Table of Contents


```
clear;
clc;
```

Initial Position calculations

```
A=[1.4 .485 0];
B=[1.67 0.99 0];
C=[.255  1.035 0];
D=[.285 .055 0];
E=[.195 2.54 0];
F=[-.98 2.57 0];
G=[.05 .2 0];

initalPosition = linkageAnalysis(B,C,E,F);
```

Full Rotation Position Calculator

```
%length of each link/ distance between joints
AB=norm(B-A);
BC=norm(C-B);
CD=norm(D-C);
CE=norm(E-C);
DE=norm(E-D);
BE=norm(E-B);
EF=norm(F-E);
FG=norm(G-F);
```

Circle Method

```
%now obtain the new positions
%initial angle
initialAngle_AB=atan2(B(2)-A(2),B(1)-A(1));

%if this is negative, then we should subtract as shown below

if(initialAngle_AB<0)
```

```
angleAB_horizontal=2*pi+initialAngle_AB; %adjusting the angle to be in
 the ccw direction from the hozizontal
else
    angleAB_horizontal = initialAngle_AB;
end

%Iterate through 360 degrees
for theta=0:1:360
theta
%position analysis
%increase by 1 deg
%new position of B
B_new = vpa(A+[AB*cos(angleAB_horizontal+deg2rad(theta))
 AB*sin(angleAB_horizontal+deg2rad(theta)) 0]);
%new position of C
[C_x,C_y]=circcirc(B_new(1),B_new(2),BC,D(1),D(2),CD);
%checking if circles are not intersecting
circIntersect_x = any(isnan(vpa(C_x))); %checking for Not-a-Number
circIntersect_y = any(isnan(vpa(C_y)));

if circIntersect_x==0 && circIntersect_y==0 % if the circles are not
 intersecting
    C_1=[C_x(1) C_y(1) 0]; %adding the two solutions
    C_2=[C_x(2) C_y(2) 0];
    dist1 = norm(C_1-C);
    dist2 = norm(C_2-C);

    if(dist1<dist2) %checking which new C is closer
      C_new=vpa(C_1);
    else
      C_new=vpa(C_2);
    end

    %new position of E

    [E_x,E_y]=circcirc(C_new(1),C_new(2),CE,D(1),D(2),DE);

    %checking if circles are not intersecting

    circIntersect_x = any(isnan(vpa(E_x))); %checking for Not-a-Number
    circIntersect_y = any(isnan(vpa(E_y)));


    if circIntersect_x==0 && circIntersect_y==0 % if the circles are
 not intersecting
         E_1=[E_x(1) E_y(1) 0]; %adding the two solutions
         E_2=[E_x(2) E_y(2) 0];
         dist1 = norm(E_1-E);
         dist2 = norm(E_2-E);

        if(dist1<dist2)
            E_new=vpa(E_1);
        else
            E_new=vpa(E_2);
```

```
        end

    % new position of F

        [F_x,F_y]=circcirc(E_new(1),E_new(2),EF,G(1),G(2),FG);

          %checking if circles are not intersecting

        circIntersect_x = any(isnan(vpa(F_x))); %checking for Not-a-
Number
        circIntersect_y = any(isnan(vpa(F_y)));

        if circIntersect_x==0 && circIntersect_y==0  % if the circles
 are not intersecting
             F_1=[F_x(1) F_y(1) 0]; %adding the two solutions
             F_2=[F_x(2) F_y(2) 0];
             dist1 = norm(F_1-F);
             dist2 = norm(F_2-F);

             if(dist1<dist2)
                  F_new=vpa(F_1);
             else
                  F_new=vpa(F_2);
             end


             %storing values
             newB_x(theta+1)=double(B_new(1));
             newB_y(theta+1)=double(B_new(2));
             newC_x(theta+1)=double(C_new(1));
             newC_y(theta+1)=double(C_new(2));
             newE_x(theta+1)=double(E_new(1));
             newE_y(theta+1)=double(E_new(2));
             newF_x(theta+1)=double(F_new(1));
             newF_y(theta+1)=double(F_new(2));

                 %saving this into an Excel spreadsheet


            positionsMatrix = [B_new C_new E_new F_new];

            if (theta==0)


 dlmwrite('PositionsAndForceDiffPos.xls',positionsMatrix,'delimiter','\t','precisi
            else
            dlmwrite('PositionsAndForceDiffPos.xls',positionsMatrix,'-
append',...
            'delimiter','\t','precision',4);
             end

        else
            figure
```

```
            ax1= subplot(2,2,1);
            plot(newB_x,newB_y);
            title(ax1,'Joint B')
            ax2=  subplot(2,2,2);
            plot(newC_x,newC_y);
            title(ax2,'Joint C')
            ax3=  subplot(2,2,3);
            plot(newE_x,newE_y);
            title(ax3,'Joint E')
            ax4=  subplot(2,2,4);
            plot(newF_x,newF_y);
            title(ax4,'Joint F')
            fprintf('New position cannot be determined at this angle
 from the initial: %d',theta);
            return
        end
    else
     fprintf('New position cannot be determined at this angle  from
 the initial: %d',theta);
    return
    end
else
    fprintf('New position cannot be determined at this angle:
 %d',theta);
    return
end

%Calculate and record updated joint parameters
values = linkageAnalysis(B,C,E,F);
statics(:,theta+1) = values.staticSol.';
angulars(:,theta+1) = values.angSol.';
dynamics(:,theta+1) = values.dynamicSol.';

%Update joint Positions
B=B_new;
C=C_new;
E=E_new;
F=F_new;

end


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Plot final joint parameters

```
jointPos = [newB_x;newB_y;newC_x;newC_y;newE_x;newE_y;newF_x;newF_y]
plotJoints(jointPos,statics,angulars,dynamics);
```

```
jointPos =

  Columns 1 through 7

    1.6700    1.6611    1.6522    1.6432    1.6341    1.6250    1.6157
    0.9900    0.9946    0.9991    1.0034    1.0076    1.0116    1.0155
    0.2550    0.2460    0.2369    0.2278    0.2186    0.2094    0.2001
    1.0350    1.0347    1.0343    1.0338    1.0332    1.0325    1.0318
    0.1950    0.2000    0.1770    0.1539    0.1306    0.1071    0.0836
    2.5400    2.5402    2.5393    2.5382    2.5368    2.5353    2.5335
   -0.9800   -0.9750   -0.9982   -1.0214   -1.0448   -1.0682   -1.0917
    2.5700    2.5722    2.5620    2.5516    2.5408    2.5297    2.5183

  Columns 8 through 14

    1.6064    1.5971    1.5877    1.5782    1.5687    1.5591    1.5495
    1.0191    1.0227    1.0260    1.0292    1.0322    1.0351    1.0378
    0.1908    0.1814    0.1720    0.1625    0.1530    0.1434    0.1338
    1.0309    1.0300    1.0289    1.0278    1.0265    1.0252    1.0237
    0.0599    0.0361    0.0122   -0.0119   -0.0360   -0.0603   -0.0846
    2.5314    2.5291    2.5266    2.5238    2.5208    2.5175    2.5140
   -1.1152   -1.1388   -1.1624   -1.1860   -1.2096   -1.2333   -1.2569
    2.5065    2.4945    2.4821    2.4694    2.4563    2.4430    2.4293

  Columns 15 through 21

    1.5398    1.5301    1.5203    1.5106    1.5007    1.4909    1.4810
    1.0403    1.0427    1.0449    1.0469    1.0487    1.0504    1.0519
    0.1242    0.1146    0.1049    0.0952    0.0854    0.0757    0.0659
    1.0222    1.0205    1.0188    1.0169    1.0149    1.0129    1.0107
   -0.1091   -0.1336   -0.1582   -0.1828   -0.2075   -0.2323   -0.2571
    2.5102    2.5061    2.5018    2.4972    2.4924    2.4872    2.4818
   -1.2806   -1.3042   -1.3278   -1.3514   -1.3750   -1.3984   -1.4219
    2.4152    2.4009    2.3862    2.3711    2.3558    2.3400    2.3240

  Columns 22 through 28
```

```
  1.4711    1.4612    1.4512    1.4413    1.4313    1.4213    1.4113
  1.0532    1.0544    1.0554    1.0562    1.0568    1.0573    1.0575
  0.0561    0.0463    0.0365    0.0266    0.0168    0.0069   -0.0029
  1.0084    1.0060    1.0034    1.0008    0.9981    0.9952    0.9922
 -0.2820   -0.3069   -0.3319   -0.3569   -0.3818   -0.4068   -0.4319
  2.4761    2.4701    2.4639    2.4574    2.4505    2.4434    2.4361
 -1.4453   -1.4686   -1.4918   -1.5149   -1.5380   -1.5609   -1.5837
  2.3076    2.2909    2.2738    2.2564    2.2387    2.2206    2.2022

Columns 29 through 35

  1.4013    1.3913    1.3813    1.3713    1.3614    1.3514    1.3414
  1.0576    1.0576    1.0573    1.0569    1.0563    1.0556    1.0546
 -0.0127   -0.0226   -0.0324   -0.0422   -0.0521   -0.0619   -0.0716
  0.9892    0.9860    0.9827    0.9792    0.9757    0.9721    0.9683
 -0.4569   -0.4819   -0.5068   -0.5318   -0.5567   -0.5816   -0.6065
  2.4284    2.4204    2.4122    2.4036    2.3948    2.3857    2.3763
 -1.6064   -1.6290   -1.6514   -1.6737   -1.6959   -1.7179   -1.7397
  2.1834    2.1644    2.1450    2.1252    2.1052    2.0848    2.0641

Columns 36 through 42

  1.3315    1.3216    1.3117    1.3019    1.2920    1.2822    1.2725
  1.0535    1.0523    1.0508    1.0492    1.0474    1.0454    1.0433
 -0.0814   -0.0911   -0.1008   -0.1105   -0.1202   -0.1298   -0.1394
  0.9644    0.9604    0.9563    0.9521    0.9478    0.9434    0.9388
 -0.6313   -0.6561   -0.6808   -0.7054   -0.7299   -0.7544   -0.7788
  2.3666    2.3567    2.3464    2.3359    2.3251    2.3140    2.3026
 -1.7613   -1.7827   -1.8040   -1.8250   -1.8459   -1.8665   -1.8869
  2.0431    2.0218    2.0002    1.9782    1.9560    1.9335    1.9106

Columns 43 through 49

  1.2627    1.2531    1.2434    1.2338    1.2243    1.2148    1.2054
  1.0410    1.0385    1.0358    1.0330    1.0300    1.0269    1.0236
 -0.1489   -0.1585   -0.1679   -0.1773   -0.1867   -0.1960   -0.2053
  0.9342    0.9294    0.9246    0.9196    0.9145    0.9094    0.9041
 -0.8031   -0.8272   -0.8513   -0.8753   -0.8991   -0.9228   -0.9464
  2.2909    2.2790    2.2668    2.2543    2.2416    2.2286    2.2153
 -1.9071   -1.9270   -1.9467   -1.9661   -1.9852   -2.0041   -2.0228
  1.8875    1.8641    1.8405    1.8165    1.7923    1.7679    1.7432

Columns 50 through 56

  1.1960    1.1867    1.1775    1.1683    1.1592    1.1501    1.1412
  1.0201    1.0164    1.0126    1.0087    1.0045    1.0003    0.9958
 -0.2145   -0.2236   -0.2327   -0.2417   -0.2507   -0.2596   -0.2684
  0.8987    0.8932    0.8876    0.8819    0.8762    0.8703    0.8643
 -0.9698   -0.9931   -1.0162   -1.0392   -1.0620   -1.0846   -1.1070
  2.2018    2.1880    2.1740    2.1597    2.1452    2.1305    2.1155
 -2.0411   -2.0592   -2.0769   -2.0944   -2.1115   -2.1284   -2.1449
  1.7182    1.6931    1.6676    1.6420    1.6162    1.5901    1.5639
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Columns 57 through 63

  1.1323    1.1235    1.1148    1.1062    1.0977    1.0892    1.0809
  0.9912    0.9865    0.9816    0.9765    0.9713    0.9660    0.9605
 -0.2771   -0.2858   -0.2944   -0.3029   -0.3113   -0.3196   -0.3279
  0.8583    0.8522    0.8460    0.8397    0.8333    0.8268    0.8203
 -1.1293   -1.1513   -1.1732   -1.1948   -1.2163   -1.2375   -1.2585
  2.1003    2.0848    2.0692    2.0533    2.0373    2.0210    2.0046
 -2.1611   -2.1770   -2.1926   -2.2078   -2.2226   -2.2372   -2.2513
  1.5374    1.5108    1.4840    1.4571    1.4300    1.4028    1.3754

Columns 64 through 70

  1.0726    1.0645    1.0564    1.0485    1.0406    1.0329    1.0253
  0.9548    0.9491    0.9431    0.9371    0.9309    0.9245    0.9180
 -0.3360   -0.3441   -0.3521   -0.3599   -0.3677   -0.3754   -0.3829
  0.8137    0.8070    0.8003    0.7935    0.7866    0.7797    0.7727
 -1.2793   -1.2998   -1.3201   -1.3402   -1.3600   -1.3795   -1.3988
  1.9880    1.9712    1.9542    1.9371    1.9198    1.9024    1.8848
 -2.2652   -2.2786   -2.2917   -2.3045   -2.3169   -2.3289   -2.3405
  1.3480    1.3204    1.2928    1.2650    1.2372    1.2093    1.1814

Columns 71 through 77

  1.0178    1.0104    1.0032    0.9960    0.9890    0.9821    0.9753
  0.9114    0.9047    0.8978    0.8908    0.8837    0.8765    0.8692
 -0.3904   -0.3977   -0.4050   -0.4121   -0.4191   -0.4260   -0.4328
  0.7657    0.7587    0.7516    0.7444    0.7373    0.7301    0.7229
 -1.4178   -1.4366   -1.4550   -1.4732   -1.4911   -1.5087   -1.5260
  1.8671    1.8493    1.8314    1.8134    1.7953    1.7772    1.7590
 -2.3518   -2.3627   -2.3732   -2.3834   -2.3932   -2.4026   -2.4116
  1.1535    1.1256    1.0976    1.0697    1.0418    1.0140    0.9862

Columns 78 through 84

  0.9687    0.9622    0.9558    0.9496    0.9435    0.9375    0.9317
  0.8617    0.8541    0.8464    0.8386    0.8307    0.8227    0.8145
 -0.4395   -0.4460   -0.4524   -0.4587   -0.4649   -0.4710   -0.4769
  0.7156    0.7084    0.7011    0.6939    0.6866    0.6794    0.6721
 -1.5430   -1.5597   -1.5761   -1.5922   -1.6079   -1.6233   -1.6384
  1.7407    1.7224    1.7041    1.6858    1.6675    1.6492    1.6310
 -2.4203   -2.4286   -2.4366   -2.4441   -2.4514   -2.4582   -2.4647
  0.9585    0.9309    0.9034    0.8761    0.8489    0.8219    0.7950

Columns 85 through 91

  0.9260    0.9205    0.9151    0.9098    0.9047    0.8998    0.8950
  0.8063    0.7980    0.7896    0.7811    0.7725    0.7638    0.7550
 -0.4826   -0.4883   -0.4938   -0.4992   -0.5044   -0.5095   -0.5145
  0.6649    0.6578    0.6506    0.6435    0.6365    0.6295    0.6225
 -1.6532   -1.6676   -1.6817   -1.6955   -1.7089   -1.7219   -1.7346
  1.6128    1.5946    1.5766    1.5587    1.5409    1.5232    1.5057
 -2.4709   -2.4767   -2.4821   -2.4873   -2.4921   -2.4965   -2.5007
  0.7684    0.7420    0.7159    0.6900    0.6644    0.6392    0.6143
```

Columns 92 through 98

```
  0.8904    0.8859    0.8816    0.8774    0.8734    0.8695    0.8659
  0.7461    0.7372    0.7282    0.7191    0.7100    0.7007    0.6914
 -0.5193   -0.5240   -0.5285   -0.5329   -0.5372   -0.5413   -0.5452
  0.6157    0.6089    0.6022    0.5956    0.5892    0.5828    0.5766
 -1.7469   -1.7589   -1.7705   -1.7817   -1.7925   -1.8030   -1.8131
  1.4884    1.4713    1.4544    1.4378    1.4214    1.4054    1.3897
 -2.5046   -2.5081   -2.5114   -2.5144   -2.5171   -2.5196   -2.5218
  0.5898    0.5657    0.5420    0.5187    0.4960    0.4737    0.4520
```

Columns 99 through 105

```
  0.8623    0.8590    0.8558    0.8528    0.8499    0.8472    0.8447
  0.6821    0.6727    0.6632    0.6537    0.6441    0.6345    0.6248
 -0.5490   -0.5526   -0.5561   -0.5594   -0.5625   -0.5655   -0.5684
  0.5705    0.5646    0.5589    0.5533    0.5479    0.5427    0.5378
 -1.8228   -1.8321   -1.8409   -1.8494   -1.8575   -1.8652   -1.8724
  1.3743    1.3594    1.3448    1.3308    1.3171    1.3041    1.2915
 -2.5238   -2.5256   -2.5271   -2.5285   -2.5296   -2.5306   -2.5314
  0.4309    0.4104    0.3905    0.3714    0.3529    0.3352    0.3183
```

Columns 106 through 112

```
  0.8423    0.8401    0.8381    0.8363    0.8346    0.8331    0.8318
  0.6151    0.6053    0.5956    0.5857    0.5759    0.5660    0.5561
 -0.5710   -0.5735   -0.5758   -0.5779   -0.5799   -0.5816   -0.5832
  0.5331    0.5286    0.5244    0.5205    0.5168    0.5135    0.5106
 -1.8792   -1.8855   -1.8915   -1.8969   -1.9019   -1.9064   -1.9104
  1.2796    1.2683    1.2577    1.2477    1.2386    1.2302    1.2227
 -2.5321   -2.5327   -2.5331   -2.5335   -2.5337   -2.5339   -2.5340
  0.3023    0.2871    0.2729    0.2596    0.2474    0.2363    0.2264
```

Columns 113 through 119

```
  0.8306    0.8296    0.8288    0.8282    0.8277    0.8275    0.8274
  0.5462    0.5362    0.5263    0.5163    0.5063    0.4963    0.4863
 -0.5846   -0.5857   -0.5867   -0.5874   -0.5880   -0.5882   -0.5883
  0.5079    0.5057    0.5038    0.5024    0.5014    0.5008    0.5007
 -1.9139   -1.9169   -1.9194   -1.9213   -1.9226   -1.9233   -1.9235
  1.2160    1.2104    1.2057    1.2020    1.1995    1.1980    1.1978
 -2.5341   -2.5341   -2.5341   -2.5341   -2.5341   -2.5341   -2.5341
  0.2176    0.2101    0.2039    0.1991    0.1957    0.1938    0.1935
```

Columns 120 through 126

```
  0.8274    0.8277    0.8281    0.8287    0.8294    0.8304    0.8315
  0.4763    0.4663    0.4563    0.4464    0.4364    0.4264    0.4165
 -0.5881   -0.5876   -0.5869   -0.5858   -0.5845   -0.5828   -0.5808
  0.5011    0.5021    0.5035    0.5055    0.5081    0.5113    0.5151
 -1.9229   -1.9217   -1.9198   -1.9171   -1.9137   -1.9094   -1.9043
  1.1989    1.2012    1.2049    1.2100    1.2165    1.2245    1.2341
 -2.5341   -2.5341   -2.5341   -2.5341   -2.5341   -2.5340   -2.5338
```

```
  0.1949    0.1980    0.2028    0.2095    0.2182    0.2288    0.2415

Columns 127 through 133

  0.8327    0.8342    0.8358    0.8376    0.8396    0.8417    0.8440
  0.4066    0.3967    0.3869    0.3770    0.3672    0.3575    0.3477
 -0.5785   -0.5757   -0.5726   -0.5691   -0.5651   -0.5607   -0.5558
  0.5195    0.5245    0.5302    0.5365    0.5435    0.5511    0.5594
 -1.8983   -1.9046   -1.8968   -1.8879   -1.8779   -1.8668   -1.8544
  1.2452    1.2335    1.2479    1.2640    1.2818    1.3012    1.3223
 -2.5335   -2.5338   -2.5334   -2.5329   -2.5320   -2.5308   -2.5292
  0.2563    0.2407    0.2599    0.2814    0.3052    0.3314    0.3599

Columns 134 through 140

  0.8465    0.8492    0.8520    0.8550    0.8581    0.8614    0.8649
  0.3381    0.3284    0.3188    0.3093    0.2998    0.2904    0.2810
 -0.5503   -0.5444   -0.5379   -0.5308   -0.5232   -0.5149   -0.5060
  0.5683    0.5779    0.5881    0.5988    0.6101    0.6220    0.6343
 -1.8408   -1.8259   -1.8095   -1.7918   -1.7725   -1.7517   -1.7293
  1.3450    1.3694    1.3952    1.4226    1.4514    1.4816    1.5130
 -2.5271   -2.5244   -2.5211   -2.5169   -2.5120   -2.5060   -2.4990
  0.3908    0.4241    0.4597    0.4976    0.5378    0.5802    0.6247

Columns 141 through 147

  0.8686    0.8724    0.8763    0.8805    0.8847    0.8892    0.8938
  0.2717    0.2625    0.2533    0.2442    0.2351    0.2262    0.2173
 -0.4965   -0.4863   -0.4755   -0.4640   -0.4519   -0.4391   -0.4257
  0.6471    0.6603    0.6739    0.6877    0.7018    0.7161    0.7304
 -1.7053   -1.6797   -1.6525   -1.6236   -1.5930   -1.5608   -1.5270
  1.5456    1.5792    1.6137    1.6490    1.6849    1.7212    1.7579
 -2.4908   -2.4814   -2.4706   -2.4583   -2.4445   -2.4292   -2.4121
  0.6712    0.7196    0.7697    0.8215    0.8747    0.9291    0.9846

Columns 148 through 154

  0.8985    0.9034    0.9085    0.9137    0.9190    0.9245    0.9302
  0.2085    0.1998    0.1912    0.1827    0.1742    0.1659    0.1576
 -0.4117   -0.3970   -0.3818   -0.3660   -0.3498   -0.3330   -0.3158
  0.7449    0.7594    0.7738    0.7881    0.8022    0.8162    0.8298
 -1.4916   -1.4547   -1.4163   -1.3766   -1.3355   -1.2932   -1.2497
  1.7948    1.8317    1.8685    1.9050    1.9411    1.9767    2.0115
 -2.3935   -2.3730   -2.3509   -2.3271   -2.3015   -2.2743   -2.2454
  1.0410    1.0981    1.1557    1.2136    1.2715    1.3294    1.3870

Columns 155 through 161

  0.9359    0.9419    0.9479    0.9541    0.9605    0.9670    0.9736
  0.1495    0.1414    0.1335    0.1256    0.1179    0.1103    0.1028
 -0.2982   -0.2802   -0.2618   -0.2432   -0.2244   -0.2053   -0.1861
  0.8432    0.8562    0.8688    0.8810    0.8928    0.9041    0.9149
 -1.2052   -1.1597   -1.1134   -1.0664   -1.0187   -0.9705   -0.9220
  2.0457    2.0789    2.1112    2.1424    2.1725    2.2014    2.2291
```

```
  -2.2149   -2.1830   -2.1496   -2.1148   -2.0788   -2.0417   -2.0035
   1.4441    1.5006    1.5563    1.6111    1.6649    1.7175    1.7688

Columns 162 through 168

   0.9803    0.9872    0.9942    1.0013    1.0085    1.0158    1.0233
   0.0954    0.0882    0.0810    0.0740    0.0671    0.0603    0.0537
  -0.1668   -0.1474   -0.1279   -0.1085   -0.0891   -0.0697   -0.0505
   0.9252    0.9350    0.9443    0.9530    0.9613    0.9690    0.9763
  -0.8731   -0.8240   -0.7748   -0.7257   -0.6766   -0.6276   -0.5789
   2.2555    2.2806    2.3045    2.3270    2.3482    2.3681    2.3867
  -1.9643   -1.9243   -1.8836   -1.8422   -1.8004   -1.7581   -1.7155
   1.8187    1.8673    1.9144    1.9599    2.0039    2.0463    2.0870

Columns 169 through 175

   1.0309    1.0386    1.0464    1.0543    1.0623    1.0705    1.0787
   0.0472    0.0408    0.0346    0.0285    0.0225    0.0167    0.0110
  -0.0314   -0.0124    0.0063    0.0249    0.0432    0.0614    0.0792
   0.9830    0.9893    0.9950    1.0003    1.0052    1.0096    1.0136
  -0.5306   -0.4826   -0.4351   -0.3881   -0.3416   -0.2958   -0.2506
   2.4041    2.4202    2.4351    2.4488    2.4614    2.4729    2.4833
  -1.6726   -1.6297   -1.5867   -1.5437   -1.5008   -1.4581   -1.4157
   2.1262    2.1638    2.1998    2.2342    2.2671    2.2984    2.3283

Columns 176 through 182

   1.0870    1.0954    1.1039    1.1125    1.1212    1.1300    1.1389
   0.0055    0.0001   -0.0052   -0.0103   -0.0152   -0.0200   -0.0246
   0.0968    0.1141    0.1311    0.1478    0.1642    0.1802    0.1960
   1.0172    1.0204    1.0233    1.0258    1.0280    1.0298    1.0314
  -0.2060   -0.1622   -0.1192   -0.0768   -0.0353    0.0054    0.0454
   2.4927    2.5011    2.5086    2.5152    2.5209    2.5259    2.5301
  -1.3735   -1.3317   -1.2903   -1.2494   -1.2089   -1.1690   -1.1296
   2.3567    2.3837    2.4094    2.4337    2.4567    2.4786    2.4992

Columns 183 through 189

   1.1478    1.1568    1.1659    1.1750    1.1843    1.1936    1.2029
  -0.0291   -0.0334   -0.0376   -0.0416   -0.0455   -0.0491   -0.0527
   0.2114    0.2265    0.2413    0.2557    0.2699    0.2837    0.2971
   1.0327    1.0337    1.0345    1.0350    1.0353    1.0355    1.0354
   0.0845    0.1228    0.1602    0.1969    0.2327    0.2677    0.3019
   2.5335    2.5363    2.5385    2.5401    2.5411    2.5416    2.5416
  -1.0908   -1.0526   -1.0150   -0.9781   -0.9418   -0.9062   -0.8712
   2.5187    2.5371    2.5545    2.5708    2.5862    2.6007    2.6144

Columns 190 through 196

   1.2123    1.2218    1.2313    1.2409    1.2505    1.2602    1.2699
  -0.0560   -0.0592   -0.0622   -0.0651   -0.0678   -0.0703   -0.0727
   0.3103    0.3231    0.3357    0.3479    0.3598    0.3714    0.3827
   1.0351    1.0347    1.0341    1.0334    1.0326    1.0316    1.0306
   0.3353    0.3678    0.3996    0.4306    0.4608    0.4903    0.5190
```

```
  2.5411    2.5402    2.5390    2.5374    2.5354    2.5331    2.5306
 -0.8370   -0.8034   -0.7705   -0.7383   -0.7067   -0.6759   -0.6457
  2.6272    2.6392    2.6504    2.6610    2.6709    2.6801    2.6887

Columns 197 through 203

  1.2797    1.2894    1.2993    1.3091    1.3190    1.3289    1.3388
 -0.0749   -0.0769   -0.0787   -0.0804   -0.0819   -0.0832   -0.0844
  0.3937    0.4045    0.4149    0.4251    0.4350    0.4446    0.4540
  1.0294    1.0282    1.0268    1.0254    1.0239    1.0224    1.0208
  0.5470    0.5742    0.6007    0.6266    0.6517    0.6762    0.7000
  2.5278    2.5248    2.5215    2.5181    2.5144    2.5107    2.5068
 -0.6162   -0.5874   -0.5592   -0.5317   -0.5049   -0.4787   -0.4531
  2.6968    2.7043    2.7113    2.7178    2.7239    2.7295    2.7347

Columns 204 through 210

  1.3488    1.3587    1.3687    1.3787    1.3887    1.3987    1.4087
 -0.0854   -0.0862   -0.0868   -0.0873   -0.0875   -0.0876   -0.0876
  0.4631    0.4720    0.4806    0.4890    0.4972    0.5051    0.5128
  1.0191    1.0175    1.0157    1.0140    1.0122    1.0104    1.0086
  0.7231    0.7456    0.7675    0.7888    0.8096    0.8297    0.8492
  2.5027    2.4986    2.4944    2.4900    2.4857    2.4812    2.4768
 -0.4282   -0.4038   -0.3801   -0.3570   -0.3345   -0.3125   -0.2911
  2.7395    2.7440    2.7481    2.7519    2.7554    2.7586    2.7615

Columns 211 through 217

  1.4187    1.4287    1.4386    1.4486    1.4586    1.4685    1.4784
 -0.0873   -0.0869   -0.0863   -0.0856   -0.0846   -0.0835   -0.0823
  0.5203    0.5276    0.5346    0.5415    0.5481    0.5546    0.5608
  1.0068    1.0050    1.0032    1.0013    0.9995    0.9977    0.9959
  0.8682    0.8867    0.9046    0.9220    0.9389    0.9553    0.9712
  2.4723    2.4677    2.4632    2.4587    2.4541    2.4496    2.4451
 -0.2703   -0.2501   -0.2303   -0.2111   -0.1925   -0.1743   -0.1567
  2.7642    2.7667    2.7689    2.7709    2.7727    2.7744    2.7759

Columns 218 through 224

  1.4883    1.4981    1.5080    1.5178    1.5275    1.5373    1.5469
 -0.0808   -0.0792   -0.0774   -0.0754   -0.0733   -0.0710   -0.0685
  0.5669    0.5728    0.5785    0.5840    0.5894    0.5946    0.5996
  0.9941    0.9923    0.9905    0.9887    0.9870    0.9853    0.9836
  0.9866    1.0016    1.0161    1.0302    1.0438    1.0570    1.0698
  2.4406    2.4361    2.4317    2.4273    2.4230    2.4188    2.4145
 -0.1395   -0.1229   -0.1067   -0.0910   -0.0757   -0.0609   -0.0466
  2.7772    2.7784    2.7794    2.7803    2.7811    2.7818    2.7823

Columns 225 through 231

  1.5566    1.5662    1.5757    1.5852    1.5946    1.6040    1.6133
 -0.0658   -0.0630   -0.0600   -0.0569   -0.0536   -0.0501   -0.0464
  0.6045    0.6092    0.6138    0.6182    0.6224    0.6265    0.6305
  0.9819    0.9803    0.9787    0.9771    0.9756    0.9740    0.9726
```

```
  1.0822    1.0941    1.1057    1.1169    1.1277    1.1382    1.1482
  2.4104    2.4063    2.4023    2.3983    2.3945    2.3907    2.3870
 -0.0327   -0.0192   -0.0061    0.0065    0.0187    0.0306    0.0420
  2.7828    2.7832    2.7835    2.7838    2.7840    2.7841    2.7841

Columns 232 through 238

  1.6225    1.6317    1.6408    1.6499    1.6588    1.6677    1.6765
 -0.0426   -0.0387   -0.0345   -0.0303   -0.0258   -0.0212   -0.0165
  0.6343    0.6380    0.6416    0.6450    0.6483    0.6514    0.6545
  0.9711    0.9697    0.9683    0.9670    0.9657    0.9644    0.9632
  1.1580    1.1673    1.1763    1.1850    1.1934    1.2014    1.2091
  2.3834    2.3798    2.3764    2.3730    2.3698    2.3666    2.3635
  0.0530    0.0637    0.0739    0.0838    0.0933    0.1025    0.1113
  2.7841    2.7841    2.7840    2.7839    2.7838    2.7836    2.7834

Columns 239 through 245

  1.6852    1.6938    1.7023    1.7108    1.7191    1.7274    1.7355
 -0.0116   -0.0065   -0.0013    0.0040    0.0095    0.0152    0.0209
  0.6574    0.6602    0.6628    0.6654    0.6678    0.6701    0.6723
  0.9620    0.9608    0.9597    0.9587    0.9576    0.9567    0.9557
  1.2165    1.2236    1.2304    1.2368    1.2430    1.2489    1.2545
  2.3606    2.3577    2.3549    2.3522    2.3497    2.3472    2.3449
  0.1197    0.1278    0.1356    0.1430    0.1501    0.1568    0.1633
  2.7832    2.7830    2.7827    2.7825    2.7822    2.7819    2.7817

Columns 246 through 252

  1.7436    1.7515    1.7594    1.7671    1.7747    1.7822    1.7896
  0.0269    0.0329    0.0391    0.0455    0.0520    0.0586    0.0653
  0.6744    0.6764    0.6782    0.6800    0.6816    0.6832    0.6846
  0.9548    0.9540    0.9531    0.9524    0.9517    0.9510    0.9503
  1.2598    1.2648    1.2695    1.2740    1.2782    1.2821    1.2858
  2.3426    2.3405    2.3384    2.3365    2.3347    2.3330    2.3314
  0.1694    0.1751    0.1806    0.1857    0.1906    0.1951    0.1993
  2.7814    2.7811    2.7808    2.7806    2.7803    2.7801    2.7798

Columns 253 through 259

  1.7968    1.8040    1.8110    1.8179    1.8247    1.8313    1.8378
  0.0722    0.0792    0.0863    0.0935    0.1008    0.1083    0.1159
  0.6859    0.6872    0.6883    0.6893    0.6902    0.6911    0.6918
  0.9497    0.9492    0.9487    0.9482    0.9478    0.9474    0.9471
  1.2891    1.2923    1.2951    1.2977    1.3001    1.3022    1.3040
  2.3299    2.3285    2.3272    2.3261    2.3250    2.3241    2.3232
  0.2032    0.2068    0.2101    0.2131    0.2158    0.2183    0.2204
  2.7796    2.7794    2.7792    2.7790    2.7788    2.7787    2.7785

Columns 260 through 266

  1.8442    1.8504    1.8565    1.8625    1.8683    1.8740    1.8795
  0.1236    0.1314    0.1393    0.1473    0.1555    0.1637    0.1720
  0.6924    0.6930    0.6934    0.6937    0.6940    0.6941    0.6941
```

```
  0.9468    0.9466    0.9464    0.9462    0.9461    0.9460    0.9460
  1.3056    1.3070    1.3081    1.3089    1.3095    1.3099    1.3100
  2.3225    2.3219    2.3214    2.3210    2.3208    2.3206    2.3205
  0.2222    0.2238    0.2251    0.2261    0.2268    0.2272    0.2273
  2.7784    2.7783    2.7782    2.7781    2.7781    2.7781    2.7781

Columns 267 through 273

  1.8849    1.8902    1.8953    1.9002    1.9050    1.9096    1.9141
  0.1804    0.1889    0.1975    0.2062    0.2150    0.2239    0.2328
  0.6941    0.6940    0.6937    0.6934    0.6929    0.6924    0.6918
  0.9460    0.9461    0.9462    0.9464    0.9466    0.9468    0.9471
  1.3099    1.3095    1.3089    1.3080    1.3070    1.3056    1.3041
  2.3206    2.3208    2.3210    2.3214    2.3219    2.3225    2.3232
  0.2272    0.2267    0.2260    0.2251    0.2238    0.2223    0.2204
  2.7781    2.7781    2.7781    2.7782    2.7783    2.7784    2.7785

Columns 274 through 280

  1.9184    1.9226    1.9266    1.9305    1.9341    1.9377    1.9410
  0.2418    0.2509    0.2600    0.2693    0.2786    0.2879    0.2973
  0.6911    0.6903    0.6894    0.6884    0.6873    0.6861    0.6848
  0.9474    0.9478    0.9482    0.9486    0.9491    0.9497    0.9502
  1.3022    1.3002    1.2979    1.2954    1.2926    1.2896    1.2864
  2.3240    2.3250    2.3260    2.3271    2.3283    2.3297    2.3311
  0.2183    0.2160    0.2133    0.2104    0.2072    0.2037    0.2000
  2.7787    2.7788    2.7790    2.7792    2.7794    2.7796    2.7798

Columns 281 through 287

  1.9442    1.9472    1.9501    1.9528    1.9553    1.9577    1.9599
  0.3068    0.3163    0.3259    0.3355    0.3452    0.3549    0.3647
  0.6835    0.6820    0.6804    0.6788    0.6770    0.6752    0.6732
  0.9508    0.9515    0.9522    0.9529    0.9537    0.9545    0.9553
  1.2829    1.2791    1.2752    1.2710    1.2665    1.2618    1.2569
  2.3326    2.3343    2.3360    2.3378    2.3397    2.3417    2.3438
  0.1960    0.1917    0.1871    0.1822    0.1771    0.1717    0.1660
  2.7800    2.7803    2.7805    2.7808    2.7810    2.7813    2.7815

Columns 288 through 294

  1.9619    1.9637    1.9654    1.9669    1.9682    1.9694    1.9704
  0.3744    0.3843    0.3941    0.4040    0.4139    0.4238    0.4338
  0.6712    0.6691    0.6668    0.6645    0.6621    0.6596    0.6569
  0.9562    0.9571    0.9580    0.9590    0.9600    0.9611    0.9622
  1.2517    1.2463    1.2406    1.2347    1.2285    1.2221    1.2154
  2.3460    2.3483    2.3507    2.3531    2.3557    2.3583    2.3610
  0.1601    0.1538    0.1473    0.1405    0.1335    0.1261    0.1185
  2.7818    2.7821    2.7823    2.7826    2.7828    2.7830    2.7832

Columns 295 through 301

  1.9712    1.9718    1.9723    1.9725    1.9726    1.9726    1.9723
  0.4437    0.4537    0.4637    0.4737    0.4837    0.4937    0.5037
```

```
  0.6542    0.6514    0.6485    0.6455    0.6424    0.6391    0.6358
  0.9633    0.9644    0.9656    0.9668    0.9680    0.9693    0.9705
  1.2085    1.2013    1.1939    1.1863    1.1783    1.1702    1.1617
  2.3638    2.3666    2.3696    2.3726    2.3756    2.3787    2.3819
  0.1106    0.1024    0.0939    0.0852    0.0762    0.0669    0.0573
  2.7834    2.7836    2.7838    2.7839    2.7840    2.7841    2.7841

Columns 302 through 308

  1.9719    1.9713    1.9706    1.9696    1.9685    1.9673    1.9658
  0.5137    0.5236    0.5336    0.5436    0.5535    0.5634    0.5733
  0.6324    0.6289    0.6253    0.6216    0.6177    0.6138    0.6098
  0.9718    0.9732    0.9745    0.9759    0.9773    0.9787    0.9801
  1.1531    1.1441    1.1349    1.1255    1.1158    1.1058    1.0956
  2.3852    2.3885    2.3919    2.3953    2.3987    2.4023    2.4058
  0.0475    0.0373    0.0269    0.0162    0.0052   -0.0060   -0.0175
  2.7841    2.7841    2.7840    2.7839    2.7838    2.7835    2.7833

Columns 309 through 315

  1.9642    1.9624    1.9604    1.9583    1.9560    1.9535    1.9508
  0.5831    0.5930    0.6028    0.6125    0.6223    0.6319    0.6416
  0.6057    0.6014    0.5971    0.5927    0.5881    0.5835    0.5788
  0.9815    0.9830    0.9845    0.9859    0.9874    0.9889    0.9904
  1.0851    1.0744    1.0634    1.0521    1.0406    1.0288    1.0167
  2.4094    2.4130    2.4167    2.4204    2.4241    2.4278    2.4315
 -0.0293   -0.0414   -0.0538   -0.0664   -0.0793   -0.0925   -0.1060
  2.7829    2.7825    2.7821    2.7815    2.7809    2.7802    2.7794

Columns 316 through 322

  1.9480    1.9450    1.9419    1.9386    1.9351    1.9314    1.9276
  0.6512    0.6607    0.6702    0.6796    0.6890    0.6983    0.7075
  0.5739    0.5690    0.5639    0.5588    0.5535    0.5481    0.5427
  0.9919    0.9934    0.9950    0.9965    0.9980    0.9995    1.0010
  1.0044    0.9918    0.9790    0.9659    0.9526    0.9658    0.9519
  2.4353    2.4390    2.4428    2.4466    2.4503    2.4466    2.4505
 -0.1197   -0.1337   -0.1480   -0.1625   -0.1774   -0.1627   -0.1781
  2.7786    2.7776    2.7765    2.7754    2.7741    2.7754    2.7741

Columns 323 through 329

  1.9237    1.9195    1.9153    1.9108    1.9062    1.9015    1.8966
  0.7167    0.7258    0.7349    0.7438    0.7527    0.7615    0.7702
  0.5371    0.5314    0.5257    0.5198    0.5138    0.5077    0.5015
  1.0025    1.0040    1.0055    1.0069    1.0084    1.0098    1.0112
  0.9378    0.9235    0.9088    0.8940    0.8788    0.8634    0.8478
  2.4544    2.4583    2.4621    2.4659    2.4697    2.4734    2.4771
 -0.1937   -0.2095   -0.2257   -0.2421   -0.2587   -0.2756   -0.2927
  2.7726    2.7711    2.7694    2.7676    2.7656    2.7635    2.7613

Columns 330 through 336

  1.8915    1.8863    1.8810    1.8755    1.8698    1.8641    1.8581
```

```
    0.7788    0.7873    0.7958    0.8041    0.8124    0.8205    0.8286
    0.4953    0.4889    0.4824    0.4758    0.4691    0.4624    0.4555
    1.0126    1.0140    1.0154    1.0167    1.0180    1.0193    1.0205
    0.8318    0.8157    0.7993    0.7826    0.7657    0.7485    0.7311
    2.4808    2.4843    2.4879    2.4913    2.4947    2.4981    2.5013
   -0.3101   -0.3278   -0.3457   -0.3638   -0.3822   -0.4008   -0.4196
    2.7589    2.7564    2.7537    2.7508    2.7478    2.7445    2.7411

  Columns 337 through 343

    1.8521    1.8459    1.8395    1.8330    1.8264    1.8197    1.8128
    0.8365    0.8444    0.8521    0.8597    0.8672    0.8746    0.8818
    0.4485    0.4414    0.4343    0.4270    0.4197    0.4122    0.4047
    1.0217    1.0229    1.0240    1.0251    1.0262    1.0272    1.0281
    0.7134    0.6955    0.6774    0.6590    0.6403    0.6215    0.6024
    2.5044    2.5075    2.5105    2.5133    2.5161    2.5188    2.5213
   -0.4386   -0.4579   -0.4774   -0.4971   -0.5170   -0.5371   -0.5575
    2.7375    2.7337    2.7298    2.7256    2.7212    2.7166    2.7117

  Columns 344 through 350

    1.8058    1.7987    1.7915    1.7842    1.7767    1.7691    1.7614
    0.8890    0.8960    0.9029    0.9097    0.9163    0.9228    0.9292
    0.3971    0.3894    0.3816    0.3737    0.3657    0.3577    0.3495
    1.0290    1.0299    1.0307    1.0314    1.0321    1.0328    1.0333
    0.5831    0.5635    0.5438    0.5238    0.5036    0.4831    0.4625
    2.5237    2.5260    2.5281    2.5301    2.5320    2.5337    2.5353
   -0.5780   -0.5987   -0.6196   -0.6407   -0.6619   -0.6834   -0.7050
    2.7067    2.7014    2.6959    2.6901    2.6841    2.6779    2.6714

  Columns 351 through 357

    1.7536    1.7457    1.7377    1.7295    1.7213    1.7130    1.7046
    0.9354    0.9415    0.9475    0.9533    0.9590    0.9645    0.9699
    0.3413    0.3330    0.3246    0.3162    0.3076    0.2990    0.2904
    1.0338    1.0343    1.0347    1.0350    1.0352    1.0354    1.0354
    0.4417    0.4206    0.3994    0.3780    0.3563    0.3345    0.3125
    2.5367    2.5379    2.5390    2.5399    2.5406    2.5411    2.5415
   -0.7267   -0.7486   -0.7707   -0.7929   -0.8152   -0.8377   -0.8603
    2.6647    2.6576    2.6504    2.6428    2.6350    2.6269    2.6185

  Columns 358 through 361

    1.6961    1.6875    1.6788    1.6700
    0.9752    0.9803    0.9852    0.9900
    0.2816    0.2728    0.2639    0.2550
    1.0355    1.0354    1.0352    1.0350
    0.2904    0.2680    0.2455    0.2228
    2.5416    2.5416    2.5413    2.5409
   -0.8830   -0.9059   -0.9288   -0.9518
    2.6098    2.6009    2.5916    2.5820


function values = linkageAnalysis(JB,JC,JE,JF)
```

Static Analysis

```
%static force,static torque, dynamic force,
%dynamic torque, velocity of joints, angular velocity of links,
 angular accelerations of
%links, accelerations of joints, positions of joints
% Assume assembly is made out of aluminium
%coordinates of joints
A=[1.4 .485 0];
B=JB;
C=JC;
D=[.285 .055 0];
E=JE;
F=JF;
G=[.05 .2 0];
%coordinates of link's COM
Hab = [((A(1,1) + B(1,1)) / 2) ((A(1,2) + B(1,2)) / 2) 0];
Hbc = [((B(1,1) + C(1,1)) / 2) ((B(1,2) + C(1,2)) / 2) 0];
Hde = [((D(1,1) + E(1,1)) / 2) ((D(1,2) + E(1,2)) / 2) 0];
Hef = [((E(1,1) + F(1,1)) / 2) ((E(1,2) + F(1,2)) / 2) 0];

%position vectors of COM & relative points
pvHab = Hab-A;
pvHbc = Hbc-B;
pvHde = Hde-D;
pvHef = Hef-E;

%length of each link/ distance between joints
AB=norm(B-A);
BC=norm(C-B);
CD=norm(D-C);
DE=norm(E-D);
BE=norm(E-B);
EF=norm(F-E);
FG=norm(G-F);
LF=1.843; % distance between load and joint F

%position vectors
pvAB=B-A;
pvBC=C-B;
pvCD=D-C;
pvDA=A-D;
pvDE=E-D;
pvEF=F-E;
pvFG=G-F;

unit_GF=-pvFG/FG;
pvFL=unit_GF*LF;
pvGL=pvFL-pvFG; %load from G to L
L=pvGL+G; %location of load
Hlg = [((L(1,1) + G(1,1)) / 2) ((L(1,2) + G(1,2)) / 2) 0]; % location
 of COM
pvHlg = Hlg-G; % position of COM from G to Hlg
```

```
%without weight of each link considered
syms Ax Ay Bx By Cx Cy Dx Dy Ex Ey Fx Fy Gx Gy inTorque
fA=[Ax Ay 0];
fB=[Bx By 0];
fC=[Cx Cy 0];
fD=[Dx Dy 0];
fE=[Ex Ey 0];
fF=[Fx Fy 0];
fG=[Gx Gy 0];
Ta=[0 0 inTorque];

%weight of links in Newtons (assuming the link material is Al 6061 T6)
linkDensity = [0 2710 0]; % kg/m^3
linkWidth = [0 0.10 0]; % m
linkThickness = [0 0.05 0]; % m
jointDiameter = [0 0.06 0]; % m
Wab = (linkDensity .* linkWidth .* linkThickness .* AB .* -9.8); % N
Wbc = (linkDensity .* linkWidth .* linkThickness .* BC .* -9.8); % N
Wcd = (linkDensity .* linkWidth .* linkThickness .* CD .* -9.8); % N
Wde = (linkDensity .* linkWidth .* linkThickness .* DE .* -9.8); % N
Wef = (linkDensity .* linkWidth .* linkThickness .* EF .* -9.8); % N
Wfg = (linkDensity .* linkWidth .* linkThickness .* (LF + FG) .*
 -9.8); % N
Wl = [0 -200 0] ; %given weight of load in NEWTONS
```

Static Solution

```
%Link AB/1
%First equation represents sum of forces
%Second Equation represents sum of moments
eqn1=fA-fB+Wab==0;
eqn2=Ta+cross(pvHab,Wab)+cross(pvAB,-fB)==0;
%Link BC
eqn3=fB-fC+Wbc==0;
eqn4=cross(pvBC,-fC)+cross(pvHbc,Wbc)==0;
%Link DEC
eqn5=fC-fD+fE+Wde==0;
eqn6=cross(pvDE,fE)+cross(pvHde,Wde)+cross(-pvCD,fC)==0;
%Link EF
eqn7=-fE+fF+Wef==0;
eqn8=cross(pvEF,fF)+cross(pvHef,Wef)==0;
%Link FG with load L
eqn9=-fF+fG+Wfg+Wl==0;
eqn10=cross(-pvFG,-fF)+cross(pvGL,Wl)+cross(pvHlg,Wfg)==0;

staticsolution =
 (solve([eqn1,eqn2,eqn3,eqn4,eqn5,eqn6,eqn7,eqn8,eqn9,eqn10],
[Ax,Ay,Bx,By,Cx,Cy,Dx,Dy,Ex,Ey,Fx,Fy,Gx,Gy,inTorque]));

noWeightforce_Ax=double(staticsolution.Ax);
noWeightforce_Ay=double(staticsolution.Ay);
noWeightforce_Bx=double(staticsolution.Bx);
```

```
noWeightforce_By=double(staticsolution.By);
noWeightforce_Cx=double(staticsolution.Cx);
noWeightforce_Cy=double(staticsolution.Cy);
noWeightforce_Dx=double(staticsolution.Dx);
noWeightforce_Dy=double(staticsolution.Dy);
noWeightforce_Ex=double(staticsolution.Ex);
noWeightforce_Ey=double(staticsolution.Ey);
noWeightforce_Fx=double(staticsolution.Fx);
noWeightforce_Fy=double(staticsolution.Fy);
noWeightforce_Gx=double(staticsolution.Gx);
noWeightforce_Gy=double(staticsolution.Gy);
noWeighttorque_T=double(staticsolution.inTorque);

staticsolution =
 [noWeightforce_Ax;noWeightforce_Ay;noWeightforce_Bx;noWeightforce_By;noWeightforc

 noWeightforce_Dx;noWeightforce_Dy;noWeightforce_Ex;noWeightforce_Ey;noWeightforce
    noWeightforce_Gx;noWeightforce_Gy;noWeighttorque_T];
```

position analysis

```
omegaAB=[0 0 (7450/7)/3600*2*pi]; % 7450 parts per 7 hours assuming 1
 revolution is 1 part
alphaAB=[0 0 0]; % input link rotating at a constant velocity

syms omegaBCz omegaDEz omegaEFz omegaFGz alphaBCz alphaDEz alphaEFz alphaFGz
omegaBC=[0 0 omegaBCz];
omegaDE=[0 0 omegaDEz];
omegaEF=[0 0 omegaEFz];
omegaFG=[0 0 omegaFGz];
alphaBC=[0 0 alphaBCz];
alphaDE=[0 0 alphaDEz];
alphaEF=[0 0 alphaEFz];
alphaFG=[0 0 alphaFGz];

eqn11=cross(omegaAB,pvAB)+cross(omegaBC,pvBC)+cross(omegaDE,pvCD)==0;
eqn12=cross(alphaAB,pvAB)+cross(omegaAB,cross(omegaAB,pvAB))+cross(alphaBC,pvBC)+c
eqn13=cross(omegaDE,pvDE)+cross(omegaEF,pvEF)+cross(omegaFG,pvFG)==0;
eqn14=cross(alphaDE,pvDE)+cross(omegaDE,cross(omegaDE,pvDE))+cross(alphaEF,pvEF)+c

positionsolution= (solve([eqn11,eqn12,eqn13,eqn14],
[omegaBCz,omegaDEz,omegaEFz,omegaFGz,alphaBCz,alphaDEz,alphaEFz,alphaFGz]));

angvel_BCz=double(positionsolution.omegaBCz);
angvel_DEz=double(positionsolution.omegaDEz);
angvel_EFz=double(positionsolution.omegaEFz);
angvel_FGz=double(positionsolution.omegaFGz);

angacc_BCz=double(positionsolution.alphaBCz);
angacc_DEz=double(positionsolution.alphaDEz);
angacc_EFz=double(positionsolution.alphaEFz);
angacc_FGz=double(positionsolution.alphaFGz);
```

```
positionsolution = [angvel_BCz;angvel_DEz;angvel_EFz;angvel_FGz;
                    angacc_BCz;angacc_DEz;angacc_EFz;angacc_FGz;

 angvel_BCz*BC;angvel_DEz*DE;angvel_EFz*EF;angvel_FGz*FG;

 angacc_BCz*BC;angacc_DEz*DE;angacc_EFz*EF;angacc_FGz*FG];


%extra acceleration values

angvel_BC=[0 0 angvel_BCz];
angvel_DE=[0 0 angvel_DEz];
angvel_EF=[0 0 angvel_EFz];
angvel_FG=[0 0 angvel_FGz];
angacc_BC=[0 0 angacc_BCz];
angacc_DE=[0 0 angacc_DEz];
angacc_EF=[0 0 angacc_EFz];
angacc_FG=[0 0 angacc_FGz];

accH_AB=cross(alphaAB,pvHab)+cross(omegaAB,cross(omegaAB,pvHab));
accH_BC=cross(angacc_BC,pvHbc)+cross(angvel_BC,cross(angvel_BC,pvHbc));
accH_DE=cross(angacc_DE,pvHde)+cross(angvel_DE,cross(angvel_DE,pvHde));
accH_EF=cross(angacc_EF,pvHef)+cross(angvel_EF,cross(angvel_EF,pvHef));
accH_GL=cross(angacc_FG,pvHlg)+cross(angvel_FG,cross(angvel_FG,pvHlg));
```

Dynamic Analysis

```
JAB_A=1/12*(Wab(2)/-9.8)*(linkWidth(2)^2+AB^2)+(Wab(2)/-9.8)*norm(pvHab)^2;
JBC_B=1/12*(Wbc(2)/-9.8)*(linkWidth(2)^2+BC^2)+(Wbc(2)/-9.8)*norm(pvHbc)^2;
JDE_D=1/12*(Wde(2)/-9.8)*(linkWidth(2)^2+DE^2)+(Wde(2)/-9.8)*norm(pvHde)^2;
JEF_E=1/12*(Wef(2)/-9.8)*(linkWidth(2)^2+EF^2)+(Wef(2)/-9.8)*norm(pvHef)^2;
JLG_G=1/12*(Wfg(2)/-9.8)*(linkWidth(2)^2+(LF
+FG)^2)+(Wfg(2)/-9.8)*norm(pvHlg)^2;

eqn15=fA-fB+Wab==(Wab(2)/-9.8)*accH_AB;
eqn16=Ta+cross(pvHab,Wab)+cross(pvAB,-fB)==JAB_A*alphaAB;
%Link BC
eqn17=fB-fC+Wbc==(Wbc(2)/-9.8)*accH_BC;
eqn18=cross(pvBC,-fC)+cross(pvHbc,Wbc)==JBC_B*angacc_BC;
%Link DEC
eqn19=fC-fD+fE+Wde==(Wde(2)/-9.8)*accH_DE;
eqn20=cross(pvDE,fE)+cross(pvHde,Wde)+cross(-
pvCD,fC)==JDE_D*angacc_DE;
%Link EF
eqn21=-fE+fF+Wef==(Wef(2)/-9.8)*accH_EF;
eqn22=cross(pvEF,fF)+cross(pvHef,Wef)==JEF_E*angacc_EF;
%Link FG with load L
eqn23=-fF+fG+Wfg+Wl==(Wfg(2)/-9.8)*accH_GL;
eqn24=cross(-pvFG,-
fF)+cross(pvGL,Wl)+cross(pvHlg,Wfg)==JLG_G*angacc_FG;
```

```
dynamicsolution =
 (solve([eqn15,eqn16,eqn17,eqn18,eqn19,eqn20,eqn21,eqn22,eqn23,eqn24],
[Ax,Ay,Bx,By,Cx,Cy,Dx,Dy,Ex,Ey,Fx,Fy,Gx,Gy,inTorque]));

dynamicforce_Ax=double(dynamicsolution.Ax);
dynamicforce_Ay=double(dynamicsolution.Ay);
dynamicforce_Bx=double(dynamicsolution.Bx);
dynamicforce_By=double(dynamicsolution.By);
dynamicforce_Cx=double(dynamicsolution.Cx);
dynamicforce_Cy=double(dynamicsolution.Cy);
dynamicforce_Dx=double(dynamicsolution.Dx);
dynamicforce_Dy=double(dynamicsolution.Dy);
dynamicforce_Ex=double(dynamicsolution.Ex);
dynamicforce_Ey=double(dynamicsolution.Ey);
dynamicforce_Fx=double(dynamicsolution.Fx);
dynamicforce_Fy=double(dynamicsolution.Fy);
dynamicforce_Gx=double(dynamicsolution.Gx);
dynamicforce_Gy=double(dynamicsolution.Gy);
dynamictorque_T=double(dynamicsolution.inTorque);

dynamicsolution =
 [dynamicforce_Ax;dynamicforce_Ay;dynamicforce_Bx;dynamicforce_By;dynamicforce_Cx;

 dynamicforce_Dx;dynamicforce_Dy;dynamicforce_Ex;dynamicforce_Ey;dynamicforce_Fx;d
    dynamicforce_Gx;dynamicforce_Gy;dynamictorque_T];

values.staticSol = staticsolution;
values.angSol = positionsolution;
values.dynamicSol = dynamicsolution;

end
```

Function for plotting joint parameters

```
function plotJoints(jointPos,statics,angulars,dynamics)
%Plot Joint Positions
theta = 0:1:360
ax1= subplot(2,2,1);
plot(jointPos(1,:),jointPos(2,:));
title(ax1,'Joint B')
xlabel('X Position [m]')
ylabel('Y Position [m]')
ax2=  subplot(2,2,2);
plot(jointPos(3,:),jointPos(4,:));
title(ax2,'Joint C')
xlabel('X Position [m]')
ylabel('Y Position [m]')
ax3=  subplot(2,2,3);
plot(jointPos(5,:),jointPos(6,:));
title(ax3,'Joint E')
xlabel('X Position [m]')
ylabel('Y Position [m]')
ax4=  subplot(2,2,4);
```

```
plot(jointPos(7,:),jointPos(8,:));
title(ax4,'Joint F')
xlabel('X Position [m]')
ylabel('Y Position [m]')

%Plot Static Forces/Torque
figure('name','Static Joint Forces/Torque');
ax1= subplot(3,3,1);
plot(theta,statics(1,:),theta,statics(2,:));
title(ax1,'Forces on Joint A')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,2);
plot(theta,statics(3,:),theta,statics(4,:));
title(ax1,'Forces on Joint B')
legend('X Force','Y Force','Location','northeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,3);
plot(theta,statics(5,:),theta,statics(6,:));
title(ax1,'Forces on Joint C')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,4);
plot(theta,statics(7,:),theta,statics(8,:));
title(ax1,'Forces on Joint D')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,5);
plot(theta,statics(9,:),theta,statics(10,:));
title(ax1,'Forces on Joint E')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,6);
plot(theta,statics(11,:),theta,statics(12,:));
title(ax1,'Forces on Joint F')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,7);
plot(theta,statics(13,:),theta,statics(14,:));
title(ax1,'Forces on Joint G')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,8);
plot(theta,statics(15,:));
title(ax1,'Torque on Joint A')
legend('Torque','Location','southeast');
xlabel('Angular Displacement [deg]')
```

```
ylabel('Torque [N-m]')

%Dynamic Graphs
figure('name','Dynamic Joint Forces/Torque');
ax1= subplot(3,3,1);
plot(theta,dynamics(1,:),theta,dynamics(2,:));
title(ax1,'Forces on Joint A')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,2);
plot(theta,dynamics(3,:),theta,dynamics(4,:));
title(ax1,'Forces on Joint B')
legend('X Force','Y Force','Location','northeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,3);
plot(theta,dynamics(5,:),theta,dynamics(6,:));
title(ax1,'Forces on Joint C')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,4);
plot(theta,dynamics(7,:),theta,dynamics(8,:));
title(ax1,'Forces on Joint D')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,5);
plot(theta,dynamics(9,:),theta,dynamics(10,:));
title(ax1,'Forces on Joint E')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,6);
plot(theta,dynamics(11,:),theta,dynamics(12,:));
title(ax1,'Forces on Joint F')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,7);
plot(theta,dynamics(13,:),theta,dynamics(14,:));
title(ax1,'Forces on Joint G')
legend('X Force','Y Force','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Force [N]')
ax1= subplot(3,3,8);
plot(theta,dynamics(15,:));
title(ax1,'Torque on Joint A')
legend('Torque','Location','southeast');
xlabel('Angular Displacement [deg]')
ylabel('Torque [N-m]')

%Angular Accel/Velocity Graphs
```

```
figure('name','Angular Accelerations and Velocities');

%Plot velocities
ax1= subplot(2,4,1);
plot(theta,angulars(1,:));
title(ax1,'Angular Vel of link BC')
xlabel('Angular Displacement [deg]')
ylabel('Angular Velocity [rad/s]')
ax1= subplot(2,4,2);
plot(theta,angulars(1,:));
title(ax1,'Angular Vel of link DE')
xlabel('Angular Displacement [deg]')
ylabel('Angular Velocity [rad/s]')
ax1= subplot(2,4,3);
plot(theta,angulars(3,:));
title(ax1,'Angular Vel of link EF')
xlabel('Angular Displacement [deg]')
ylabel('Angular Velocity [rad/s]')
ax1= subplot(2,4,4);
plot(theta,angulars(4,:));
title(ax1,'Angular Vel of link FG')
xlabel('Angular Displacement [deg]')
ylabel('Angular Velocity [rad/s]')

%Plot accelerations
ax1= subplot(2,4,5);
plot(theta,angulars(5,:));
title(ax1,'Angular Accel of link BC')
xlabel('Angular Displacement [deg]')
ylabel('Angular Acceleration [rad/s^2]')
ax1= subplot(2,4,6);
plot(theta,angulars(6,:));
title(ax1,'Angular Accel of link DE')
xlabel('Angular Displacement [deg]')
ylabel('Angular Acceleration [rad/s^2]')
ax1= subplot(2,4,7);
plot(theta,angulars(7,:));
title(ax1,'Angular Accel of link EF')
xlabel('Angular Displacement [deg]')
ylabel('Angular Acceleration [rad/s^2]')
ax1= subplot(2,4,8);
plot(theta,angulars(8,:));
title(ax1,'Angular Accel of link FG')
xlabel('Angular Displacement [deg]')
ylabel('Angular Acceleration [rad/s^2]')

%Linear Accel/Velocity Graphs
figure('name','Linear Accelerations and Velocities');
ax1= subplot(2,4,1);
plot(theta,angulars(9,:));
title(ax1,'Linear Vel of link BC')
xlabel('Angular Displacement [deg]')
ylabel('Linear Velocity [m/s]')
ax1= subplot(2,4,2);
```

```
plot(theta,angulars(10,:));
title(ax1,'Linear Vel of link DE')
xlabel('Angular Displacement [deg]')
ylabel('Linear Velocity [m/s]')
ax1= subplot(2,4,3);
plot(theta,angulars(11,:));
title(ax1,'Linear Vel of link EF')
xlabel('Angular Displacement [deg]')
ylabel('Linear Velocity [m/s]')
ax1= subplot(2,4,4);
plot(theta,angulars(12,:));
title(ax1,'Linear Vel of link FG')
xlabel('Angular Displacement [deg]')
ylabel('Linear Velocity [m/s]')

%Plot acceleration
ax1= subplot(2,4,5);
plot(theta,angulars(13,:));
title(ax1,'Linear Accel of link BC')
xlabel('Angular Displacement [deg]')
ylabel('Linear Acceleration [m/s^2]')
ax1= subplot(2,4,6);
plot(theta,angulars(14,:));
title(ax1,'Linear Accel of link DE')
xlabel('Angular Displacement [deg]')
ylabel('Linear Acceleration [m/s^2]')
ax1= subplot(2,4,7);
plot(theta,angulars(15,:));
title(ax1,'Linear Accel of link EF')
xlabel('Angular Displacement [deg]')
ylabel('Linear Acceleration [m/s^2]')
ax1= subplot(2,4,8);
plot(theta,angulars(16,:));
title(ax1,'Linear Accel of link FG')
xlabel('Angular Displacement [deg]')
ylabel('Linear Acceleration [m/s^2]')

end


theta =

  Columns 1 through 13

     0     1     2     3     4     5     6     7     8     9    10
 11    12

  Columns 14 through 26

    13    14    15    16    17    18    19    20    21    22    23
 24    25

  Columns 27 through 39
```

```
   26    27    28    29    30    31    32    33    34    35    36
37    38

 Columns 40 through 52

   39    40    41    42    43    44    45    46    47    48    49
50    51

 Columns 53 through 65

   52    53    54    55    56    57    58    59    60    61    62
63    64

 Columns 66 through 78

   65    66    67    68    69    70    71    72    73    74    75
76    77

 Columns 79 through 91

   78    79    80    81    82    83    84    85    86    87    88
89    90

 Columns 92 through 104

   91    92    93    94    95    96    97    98    99   100   101
102   103

 Columns 105 through 117

  104   105   106   107   108   109   110   111   112   113   114
115   116

 Columns 118 through 130

  117   118   119   120   121   122   123   124   125   126   127
128   129

 Columns 131 through 143

  130   131   132   133   134   135   136   137   138   139   140
141   142

 Columns 144 through 156

  143   144   145   146   147   148   149   150   151   152   153
154   155

 Columns 157 through 169

  156   157   158   159   160   161   162   163   164   165   166
167   168

 Columns 170 through 182
```

```
  169   170   171   172   173   174   175   176   177   178   179
180   181

 Columns 183 through 195

  182   183   184   185   186   187   188   189   190   191   192
193   194

 Columns 196 through 208

  195   196   197   198   199   200   201   202   203   204   205
206   207

 Columns 209 through 221

  208   209   210   211   212   213   214   215   216   217   218
219   220

 Columns 222 through 234

  221   222   223   224   225   226   227   228   229   230   231
232   233

 Columns 235 through 247

  234   235   236   237   238   239   240   241   242   243   244
245   246

 Columns 248 through 260

  247   248   249   250   251   252   253   254   255   256   257
258   259

 Columns 261 through 273

  260   261   262   263   264   265   266   267   268   269   270
271   272

 Columns 274 through 286

  273   274   275   276   277   278   279   280   281   282   283
284   285

 Columns 287 through 299

  286   287   288   289   290   291   292   293   294   295   296
297   298

 Columns 300 through 312

  299   300   301   302   303   304   305   306   307   308   309
310   311
```

```
 Columns 313 through 325

  312   313   314   315   316   317   318   319   320   321   322
323   324

 Columns 326 through 338

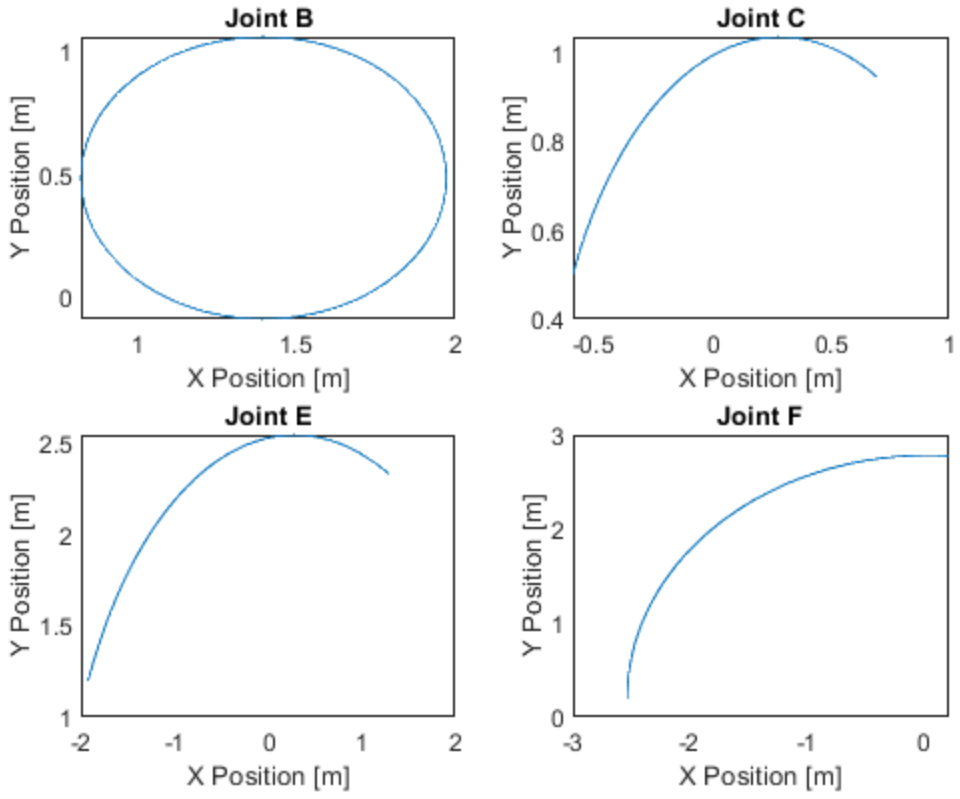
  325   326   327   328   329   330   331   332   333   334   335
336   337

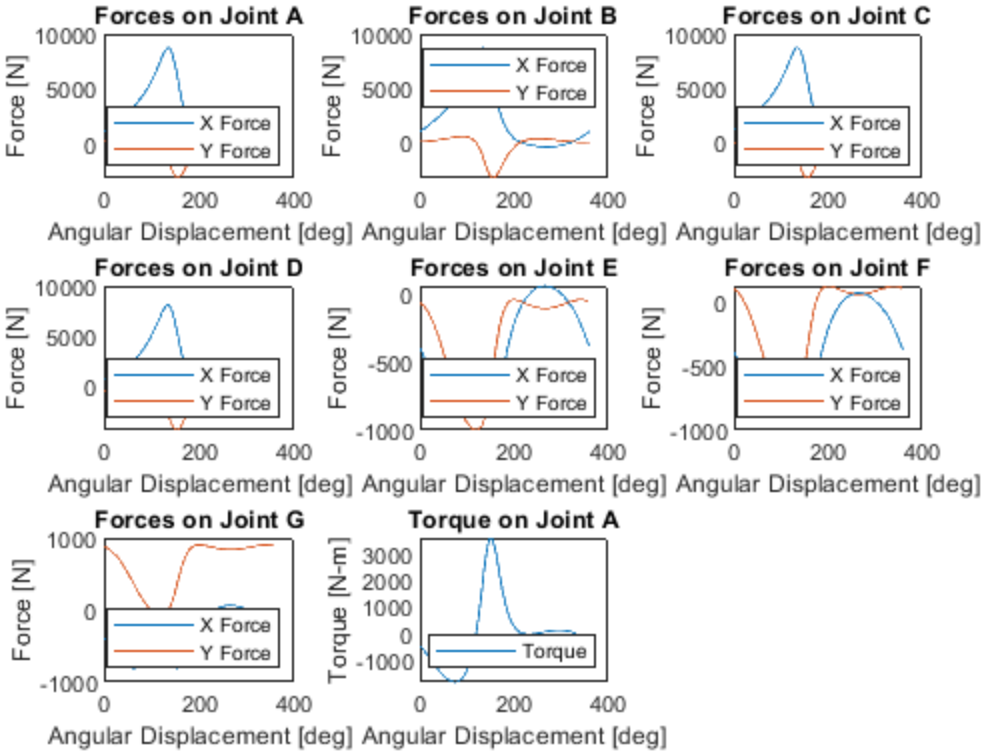
 Columns 339 through 351

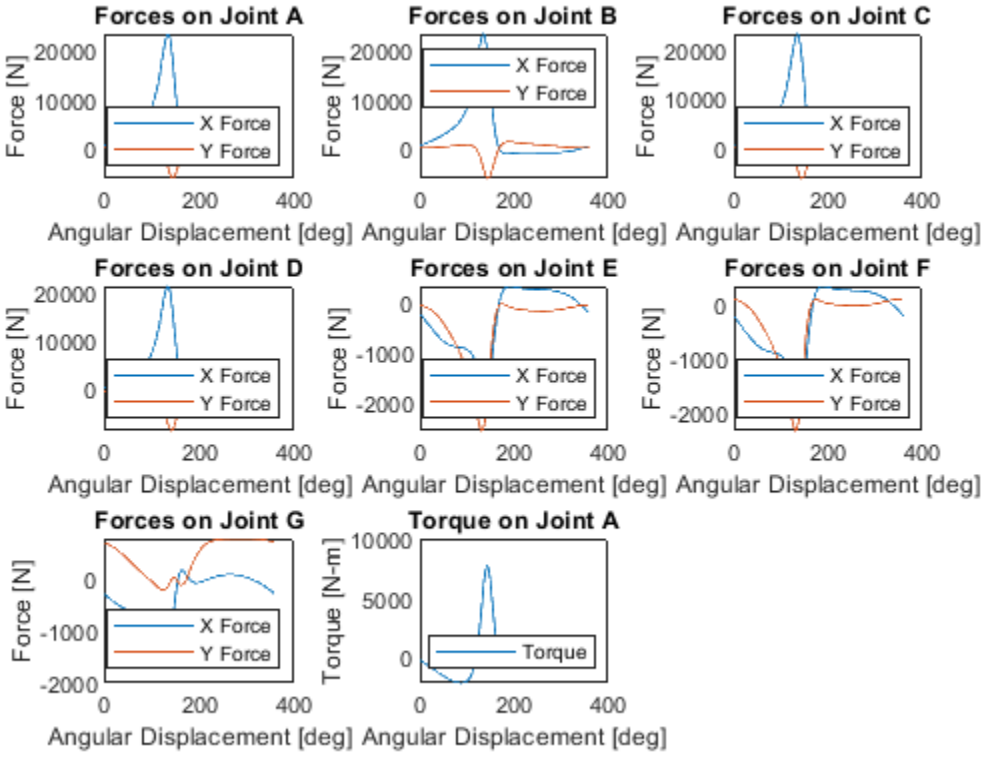
  338   339   340   341   342   343   344   345   346   347   348
349   350

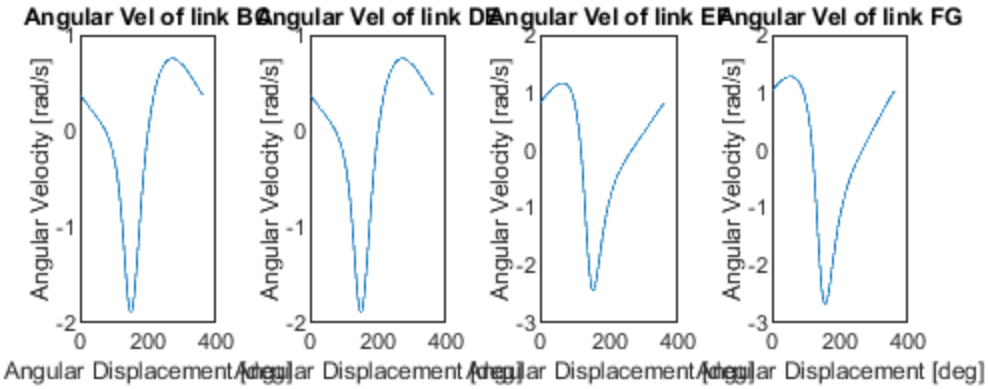
 Columns 352 through 361

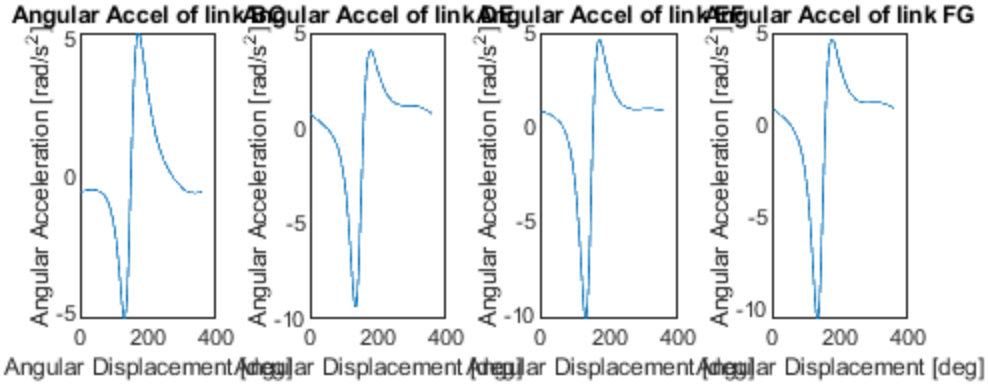
  351   352   353   354   355   356   357   358   359   360
```

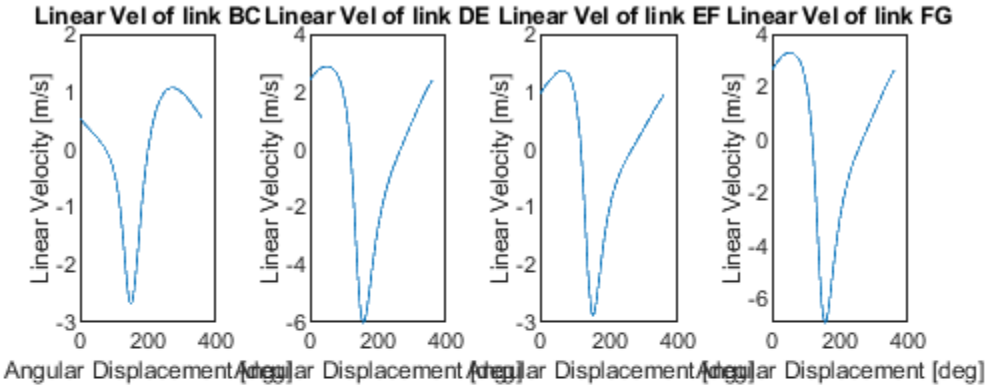


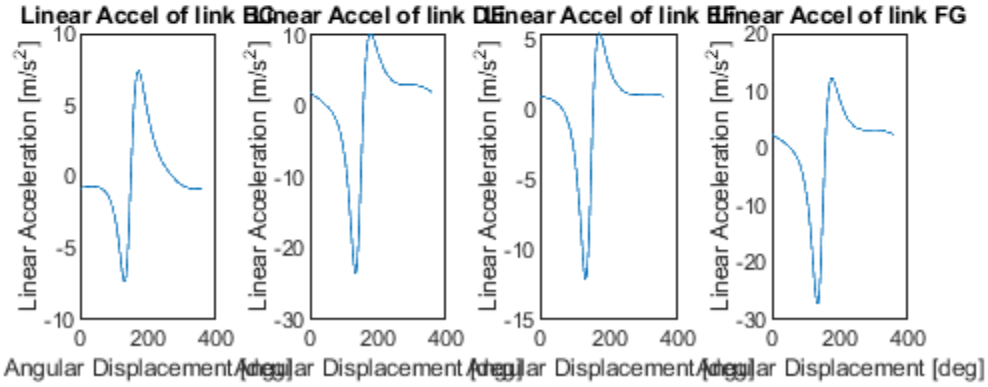

Forces on Joint A
Forces on Joint B
Forces on Joint C
Forces on Joint D
Forces on Joint E
Forces on Joint F
Forces on Joint G
Torque on Joint A
Force [N]
Torque [N-m]
X Force
Y Force
Torque
Angular Displacement [deg]


Forces on Joint A
Forces on Joint B
Forces on Joint C
Forces on Joint D
Forces on Joint E
Forces on Joint F
Forces on Joint G
Torque on Joint A
Force [N]
Torque [N-m]
X Force
Y Force
Torque
Angular Displacement [deg]


Angular Vel of link BC
Angular Vel of link DE
Angular Vel of link EF
Angular Vel of link FG
Angular Velocity [rad/s]
Angular Displacement [deg]


Angular Accel of link BC
Angular Accel of link DE
Angular Accel of link EF
Angular Accel of link FG
Angular Acceleration [rad/s^2]
Angular Displacement [deg]


Linear Vel of link BC
Linear Vel of link DE
Linear Vel of link EF
Linear Vel of link FG
Linear Velocity [m/s]
Angular Displacement [deg]


Linear Accel of link BC
Linear Accel of link DE
Linear Accel of link EF
Linear Accel of link FG
Linear Acceleration [m/s^2]
Angular Displacement [deg]

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