Welding poses

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link: https://drive.matlab.com/sharing/d4065529-43e8-4d14-8f7d-6a6cefcb35de

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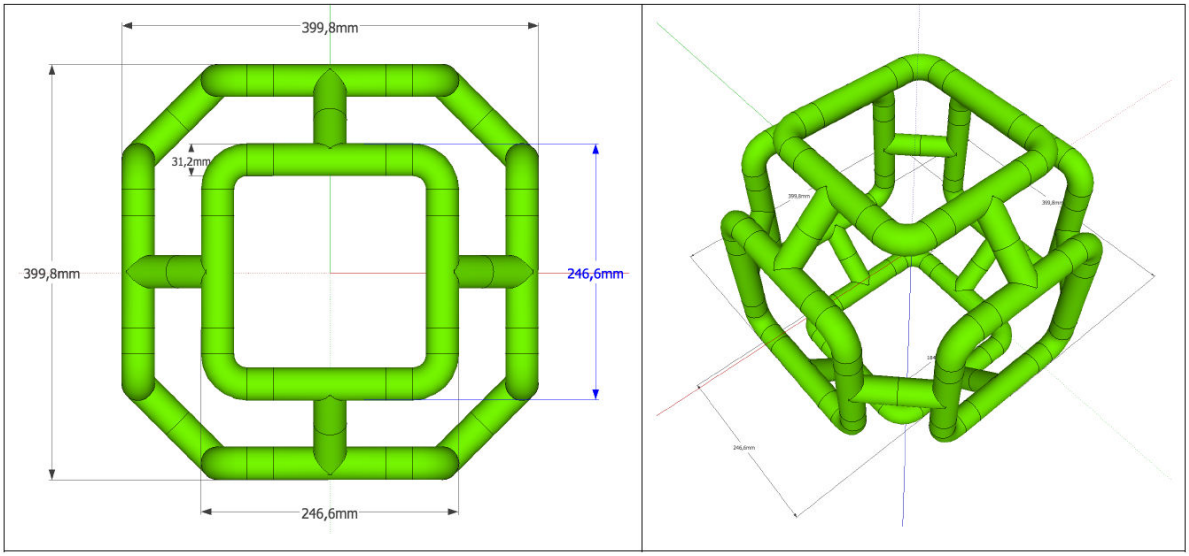
A Unimation Puma 560 robot is used to weld a folded tubes frame as it is shown in the next figures.



The task for the Puma 560 consists in welding the six folded squared tube among them with 32 points. The welding trajectory can be assumed to as two orthogonal and intersecting cylinders with radius = 15.6mm. The trajectory to be followed by the welder can be parameterized as follows:

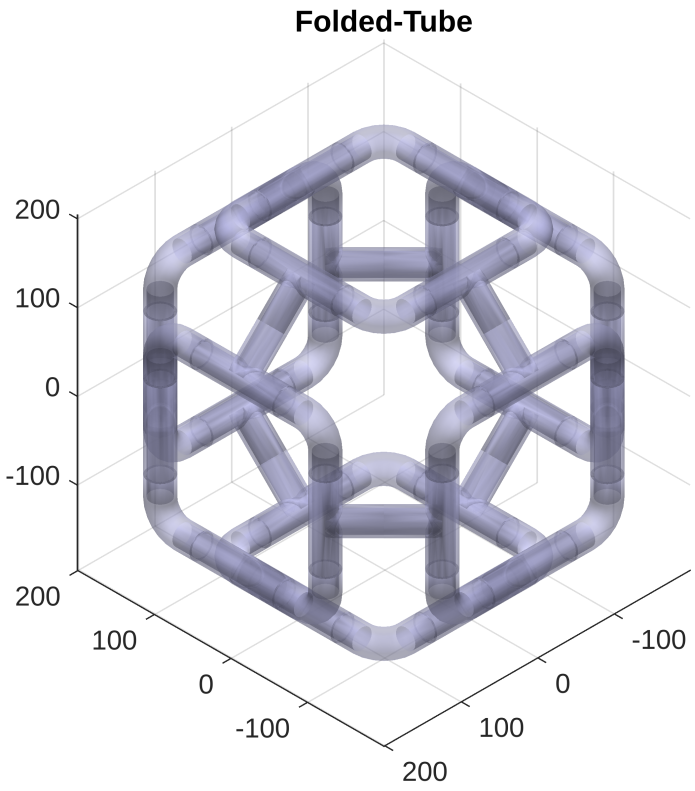
$$p(t) = \begin{bmatrix} x(t) \\ y(t) \\ z(t) \end{bmatrix} = \begin{bmatrix} r\cos(t) \\ r\sin(t) \\ [[r\cos(t)]] \end{bmatrix}; t \in [0 \quad 2\pi]$$

Read and plot the part

Download STLtools from Matlab: https://es.mathworks.com/matlabcentral/fileexchange/51200-stltools

Add it to the path.

```
clear
[V,F, N,name]=stlRead('Folded_Tubes.stl');
clf
stlPlot(V,F,name)
alpha 0.4
axis equal
hold on
```



Setting up dimensions

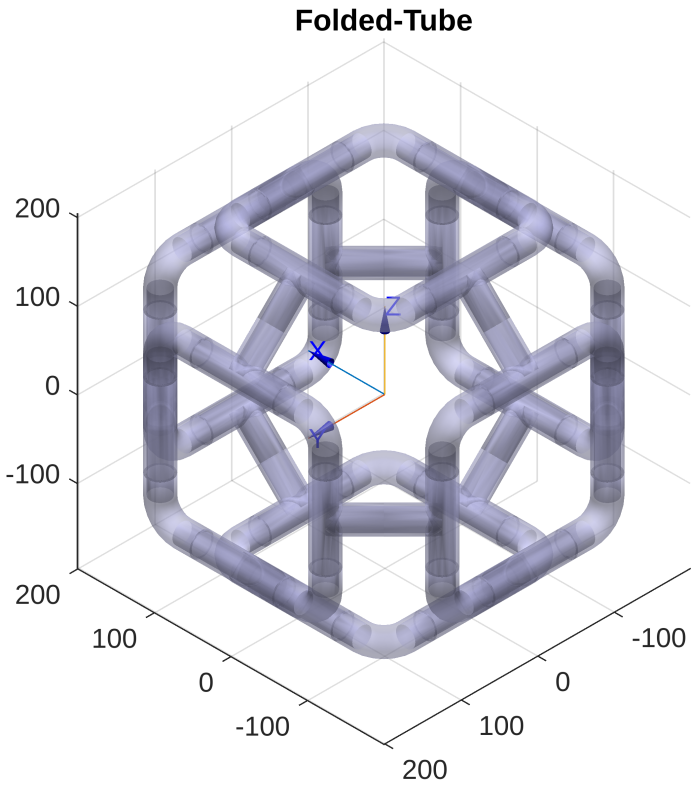
```
r=15.6; % Tube radius
t=0:pi/16:2*pi; % Scan variable
cp0=[r*cos(t);r*sin(t);abs(r*cos(t));ones(1,length(t))]% dot height
```

```
cp0 = 4×33
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
         0    3.0434    5.9699    8.6669   11.0309   12.9709   14.4125   15.3003
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

Plotting

Frame description

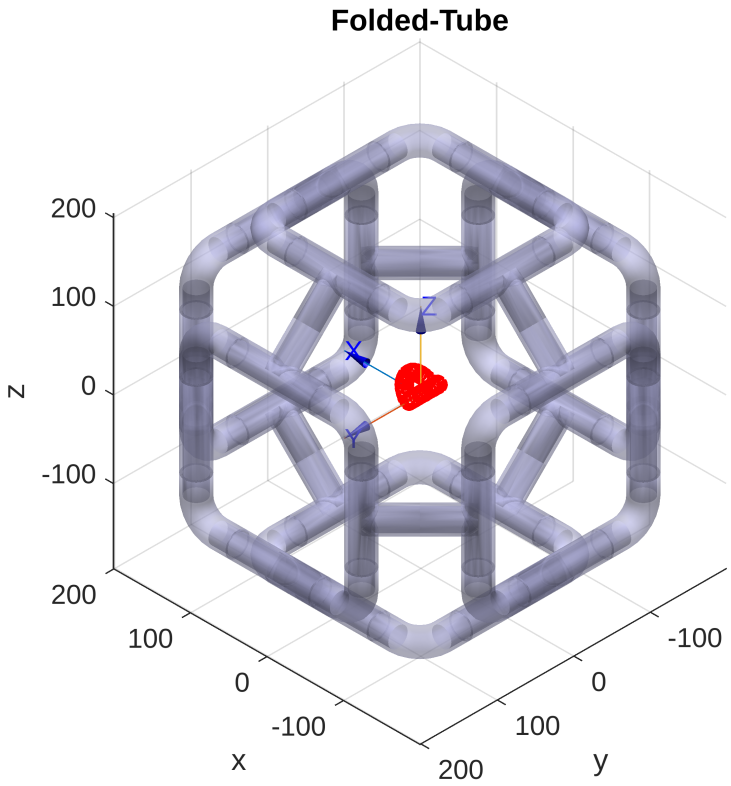
```
trplot(eye(4), 'length', 100,'arrow','width', 1 )
```



Weld points

At origen

```
scatter3(cp0(1,:),cp0(2,:),cp0(3,:),'r','LineWidth',2)
xyzlabel% RTB function
```



Obtain the weld point coordinates of two tubes

Get familiar with the following RTB functions:

help on: transl, trotx, troty, trotz

I'am solving for you two tubes welding at origen as an example.

Load cylinder/tube info

Get familiar with the variable: V_Cylinder

```
figure
load('Vertices_Faces_Cylinder.mat')
```

Plotting tube

First reshape the Cylinder vertices: radius 15.6 and height 50

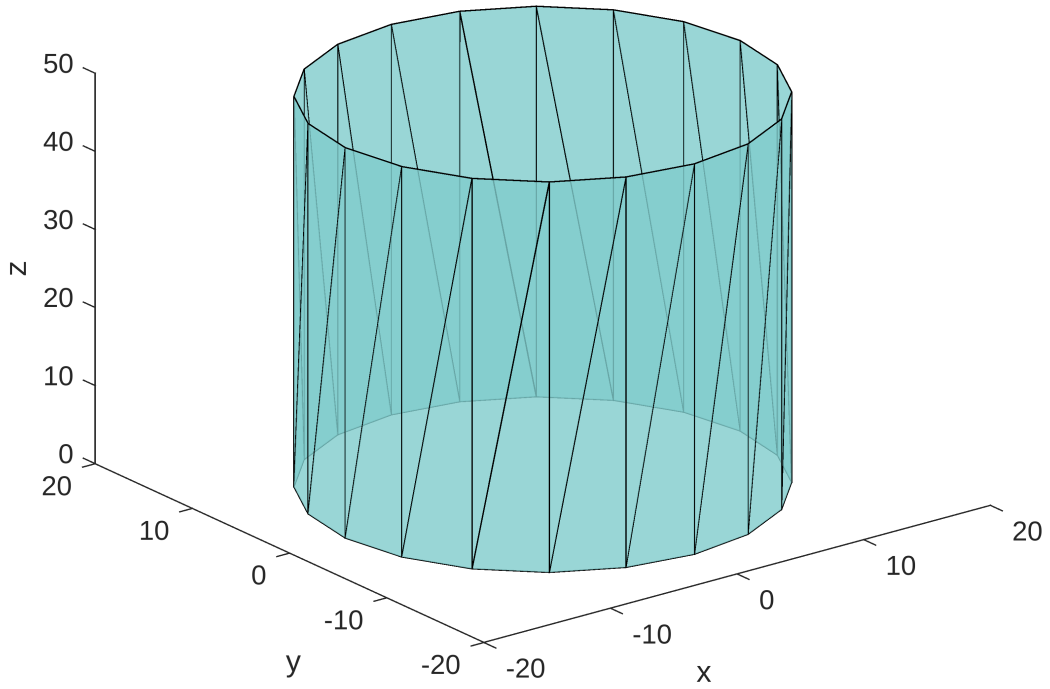
```
V_Cylinder=[15.6*V_Cylinder(:,1:2) 50*V_Cylinder(:,3)]
```

```
V_Cylinder = 42×3
   15.6000         0         0
   15.6000         0   50.0000
   14.8365    4.8207         0
   14.8365    4.8207   50.0000
   12.6207    9.1694         0
   12.6207    9.1694   50.0000
```

```
    9.1694   12.6207         0
    9.1694   12.6207   50.0000
    4.8207   14.8365         0
    4.8207   14.8365   50.0000
     ⋮
```

Plot it

```
patch('Vertices',V_Cylinder,'Faces',F_Cylinder,'facecolor',[0.5 0.8 0.8],'facealpha',0.
xyzlabel
view(3)
hold on
```



Another tube

```
V2_Cylinder=troty(pi/2)*transl(0,0,-25)*[V_Cylinder' ;ones(1,length(V_Cylinder))]
```

```
V2_Cylinder = 4×42
  -25.0000   25.0000  -25.0000   25.0000  -25.0000   25.0000  -25.0000   25.0000 ···
         0         0    4.8207    4.8207    9.1694    9.1694   12.6207   12.6207
  -15.6000  -15.6000  -14.8365  -14.8365  -12.6207  -12.6207   -9.1694   -9.1694
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

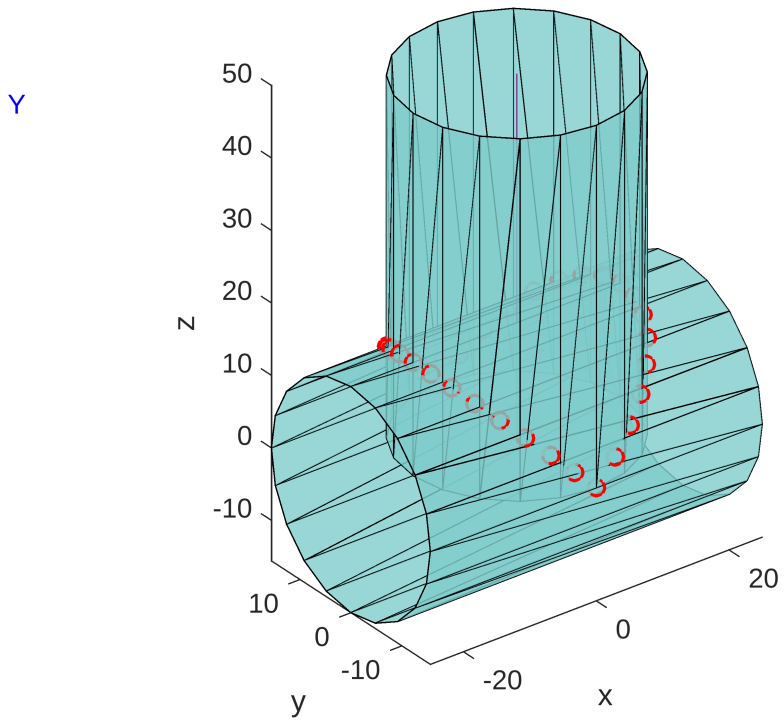
```
patch('Vertices',V2_Cylinder(1:3,:)','Faces',F_Cylinder,'facecolor',[0.5 0.8 0.8],'face
axis equal
```

Visualize the 32 welding points

```
scatter3(cp0(1,:),cp0(2,:),cp0(3,:),'r','LineWidth',2)
hold on
```

Visualize the frame wrt are drawn

```
trplot(eye(4), 'length', 100,'arrow','width', 1 )
```



All weldding points

The final graphical result must be: (doble click on: 32x24_Welding_Points_Solution.fig) in case the 'open' command do not work!

Add reference frame for all cloud weld points.

Obtain a vector with all weldding points, i.e the six folded squared. Take advantage of the figure symetry.

Notice that there is small misalignement due to incorrect 'stl' file.

```
open('32x24_Welding_Points_Solution.fig')
alpha 0.3
```

```
r=15.6; % Tube radius
t=0:pi/16:2*pi; % Scan variable
cp0=[r*cos(t);r*sin(t);abs(r*cos(t));ones(1,length(t))]% dot height
```

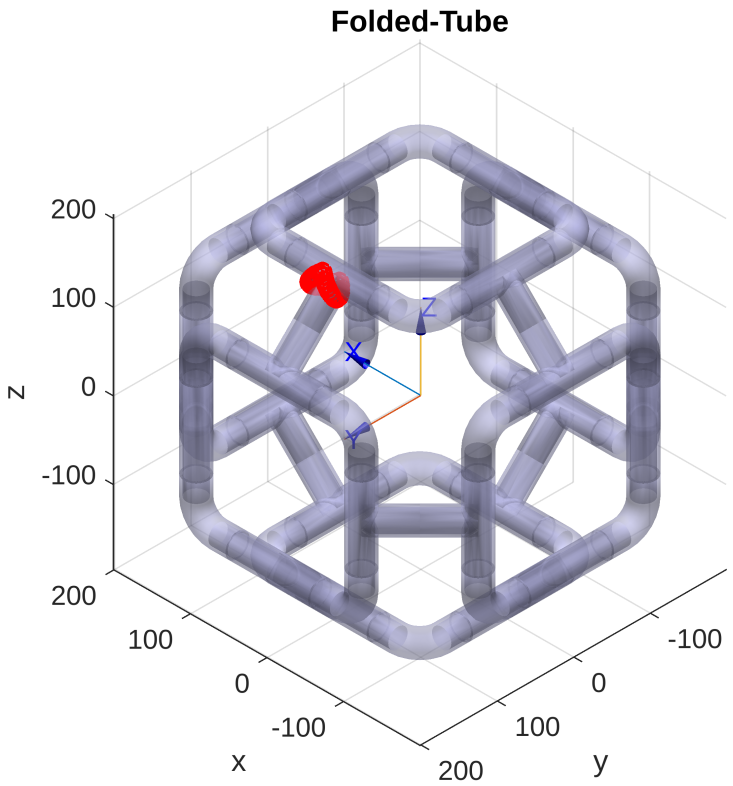
```
cp0 = 4×33
```

```
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
         0    3.0434    5.9699    8.6669   11.0309   12.9709   14.4125   15.3003
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp1 = transl(0,117.5,192.1)*trotx(-135, 'deg')*cp0
```

```
cp1 = 4×33
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
[V,F, N,name]=stlRead('Folded_Tubes.stl');
clf
stlPlot(V,F,name)
alpha 0.4
axis equal
hold on
trplot(eye(4), 'length', 100,'arrow','width', 1 )
scatter3(cp1(1,:),cp1(2,:),cp1(3,:),'r','LineWidth',2)
xyzlabel% RTB function
```




```
cp2 = trotz(pi)*cp1
```

```
cp2 = 4×33
  -15.6000  -15.3003  -14.4125  -12.9709  -11.0309   -8.6669   -5.9699   -3.0434 ···
 -128.5309 -126.1669 -123.4699 -120.5434 -117.5000 -114.4566 -111.5301 -108.8331
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp1
```

```
cp1 = 4×33
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp0
```

```
cp0 = 4×33
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
         0    3.0434    5.9699    8.6669   11.0309   12.9709   14.4125   15.3003
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp_3_4 = trotz(pi/2)*[cp1 , cp2]
```

```
cp_3_4 = 4×66
 -128.5309 -126.1669 -123.4699 -120.5434 -117.5000 -114.4566 -111.5301 -108.8331 ···
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp_over = [cp1, cp2, cp_3_4]
```

```
cp_over = 4×132
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp_under = trotx(pi/2) * cp_over
```

```
cp_under = 4×132
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
 -181.0691 -179.1291 -177.6875 -176.7997 -176.5000 -176.7997 -177.6875 -179.1291
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp_over_under = [cp_over, cp_under]
```

```
cp_over_under = 4×264
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp_sides = trotx(pi/2) * cp_over_under
```

```
cp_sides = 4×264
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
 -181.0691 -179.1291 -177.6875 -176.7997 -176.5000 -176.7997 -177.6875 -179.1291
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

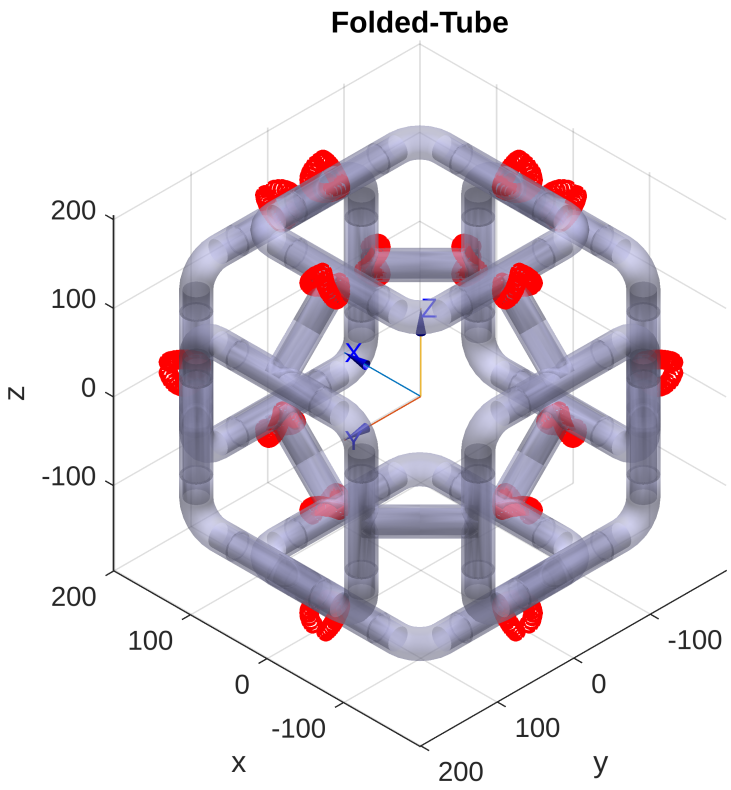
```
cp_sides2 = trotz(pi/2) * cp_sides
```

```
cp_sides2 = 4×264
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291 ···
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
cp_total = [cp_over_under, cp_sides, cp_sides2]
```

```
cp_total = 4×792
   15.6000   15.3003   14.4125   12.9709   11.0309    8.6669    5.9699    3.0434 ···
  128.5309  126.1669  123.4699  120.5434  117.5000  114.4566  111.5301  108.8331
  181.0691  179.1291  177.6875  176.7997  176.5000  176.7997  177.6875  179.1291
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
```

```
[V,F, N,name]=stlRead('Folded_Tubes.stl');
clf
stlPlot(V,F,name)
alpha 0.4
axis equal
hold on
trplot(eye(4), 'length', 100,'arrow','width', 1 )
scatter3(cp_total(1,:),cp_total(2,:),cp_total(3,:),'r','LineWidth',2)
xyzlabel% RTB function
```


Folded-Tube
200
100
0
-100
z
200
100
0
-100
x
-100
0
100
200
y
Z
X
Y