

## Contents

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```
clc
clear all
```

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## Initial point of design variable

---

```
Nelem = 250; % number of elements along spar
r_out = 3e-2; % m - Outer radius
r_in = 1.5e-2; % m - Inner radius
L = 7.5; %m - Length of spar
x = (0:L/Nelem:L)'; % discretization of length of spar
slope1 = 0;
slope2 = 0;
X0 = ones((2*(Nelem+1)),1); % Initial design variable
k = 1;
for i=1:2:(2*Nelem+1)
    X0(i) = r_out+x(k)*slope1;
    X0(i+1) = r_in+x(k)*slope2;
    k = k+1;
end
```

---

## Setting up Linear Inequality constraint

---

```
Nnodes = Nelem + 1;
% rin > 1cm ----> -rin < -1cm
A1 = zeros(Nnodes,2*Nnodes);
k=2;
for i=1:(Nnodes)
    A1(i,k) = -1;
    k = k+2;
end
b1 = -1e-2*ones(Nnodes,1);

% rout - rin > 2.5mm ----> -rout + rin < -2.5mm
A2 = zeros((Nnodes),2*(Nnodes));
k = 1;
for i=1:(Nnodes)
    A2(i,k) = -1;
    A2(i,k+1) = 1;
    k = k+2;
end
b2 = -2.5e-3*ones(Nnodes,1);

% rout < 5cm
A3 = zeros((Nnodes),2*(Nnodes));
k=1;
for i=1:(Nnodes)
    A3(i,k) = 1;
    k = k+2;
```

```

end
b3 = 5e-2*ones(Nnodes,1);

% -rout + rin < 0 ----> rout > rin
A4 = zeros(Nnodes,2*Nnodes);
k=1;
for i=1:Nnodes
    A4(i,k) = -1;
    A4(i,k+1) = 1;
    k = k+2;
end
b4 = zeros(Nnodes,1);
A = [A1;A2;A3;A4];
b = [b1;b2;b3;b4];

lb = ones(2*Nnodes,1);
ub = lb;
lb(2:2:end) = 0.01;
lb(1:2:end) = 0.0175;
ub(2:2:end) = 0.0475;
ub(1:2:end) = 0.05;

```

## Running Optimization

```

options = optimoptions('fmincon','Display','iter-detailed','Algorithm','sqp',...
    'SpecifyObjectiveGradient',true,'SpecifyConstraintGradient',true);

[X_opt,fvalue,~,op,~,grad]=fmincon(@obj_func,X0,A,b,[],[],lb,ub,@NonLnCons,options);

```

## Plotting section

```

Iyy = Calc_Iyy(X_opt,Nnodes);
force = Calc_force(x,500,L);
[u] = CalcBeamDisplacement(L, 70e9,Iyy, force, Nelem);
zmax = X_opt(1:2:end);
[sigma] = CalcBeamStress(L, 70e9, zmax, u, Nnodes-1);
norm_sigma = sigma/600e6;

figure
plot(x,norm_sigma,'ks-')
xlabel('distance along wing')
ylabel('magnitude of normal stress')

figure
plot(x,sigma,'ks-')
xlabel('distance along wing')
ylabel('magnitude of normal stress')

figure
plot(x,u(1:2:2*(Nelem+1)),'ks-');
xlabel('distance along wing')
ylabel('vertical displacement of spar')

figure
plot(x,X_opt(1:2:end),'bv-');
hold on;
plot(x,X_opt(2:2:end),'k^');
plot(x,-X_opt(1:2:end),'bv-');
plot(x,-X_opt(2:2:end),'k^');

```

```

plot(x,0*X_opt(1:2:end),'k--','lineWidth',2);
xlabel('Length of Spar');
ylabel('Radius');
legend('$R_{out}$','$R_{in}$','Interpreter','latex');
title('Cross-sectional View of Spar')

```

```

figure
plot(x,X0(1:2:end),'bv-');
hold on;
plot(x,X0(2:2:end),'k^');
plot(x,-X0(1:2:end),'bv-');
plot(x,-X0(2:2:end),'k^');
plot(x,0*X0(1:2:end),'k--','lineWidth',2);
xlabel('Length of Spar');
ylabel('Radius');
legend('$R_{out}$','$R_{in}$','Interpreter','latex');
title('Cross-sectional View of Spar')

```