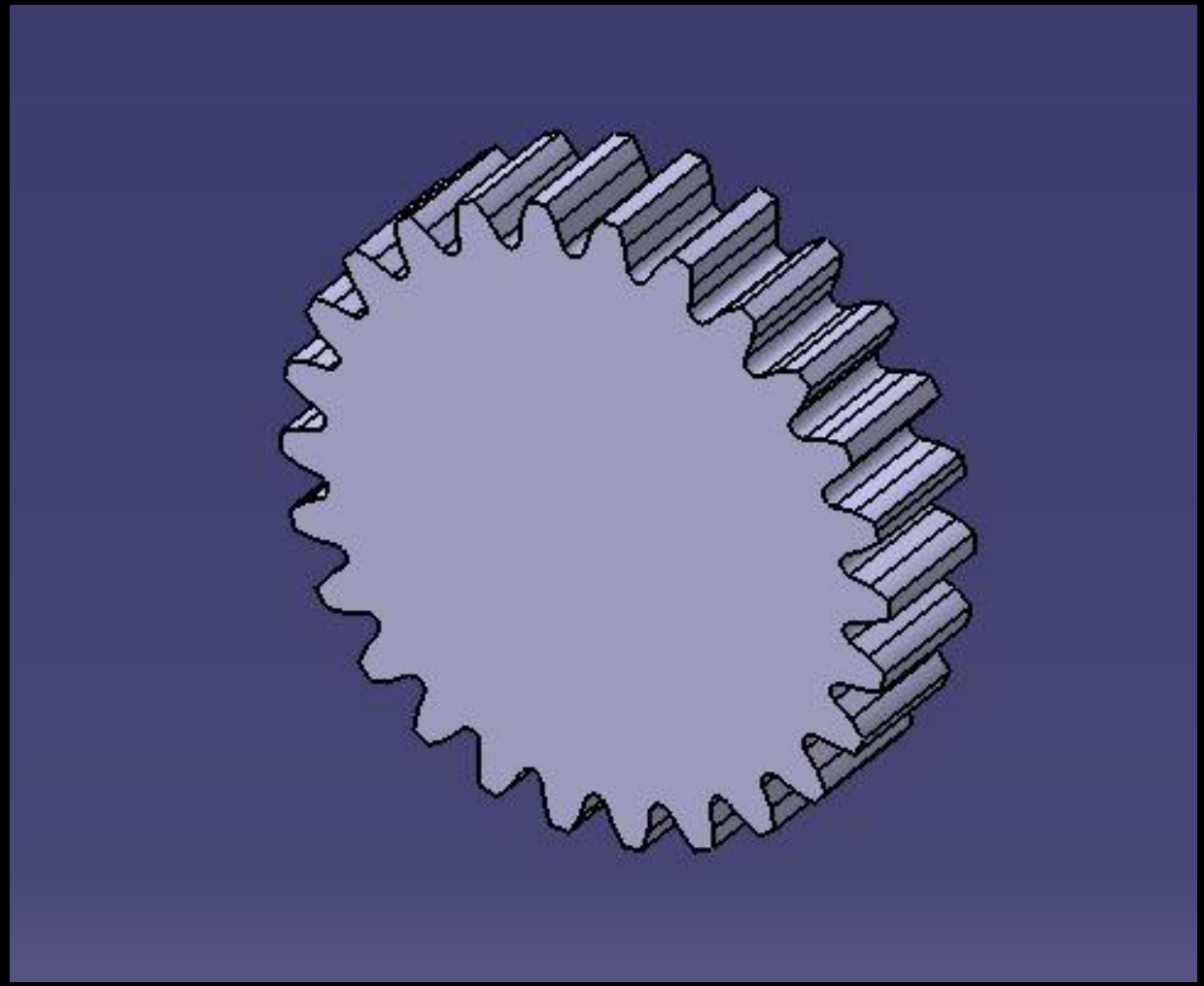
PART 3

[COMSOL - Stress]

Yeong-Seok Jang

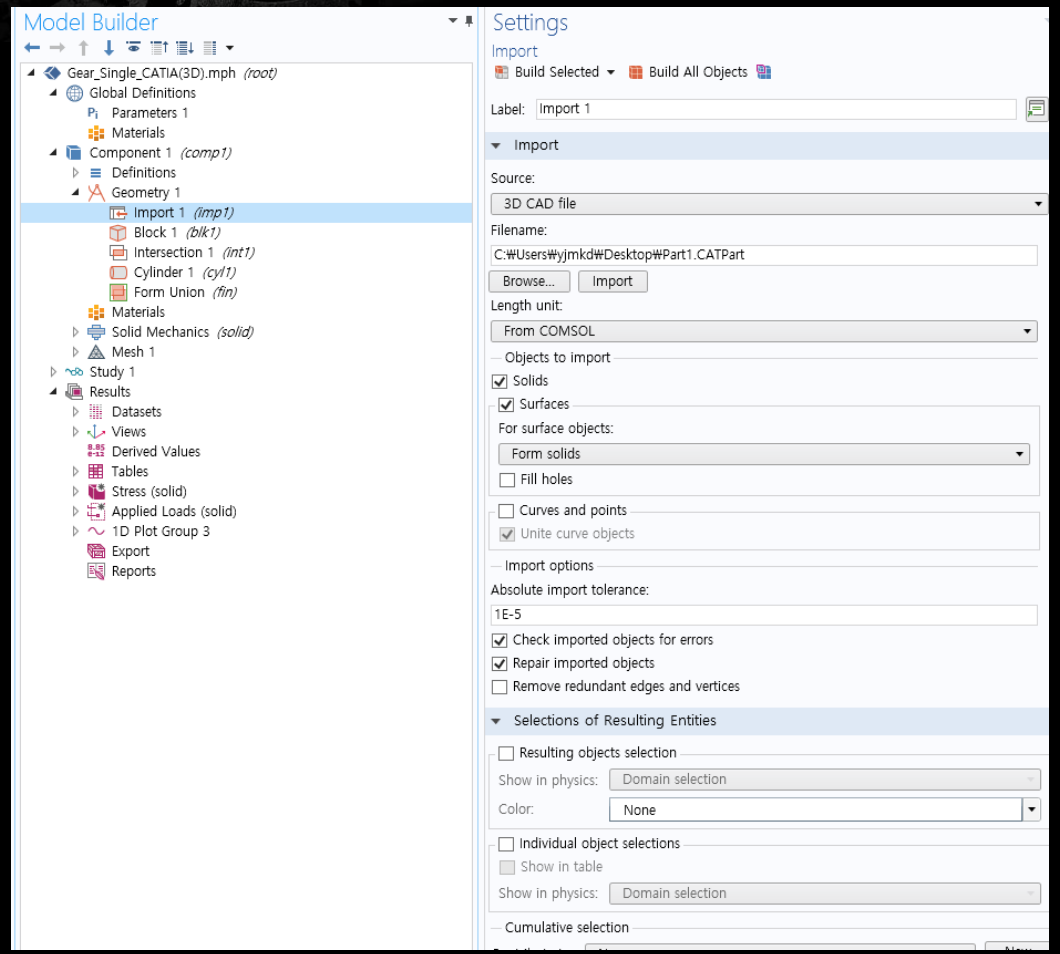
COMSOL

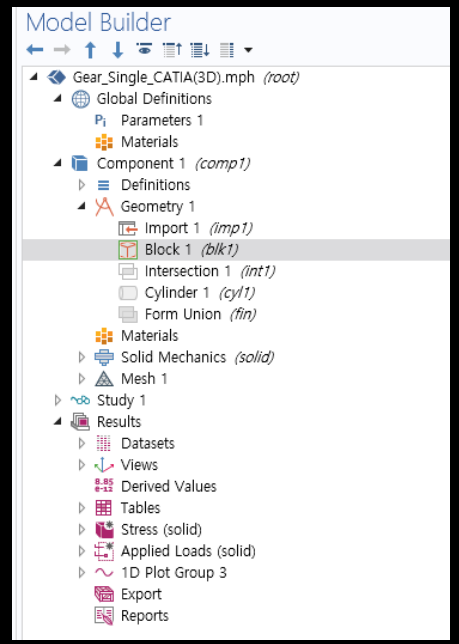
Catia modeling

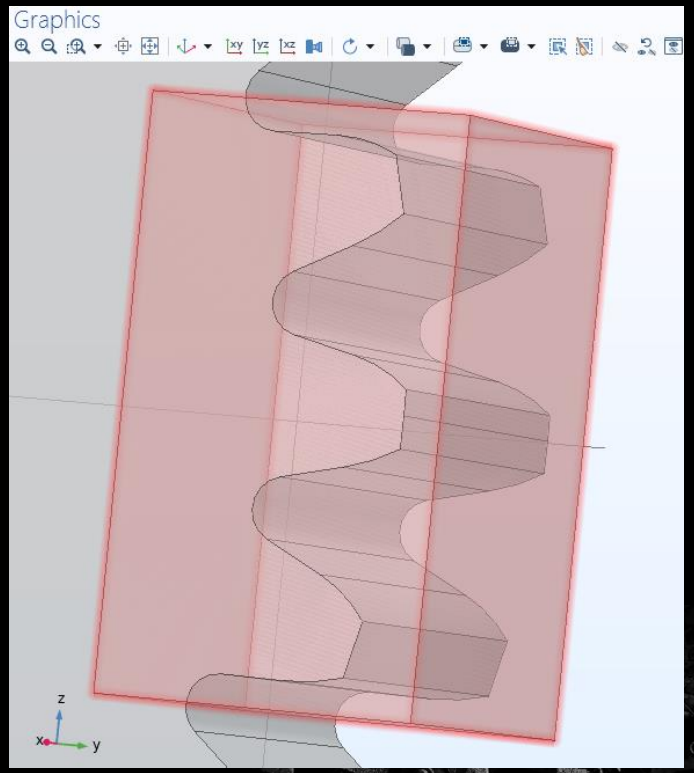


COMSOL

3D Modeling

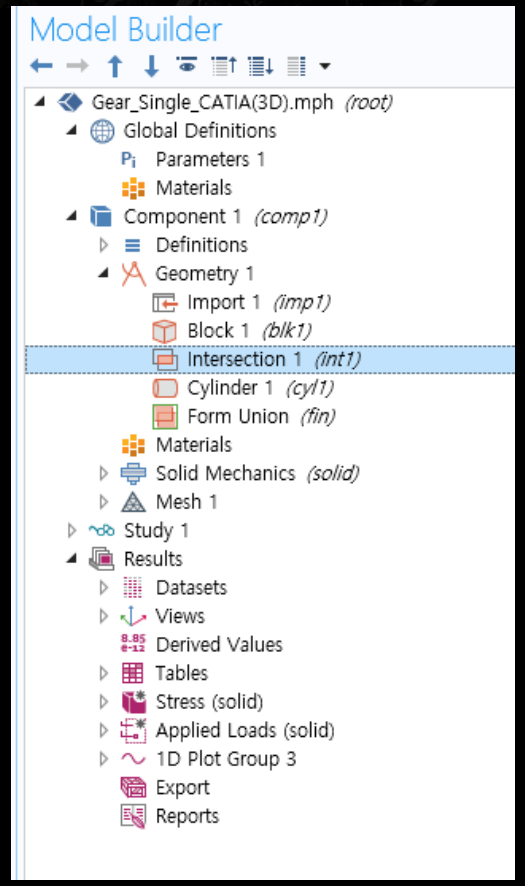


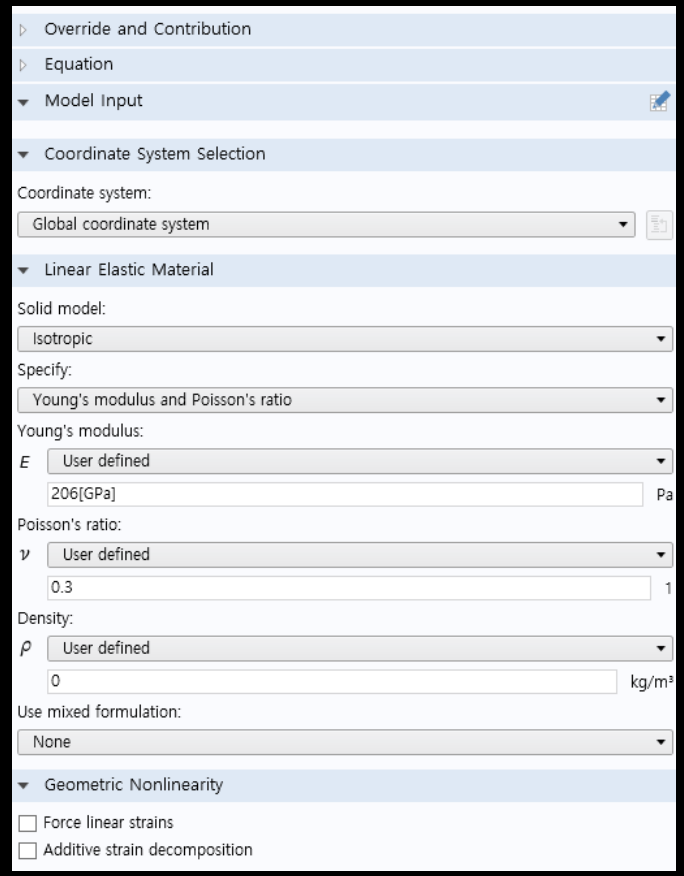


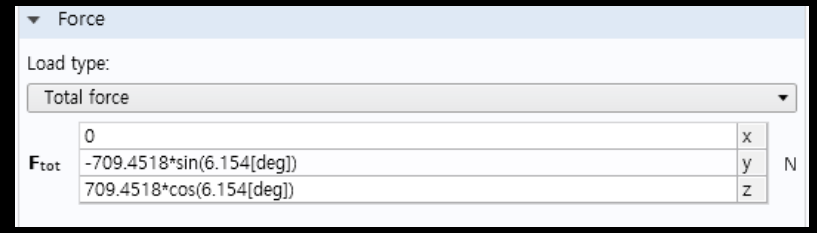


COMSOL

3D Modeling

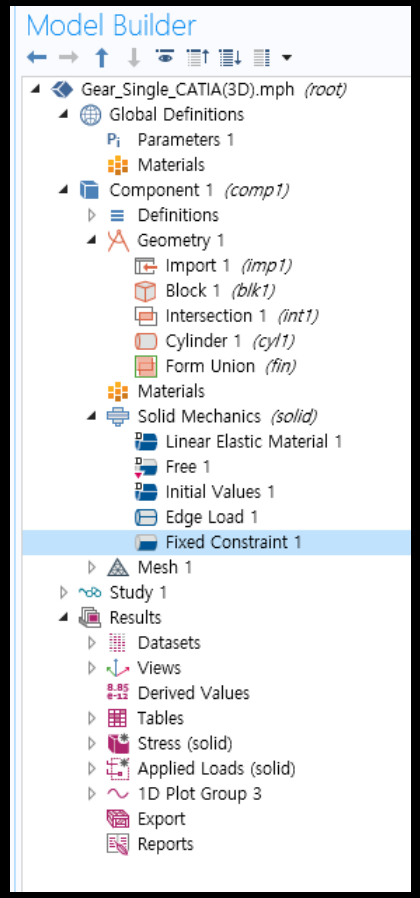


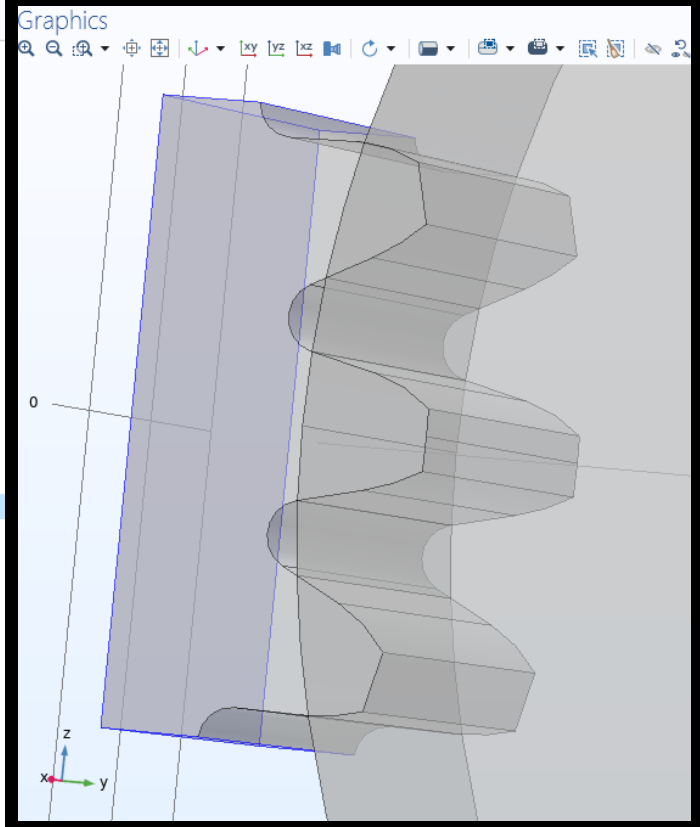


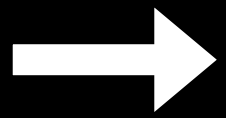


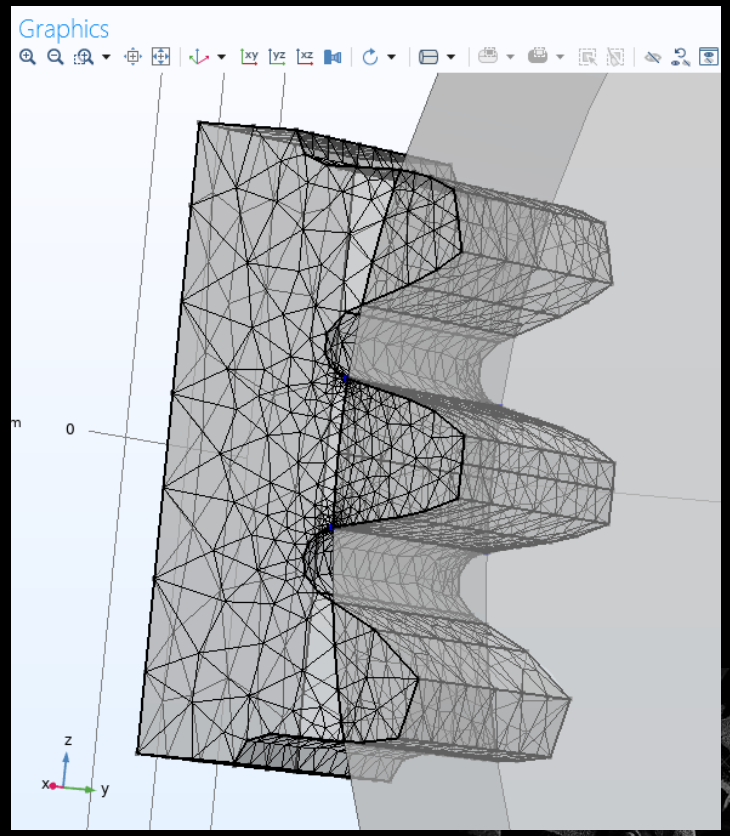
COMSOL

3D Modeling









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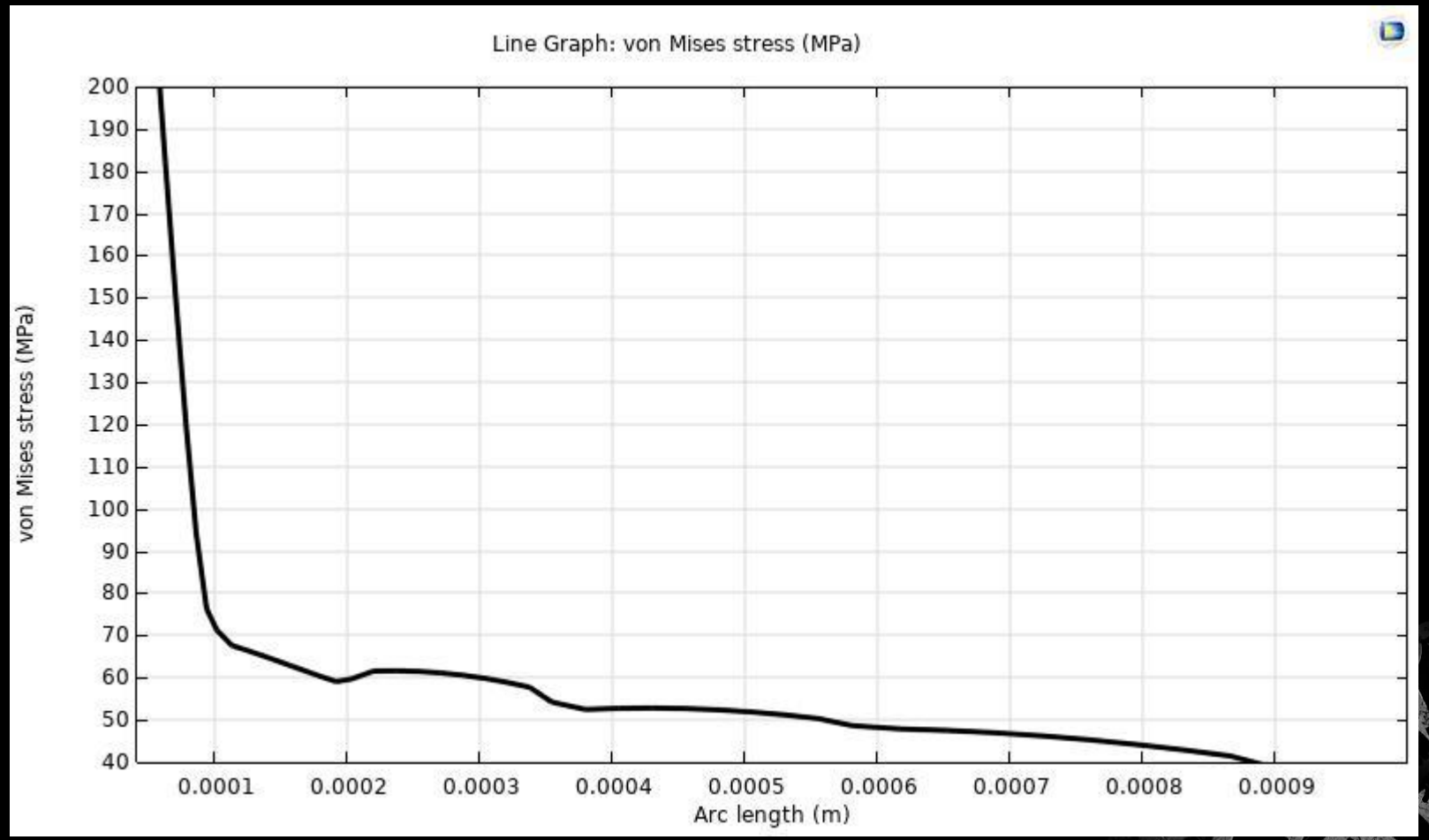
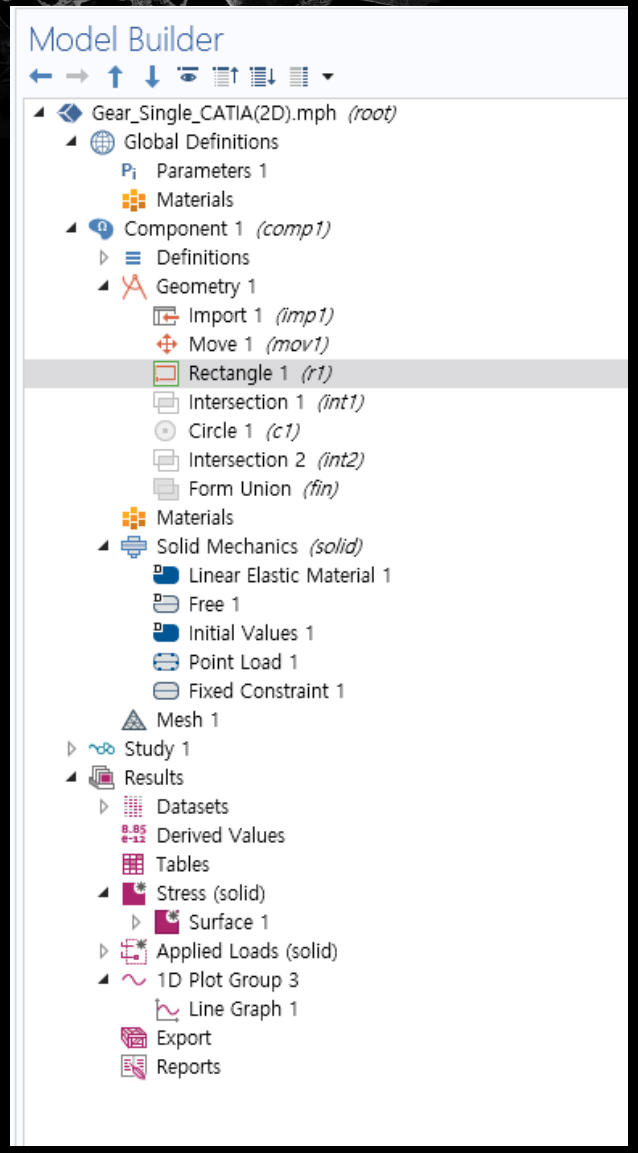
3D Modeling data

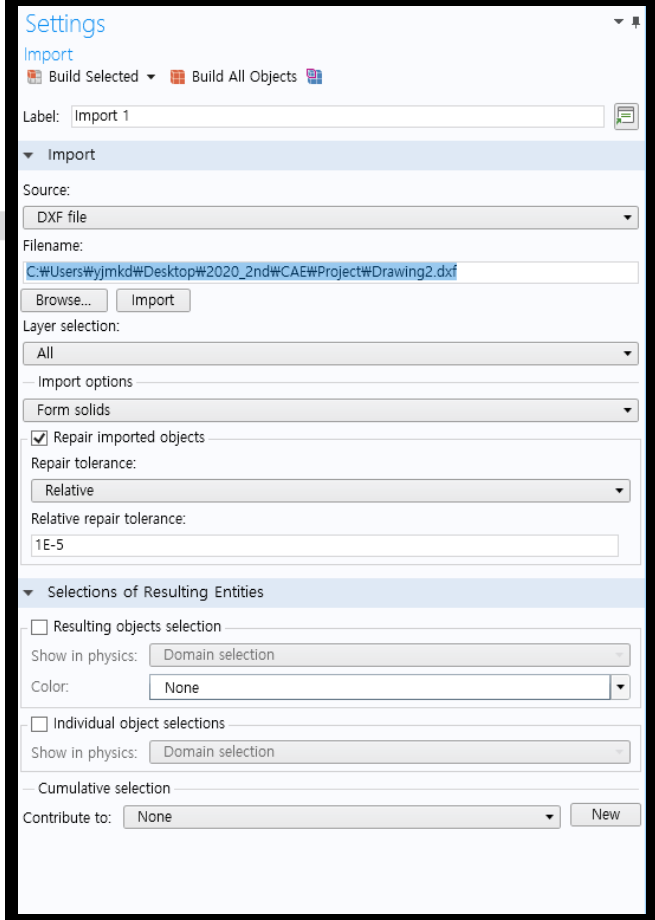
3D Solid element

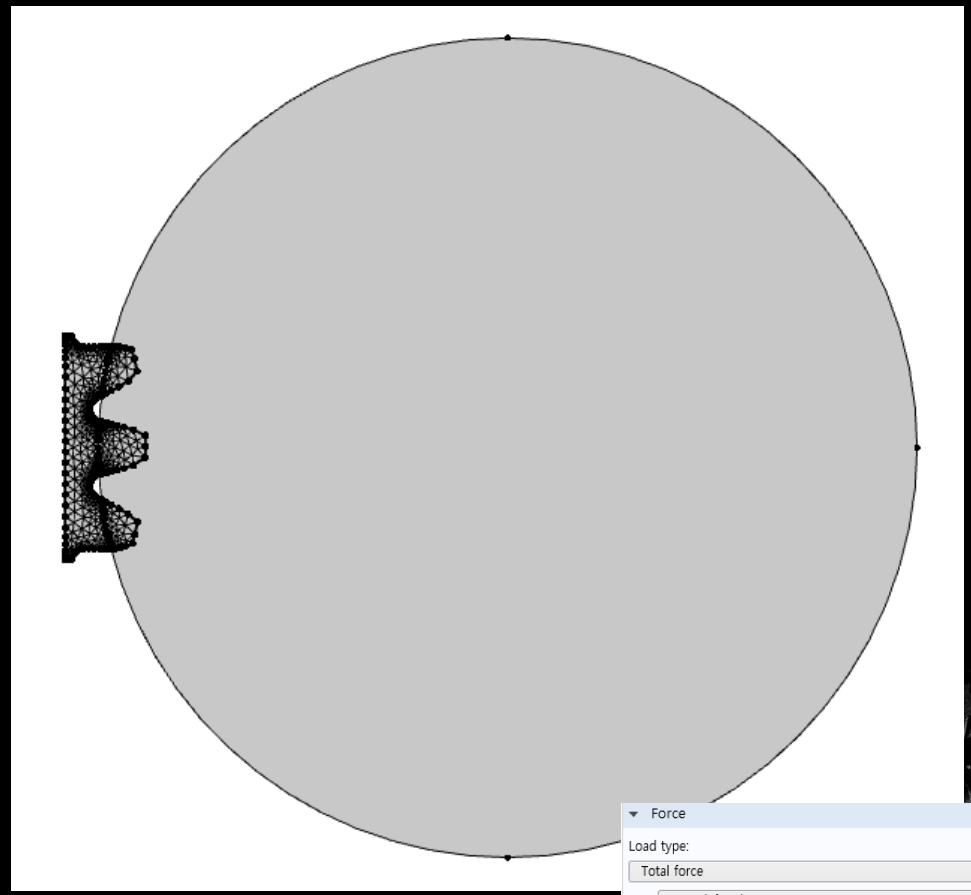


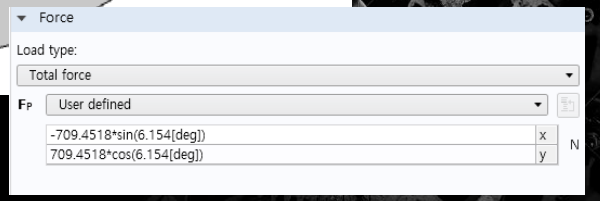
COMSOL

2D Modeling



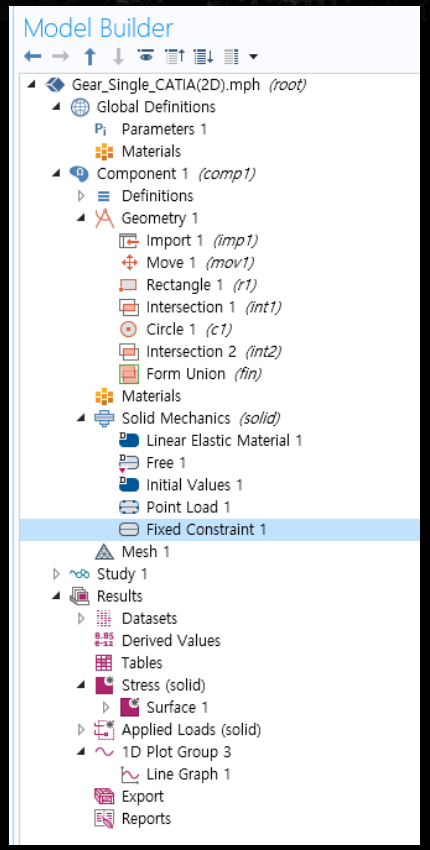


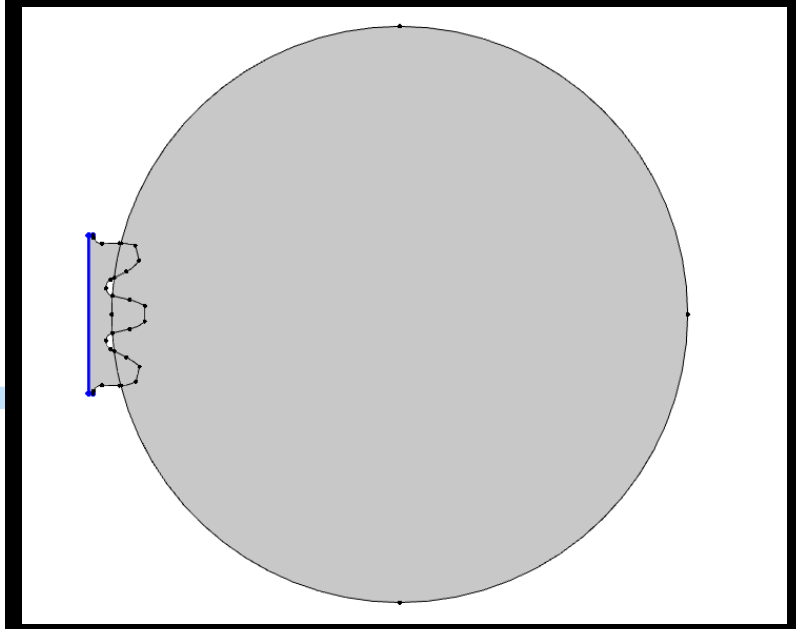


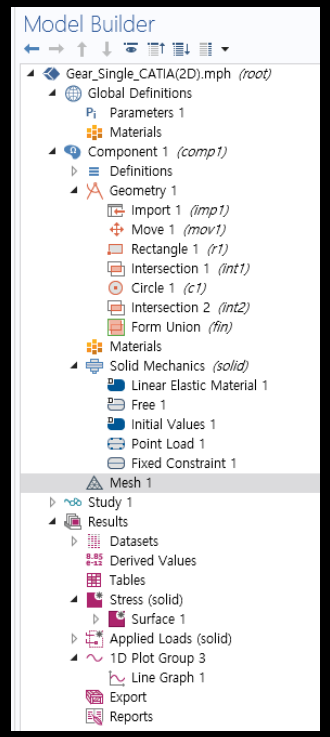


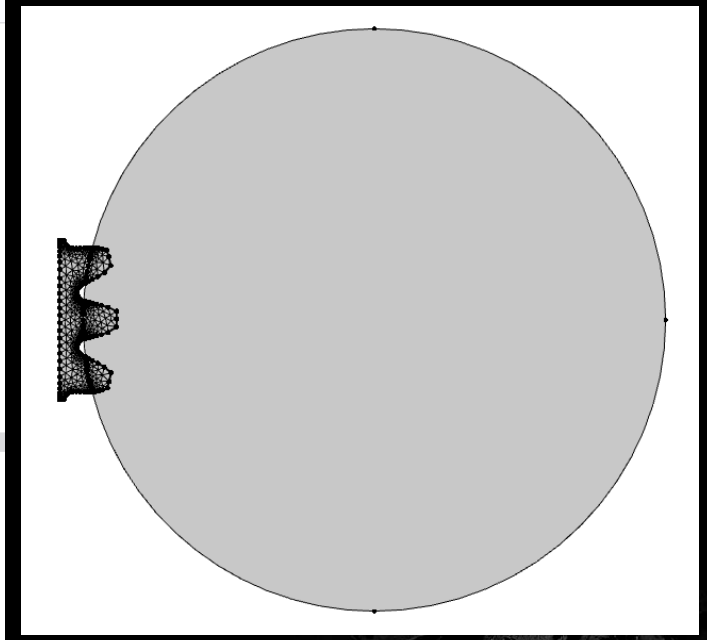
COMSOL

2D Modeling



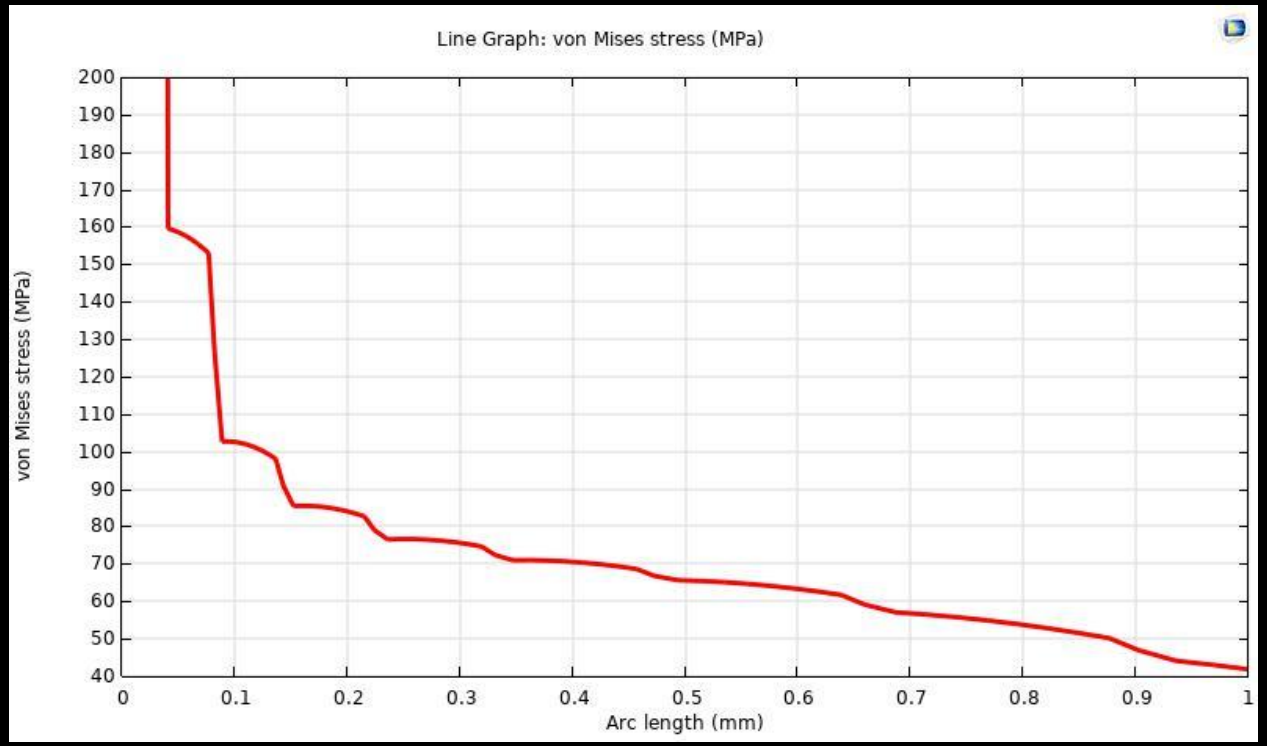


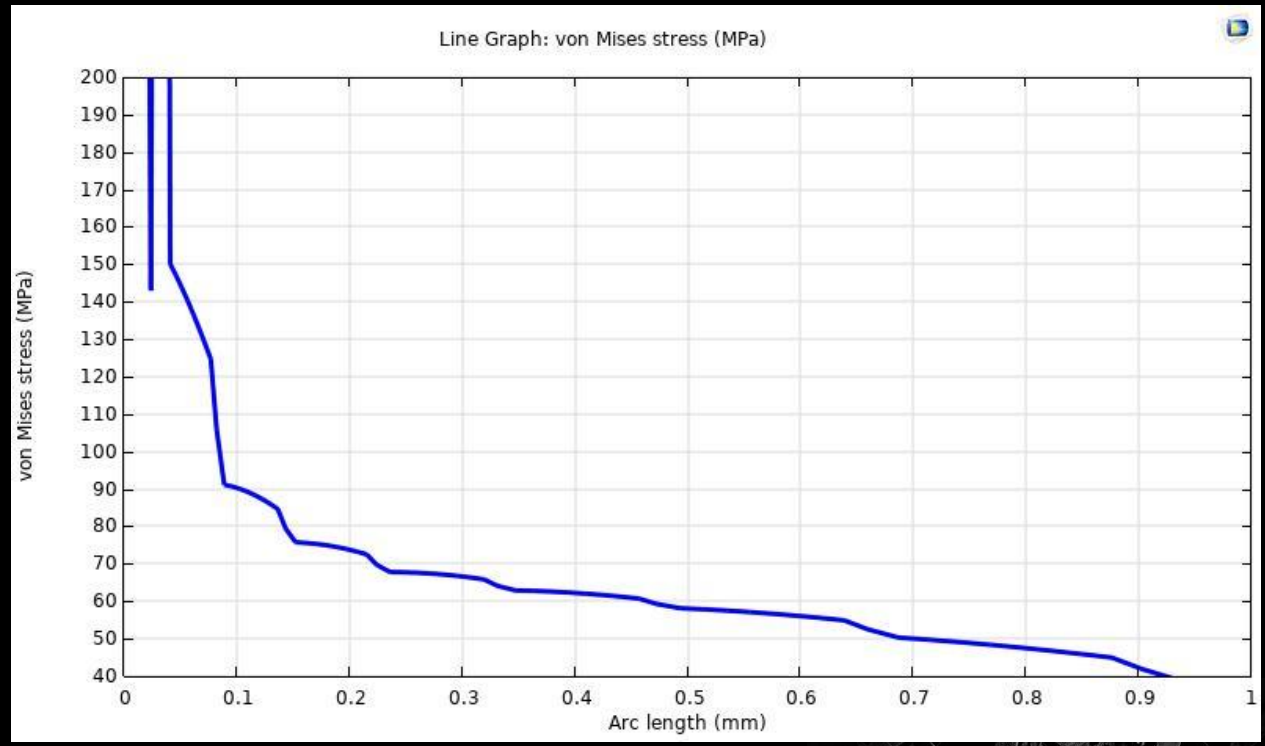




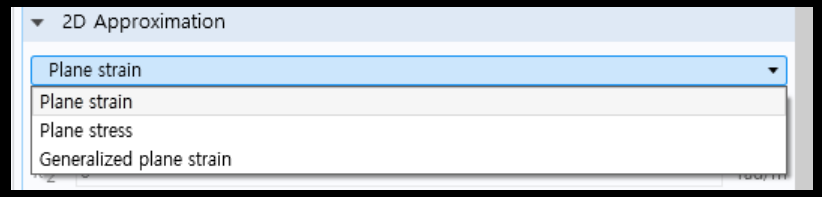
COMSOL

2D Modeling data





Plane stress



Plane strain

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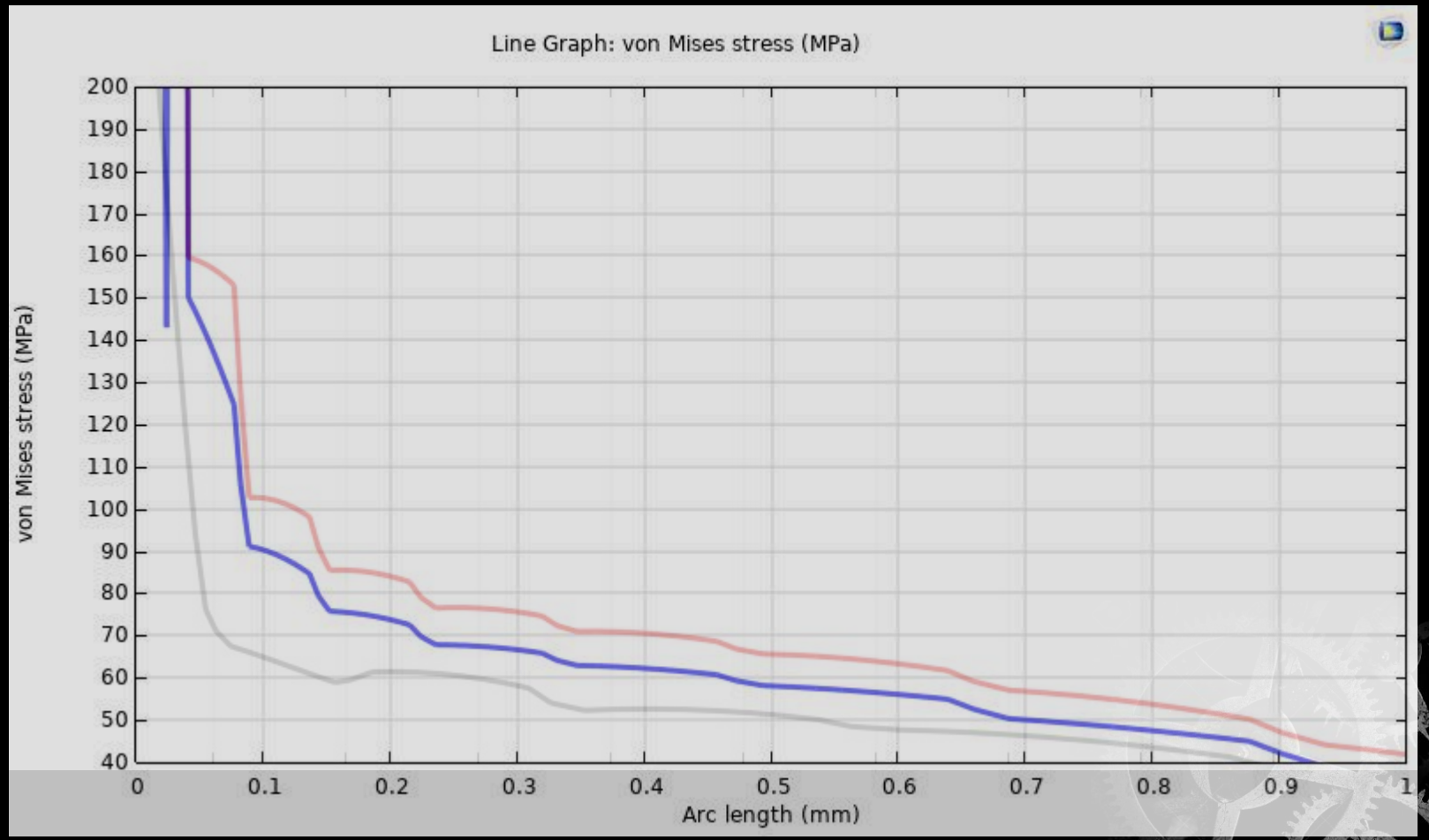
2D, 3D Modeling data

Plane stress, Plane strain, 3D element

- 3D
- Plane strain
- Plane stress



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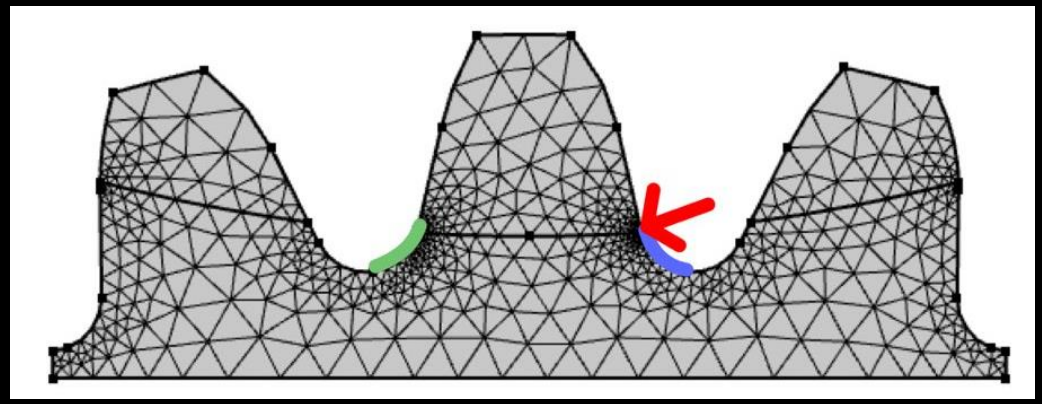
Stress

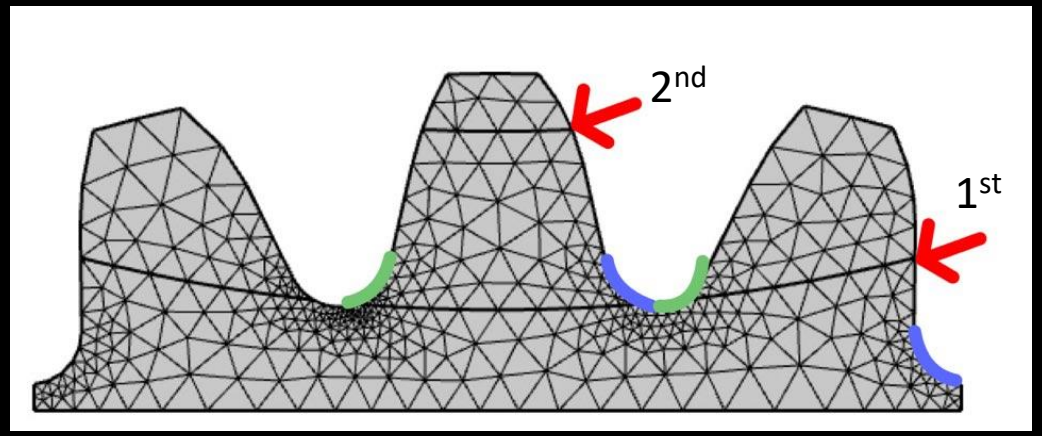
Compression

Tension



Compression

Tension



4

PART 4

[Analysis]

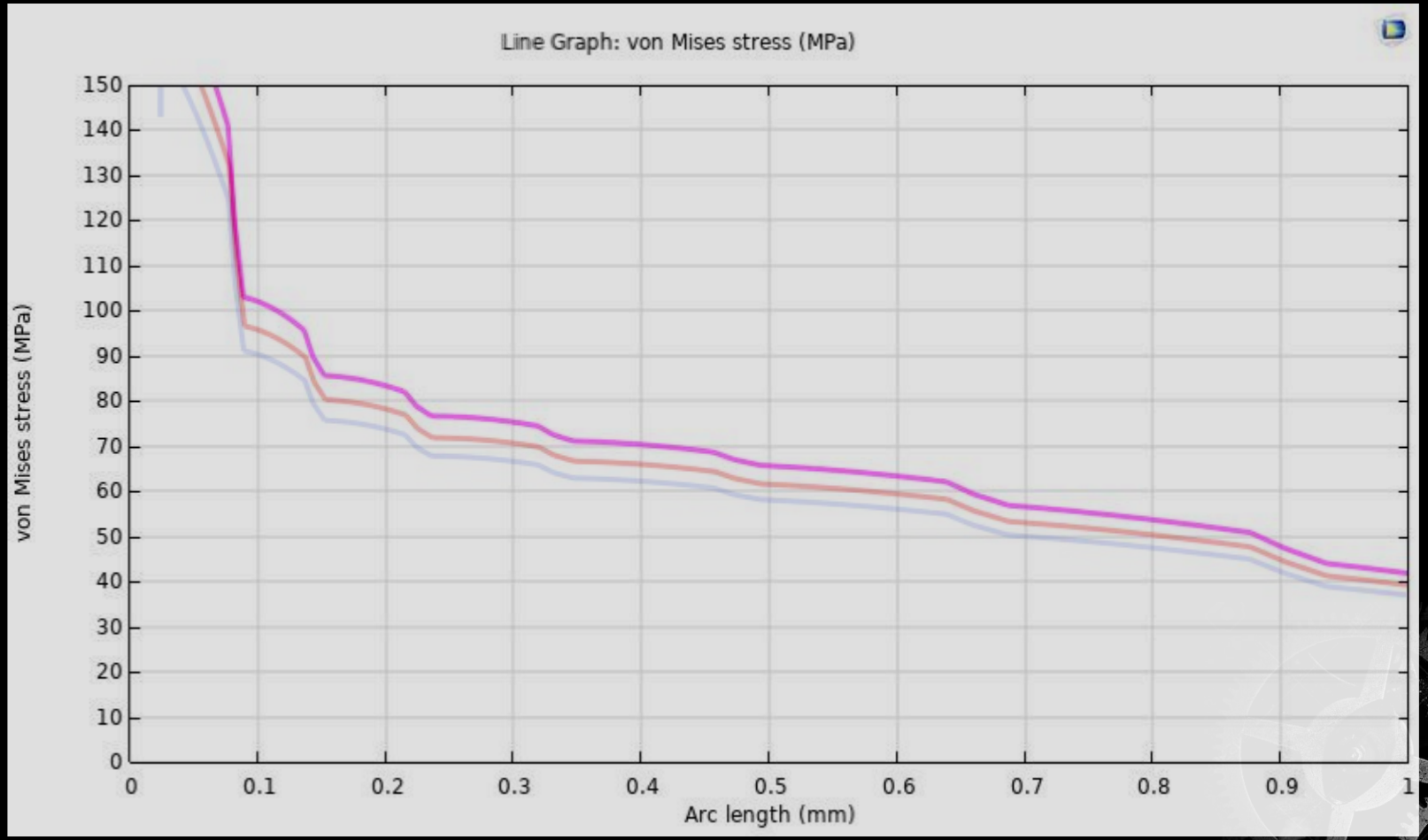
Du-Ha Park

Analysis

Data

Single Teeth
Tension

- μ = 0
- μ = 0.1
- μ = 0.2

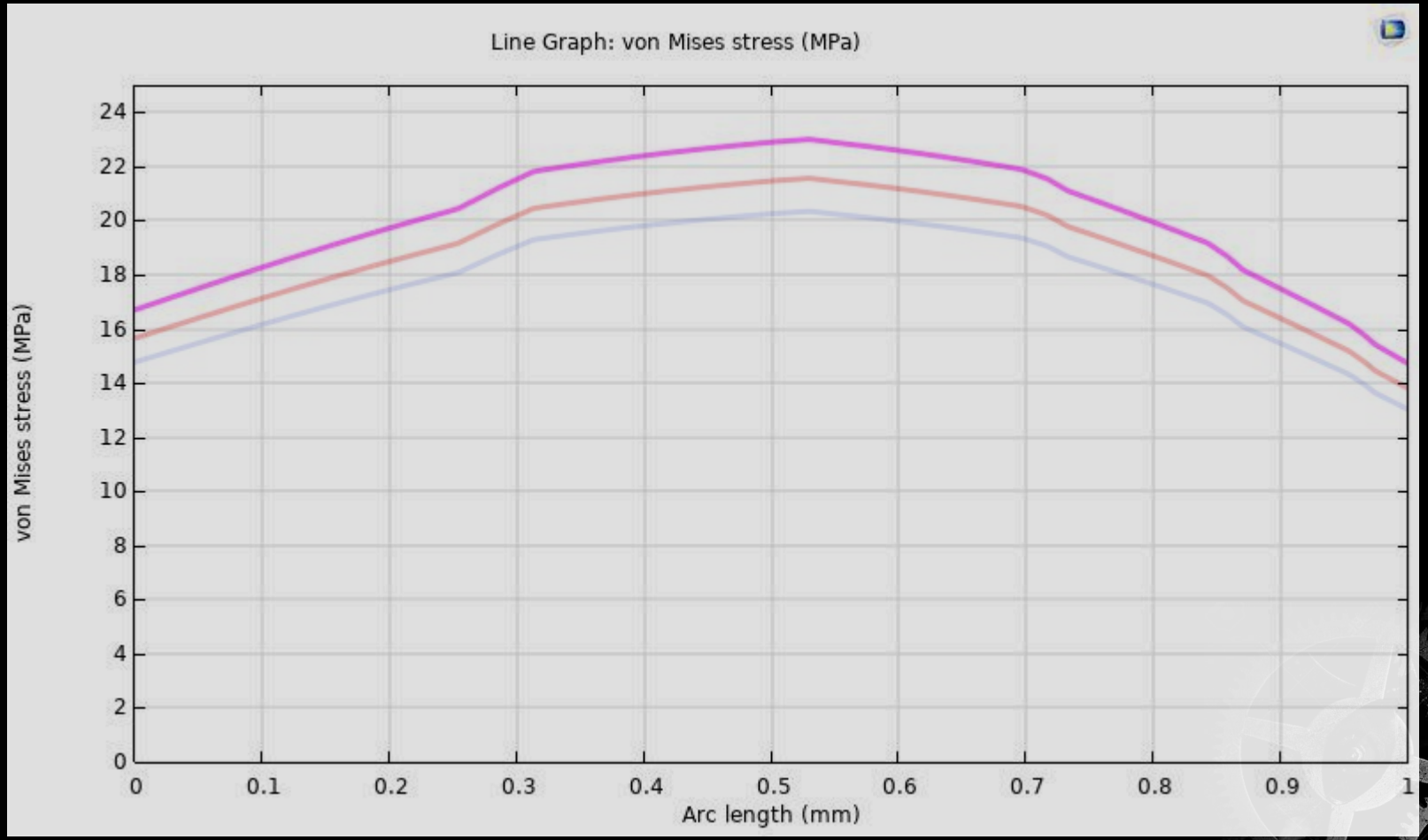


Analysis

Data

Single Teeth
Compression

- μ = 0
- μ = 0.1
- μ = 0.2

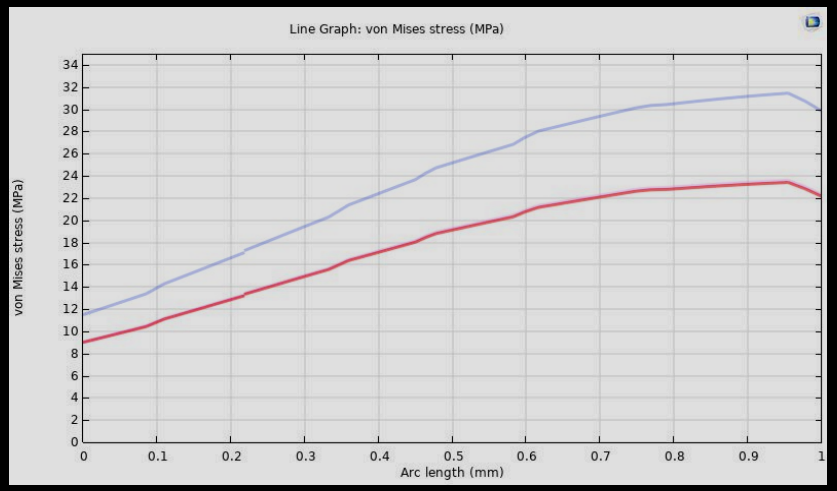


Analysis

Data

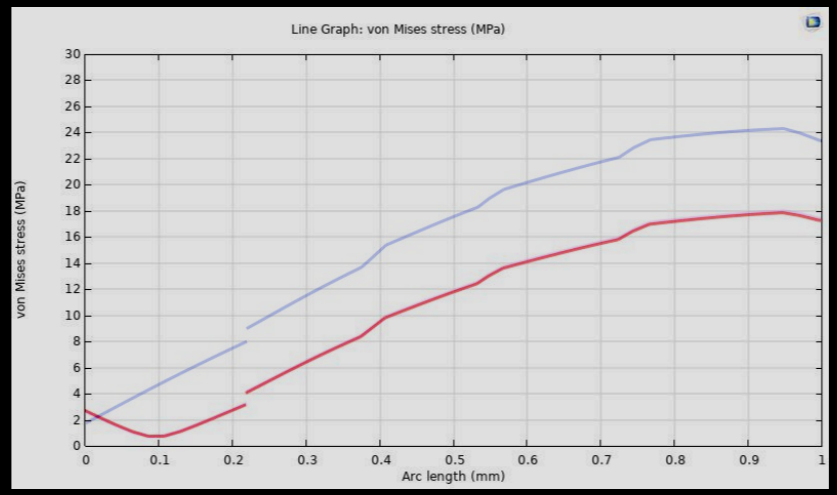
Double Tooth
2nd Compression

- μ = 0
- μ = 0.1
- μ = 0.2



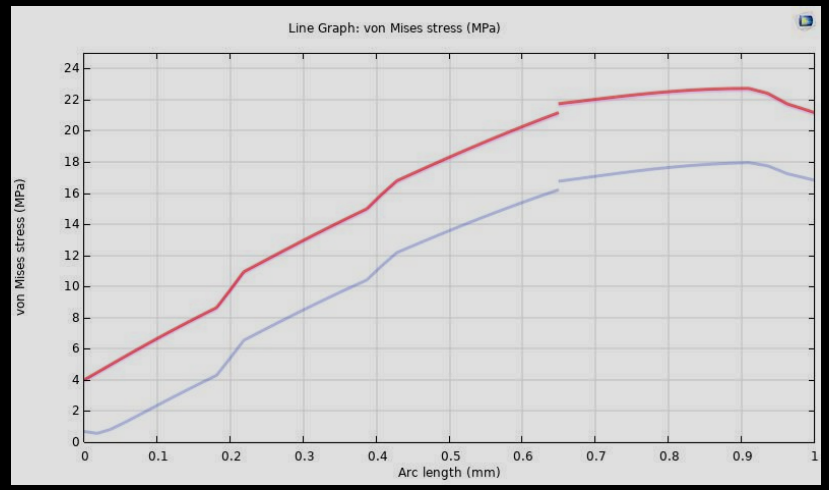
Double Tooth
2nd Tension

- μ = 0
- μ = 0.1
- μ = 0.2



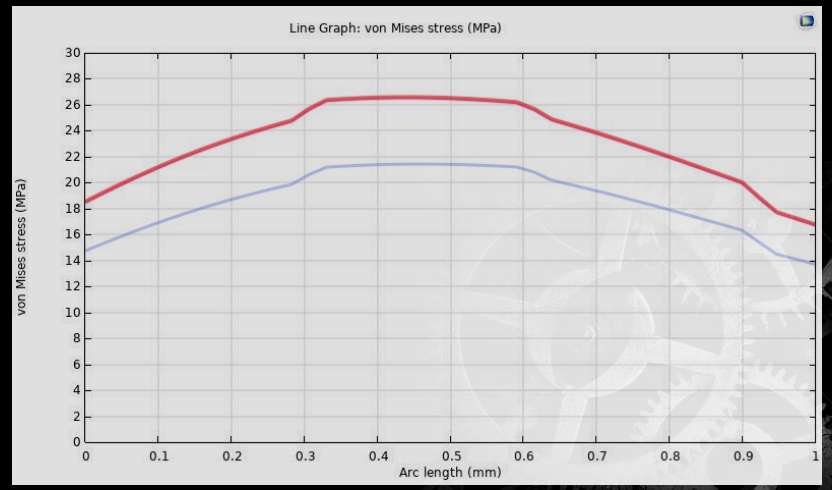
Double Tooth
1st Compression

- μ = 0
- μ = 0.1
- μ = 0.2



Double Tooth
1st Tension

- μ = 0
- μ = 0.1
- μ = 0.2




Q&A

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Thank You

We are Gear Second