바우싱거 효과를 고려한 KILLING ROLLER의 최적 설계

(OPIMUM DESIGN OF KILLING ROLLER CONSIDERING BAUSCHINGER EFFECT)

팀명 : 죽여조
조원 : 김형한 (2003006698)
오윤중 (2006005230)

목차 소개

1. 기존설계 설명

2. 최적설계 문제 5단계에 따라 Formulation

3. Matlab을 통한 모델링, 해 도출

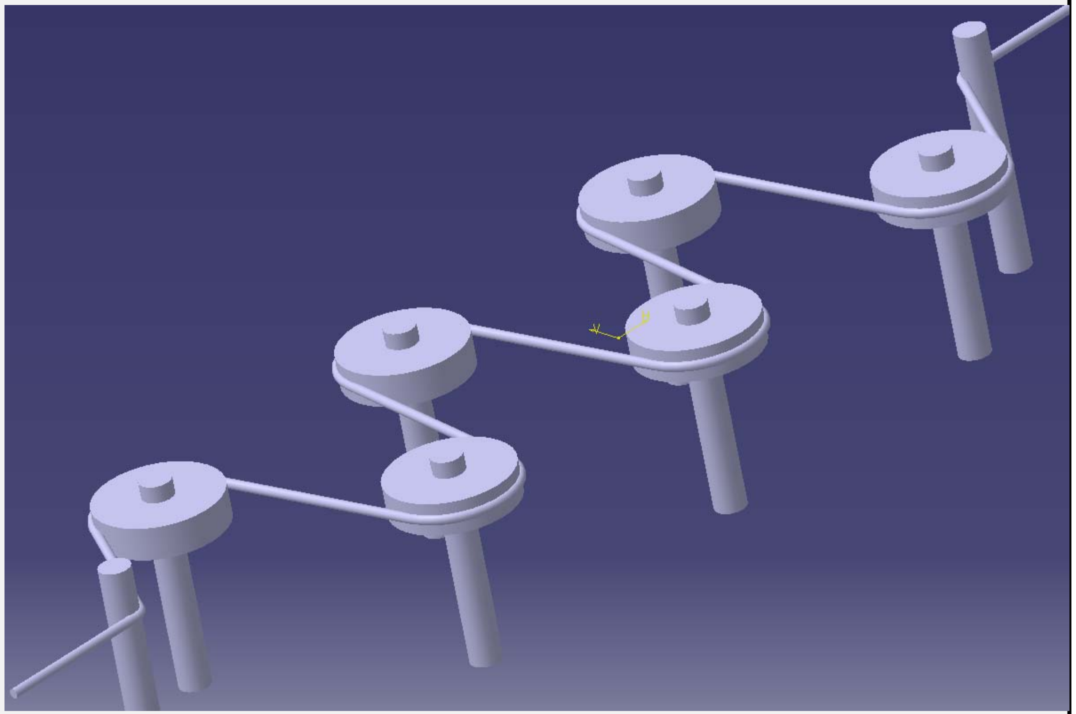
4. 참고문헌

▪기존설계

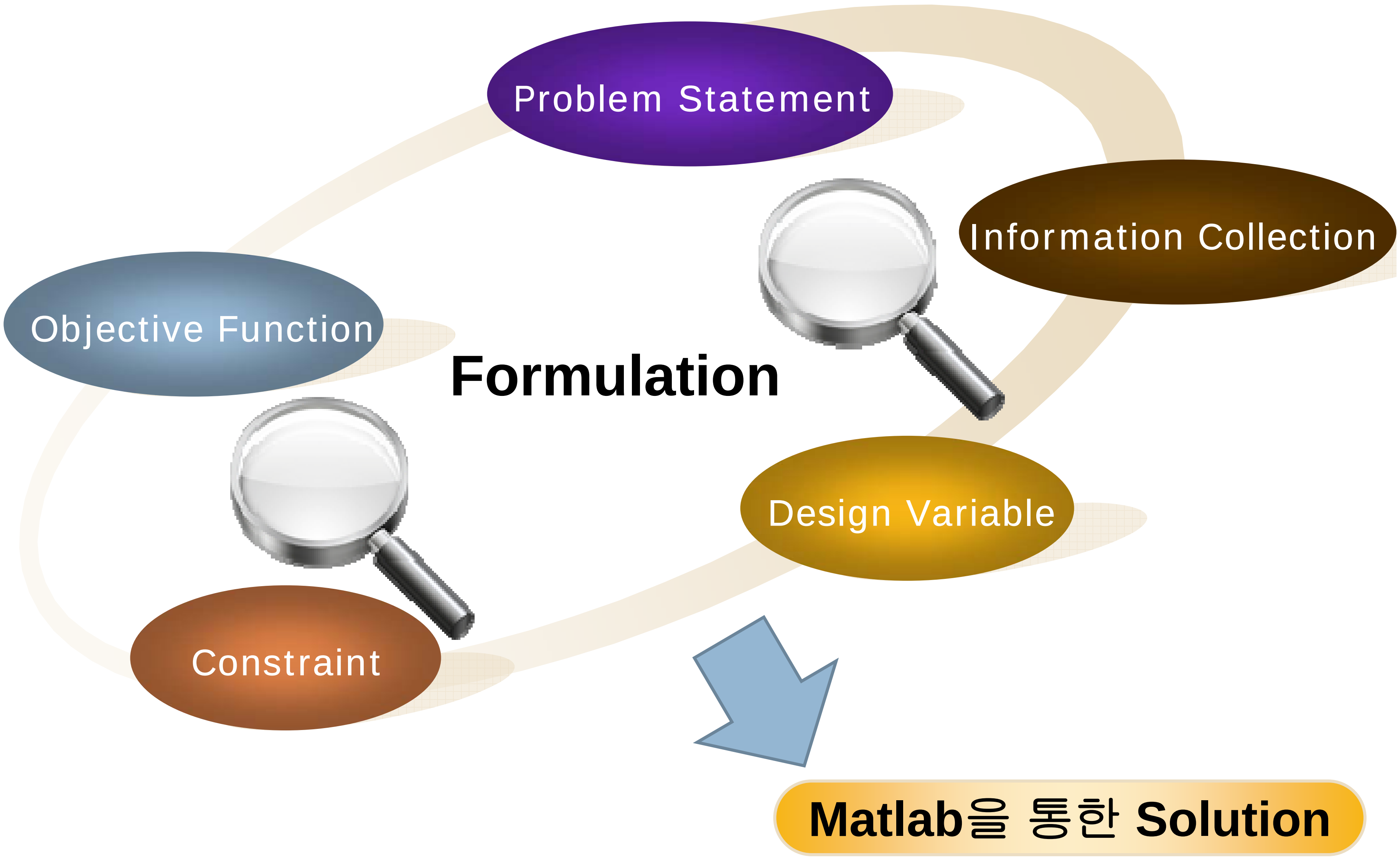
LS전선의 연성공정 Killing Roller 최적설계 (시행자: 주식회사 피엔에스)
(FEM을 통한 킬링 롤러 형상의 최적화)

▪ 바우싱거효과
(Bauschinger effect)

인장하중을 인장 항복점을 넘어서까지 부하한 후, 하중을 제거하고 이어서 압축하중을 부하하면 재료는 압축항복응력보다 훨씬 낮은 부분에서 소성변형이 일어난다



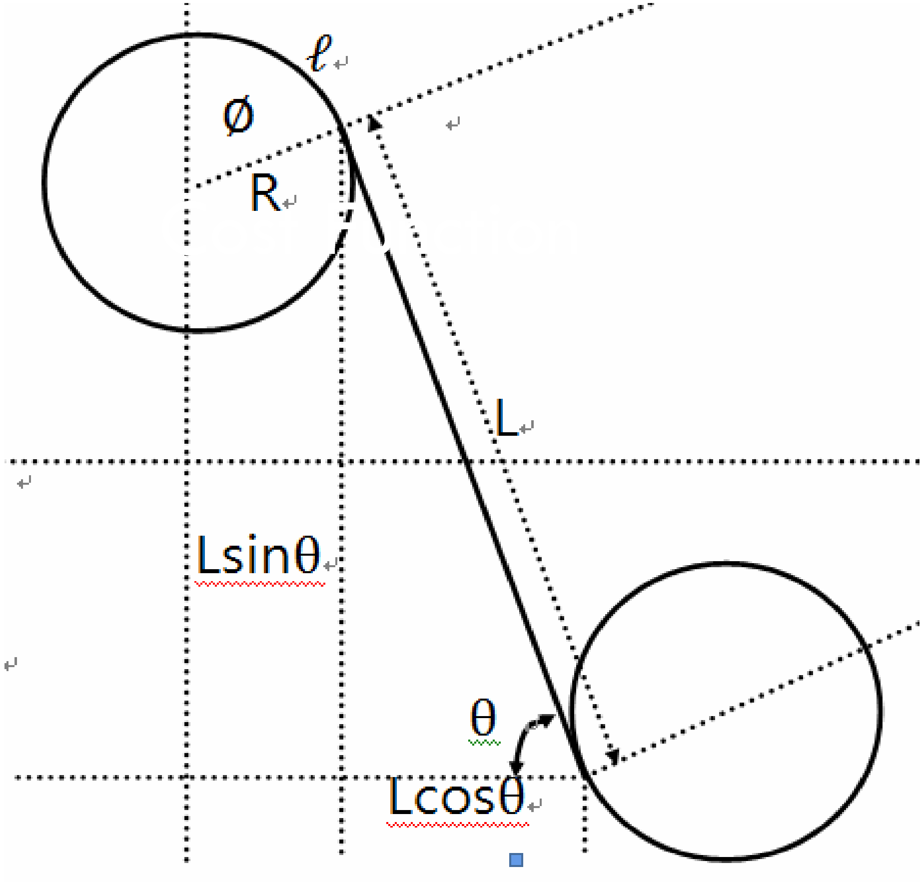
Killing roller의 설계 정식화 5단계



Problem Statement

저희가 세운 목적함수식의 기준은 killing roller 가 차지하는 면적의 최소화 입니다.
목적함수에 대한 식을 세우면 다음과 같습니다.

$$A=(L\sin\theta+2r)(L\cos\theta+2r)$$



Information Collection

전선의 이동속도V=5 cm/s
(L.S전선에서 홈 페이지 참조한값)
Roller와 전선사이의 마찰계수 μ =0
전선길이L=0.1 m
전선두께 =9 mm
Roller의 두께=30 mm
Roller의 밀도 ρ=7870 kg/m^3
Shaft의 반지름=10 mm
Shaft의 길이=100 mm
G=200*10^.9 Pa
E=80*10^.9 Pa

Design Variable

$$\theta(radian), R(mm)$$

Constraint

1.롤러에 대한 기하학적 조건

$\theta < L\cos^{-1}\frac{R}{L}$ (roller가 위치하는데 필요한 길이)

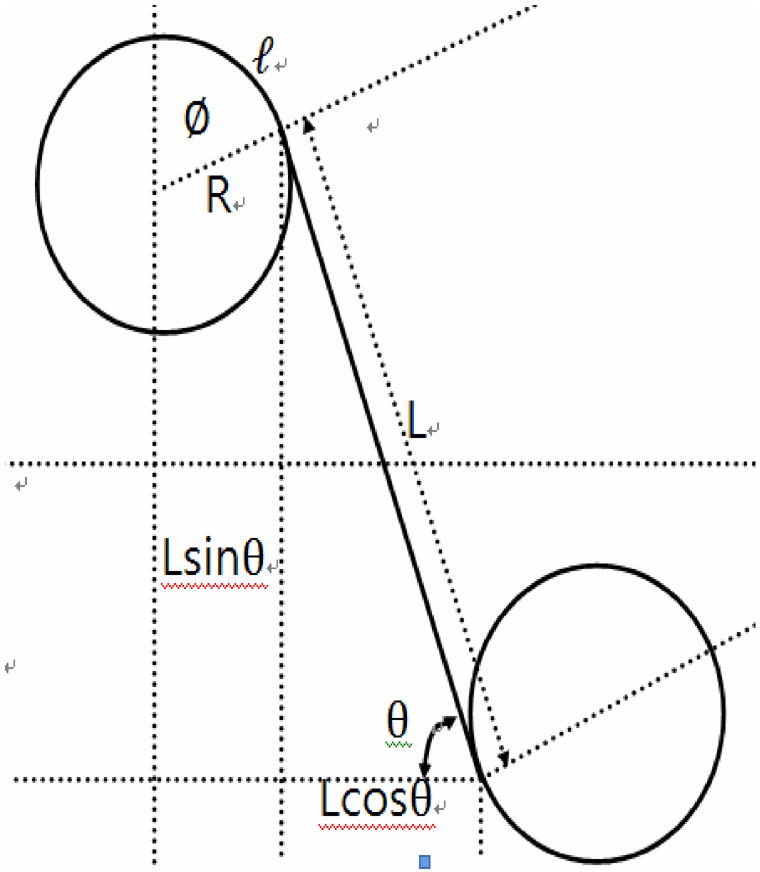
2. $0^\circ \le \theta \le 90^\circ$(선이 지나는 경사도)

3. $w_n = \sqrt{\frac{k}{J}}, k = \frac{GJ_p}{l} = \frac{G\pi r^4}{2l}, J = \frac{1}{2}mr^2$

정리하면 $w_n = r\sqrt{\frac{G\pi}{lm}}$이고 이 natural frequency고려 (resonance방지)

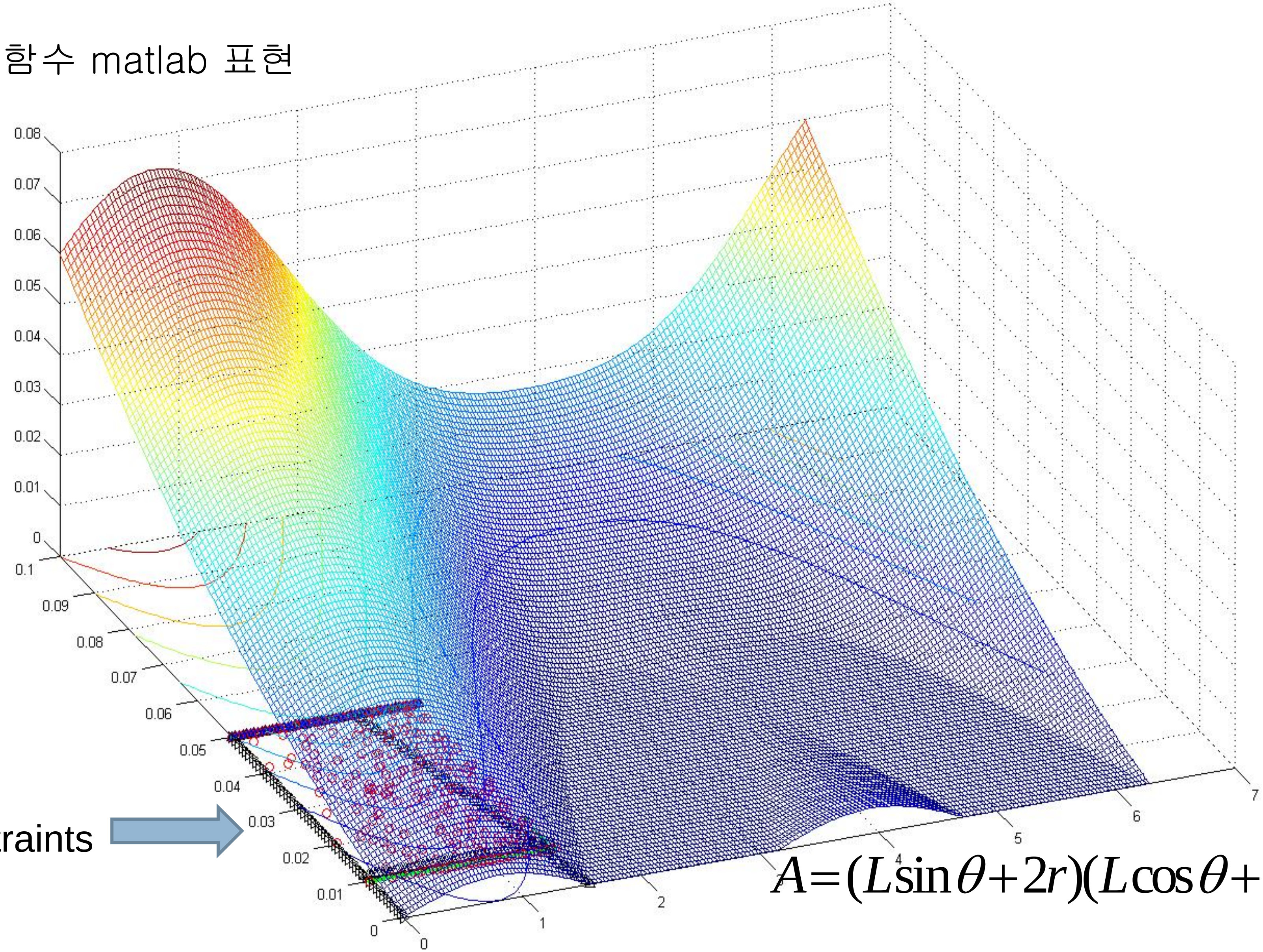
4. Necking이 일어나는 롤러반지름 $= \frac{0.0045}{e^{0.33} - 1}$ 고려

5. 항복이 일어나는 구리선의 최대 반지름 고려



Objective Function

목적함수 matlab 표현



$$A=(L\sin\theta+2r)(L\cos\theta+2r)$$

Solution with Matlab

```matlab
clear all
close all

% Variables %
q= [0 : pi/100 : pi/2]; %Theta
r= [0 : 0.001 : 0.05]; %roller_radius
[Q,R]=meshgrid(q,r);

% Objective Function %
Area=(L.*sin(Q)+2.*R).*(L.*cos(Q)+2.*R);

% Shaft's Parameters (steel)%
L=0.1; % Length(m)
t=0.009*1000; % Roller thickness(mm)
V=0.05; % Wire speed (m/s)
R_shaft= 10/1000; % Shaft radius(m)
L_shaft= 100/1000; % Shaft length(m)
t_roller=30/1000; % Roller thickness(m)
G_shear= 200*10.^9; % (Pa)
E_young= 80*10.^9; % (Pa)
density= 7870; % (kg/m^3)
J_psm=pi*R_shaft.^4./2; % polar second moment
I_moi=pi*(R_shaft.^4)/4  % Mass moment of ine
k_spring=G_shear.*J_psm./L_shaft %spring cons

% Copper wire's properties %
n=0.33; % Hardning coefficient
K=450; % Power law coefficient
elong_neck=0.33; %Necking elongation
Sigma_neck=K*(0.33^0.33); %Necking Stress
Sigma_yield=78*10.^6;  %(Pa)
Inertia=pi*(0.0045.^4)/4; %Wire's inertia

% Indep Vars %
alpha=-acos(2.*R./L)+(pi/2)+Q; %Punch angle
Upsilon_true=log((R+0.0045)./(R)); %Ture strain of wire
Sigma_true=K*Upsilon_true.^n; %Ture stress of wire(MPa)
[Width]=2.*L.*cos(Q); %Distance cneter from center of roller
Bending_load=(2.*L.*cos(Q)).*(Sigma_true.*(t.^2).*cos(alpha).*(cos(alpl
%Bending_load=(2.*L.*cos(Q)).*(Sigma_true.*(t.^2).*cos(alpha).*(cos(al
%sin(alpha))./((2.*L.*cos(Q))-2.*(R*1000+t).*sin(alpha)+t.*cos(alpha)
%If considering friction effect%
Normal_Reaction=Bending_load./(2*(cos(alpha)+sin(alpha))); % Punch rea
Load_total=-1*(2*Normal_Reaction+Bending_load); %(kN)
M_bend=1000*Load_total.*Width./2; %Transfrom to moment(N/m)
delta=Load_total*L_shaft.^3./(3*E_young*I_moi); % shaft's displace
m_roller=t.*R.*density; % roller's mass
m_shaft=pi*R_shaft.^2*L_shaft; % shaft's mass
I_mmi=m_roller*R.^2/2; %mass moment of inertia (kg*m^2);
Wn_tor=(30/pi)*(k_spring./I_mmi).^(1/2); % Natural friquency for torti
Wn_whirl=(30/pi)*(9.806.*abs(delta)).^(1/2); % Natural friquency for sl
[Z_dummy]=meshgrid((q*0),(r*0)); % Zero Matrix for dimension meet

% Constraint %
Theta_const1=acos(R./L); % rad <
[Theta_const2]=[Z_dummy]; % rad >
[R_neck]=[Z_dummy+0.0045/(exp(0.33)-1)]; % (m) >
R_upper=ones(size(q,2)).*L./2;  % (m) >
R_yield=-1*(Sigma_yield.*Inertia./M_bend-0.009); % (m) <
k=size(q,2);
for m = 1:k
    for n = 1:k
        if abs(R_yield(m,n)) > 0.05
           R_yield(m,n) = 0.05;
        elseif (R_yield(m,n)) < R_neck
           R_yield(m,n) = 0.01;
        elseif (R_yield(m,n)) < 0
            R_yield(m,n) = 0;
        end
    end
end

R_whirl=Wn_whirl./(5*V);
for m = 1:k
    for n = 1:k
        if abs(R_whirl(m,n)) > 0.05
           R_whirl(m,n) = 0.05;
        elseif (R_whirl(m,n)) < R_ne
           R_whirl(m,n) = 0.01;
        end
    end
end

R_tor=Wn_tor./(5*V);
for m = 1:k
    for n = 1:k
        if abs(R_tor(m,n)) > 0.05
           R_tor(m,n) = 0.05;
        elseif (R_tor(m,n)) < R_neck
           R_tor(m,n) = 0.01;
        end
    end
end

% Plot graph %
contour(Q,R,Area)
hold on
% meshc(Q,R,Sigma_true./(10^4.5))
% hold on
plot3(Theta_const1,R,Z_dummy,'k^')
hold on
plot3(Theta_const2,R,Z_dummy,'k>')
hold on
plot3(Q,R_neck,Z_dummy,'k^')
hold on
plot3(Q,R_yield,Z_dummy,'g.')
hold on
plot3(Q,R_upper,Z_dummy,'k^')
hold on
plot3(Q,R_whirl,Z_dummy,'ro')
hold on
plot3(Q,R_tor,Z_dummy,'bh')
hold on
```

Solution with Matlab

```
% Variables %
q= [0 : pi/100 : pi/2]; %Theta
r= [0 : 0.001 : 0.05]; %roller_radius
[Q,R]=meshgrid(q,r);
```

변수인 $\theta(radian), R(mm)$에 대해 범위를 지정해줍니다.

```
% Shaft's Parameters (steel)%
L=0.1; % Length(m)
t=0.009*1000; % Roller thickness(mm)
V=0.05; % Wire speed (m/s)
R_shaft= 10/1000; % Shaft radius(m)
L_shaft= 100/1000; % Shaft length(m)
t_roller=30/1000; % Roller thickness(m)
G_shear= 200*10.^9; % (Pa)
E_young= 80*10.^9; % (Pa)
density= 7870; % (kg/m^3)
J_psm=pi*R_shaft.^4./2; % polar second moment of inertia(m^4)
I_moi=pi*(R_shaft.^4)/4  % Mass moment of inertia
k_spring=G_shear.*J_psm./L_shaft %spring constant
```

```
% Copper wire's properties %
n=0.33; % Hardning coefficient
K=450; % Power law coefficient
elong_neck=0.33; %Necking elongation
Sigma_neck=K*(0.33^0.33); %Necking Stress
Sigma_yield=78*10.^6;  %(Pa)
Inertia=pi*(0.0045.^4)/4; %Wire's inertia
```

Shaft와 구리선에 대한 parameter 값들입니다.

Solution with Matlab

```matlab
% Constraint %
Theta_const1=acos(R./L); % rad <
[Theta_const2]=[Z_dummy]; % rad >
[R_neck]=[Z_dummy+0.0045/(exp(0.33)-1)]; % (m) >
R_upper=ones(size(q,2)).*L./2;  % (m) >
R_yield=-1*(Sigma_yield.*Inertia./M_bend-0.009); % (m) <
k=size(q,2);
for m = 1:k
    for n = 1:k
        if abs(R_yield(m,n)) > 0.05
           R_yield(m,n) = 0.05;
        elseif (R_yield(m,n)) < R_neck
           R_yield(m,n) = 0.01;
        elseif (R_yield(m,n)) < 0
             R_yield(m,n) = 0;          end     end  end

R_whirl_cri=Wn_whirl./(V);
for m = 1:k
    for n = 1:k
        if abs(R_whirl_cri(m,n)) > 0.05
           R_whirl_cri(m,n) = 0.05;
        elseif (R_whirl_cri(m,n)) < R_neck
           R_whirl_cri(m,n) = 0.01;          end     end  end

R_tor=Wn_tor./(V);
for m = 1:k
    for n = 1:k
        if abs(R_tor(m,n)) > 0.05
           R_tor(m,n) = 0.05;
        elseif (R_tor(m,n)) < R_neck
           R_tor(m,n) = 0.01;          end     end  end
```

Wire의 항복조건 고려

(바우싱거 효과를 위해 많은 굽힘응력이 가해져야 한다.)

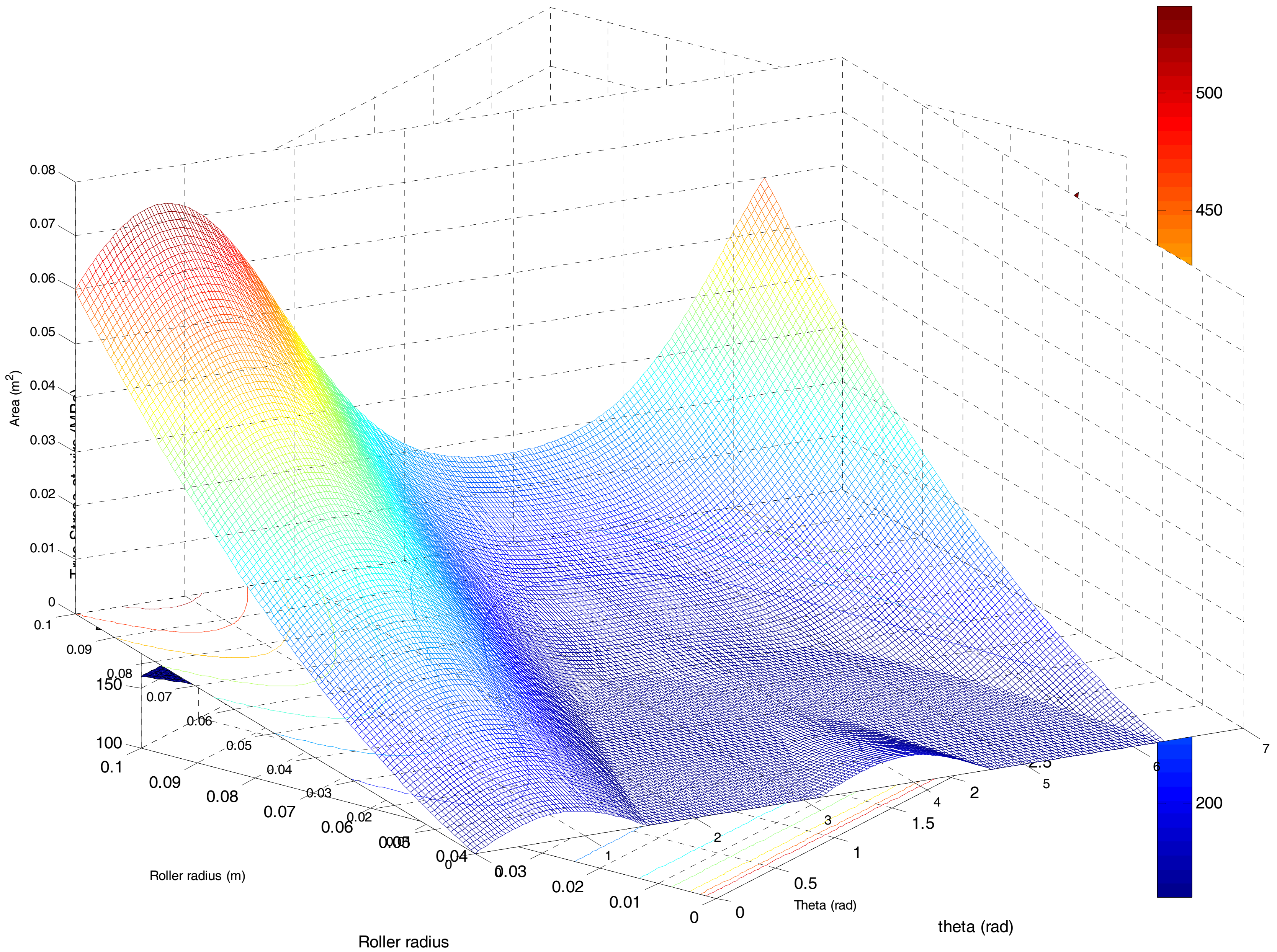
롤러의 기하학적 충돌 고려

Wire의 Necking 고려

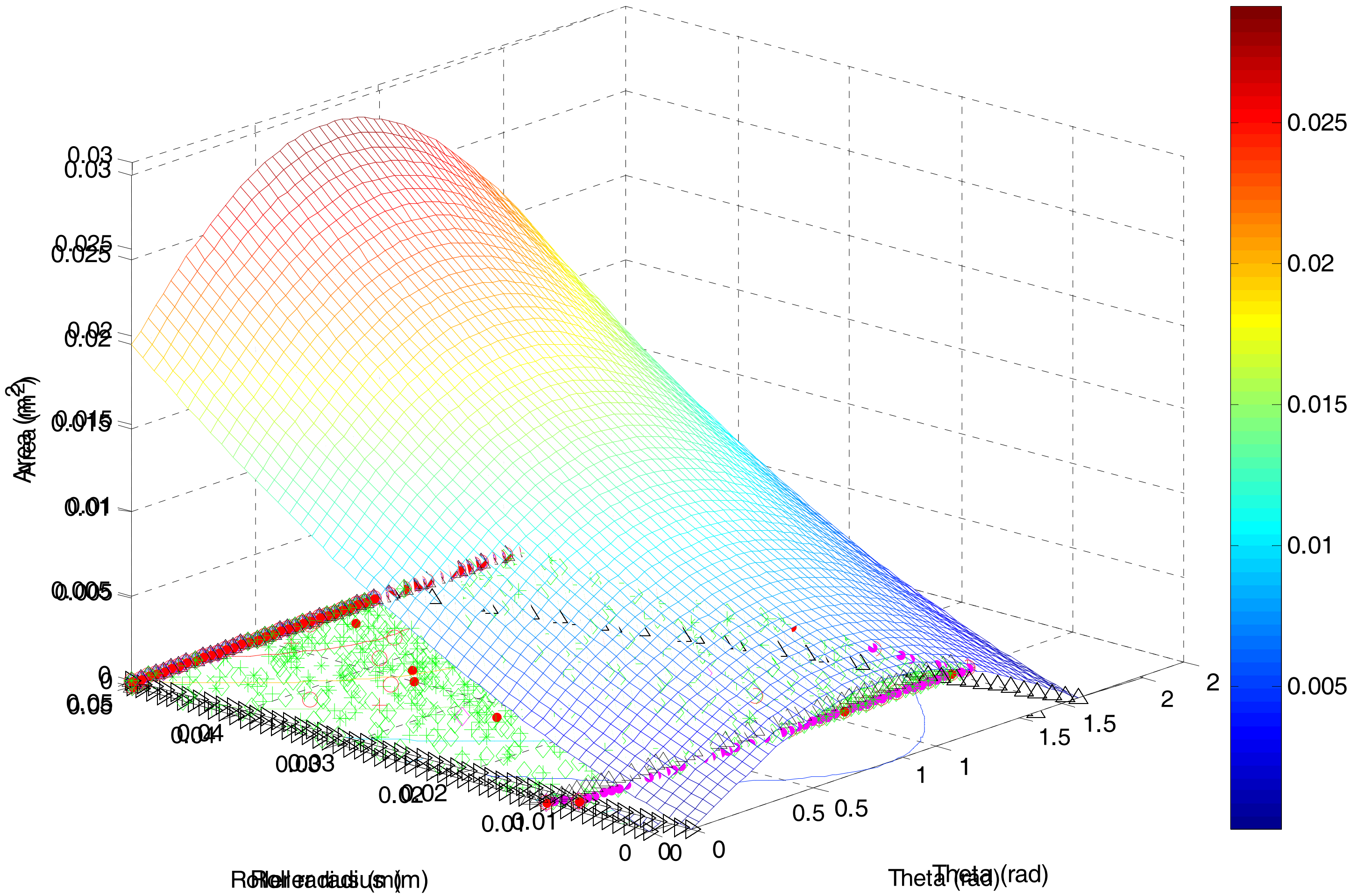
Shaft Whirling 고려

Torsional vibratoin 고려

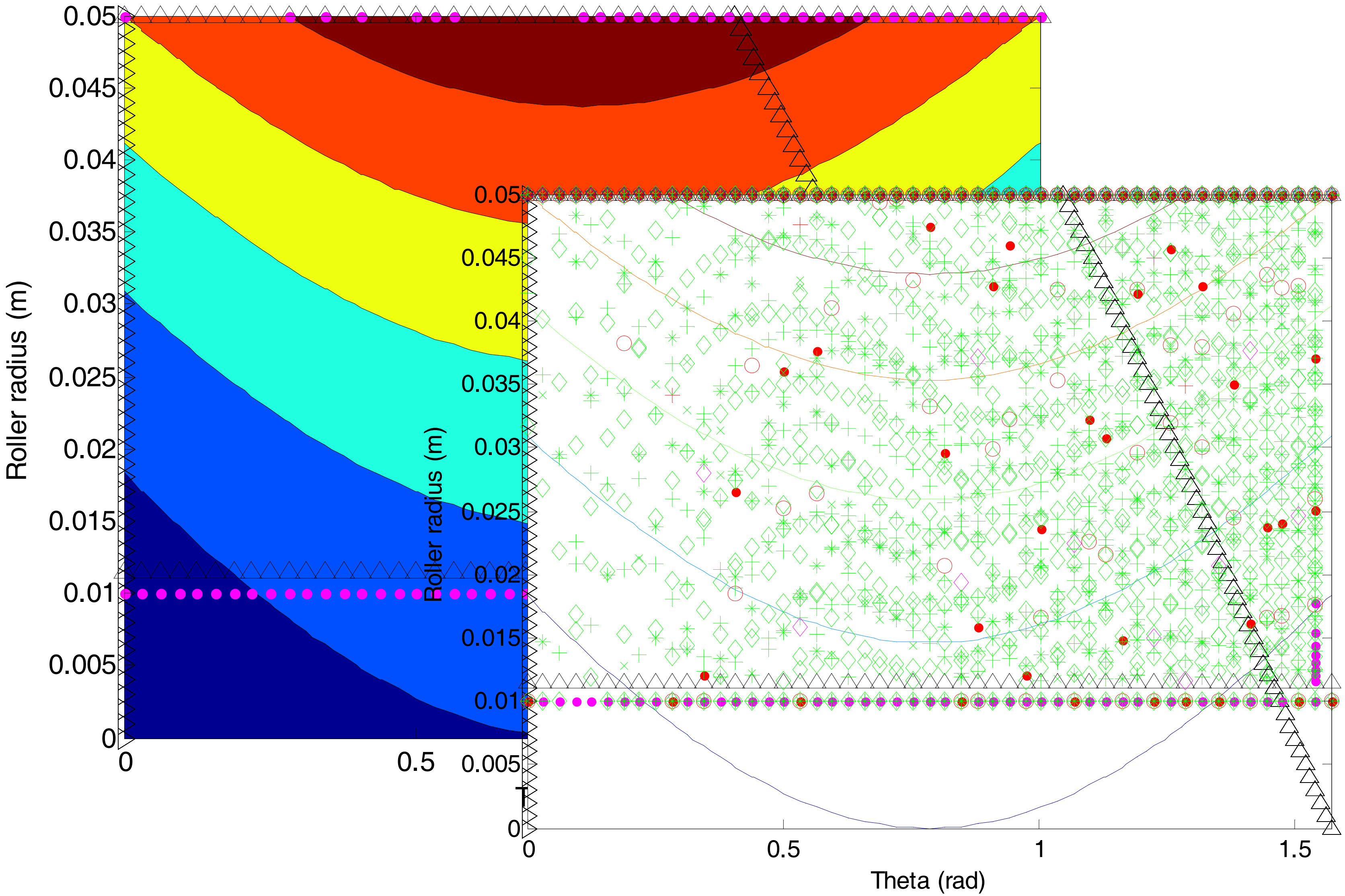
Solution with Matlab



Solution with Matlab



Solution with Matlab



Reference

(1) Ferdinand P.Beer,2006,Mechanics of Materials,562~568P,Mc Grow Hill,New York

(2) R.W.Cahn,P.Haasen,E.J.Kramer,2005,Material Science and Technology,383~395P,WIIEY-VCH,Fedral Republic of Germany

(3) 김영석,2001,소성역학,123~128P,시그마프레스,서울 마포구

(4) 서영섭,최병도,송광호,2001,소성가공,인201~206P,기전연구사,서울 동대문구

(5) Serope KalpakJian,Steven R.Schmid,2006,Manufacturing Engineering And Technology,345~347p,Person Education ,United State

(6) 염영하,2004기계제작공정,401~424p,동명사,서울 중구

(7) Edward M.Mielnik,1991,Metalworking Science And Engineering,364~372p,Mc Grow Hill,New York

감사합니다.