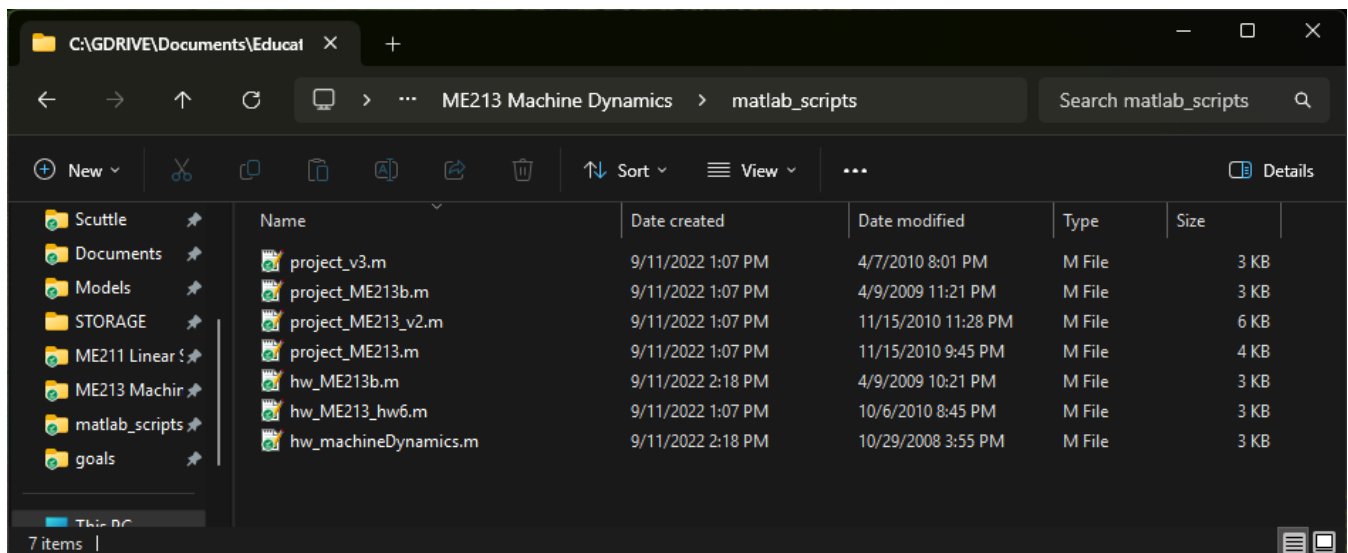


Matlab Scripts Exported to PDF
From ME213 Machine Dynamics directory.
David Malaway 2025.05

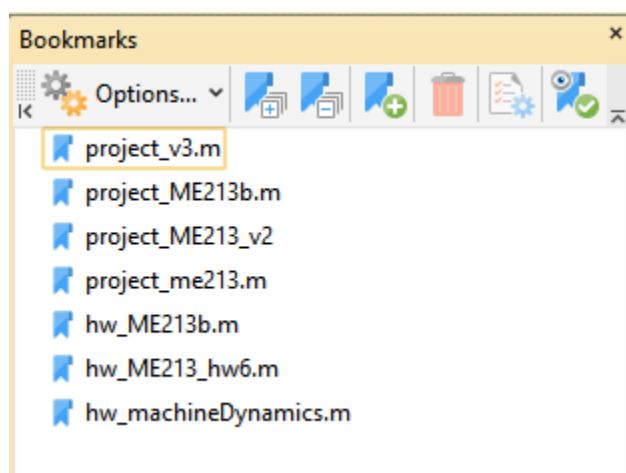
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```

1   format short e;
2   R1=1;
3   R2=2.17;
4   R3=2.067;
5   R4=2.310;
6   R5=5.4;
7   theta2=[0:pi/360:2*pi];
8   omega2=zeros(size(theta2));
9   theta3=zeros(size(theta2));
10  theta4=zeros(size(theta2));
11  th4=zeros(size(theta2));
12  omega3=zeros(size(theta2));
13  omega4=zeros(size(theta2));
14  omega5=zeros(size(theta2));
15  alpha3=zeros(size(theta2));
16  alpha4=zeros(size(theta2));
17  alpha6=zeros(size(theta2));
18  alpha2=0;
19  n=max(size(theta2));
20  for j=1:n;
21      omega2(j)=sqrt(4+2*alpha2*theta2(j));
22  end
23  for k=1:n;
24      K1=R1/R2;
25      K2=R1/R4;
26      K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
27      K4=R1/R3;
28      K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
29      D=(1+K4)*cos(theta2(k))+K5-K1;
30      F=(K4-1)*cos(theta2(k))+K5+K1;
31      A=cos(theta2(k))-K1-K2*cos(theta2(k))+K3;
32      B=-2*sin(theta2(k));
33      C=K1-(K2+1)*cos(theta2(k))+K3;
34      z1=(-B+sqrt(B^2-4*A*C))/(2*A);
35      w1=(-B+sqrt(B^2-4*D*F))/(2*D);
36      L1=2*z1/(1+z1^2);
37      M1=(1-z1^2)/(1+z1^2);
38      N1=2*w1/(1+w1^2);
39      P1=(1-w1^2)/(1+w1^2);
40      theta4(k)=atan2(L1,M1);
41      theta3(k)=atan2(N1,P1);
42
43  end
44  for k=1:n;
45      Q=[R3*cos(theta3(k)) -R4*cos(theta4(k));R3*sin(theta3(k)) -R4*sin(theta4(k))];
46      h=[-R2*omega2(k)*cos(theta2(k));-R2*omega2(k)*sin(theta2(k))];
47      z=inv(Q)*h;
48      omega3(k)=z(1);
49      omega4(k)=z(2);
50      p1=[-R2*alpha2*cos(theta2(k));-R2*alpha2*sin(theta2(k))];
51      p2=[R2*omega2(k)^2*sin(theta2(k));-R2*omega2(k)^2*cos(theta2(k))];
52      p3=[R3*omega3(k)^2*sin(theta3(k));-R3*omega3(k)^2*cos(theta3(k))];
53      p4=[-R4*omega4(k)^2*sin(theta4(k));R4*omega4(k)^2*cos(theta4(k))];
54      f=p1+p2+p3+p4;
55      l=inv(Q)*f;
56      alpha3(k)=l(1);
57      alpha4(k)=l(2);
58  end
59
60  for p=1:n;
61      th4(p)=theta4(p)-(102/180)*pi;
62  end
63
64  Vc=zeros(size(theta2));
65  theta5=zeros(size(theta2));
66  Dist=zeros(size(theta2));
67  Ac=zeros(size(theta2));
68  alpha5=zeros(size(theta2));
69  for k=1:n;

```

```

70     T=sqrt(R5^2-R4^2*(sin(th4(k))^2));
71     theta5(k)=atan2(R4*sin(th4(k)),-T);
72 end
73 Vcdeg=zeros(size(theta2));
74 for k=1:n;
75     Q=[R5*sin(theta5(k)) -1;-R5*cos(theta5(k)) +0];
76     h=[R4*omega4*sin(th4(k));-R4*omega4*sin(th4(k))];
77     z=inv(Q)*h;
78     omega5(k)=z(1);
79     Vc(k)=z(2);
80     p1=[R4*alpha4(k)*sin(th4(k));R4*omega4(k)^2*cos(th4(k))];
81     p2=[R4*omega4(k)^2*cos(th4(k));-R4*alpha4(k)*cos(th4(k))];
82     p3=[-R5*omega5(k)^2*cos(theta5(k));-R5*omega5(k)^2*sin(theta5(k))];
83     f=p1+p2+p3;
84     l=inv(Q)*f;
85     alpha5(k)=l(1);
86     Ac(k)=l(2);
87 end
88
89
90
91 %plot(theta2,Vc,'-',theta2,Ac,'-',theta2,omega4,'-',theta2,alpha4,'-');
92 %plot(theta2,Vc);
93 %xlabel('Theta 2');
94 %ylabel('Velocity');
95 %title('Velocity vs. Theta 2');
96 %plot(theta2,Ac);
97 %xlabel('Theta 2');
98 %ylabel('Acceleration');
99 %title('Acceleration vs. Theta 2');
100 %plot(theta2,omega4);
101 %xlabel('Theta 2');
102 %ylabel('Omega 4');
103 %title('Omega 4 vs. Theta 2');
104 plot(theta2,alpha4);
105 xlabel('Theta 2');
106 ylabel('Alpha 4');
107 title('Alpha 4 vs. Theta 2');
108
109
110
111

```

```

1   format short e;
2   J=zeros(2,2);
3
4   d=7.487;
5   a=9.174;
6   b=12.971;
7   c=9.573;
8   p=15;
9   MINVAL = -26;
10  MAXVAL = -20.55;
11  delta = 0.25;
12
13  Maxits=500;
14  Tol=1.0e-6;
15
16  X=[4;2];
17
18  for i=MINVAL:delta:MAXVAL;
19
20      theta2=i*(pi/180);
21
22  for i=1:Maxits;
23      theta3=X(1);
24      theta4=X(2);
25
26      F1=a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d;
27      F2=a*sin(theta2)+b*sin(theta3)-c*sin(theta4);
28
29      J(1,1)=-b*sin(theta3);
30      J(1,2)=c*sin(theta4);
31      J(2,1)=b*cos(theta3);
32      J(2,2)=-c*cos(theta4);
33
34      deltaX=inv(J)*[-F1;-F2];
35      X=X+deltaX;
36
37      theta3=X(1);
38      theta4=X(2);
39
40      F1check=abs(a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d);
41      F2check=abs(a*sin(theta2)+b*sin(theta3)-c*sin(theta4));
42
43      Fmax=max([F1check,F2check]);
44      if Fmax<Tol
45          break
46      end
47  end
48
49  if i<Maxits
50      fprintf('\n')
51      fprintf('***** Newton Raphson Method *****\n\n');
52      fprintf('Position Analysis:\n');
53      fprintf('Inputs:\n');
54      fprintf('a = %-2g mm  b = %-2g mm  c = %-2g mm  d = %-2g mm  theta2 = %-2.2f degrees'
55      ,a,b,c,d,theta2*180/pi);
56      fprintf('\nIterations=%-5g\n',i);
57      fprintf('Outputs:\n');
58      fprintf('theta3 = %-6.2f degrees',X(1)*180/pi);
59      fprintf('theta4 = %-6.2f degrees\n',X(2)*180/pi);
60  else
61      fprintf('we did not converge!\n');
62  end
63
64  theta3=X(1);
65  theta4=X(2);
66
67  w2=2;
68
69  w3 = (a*sin(theta4 - theta2))/(b*sin(theta3-theta4))*w2;
70  w4 = (a*sin(theta2 - theta3))/(c*sin(theta4-theta3))*w2;

```

```

69
70 fprintf('\nVelocity Analysis:\n');
71 fprintf('Inputs:\n');
72 fprintf('w2 = %-2g rad/s\n',w2);
73 fprintf('Outputs:\n');
74 fprintf('w3 = %-6.2f rad/s',w3);
75 fprintf('  w4 = %-6.2f rad/s\n',w4);
76
77 A = c*sin(theta4);
78 B = b*sin(theta3);
79 C = a*(w2^2)*cos(theta2)+b*(w3^2)*cos(theta3)-c*(w4^2)*cos(theta4);
80 D = c*cos(theta4);
81 E = b*cos(theta3);
82 F = -a*(w2^2)*sin(theta2)-b*(w3^2)*sin(theta3)+c*(w4^2)*sin(theta4);
83
84 a3 = (C*D-A*F)/(A*E-B*D);
85 a4 = (C*E-B*F)/(A*E-B*D);
86
87 Vax = a*w2*-sin(theta2);
88 Vpax = p*w3*-sin(theta3);
89
90 Vay = a*w2*cos(theta2);
91 Vpay = p*w3*cos(theta3);
92
93 Vpx = Vax+Vpax;
94 Vpy = Vay+Vpay;
95
96 Vp = sqrt(Vpx^2+Vpy^2);
97
98 Aax = -a*w2^2*cos(theta2);
99 Apax = p*a3*-sin(theta3)-p*w3^2*cos(theta3);
100
101 Aay = -a*w2^2*sin(theta2);
102 Apay = p*a3*cos(theta3)-p*w3^2*sin(theta3);
103
104 Apx = Aax+Apax;
105 Apy = Aay+Apay;
106
107 Ap = sqrt(Apx^2+Apy^2);
108
109 fprintf('\nAcceleration Analysis:');
110 fprintf('\nOutputs:\n');
111 fprintf('a3 = %-6.2f rad/s^2',a3);
112 fprintf('  a4 = %-6.2f rad/s^2\n\n',a4);
113 fprintf('Vp = %-6.2f in/s\n',Vp);
114 fprintf('Ap = %-6.2f in/s\n',Ap);
115
116 end
117

```

```

1   format long e;
2   R1=2.22;
3   R2=1;
4   R3=2.067;
5   R4=2.33;
6   FPX=0;
7   FPY=-100;
8   M2=9.75;
9   M3=113.6331;
10  M4=22.7175;
11  IG2=.8145;
12  IG3=51.7916;
13  IG4=10.2823;
14  T4=0;
15
16
17  TH2=0:0.001:2*pi;
18  TH3=zeros(size(TH2));
19  TH4=zeros(size(TH2));
20  TH31=zeros(size(TH2));
21  TH41=zeros(size(TH2));
22  TH32=zeros(size(TH2));
23  TH42=zeros(size(TH2));
24  OM2=zeros(size(TH2));
25  OM3=zeros(size(TH2));
26  OM4=zeros(size(TH2));
27  AL3=zeros(size(TH2));
28  AL4=zeros(size(TH2));
29
30  A=zeros(2,2);
31  g=zeros(2,1);
32  q=zeros(2,1);
33  B=zeros(9,9);
34  H=zeros(9,1);
35  psi=(31-12.401)*(pi/180);
36  d=(1.6470);
37
38  RPX=zeros(size(TH2));
39  RPY=zeros(size(TH2));
40
41
42  R12X=zeros(size(TH2));
43  R12Y=zeros(size(TH2));
44  R32X=zeros(size(TH2));
45  R32Y=zeros(size(TH2));
46  R23X=zeros(size(TH2));
47  R23Y=zeros(size(TH2));
48  R43X=zeros(size(TH2));
49  R43Y=zeros(size(TH2));
50  R34X=zeros(size(TH2));
51  R34Y=zeros(size(TH2));
52  R14X=zeros(size(TH2));
53  R14Y=zeros(size(TH2));
54
55  F12X=zeros(size(TH2));
56  F12Y=zeros(size(TH2));
57  F32X=zeros(size(TH2));
58  F32Y=zeros(size(TH2));
59  F43X=zeros(size(TH2));
60  F43Y=zeros(size(TH2));
61  F14X=zeros(size(TH2));
62  F14Y=zeros(size(TH2));
63  T12=zeros(size(TH2));
64
65  AG2X=zeros(size(TH2));
66  AG2Y=zeros(size(TH2));
67  AG3X=zeros(size(TH2));
68  AG3Y=zeros(size(TH2));
69  AG4X=zeros(size(TH2));

```

```

70 AG4Y=zeros(size (TH2));
71
72
73 n=max(size (TH2));
74
75 for k=1:n;
76     theta2=TH2(k);
77     K1=R1/R2;
78     K2=R1/R4;
79     K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
80     K4=R1/R3;
81     K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
82     D=(1+K4)*cos(theta2)+K5-K1;
83     F=(K4-1)*cos(theta2)+K5+K1;
84     A=cos(theta2)-K1-K2*cos(theta2)+K3;
85     B=-2*sin(theta2);
86     C=K1-(K2+1)*cos(theta2)+K3;
87     z1=(-B+sqrt(B^2-4*A*C))/(2*A);
88     z2=(-B-sqrt(B^2-4*A*C))/(2*A);
89     w1=(-B+sqrt(B^2-4*D*F))/(2*D);
90     w2=(-B-sqrt(B^2-4*D*F))/(2*D);
91     L1=2*z1/(1+z1^2);
92     M1=(1-z1^2)/(1+z1^2);
93     L2=2*z2/(1+z2^2);
94     M2=(1-z2^2)/(1+z2^2);
95     N1=2*w1/(1+w1^2);
96     P1=(1-w1^2)/(1+w1^2);
97     N2=2*w2/(1+w2^2);
98     P2=(1-w2^2)/(1+w2^2);
99     TH41(k)=atan2(L1,M1);
100    TH42(k)=atan2(L2,M2);
101    TH31(k)=atan2(N1,P1);
102    TH32(k)=atan2(N2,P2);
103 end
104
105 OM2(1)=40;
106 AL2=-2;
107
108 for k=2:n;
109     OM2(k)=sqrt(OM2(1)^2+2*AL2*TH2(k));
110 end
111
112 for k=1:n;
113     TH3(k)=TH32(k);
114     TH4(k)=TH42(k);
115 end
116 for k=1:n;
117     A(1,1)=R2*cos(TH3(k));
118     A(1,2)=-R4*cos(TH4(k));
119     A(2,1)=R3*sin(TH3(k));
120     A(2,2)=-R4*sin(TH4(k));
121     g(1)=-R2*OM2(k)*cos(TH2(k));
122     g(2)=-R2*OM2(k)*sin(TH2(k));
123     h=A\g;
124     OM3(k)=h(1);
125     OM4(k)=h(2);
126     q(1)=-R2*AL2*cos(TH2(k))+R2*OM2(k)^2*sin(TH2(k))+R3*OM3(k)^2*sin(TH3(k))-R4*OM4(k)^2*
sin(TH4(k));
127     q(2)=-R2*AL2*sin(TH2(k))-R2*OM2(k)^2*cos(TH2(k))-R3*OM3(k)^2*cos(TH3(k))+R4*OM4(k)^2*
cos(TH4(k));
128     p=A\q;
129
130     AL3(k)=p(1);
131     AL4(k)=p(2);
132
133     R12X(k)=-R2*cos(TH2(k))/2;
134     R12Y(k)=-R2*sin(TH2(k))/2;
135     R32X(k)=-R12X(k);
136     R32Y(k)=-R12Y(k);

```

```

137 R23X(k)=-d*cos (TH3 (k)-psi) ;
138 R23Y(k)=-d*sin (TH3 (k)-psi) ;
139 R43X(k)=R3*cos (TH3 (k) )+R23X(k) ;
140 R43Y(k)=R3*sin (TH3 (k) )+R23Y(k) ;
141 R34X(k)=.5*R4*cos (TH4 (k) ) ;
142 R34Y(k)=.5*R4*sin (TH4 (k) ) ;
143 R14X(k)=-R34X(k) ;
144 R14Y(k)=-R34Y(k) ;
145
146 AG2X(k)=AL2*R12Y(k)+OM2(k)^2*R12X(k) ;
147 AG2Y(k)=AL2*R12X(k)+OM2(k)^2*R12Y(k) ;
148
149 AG3X(k)=AL2*-(R32Y(k)-R12Y(k))-OM2(k)^2*(R32X(k)-R12X(k))-AL3(k)*-R23Y(k)+OM3(k)^2*
R23X(k) ;
150 AG3Y(k)=AL2*(R32X(k)-R12X(k))-OM2(k)^2*(R32Y(k)-R12Y(k))-AL3(k)*R23X(k)+OM3(k)^2*R23Y
(k) ;
151 AG4X(k)=AL4(k)*R14Y(k)+OM4(k)^2*R14X(k) ;
152 AG4Y(k)=-AL4(k)*R14X(k)+OM4(k)^2*R14Y(k) ;
153
154 RPX(k)=3.06*cos (TH3 (k)-psi)-R23X(k) ;
155 RPY(k)=3.06*sin (TH3 (k)-psi)-R23Y(k) ;
156
157
158 B(1,1)=(1) ;
159 B(1,2)=(0) ;
160 B(1,3)=(1) ;
161 B(1,4)=(0) ;
162 B(1,5)=(0) ;
163 B(1,6)=(0) ;
164 B(1,7)=(0) ;
165 B(1,8)=(0) ;
166 B(1,9)=(0) ;
167 B(2,1)=(0) ;
168 B(2,2)=(1) ;
169 B(2,3)=(0) ;
170 B(2,4)=(1) ;
171 B(2,5)=(0) ;
172 B(2,6)=(0) ;
173 B(2,7)=(0) ;
174 B(2,8)=(0) ;
175 B(2,9)=(0) ;
176 B(3,1)=(-R12Y(k)) ;
177 B(3,2)=(R12X(k)) ;
178 B(3,3)=(-R32Y(k)) ;
179 B(3,4)=(R32X(k)) ;
180 B(3,5)=(0) ;
181 B(3,6)=(0) ;
182 B(3,7)=(0) ;
183 B(3,8)=(0) ;
184 B(3,9)=(1) ;
185 B(4,1)=(0) ;
186 B(4,2)=(0) ;
187 B(4,3)=(-1) ;
188 B(4,4)=(0) ;
189 B(4,5)=(1) ;
190 B(4,6)=(0) ;
191 B(4,7)=(0) ;
192 B(4,8)=(0) ;
193 B(4,9)=(0) ;
194 B(5,1)=(0) ;
195 B(5,2)=(0) ;
196 B(5,3)=(0) ;
197 B(5,4)=(-1) ;
198 B(5,5)=(0) ;
199 B(5,6)=(1) ;
200 B(5,7)=(0) ;
201 B(5,8)=(0) ;
202 B(5,9)=(0) ;
203 B(6,1)=(0) ;

```



```

204     B(6,2)=(0);
205     B(6,3)=(-R23Y(k));
206     B(6,4)=(-R23X(k));
207     B(6,5)=(-R43Y(k));
208     B(6,6)=(R43X(k));
209     B(6,7)=(0);
210     B(6,8)=(0);
211     B(6,9)=(0);
212     B(7,1)=(0);
213     B(7,2)=(0);
214     B(7,3)=(0);
215     B(7,4)=(0);
216     B(7,5)=(-1);
217     B(7,6)=(0);
218     B(7,7)=(1);
219     B(7,8)=(0);
220     B(7,9)=(0);
221     B(8,1)=(0);
222     B(8,2)=(0);
223     B(8,3)=(0);
224     B(8,4)=(0);
225     B(8,5)=(0);
226     B(8,6)=(-1);
227     B(8,7)=(0);
228     B(8,8)=(1);
229     B(8,9)=(0);
230     B(9,1)=(0);
231     B(9,2)=(0);
232     B(9,3)=(0);
233     B(9,4)=(0);
234     B(9,5)=(R34Y(k));
235     B(9,6)=(-R34X(k));
236     B(9,7)=(-R14Y(k));
237     B(9,8)=(R14X(k));
238     B(9,9)=(0);
239
240     H(1,1)=(M2*AG2X(k));
241     H(1,2)=(M2*AG2Y(k));
242     H(1,3)=(IG2*AL2);
243     H(1,4)=(M3*AG4X(k)-FPX);
244     H(1,5)=(M3*AG4Y(k)-FPY);
245
246     H(1,6)=(IG3*AL3(k)-RPX(k)*FPY+RPY(k)*FPX);
247     H(1,7)=(M4*AG4X(k));
248     H(1,8)=(M4*AG4Y(k));
249     H(1,9)=(IG4*AL4(k)-T4);
250
251
252 end
253
254
255
256 %Plot (TH2,Vc, '-', TH2,Ac, '-', TH2,OM4, '-', TH2,AL4, '-');
257 %Plot (TH2,Vc);
258 %xlabel('TH 2');
259 %ylabel('Velocity');
260 %title('Velocity vs. TH 2');
261 %Plot (TH2,Ac);
262 %xlabel('TH 2');
263 %ylabel('Acceleration');
264 %title('Acceleration vs. TH 2');
265 %Plot (TH2,OM4);
266 %xlabel('TH 2');
267 %ylabel('OM 4');
268 %title('OM 4 vs. TH 2');
269
270 %Plot (TH2,AL4);
271 %xlabel('TH 2');
272 %ylabel('AL 4');

```

```
273 %title('AL 4 vs. TH 2');
```

```

1   format long e;
2   R1=2.22;
3   R2=1;
4   R3=2.06;
5   R4=2.33;
6   TH2=0:0.001:2*pi;
7   TH3=zeros(size(TH2));
8   TH4=zeros(size(TH2));
9   TH31=zeros(size(TH2));
10  TH41=zeros(size(TH2));
11  TH32=zeros(size(TH2));
12  TH42=zeros(size(TH2));
13  OM2=zeros(size(TH2));
14  OM3=zeros(size(TH2));
15  OM4=zeros(size(TH2));
16  AL3=zeros(size(TH2));
17  AL4=zeros(size(TH2));
18  A=zeros(2,2);
19  g=zeros(2,1);
20  q=zeros(2,1);
21  B=zeros(9,9);
22  H=zeros(9,1);
23  psi=(31-12.401)*(pi/180);
24  d=(1.6470);
25  R12X=zeros(size(TH2));
26  R12Y=zeros(size(TH2));
27  R32X=zeros(size(TH2));
28  R32Y=zeros(size(TH2));
29  R23X=zeros(size(TH2));
30  R23Y=zeros(size(TH2));
31  R43X=zeros(size(TH2));
32  R43Y=zeros(size(TH2));
33  R34X=zeros(size(TH2));
34  R34Y=zeros(size(TH2));
35  R14X=zeros(size(TH2));
36  R14Y=zeros(size(TH2));
37
38
39  n=max(size(TH2));
40  for k=1:n;
41      theta2=TH2(k);
42      K1=R1/R2;
43      K2=R1/R4;
44      K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
45      K4=R1/R3;
46      K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
47      D=(1+K4)*cos(theta2)+K5-K1;
48      F=(K4-1)*cos(theta2)+K5+K1;
49      A=cos(TH2)-K1-K2*cos(TH2(k))+K3;
50      B=-2*sin(theta2);
51      C=K1-(K2+1)*cos(theta2)+K3;
52      z1=(-B+sqrt(B^2-4*A*C))/(2*A);
53      z2=(-B-sqrt(B^2-4*A*C))/(2*A);
54      w1=(-B+sqrt(B^2-4*D*F))/(2*D);
55      w2=(-B-sqrt(B^2-4*D*F))/(2*D);
56      L1=2*z1/(1+z1^2);
57      M1=(1-z1^2)/(1+z1^2);
58      L2=2*z2/(1+z2^2);
59      M2=(1-z2^2)/(1+z2^2);
60      N1=2*w1/(1+w1^2);
61      P1=(1-w1^2)/(1+w1^2);
62      N2=2*w2/(1+w2^2);
63      P2=(1-w2^2)/(1+w2^2);
64      TH41(k)=atan2(L1,M1);
65      TH42(k)=atan2(L2,M2);
66      TH31(k)=atan2(N1,P1);
67      TH32(k)=atan2(N2,P2);
68  end
69

```

```

70 OM2(1)=40;
71 AL2=-2;
72
73 for k=2:n;
74     OM2(k)=sqrt(OM2(1)^2+2*AL2*TH2(k));
75 end
76
77 for k=1:n;
78     TH3(k)=TH32(k);
79     TH4(k)=TH42(k);
80 end
81 for k=1:n;
82     R12X(k)=-R2*cos(TH2(k))/2;
83     R12Y(k)=-R2*sin(TH2(k))/2;
84     R32X(k)=-R12X(k);
85     R32Y(k)=-R12Y(k);
86     R23X(k)=-d*cos(TH3(k)-psi);
87     R23Y(k)=-d*sin(TH3(k)-psi);
88     R43X(k)=R3*cos(TH3(k)) + R23X(k);
89     R43Y(k)=R3*sin(TH3(k)) + R23Y(k);
90     R34X(k)=.5*R4*cos(TH4(k));
91     R34Y(k)=.5*R4*sin(TH4(k));
92     R14X(k)=-R34X(k);
93     R14Y(k)=-R34Y(k);
94     A(1,1)=R3*cos(TH3(k));
95     A(1,2)=-R4*cos(TH4(k));
96     A(2,1)=R3*sin(TH3(k));
97     A(2,2)=-R4*sin(TH4(k));
98     g(1)=-R2*OM2(k)*cos(TH2(k));
99     g(2)=-R2*OM2(k)*sin(TH2(k));
100    h=A\g;
101    OM3(k)=h(1);
102    OM4(k)=h(2);
103    q(1)=-R2*AL2*cos(TH2(k))+R2*OM2(k)^2*sin(TH2(k))+R3*OM3(k)^2*sin(TH3(k))-R4*OM4(k)^
104    2*sin(TH4(k));
105    q(2)=-R2*AL2*sin(TH2(k))-R2*OM2(k)^2*cos(TH2(k))+R3*OM3(k)^2*cos(TH3(k))+R4*OM4(k)^
106    2*cos(TH4(k));
107    p=A\q;
108    AL3(k)=p(1);
109    AL4(k)=p(2);
110    B(1,1)=(1);
111    B(1,2)=(0);
112    B(1,3)=(1);
113    B(1,4)=(0);
114    B(1,5)=(0);
115    B(1,6)=(0);
116    B(1,7)=(0);
117    B(1,8)=(0);
118    B(1,9)=(0);
119    B(2,1)=(0);
120    B(2,2)=(1);
121    B(2,3)=(0);
122    B(2,4)=(1);
123    B(2,5)=(0);
124    B(2,6)=(0);
125    B(2,7)=(0);
126    B(2,8)=(0);
127    B(2,9)=(0);
128    B(3,1)=(-R12Y(k));
129    B(3,2)=(R12X(k));
130    B(3,3)=(-R32Y(k));
131    B(3,4)=(R32X(k));
132    B(3,5)=(0);
133    B(3,6)=(0);
134    B(3,7)=(0);
135    B(3,8)=(0);
136    B(3,9)=(0);
137    B(4,1)=(0);
138    B(4,2)=(0);

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```

137     B(4,3)=(-1);
138     B(4,4)=(0);
139     B(4,5)=(1);
140     B(4,6)=(0);
141     B(4,7)=(0);
142     B(4,8)=(0);
143     B(4,9)=(0);
144     B(5,1)=(0);
145     B(5,2)=(0);
146     B(5,3)=(0);
147     B(5,4)=(-1);
148     B(5,5)=(0);
149     B(5,6)=(1);
150     B(5,7)=(0);
151     B(5,8)=(0);
152     B(5,9)=(0);
153     B(6,1)=(0);
154     B(6,2)=(0);
155     B(6,3)=(-R23Y(k));
156     B(6,4)=(-R23X(k));
157     B(6,5)=(-R43Y(k));
158     B(6,6)=(R43X(k));
159     B(6,7)=(0);
160     B(6,8)=(0);
161     B(6,9)=(0);
162     B(7,1)=(0);
163     B(7,2)=(0);
164     B(7,3)=(0);
165     B(7,4)=(0);
166     B(7,5)=(-1);
167     B(7,6)=(0);
168     B(7,7)=(1);
169     B(7,8)=(0);
170     B(7,9)=(0);
171     B(8,1)=(0);
172     B(8,2)=(0);
173     B(8,3)=(0);
174     B(8,4)=(0);
175     B(8,5)=(0);
176     B(8,6)=(-1);
177     B(8,7)=(0);
178     B(8,8)=(1);
179     B(8,9)=(0);
180     B(9,1)=(0);
181     B(9,2)=(0);
182     B(9,3)=(0);
183     B(9,4)=(0);
184     B(9,5)=(R34Y(k));
185     B(9,6)=(-R34X(k));
186     B(9,7)=(-R14Y(k));
187     B(9,8)=(R14X(k));
188     B(9,9)=(0);
189
190 end
191
192
193
194

```

```

1   format short e;
2   J=zeros(2,2);
3
4   d=7.487;
5   a=9.174;
6   b=12.971;
7   c=9.573;
8   p=15;
9   MINVAL = -26;
10  MAXVAL = -20.55;
11  delta = 0.25;
12
13  Maxits=500;
14  Tol=1.0e-6;
15
16  X=[4;2];
17
18  for i=MINVAL:delta:MAXVAL;
19
20      theta2=i*(pi/180);
21
22  for i=1:Maxits;
23      theta3=X(1);
24      theta4=X(2);
25
26      F1=a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d;
27      F2=a*sin(theta2)+b*sin(theta3)-c*sin(theta4);
28
29      J(1,1)=-b*sin(theta3);
30      J(1,2)=c*sin(theta4);
31      J(2,1)=b*cos(theta3);
32      J(2,2)=-c*cos(theta4);
33
34      deltaX=inv(J)*[-F1;-F2];
35      X=X+deltaX;
36
37      theta3=X(1);
38      theta4=X(2);
39
40      F1check=abs(a*cos(theta2)+b*cos(theta3)-c*cos(theta4)-d);
41      F2check=abs(a*sin(theta2)+b*sin(theta3)-c*sin(theta4));
42
43      Fmax=max([F1check,F2check]);
44      if Fmax<Tol
45          break
46      end
47  end
48
49  if i<Maxits
50      fprintf('\n')
51      fprintf('***** Newton Raphson Method *****\n\n');
52      fprintf('Position Analysis:\n');
53      fprintf('Inputs:\n');
54      fprintf('a = %-2g mm  b = %-2g mm  c = %-2g mm  d = %-2g mm  theta2 = %-2.2f degrees'
55      ,a,b,c,d,theta2*180/pi);
56      fprintf('\nIterations=%-5g\n',i);
57      fprintf('Outputs:\n');
58      fprintf('theta3 = %-6.2f degrees',X(1)*180/pi);
59      fprintf('theta4 = %-6.2f degrees\n',X(2)*180/pi);
60  else
61      fprintf('we did not converge!\n');
62  end
63
64  theta3=X(1);
65  theta4=X(2);
66
67  w2=2;
68
69  w3 = (a*sin(theta4 - theta2))/(b*sin(theta3-theta4))*w2;
70  w4 = (a*sin(theta2 - theta3))/(c*sin(theta4-theta3))*w2;

```

```

69
70 fprintf('\nVelocity Analysis:\n');
71 fprintf('Inputs:\n');
72 fprintf('w2 = %-2g rad/s\n',w2);
73 fprintf('Outputs:\n');
74 fprintf('w3 = %-6.2f rad/s',w3);
75 fprintf('  w4 = %-6.2f rad/s\n',w4);
76
77 A = c*sin(theta4);
78 B = b*sin(theta3);
79 C = a*(w2^2)*cos(theta2)+b*(w3^2)*cos(theta3)-c*(w4^2)*cos(theta4);
80 D = c*cos(theta4);
81 E = b*cos(theta3);
82 F = -a*(w2^2)*sin(theta2)-b*(w3^2)*sin(theta3)+c*(w4^2)*sin(theta4);
83
84 a3 = (C*D-A*F)/(A*E-B*D);
85 a4 = (C*E-B*F)/(A*E-B*D);
86
87 Vax = a*w2*-sin(theta2);
88 Vpax = p*w3*-sin(theta3);
89
90 Vay = a*w2*cos(theta2);
91 Vpay = p*w3*cos(theta3);
92
93 Vpx = Vax+Vpax;
94 Vpy = Vay+Vpay;
95
96 Vp = sqrt(Vpx^2+Vpy^2);
97
98 Aax = -a*w2^2*cos(theta2);
99 Apax = p*a3*-sin(theta3)-p*w3^2*cos(theta3);
100
101 Aay = -a*w2^2*sin(theta2);
102 Apay = p*a3*cos(theta3)-p*w3^2*sin(theta3);
103
104 Apx = Aax+Apax;
105 Apy = Aay+Apay;
106
107 Ap = sqrt(Apx^2+Apy^2);
108
109 fprintf('\nAcceleration Analysis:');
110 fprintf('\nOutputs:\n');
111 fprintf('a3 = %-6.2f rad/s^2',a3);
112 fprintf('  a4 = %-6.2f rad/s^2\n\n',a4);
113 fprintf('Vp = %-6.2f in/s\n',Vp);
114 fprintf('Ap = %-6.2f in/s\n',Ap);
115
116 end
117

```

```

1   format short e;
2   J=zeros(2,2);
3   R1=8;
4   R2=4;
5   R3=7;
6   R4=6;
7   TH2=[0:pi/12:pi/2];
8   TH3=zeros(size(TH2));
9   TH4=zeros(size(TH2));
10  TH31=zeros(size(TH2));
11  TH41=zeros(size(TH2));
12  TH32=zeros(size(TH2));
13  TH42=zeros(size(TH2));
14  n=max(size(TH2));
15  for k=1:n;
16      theta2=TH2(k);
17  Maxits=500;
18  Tol=1.0e-6;
19  X=[4;2];
20
21  for i=1:Maxits;
22      theta3=X(1);
23      theta4=X(2);
24      F1=R2*cos(theta2)+R3*cos(theta3)-R4*cos(theta4)-R1;
25      F2=R2*sin(theta2)+R3*sin(theta3)-R4*sin(theta4);
26      J(1,1)=-R3*sin(theta3);
27      J(1,2)=R4*sin(theta4);
28      J(2,1)=R3*cos(theta3);
29      J(2,2)=-R4*cos(theta4);
30      deltaX=inv(J)*[-F1;-F2];
31      X=X+deltaX;
32      theta3=X(1);
33      theta4=X(2);
34      F1check=abs(R2*cos(theta2)+R3*cos(theta3)-R4*cos(theta4)-R1);
35      F2check=abs(R2*sin(theta2)+R3*sin(theta3)-R4*sin(theta4));
36      Fmax=max([F1check,F2check]);
37      if Fmax<Tol
38          break
39      end
40  end
41
42  N1=floor(X(1)/(2*pi));
43  N2=floor(X(2)/(2*pi));
44  J1=X(1)-(2*N1)*pi;
45  J2=X(2)-(2*N2)*pi;
46  if pi>J1
47      X(1)=J1;
48  else
49      X(1)=J1-2*pi;
50  end
51  if pi>J2
52      X(2)=J2;
53  else
54      X(2)=J2-2*pi;
55  end
56  if i<Maxits
57      fprintf('theta2=%-6.2f degrees\n',TH2(k)*180/pi)
58      fprintf('Iterations=%-5g\n\n',i);
59      fprintf('theta3=%-6.2f degrees\n',X(1)*180/pi);
60      fprintf('theta4=%-6.2f degrees\n',X(2)*180/pi);
61  else
62      fprintf('theta2=%-6.2f degrees\n',TH2(k)*180/pi);
63      fprintf('we did not converge!\n');
64  end
65
66  K1=R1/R2;
67  K2=R1/R4;
68  K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
69  K4=R1/R3;

```



```

70 K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
71 D=(1+K4)*cos(theta2)+K5-K1;
72 F=(K4-1)*cos(theta2)+K5+K1;
73 A=cos(theta2)-K1-K2*cos(theta2)+K3;
74 B=-2*sin(theta2);
75 C=K1-(K2+1)*cos(theta2)+K3;
76 z1=(-B+sqrt(B^2-4*A*C))/(2*A);
77 z2=(-B-sqrt(B^2-4*A*C))/(2*A);
78 w1=(-B+sqrt(B^2-4*D*F))/(2*D);
79 w2=(-B-sqrt(B^2-4*D*F))/(2*D);
80 L1=2*z1/(1+z1^2);
81 M1=(1-z1^2)/(1+z1^2);
82 L2=2*z2/(1+z2^2);
83 M2=(1-z2^2)/(1+z2^2);
84 N1=2*w1/(1+w1^2);
85 P1=(1-w1^2)/(1+w1^2);
86 N2=2*w2/(1+w2^2);
87 P2=(1-w2^2)/(1+w2^2);
88 TH41(k)=(180/pi)*atan2(L1,M1);
89 TH42(k)=(180/pi)*atan2(L2,M2);
90 TH31(k)=(180/pi)*atan2(N1,P1);
91 TH32(k)=(180/pi)*atan2(N2,P2);
92
93 fprintf('theta31=%-6.2f degrees\n',TH31(k));
94     fprintf('theta32=%-6.2f degrees\n',TH32(k));
95     fprintf('theta41=%-6.2f degrees\n',TH41(k));
96     fprintf('theta42=%-6.2f degrees\n',TH42(k));
97 end

```

```

1  format short g; J=zeros(5,5);
2  R2= 28; R3=66; R5=33; R6=93.56; theta2=1.29; gamma=0.8594; theta6=0.17197;
3
4  Maxits=500;
5  Tol=1.0e-6;
6
7  X=[-.422; 68.2; .442; 60.2; -.432];
8
9  for i=1:Maxits;
10     theta3=X(1); d1=X(2); theta5=X(3); d4=X(4); theta4=X(5);
11     F1=R2*cos(theta2)+R3*cos(theta3)-d1;
12     F2=R2*sin(theta2)+R3*sin(theta3);
13     F3=R2*cos(theta2)+R5*cos(theta5)-d4*cos(theta4)-R6*cos(theta6);
14     F4=R2*sin(theta2)+R5*sin(theta5)-d4*sin(theta4)-R6*sin(theta6);
15     F5=theta5-theta3-gamma;
16
17     J(1,1)=-R3*sin(theta3);
18     J(1,2)=-1;
19     J(2,1)=R3*cos(theta3);
20     J(3,3)=-R5*sin(theta5);
21     J(3,4)=-cos(theta4);
22     J(3,5)=d4*sin(theta4);
23     J(4,3)=R5*cos(theta5);
24     J(4,4)=-sin(theta4);
25     J(4,5)=-d4*cos(theta4);
26     J(5,1)=-1;
27     J(5,3)=1;
28
29     deltaX=inv(J)*[-F1;-F2;-F3;-F4;-F5];
30     X=X+deltaX;
31
32     theta3=X(1); d1=X(2); theta5=X(3); d4=X(4); theta4=X(5);
33     F1check=abs(+R2*cos(theta2)+R3*cos(theta3)-d1);
34     F2check=abs(+R2*sin(theta2)+R3*sin(theta3));
35     F3check=abs(+R2*cos(theta2)+R5*cos(theta5)-d4*cos(theta4)-R6*cos(theta6));
36     F4check=abs(+R2*sin(theta2)+R5*sin(theta5)-d4*sin(theta4)-R6*sin(theta6));
37     F5check=abs(+theta5-theta3-gamma);
38
39     Fmax=max([F1check,F2check,F2check,F3check,F4check,F5check]);
40     if Fmax<Tol
41         break
42     end
43 end
44
45 if i<Maxits fprintf('\n')
46     fprintf('Iterations = %-5g\n\n',i)
47     fprintf('theta3 = %-6.2f degrees\n',X(1)*180/pi);
48     fprintf('d1 = %-6.2f \n',X(2));
49     fprintf('theta5 = %-6.2f degrees\n',X(3)*180/pi);
50     fprintf('d4 = %-6.2f \n',X(4));
51     fprintf('theta4 = %-6.2f degrees\n',X(5)*180/pi);
52 else
53     fprintf('We did not converge!!!!\n')
54 end
55
56 omega2=-2;
57
58 z=[omega3; dotd1; dotd4; omega4];
59 A=zeros(4,4);
60
61 G1=-R2*sin(theta2)*omega2-R3*sin(theta3)*omega3-dotd1;
62 G2=R2*cos(theta2)*omega2+R3*cos(theta3)*omega3;
63 G3=-R2*sin(theta2)*omega2-d4*sin(theta4)*omega4-cos(theta4)*dotd4-R5sin(theta5)*omega3;
64 G4=R2*cos(theta2)*omega2-d4*cos(theta4)*omega4-sin(theta4)*dotd4+R5*cos(theta5)*omega3;
65
66 A(1,1)=-R3*sin(theta3);
67 A(1,2)=-1;
68 A(2,1)=R3*cos(theta3);
69 A(3,1)=-R5*sin(theta5);

```

```

70  A(3,3)=-cos(theta4);
71  A(3,4)=d4*sin(theta4);
72  A(4,1)=R5*cos(theta5);
73  A(4,3)=-sin(theta4);
74  A(4,4)=-d4*cos(theta4);
75
76  g1=R2*sin(theta2)*omega2;
77  g2=-R2*cos(theta2)*omega2;
78  G=[g1;g2;g1;g2];
79
80  z=inv(A)*G;
81
82
83  fprintf('theta3 = %-6.2f degrees\n',X(1)*180/pi);
84  fprintf('d1 = %-6.2f \n',X(2));
85  fprintf('theta5 = %-6.2f degrees\n',X(3)*180/pi);
86  fprintf('d4 = %-6.2f \n',X(4));
87  fprintf('theta4 = %-6.2f degrees\n',X(5)*180/pi);
88

```