

# Mekanizma Tekniđi

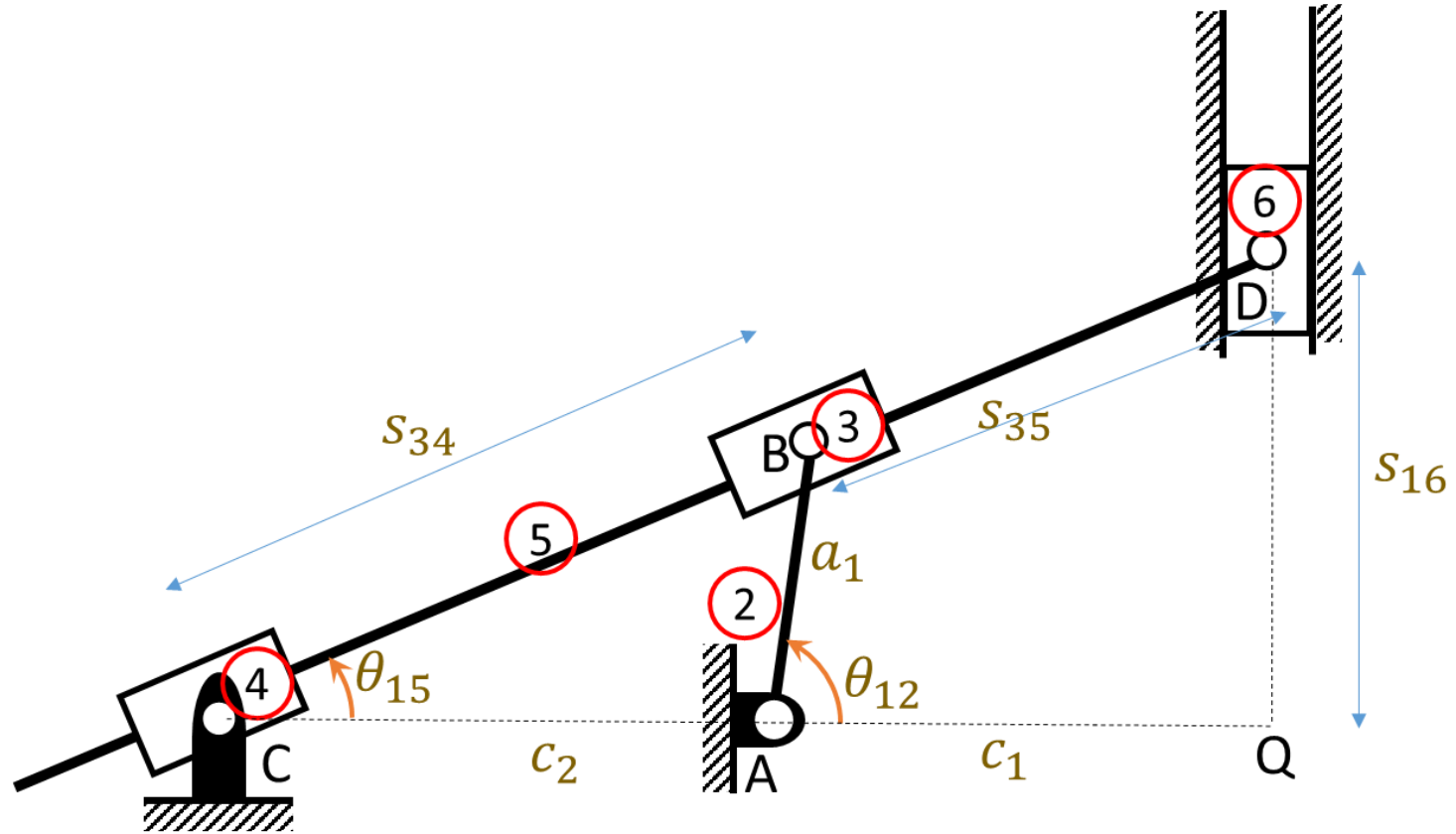
MEKANİZMALARIN KİNEMATİK ANALİZLERİ

Örnek Problemler

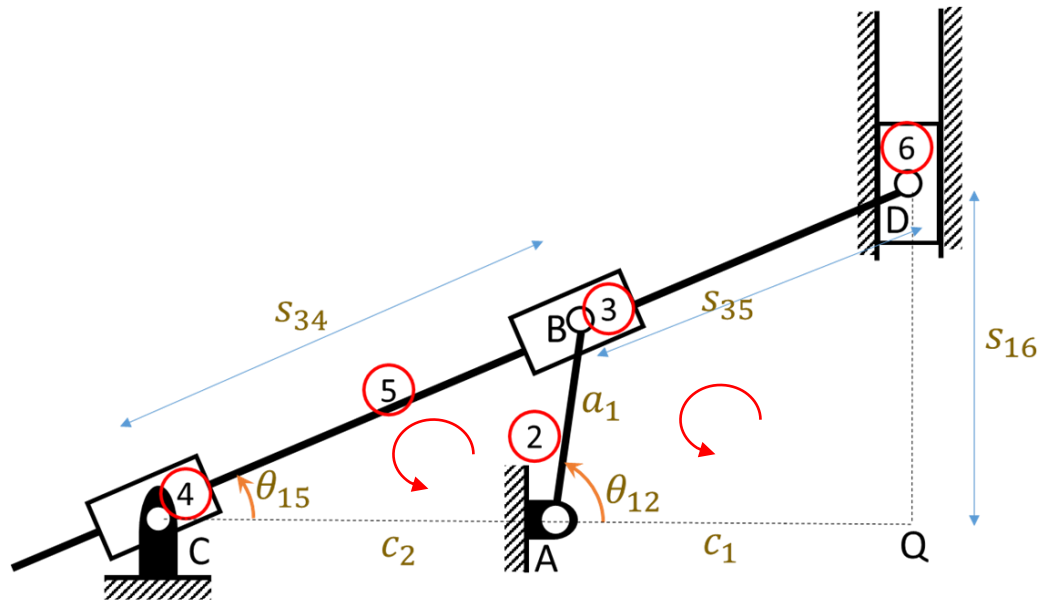
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# Örnek 1: Hızlı Dönüş Mekanizması



# Vektör Kapalılık Denklemleri



$$\overrightarrow{CA} + \overrightarrow{AB} = \overrightarrow{CB}$$

$$\overrightarrow{AB} + \overrightarrow{BD} = \overrightarrow{AD} + \overrightarrow{DB}$$

$$c_2 + a_1 e^{i\theta_{12}} = s_{34} e^{i\theta_{15}}$$

$$a_1 e^{i\theta_{12}} + s_{35} e^{i\theta_{15}} = c_1 + i s_{16}$$

# Konum Analizi

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$$c_2 + a_1 e^{i\theta_{12}} = s_{34} e^{i\theta_{15}}$$

$$a_1 e^{i\theta_{12}} + s_{35} e^{i\theta_{15}} = c_1 + i s_{16}$$

Yukarıda elde ettiğimiz vektör kapalılık denklemlerinin kompleks sayılarla gösterimini denklemleri sanal ve gerçel parçalarını ayrı ayrı yazarak skaler forma dönüştürelim.

$$c_2 + a_1 \cos\theta_{12} = s_{34} \cos\theta_{15}$$

$$a_1 \sin\theta_{12} = s_{34} \sin\theta_{15}$$

$$a_1 \cos\theta_{12} + s_{35} \cos\theta_{15} = c_1$$

$$a_1 \sin\theta_{12} + s_{35} \sin\theta_{15} = s_{16}$$

# Konum analizi, Değişkenlerin Çözümü

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$$c_2 + a_1 \cos \theta_{12} = s_{34} \cos \theta_{15}$$

$$a_1 \sin \theta_{12} = s_{34} \sin \theta_{15}$$

İlk döngüden elde ettiğimiz ilk iki denklemden bilinmeyenlerden  $\theta_{15}$ 'i yok etmek üzere denklemlerin karelerini alıp taraf tarafa toplayalım.

$$c_2^2 + a_1^2 \cos^2 \theta_{12} + 2c_2 a_1 \cos \theta_{12} = s_{34}^2 \cos^2 \theta_{15}$$

$$a_1^2 \sin^2 \theta_{12} = s_{34}^2 \sin^2 \theta_{15}$$

$$s_{34}^2 = a_1^2 + c_2^2 + 2c_2 a_1 \cos \theta_{12}$$

$$s_{34} = \sqrt{a_1^2 + c_2^2 + 2c_2 a_1 \cos \theta_{12}}$$

$$\sin \theta_{15} = \frac{a_1 \sin \theta_{12}}{s_{34}}$$

$$\cos \theta_{15} = \frac{c_2 + a_1 \cos \theta_{12}}{s_{34}}$$

$$\tan \theta_{15} = \frac{\sin \theta_{15}}{\cos \theta_{15}}$$

$$\theta_{15} = \arctan(\tan \theta_{15}) = \arctan\left(\frac{a_1 \sin \theta_{12}}{c_2 + a_1 \cos \theta_{12}}\right)$$

# Konum analizi, Değişkenlerin Çözümü

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$$a_1 \cos \theta_{12} + s_{35} \cos \theta_{15} = c_1$$

$$a_1 \sin \theta_{12} + s_{35} \sin \theta_{15} = s_{16}$$

$$s_{35} = \frac{c_1 - a_1 \cos \theta_{12}}{\cos \theta_{15}}$$

$$s_{16} = a_1 \sin \theta_{12} + s_{35} \sin \theta_{15}$$

# Sayısal Değerler

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$$a_1 = 0.15 \text{ m}; c_2 = 0.20 \text{ m};$$

$$c_1 = 0.30 \text{ m}$$

$$\theta_{12} = 70^\circ$$

$$s_{34} = \sqrt{a_1^2 + c_2^2 + 2c_2a_1\cos\theta_{12}}$$

$$\theta_{15} = \arctan\left(\frac{a_1\sin\theta_{12}}{c_2+a_1\cos\theta_{12}}\right)$$

$$s_{35} = \frac{c_1 - a_1\cos\theta_{12}}{\cos\theta_{15}}$$

$$s_{16} = a_1\sin\theta_{12} + s_{35}\sin\theta_{15}$$

$$s_{34} = \sqrt{0.15^2 + 0.20^2 + 2 * 0.2 * 0.15 * \cos 70}$$

$$s_{34} = 0.288 \text{ m}$$

$$\theta_{15} = \arctan\left(\frac{0.15*\sin 70}{0.20+0.15*\cos 70}\right) = 29.288^\circ$$

$$s_{35} = \frac{0.3-0.15\cos 70}{\cos 29.288} = 0.285 \text{ m}$$

$$s_{16} = 0.15 * \sin 70 + 0.285 * \sin 29.288$$

$$s_{16} = 0.28 \text{ m}$$

# Konum Analizi (Bilgisayar Uygulaması)

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```
% Hızlı dönüş Mekanizması;
%Verilenler
a1=0.15;c2=0.2;c1=0.3;q12=70*pi/180;
%Konum analizi
s34=sqrt(a1^2+c2^2+2*a1*c2*cos(q12));
q15=atan(a1*sin(q12)/(c2+a1*cos(q12)));
s35=(c1-a1*cos(q12))/cos(q15);
s16=a1*sin(q12)+s35*sin(q15);
disp('s34 yerdeğişimi');disp(s34)
disp('q15 açısı');disp(q15*180/pi)
disp('s35 yerdeğişimi');disp(s35)
disp('s16 yerdeğişimi');disp(s16)
```

s34 yerdeğişimi

0.2881

q15 açısı

29.2877

s35 yerdeğişimi

0.2851

s16 yerdeğişimi

0.2804



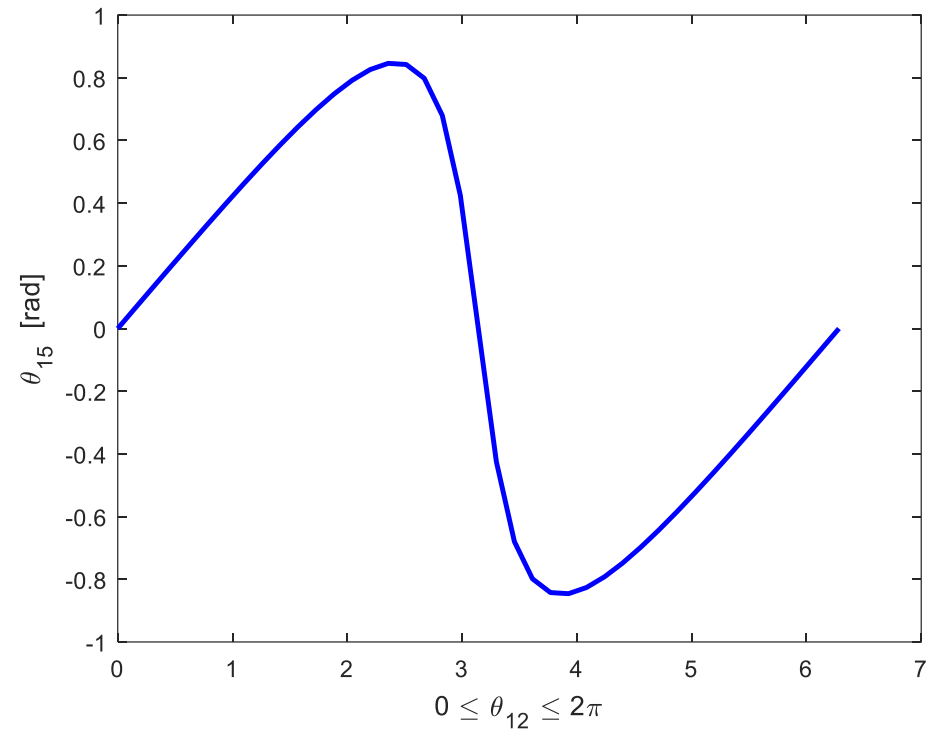
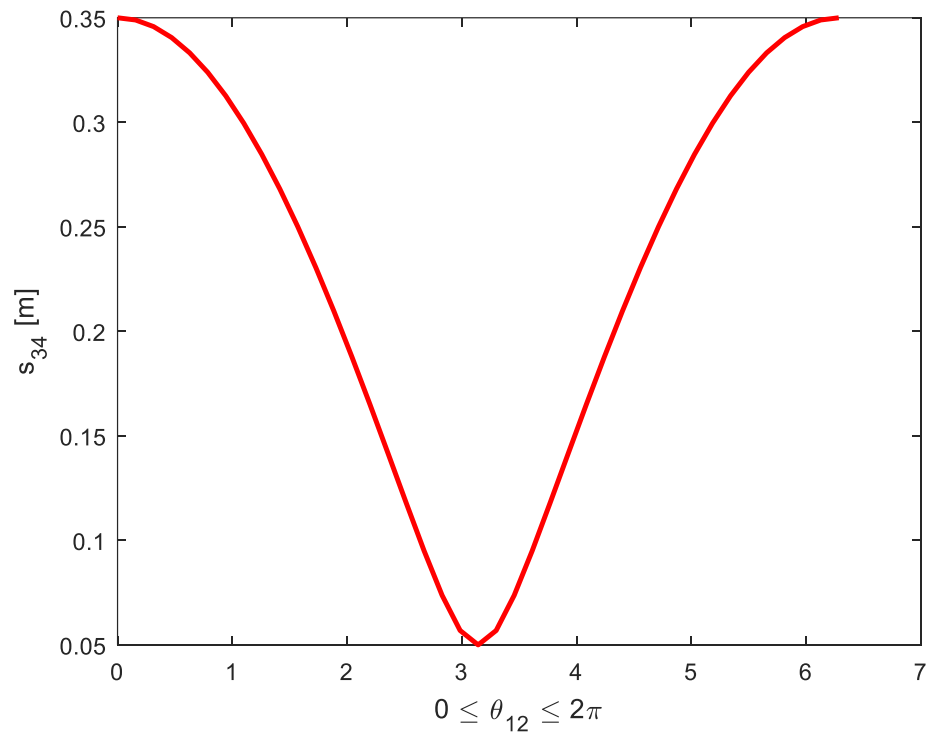
# Konum Analizi Bilgisayar Uygulaması II

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```
% Hızlı dönüş Mekanizması;
%Verilenler
a1=0.15;c2=0.2;c1=0.3;
q12=(0:0.05*pi:2*pi);
s34=zeros(1,41);s35=zeros(1,41);s16=zeros(1,41);q15=zeros(1,41);
%Konum analizi
for i=1:length(q12)
s34(i)=sqrt(a1^2+c2^2+2*a1*c2*cos(q12(i)));
q15(i)=atan(a1*sin(q12(i))/(c2+a1*cos(q12(i))));
s35(i)=(c1-a1*cos(q12(i)))/cos(q15(i));
s16(i)=a1*sin(q12(i))+s35(i)*sin(q15(i));
end
figure;plot(q12,s34);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('s_{34} [m]')
figure;plot(q12,q15);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('\theta_{15} [rad]')
figure;plot(q12,s35);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('s_{35} [m]')
figure;plot(q12,s16);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('s_{16} [m]')
```

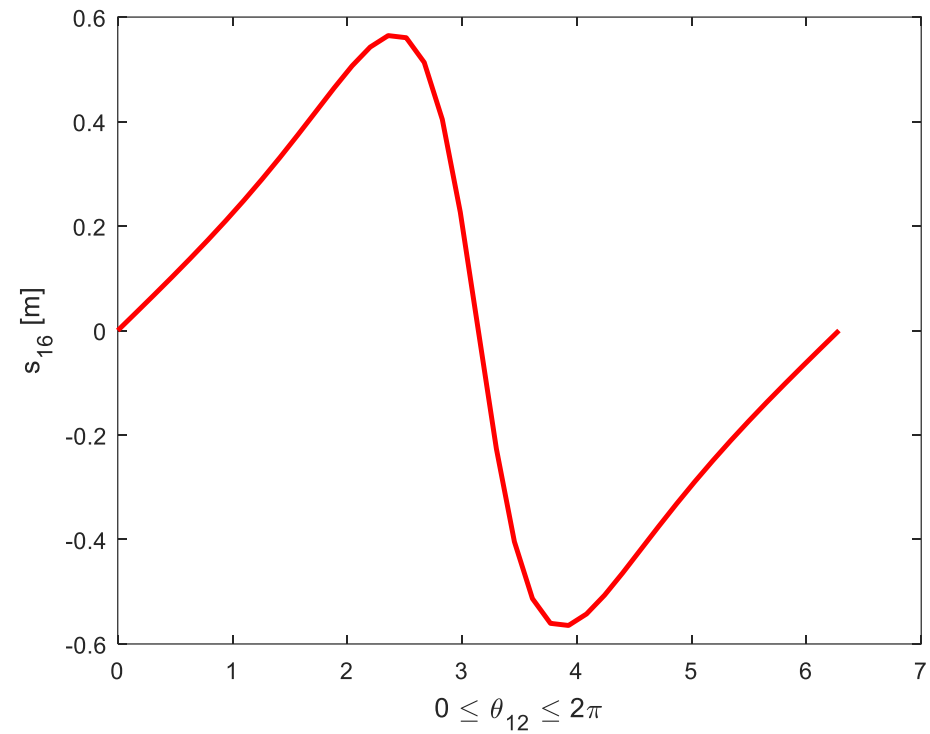
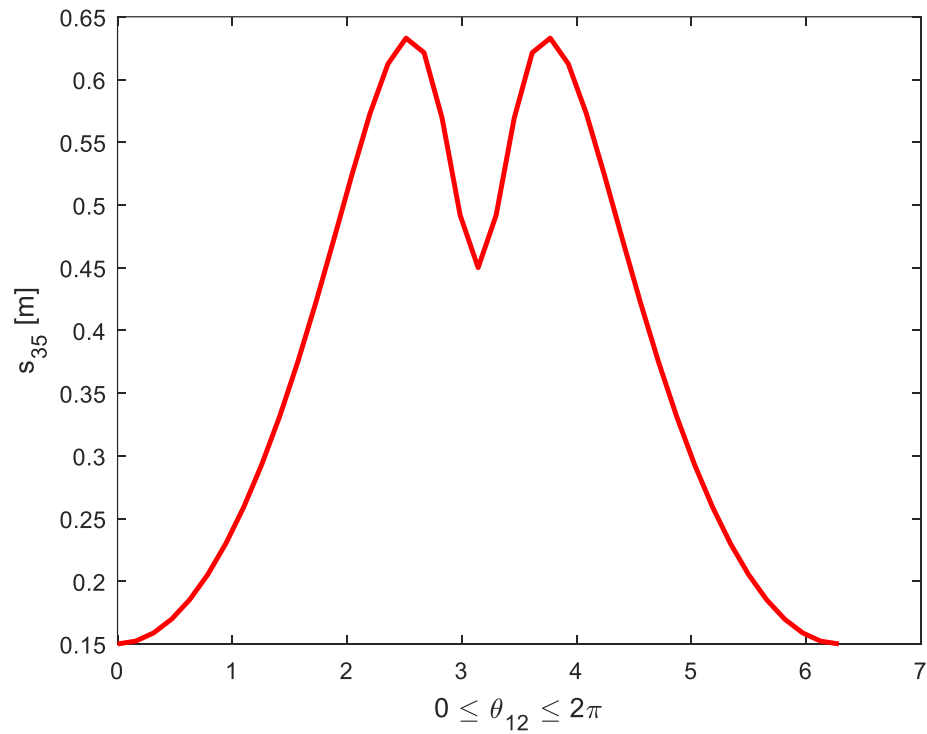
# Konum Değişkenleri Grafikleri

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# Konum Değişkenleri Grafikleri

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# Hız Analizi

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$$\omega_{12} = 2 \frac{rad}{s}$$

Sabit hız olarak veriliyor.

Bu durumda diğer hız değişkenlerini bulunuz.

$$c_2 + a_1 \cos\theta_{12} = s_{34} \cos\theta_{15}$$

$$a_1 \sin\theta_{12} = s_{34} \sin\theta_{15}$$

$$a_1 \cos\theta_{12} + s_{35} \cos\theta_{15} = c_1$$

$$a_1 \sin\theta_{12} + s_{35} \sin\theta_{15} = s_{16}$$

$$-a_1 \dot{\theta}_{12} \sin\theta_{12} = \dot{s}_{34} \cos\theta_{15} - s_{34} \dot{\theta}_{15} \sin\theta_{15}$$

$$a_1 \dot{\theta}_{12} \cos\theta_{12} = \dot{s}_{34} \sin\theta_{15} + s_{34} \dot{\theta}_{15} \cos\theta_{15}$$

$$-a_1 \dot{\theta}_{12} \sin\theta_{12} + \dot{s}_{35} \cos\theta_{15} - s_{35} \dot{\theta}_{15} \sin\theta_{15} = 0$$

$$a_1 \dot{\theta}_{12} \cos\theta_{12} + \dot{s}_{35} \sin\theta_{15} + s_{35} \dot{\theta}_{15} \cos\theta_{15} = \dot{s}_{16}$$

Bilinenler bilinmeyenler farklı taraflarda olacak şekilde denklemleri düzenleyelim.

$$\dot{s}_{34} \cos\theta_{15} - s_{34} \dot{\theta}_{15} \sin\theta_{15} = -a_1 \dot{\theta}_{12} \sin\theta_{12}$$

$$\dot{s}_{34} \sin\theta_{15} + s_{34} \dot{\theta}_{15} \cos\theta_{15} = a_1 \dot{\theta}_{12} \cos\theta_{12}$$

$$\dot{s}_{35} \cos\theta_{15} - s_{35} \dot{\theta}_{15} \sin\theta_{15} = a_1 \dot{\theta}_{12} \sin\theta_{12}$$

$$-\dot{s}_{35} \sin\theta_{15} - s_{35} \dot{\theta}_{15} \cos\theta_{15} + \dot{s}_{16} = a_1 \dot{\theta}_{12} \cos\theta_{12}$$

# Bulunan Hız Denklemlerinin Matris Formunda Düzenlenmesi

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$$\dot{s}_{34} \cos\theta_{15} - s_{34} \dot{\theta}_{15} \sin\theta_{15} = -a_1 \dot{\theta}_{12} \sin\theta_{12}$$

$$\dot{s}_{34} \sin\theta_{15} + s_{34} \dot{\theta}_{15} \cos\theta_{15} = a_1 \dot{\theta}_{12} \cos\theta_{12}$$

$$\dot{s}_{35} \cos\theta_{15} - s_{35} \dot{\theta}_{15} \sin\theta_{15} = a_1 \dot{\theta}_{12} \sin\theta_{12}$$

$$-\dot{s}_{35} \sin\theta_{15} - s_{35} \dot{\theta}_{15} \cos\theta_{15} + \dot{s}_{16} = a_1 \dot{\theta}_{12} \cos\theta_{12}$$

$$\begin{bmatrix} \cos\theta_{15} & -s_{34} \sin\theta_{15} & 0 & 0 \\ \sin\theta_{15} & s_{34} \cos\theta_{15} & 0 & 0 \\ 0 & -s_{35} \sin\theta_{15} & \cos\theta_{15} & 0 \\ 0 & -s_{35} \cos\theta_{15} & -\sin\theta_{15} & 1 \end{bmatrix} \begin{bmatrix} \dot{s}_{34} \\ \dot{\theta}_{15} \\ \dot{s}_{35} \\ \dot{s}_{16} \end{bmatrix} = \begin{bmatrix} -a_1 \dot{\theta}_{12} \sin\theta_{12} \\ a_1 \dot{\theta}_{12} \cos\theta_{12} \\ a_1 \dot{\theta}_{12} \sin\theta_{12} \\ a_1 \dot{\theta}_{12} \cos\theta_{12} \end{bmatrix} \Rightarrow \begin{bmatrix} \dot{s}_{34} \\ \dot{\theta}_{15} \\ \dot{s}_{35} \\ \dot{s}_{16} \end{bmatrix} = \begin{bmatrix} -0.1957 \\ 0.7892 \\ 0.4494 \\ 0.5187 \end{bmatrix}$$

# Kramer Kuralı Kullanarak Sayısal Çözüm;

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$$\begin{bmatrix} 0.8722 & -0.1410 & 0 & 0 \\ 0.4892 & 0.2513 & 0 & 0 \\ 0 & -0.1395 & 0.8722 & 0 \\ 0 & -0.2487 & -0.4892 & 1 \end{bmatrix} \begin{bmatrix} \dot{s}_{34} \\ \dot{\theta}_{15} \\ \dot{s}_{35} \\ \dot{s}_{16} \end{bmatrix} = \begin{bmatrix} -0.2819 \\ 0.1026 \\ 0.2819 \\ 0.1026 \end{bmatrix}$$

$$\dot{s}_{34} = \frac{\begin{vmatrix} -0.2819 & -0.1410 \\ 0.1026 & 0.2513 \end{vmatrix}}{\begin{vmatrix} 0.8722 & -0.1410 \\ 0.4892 & 0.2513 \end{vmatrix}} = \frac{-0.2819 \cdot 0.2513 + 0.1026 \cdot 0.1410}{0.8722 \cdot 0.2513 + 0.4892 \cdot 0.1410} = -0.1956 \text{ m/s}$$

$$\dot{\theta}_{15} = \frac{\begin{vmatrix} 0.8722 & -0.2819 \\ 0.4892 & 0.1026 \end{vmatrix}}{\begin{vmatrix} 0.8722 & -0.1410 \\ 0.4892 & 0.2513 \end{vmatrix}} = \frac{0.1026 \cdot 0.8722 + 0.2819 \cdot 0.4892}{0.8722 \cdot 0.2513 + 0.4892 \cdot 0.1410} = 0.7892 \text{ rad/s}$$

# Kramer Kuralı Kullanarak Sayısal Çözüm;

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$$\begin{bmatrix} 1 & 0 & 0 \\ -0.1395 & 0.8722 & 0 \\ -0.2487 & -0.4892 & 1 \end{bmatrix} \begin{bmatrix} \dot{\theta}_{15} \\ \dot{s}_{35} \\ \dot{s}_{16} \end{bmatrix} = \begin{bmatrix} 0.7892 \\ 0.2819 \\ 0.1026 \end{bmatrix}$$

$$\dot{s}_{35} = \frac{\begin{vmatrix} 1 & 0.7892 & 0 \\ -0.1395 & 0.2819 & 0 \\ -0.2487 & 0.1026 & 1 \end{vmatrix}}{\begin{vmatrix} 1 & 0 & 0 \\ -0.1395 & 0.8722 & 0 \\ -0.2487 & -0.4892 & 1 \end{vmatrix}} = \frac{0.2819 + 0.1395 \cdot 0.7892}{0.8722} = 0.4494 \text{ m/s}$$

$$\dot{s}_{16} = \frac{\begin{vmatrix} 1 & 0 & 0.7892 \\ -0.1395 & 0.8722 & 0.2819 \\ -0.2487 & -0.4892 & 0.1026 \end{vmatrix}}{\begin{vmatrix} 1 & 0 & 0 \\ -0.1395 & 0.8722 & 0 \\ -0.2487 & -0.4892 & 1 \end{vmatrix}} = \frac{(0.1026 \cdot 0.8722 + 0.2819 \cdot 0.4892) + 0.7892 \cdot (0.4892 \cdot 0.1395 + 0.8722 \cdot 0.2487)}{0.8722}$$

$$\dot{s}_{16} = 0.5187 \text{ m/s}$$

# Hız Analizi Bilgisayar Uygulaması I

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```
%Hız Analizi
```

d(s34) hızı

```
%Verilenler
```

-0.1957

```
w12=2;
```

```
A=[cos(q15) -s34*sin(q15) 0 0; sin(q15) s34*cos(q15) 0 0;
```

d(q15) açısal hızı

```
0 -s35*sin(q15) cos(q15) 0; 0 -s35*cos(q15) -sin(q15) 1];
```

0.7892

```
b=[-a1*w12*sin(q12); a1*w12*cos(q12); a1*w12*sin(q12); a1*w12*cos(q12)];
```

```
L=A\b;
```

d(s35) hızı

```
disp('d(s34) hızı'); disp(L(1))
```

0.4494

```
disp('d(q15) açısal hızı'); disp(L(2))
```

```
disp('d(s35) hızı'); disp(L(3))
```

d(s16) hızı

```
disp('d(s16) hızı'); disp(L(4))
```

0.5187

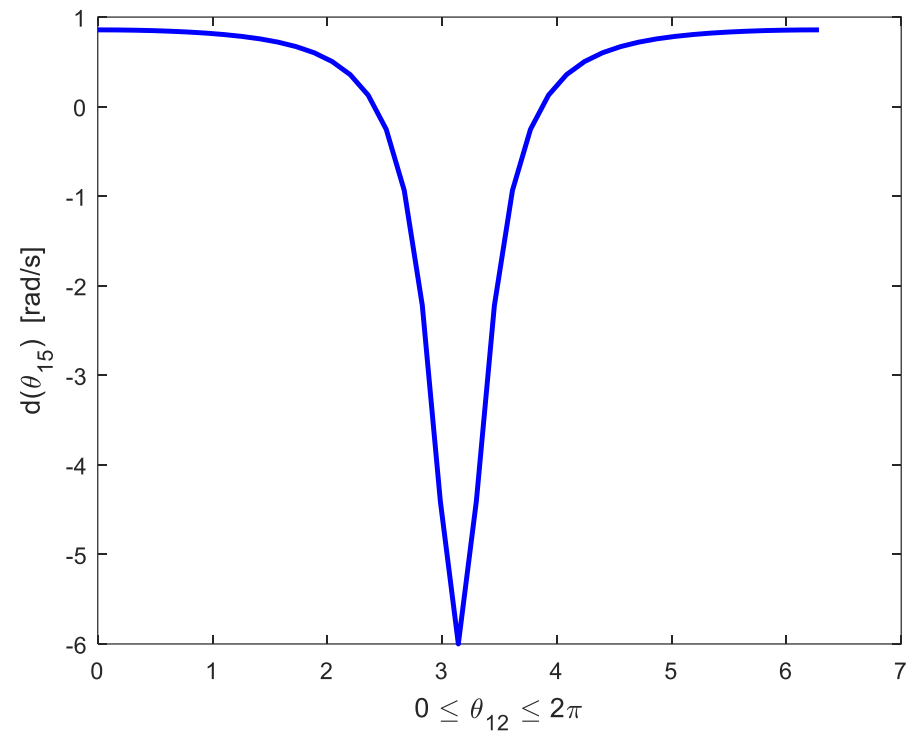
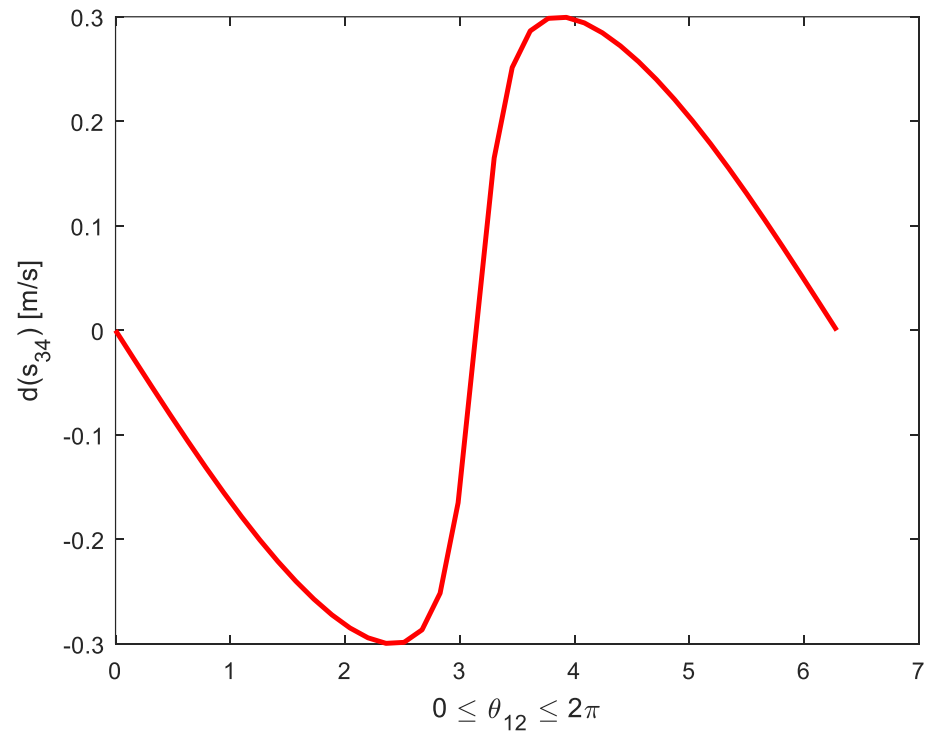


# Hız Analizi Bilgisayar Uygulaması II

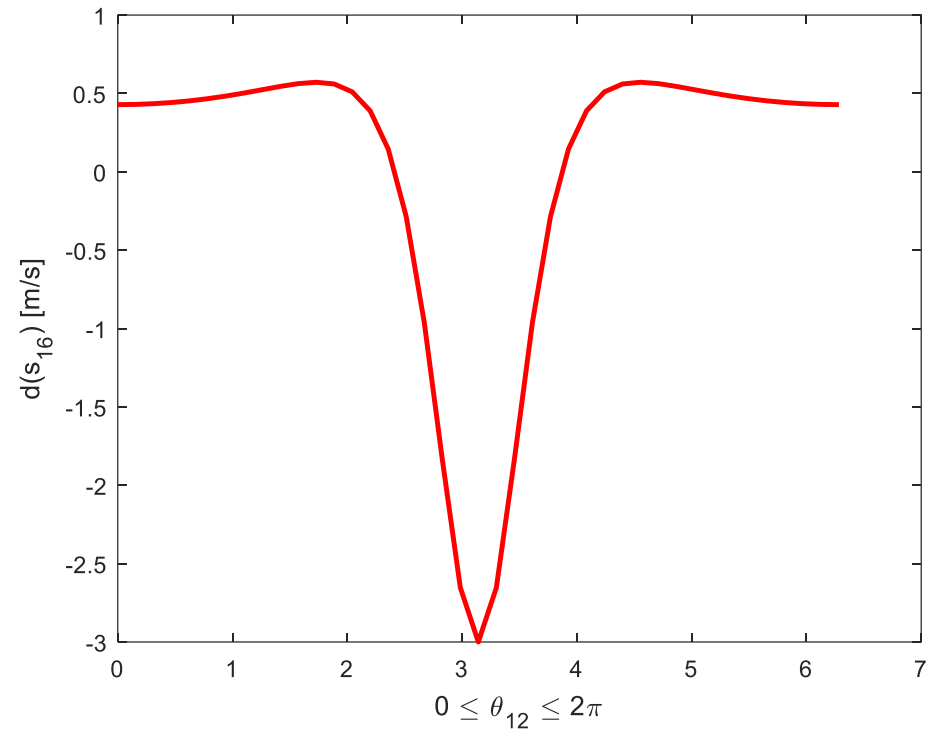
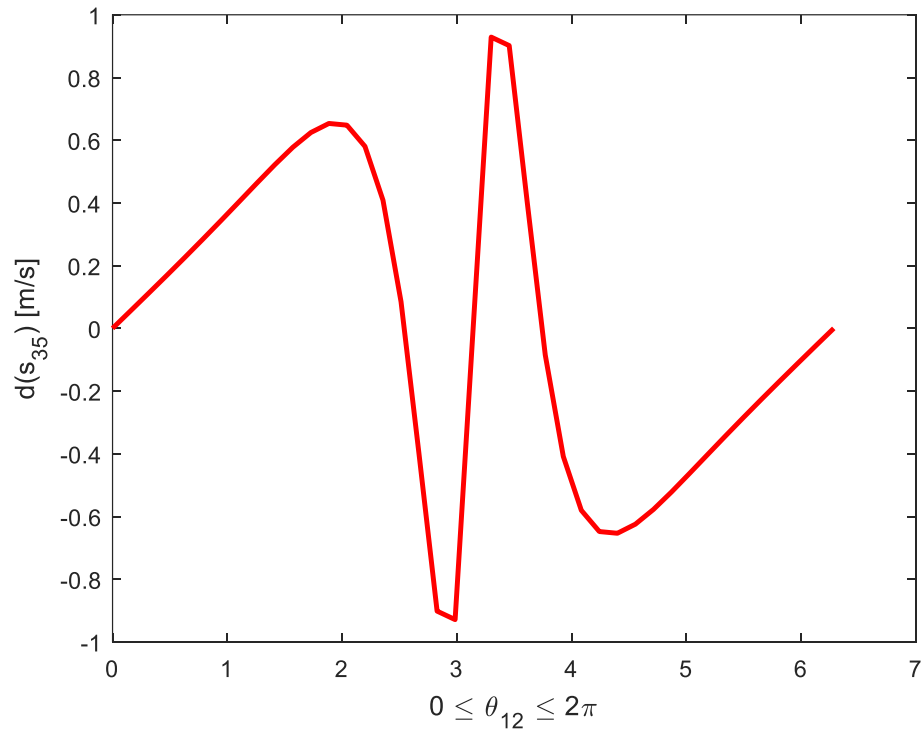
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```
%Verilenler;
w12=2;
for i=1:length(q12)
A=[cos(q15(i)) -s34(i)*sin(q15(i)) 0 0;
   sin(q15(i)) s34(i)*cos(q15(i)) 0 0;
   0 -s35(i)*sin(q15(i)) cos(q15(i)) 0;
   0 -s35(i)*cos(q15(i)) -sin(q15(i)) 1];
b=[-a1*w12*sin(q12(i));a1*w12*cos(q12(i));a1*w12*sin(q12(i));a1*w12*cos(q12(i))];
L(:,i)=A\b;
end;
figure;
plot(q12,L(1,:), 'linewidth',2, 'color',[1 0 0]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('d(s_{34}) [m/s]')
figure;
plot(q12,L(2,:), 'linewidth',2, 'color',[0 0 1]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('d(\theta_{15}) [rad/s]')
figure;
plot(q12,L(3,:), 'linewidth',2, 'color',[1 0 0]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('d(s_{35}) [m/s]')
figure;
plot(q12,L(4,:), 'linewidth',2, 'color',[1 0 0]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('d(s_{16}) [m/s]')
```

# Hız değişkenleri Grafikleri



# Hız değişkenleri Grafikleri



# Kramer Kuralı ile Hız Etki Katsayısı

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$$\begin{bmatrix} \cos\theta_{15} & -s_{34}\sin\theta_{15} \\ \sin\theta_{15} & s_{34}\cos\theta_{15} \end{bmatrix} \begin{bmatrix} \dot{s}_{34} \\ \dot{\theta}_{15} \end{bmatrix} = \begin{bmatrix} -a_1\dot{\theta}_{12}\sin\theta_{12} \\ a_1\dot{\theta}_{12}\cos\theta_{12} \end{bmatrix}$$

$$\dot{s}_{34} = \frac{\begin{vmatrix} -a_1\dot{\theta}_{12}\sin\theta_{12} & -s_{34}\sin\theta_{15} \\ a_1\dot{\theta}_{12}\cos\theta_{12} & s_{34}\cos\theta_{15} \end{vmatrix}}{\begin{vmatrix} \cos\theta_{15} & -s_{34}\sin\theta_{15} \\ \sin\theta_{15} & s_{34}\cos\theta_{15} \end{vmatrix}} = \frac{s_{34}a_1\sin(\theta_{15}-\theta_{12})}{s_{34}} \dot{\theta}_{12}$$

$$\dot{s}_{34} = a_1 \sin(\theta_{15} - \theta_{12}) \dot{\theta}_{12}$$

$$\dot{\theta}_{15} = \frac{\begin{vmatrix} \cos\theta_{15} & -a_1\dot{\theta}_{12}\sin\theta_{12} \\ \sin\theta_{15} & a_1\dot{\theta}_{12}\cos\theta_{12} \end{vmatrix}}{\begin{vmatrix} \cos\theta_{15} & -s_{34}\sin\theta_{15} \\ \sin\theta_{15} & s_{34}\cos\theta_{15} \end{vmatrix}} = \frac{a_1\cos(\theta_{15}-\theta_{12})}{s_{34}} \dot{\theta}_{12}$$

# Kramer Kuralı ile Hız Etki Katsayısı

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$$\dot{s}_{35} \cos \theta_{15} - s_{35} \dot{\theta}_{15} \sin \theta_{15} = a_1 \dot{\theta}_{12} \sin \theta_{12}$$

$$\dot{s}_{35} = \frac{s_{35} \dot{\theta}_{15} \sin \theta_{15} + a_1 \dot{\theta}_{12} \sin \theta_{12}}{\cos \theta_{15}}$$

$$\dot{\theta}_{15} = \frac{a_1 \cos(\theta_{15} - \theta_{12})}{s_{34}} \dot{\theta}_{12}$$

$$\dot{s}_{35} = \frac{\frac{a_1 s_{35}}{s_{34}} \cos(\theta_{15} - \theta_{12}) \sin \theta_{15} + a_1 \sin \theta_{12}}{\cos \theta_{15}} \dot{\theta}_{12}$$

$$-\dot{s}_{35} \sin \theta_{15} - s_{35} \dot{\theta}_{15} \cos \theta_{15} + \dot{s}_{16} = a_1 \dot{\theta}_{12} \cos \theta_{12}$$

# Kramer Kuralı ile Hız Etki Katsayısı

---

$$\dot{s}_{16} = a_1 \dot{\theta}_{12} \cos \theta_{12} + \dot{s}_{35} \sin \theta_{15} + s_{35} \dot{\theta}_{15} \cos \theta_{15}$$

$$\dot{s}_{16} = \left[ a_1 \cos \theta_{12} + \frac{\frac{a_1 s_{35}}{s_{34}} \cos(\theta_{15} - \theta_{12}) \sin \theta_{15} + a_1 \sin \theta_{12}}{\cos \theta_{15}} \sin \theta_{15} + \frac{a_1 s_{35} \cos \theta_{15} \cos(\theta_{15} - \theta_{12})}{s_{34}} \right] \dot{\theta}_{12}$$

# İvme Analizi

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$$\dot{s}_{34}\cos\theta_{15} - s_{34}\dot{\theta}_{15}\sin\theta_{15} = -a_1\dot{\theta}_{12}\sin\theta_{12}$$

$$\dot{s}_{34}\sin\theta_{15} + s_{34}\dot{\theta}_{15}\cos\theta_{15} = a_1\dot{\theta}_{12}\cos\theta_{12}$$

$$\dot{s}_{35}\cos\theta_{15} - s_{35}\dot{\theta}_{15}\sin\theta_{15} = a_1\dot{\theta}_{12}\sin\theta_{12}$$

$$-\dot{s}_{35}\sin\theta_{15} - s_{35}\dot{\theta}_{15}\cos\theta_{15} + \dot{s}_{16} = a_1\dot{\theta}_{12}\cos\theta_{12}$$

$$\ddot{s}_{34}\cos\theta_{15} - 2\dot{s}_{34}\dot{\theta}_{15}\sin\theta_{15} - s_{34}\ddot{\theta}_{15}\sin\theta_{15} - s_{34}\dot{\theta}_{15}^2\cos\theta_{15} = -a_1\dot{\theta}_{12}^2\cos\theta_{12}$$

$$\ddot{s}_{34}\sin\theta_{15} + 2\dot{s}_{34}\dot{\theta}_{15}\cos\theta_{15} + s_{34}\ddot{\theta}_{15}\cos\theta_{15} - s_{34}\dot{\theta}_{15}^2\sin\theta_{15} = -a_1\dot{\theta}_{12}^2\sin\theta_{12}$$

$$\ddot{s}_{35}\cos\theta_{15} - 2\dot{s}_{35}\dot{\theta}_{15}\sin\theta_{15} - s_{35}\ddot{\theta}_{15}\sin\theta_{15} - s_{35}\dot{\theta}_{15}^2\cos\theta_{15} = a_1\dot{\theta}_{12}^2\cos\theta_{12}$$

$$-\ddot{s}_{35}\sin\theta_{15} - 2\dot{s}_{35}\dot{\theta}_{15}\cos\theta_{15} - s_{35}\ddot{\theta}_{15}\cos\theta_{15} + s_{35}\dot{\theta}_{15}^2\sin\theta_{15} + \ddot{s}_{16} = -a_1\dot{\theta}_{12}^2\sin\theta_{12}$$

# İvme Analizi

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$$\ddot{s}_{34}\cos\theta_{15} - s_{34}\ddot{\theta}_{15}\sin\theta_{15} = -a_1\dot{\theta}_{12}^2\cos\theta_{12} + 2\dot{s}_{34}\dot{\theta}_{15}\sin\theta_{15} + s_{34}\dot{\theta}_{15}^2\cos\theta_{15}$$

$$\ddot{s}_{34}\sin\theta_{15} + s_{34}\ddot{\theta}_{15}\cos\theta_{15} = -a_1\dot{\theta}_{12}^2\sin\theta_{12} - 2\dot{s}_{34}\dot{\theta}_{15}\cos\theta_{15} + s_{34}\dot{\theta}_{15}^2\sin\theta_{15}$$

$$\ddot{s}_{35}\cos\theta_{15} - s_{35}\ddot{\theta}_{15}\sin\theta_{15} = a_1\dot{\theta}_{12}^2\cos\theta_{12} + 2\dot{s}_{35}\dot{\theta}_{15}\sin\theta_{15} + s_{35}\dot{\theta}_{15}^2\cos\theta_{15}$$

$$-\ddot{s}_{35}\sin\theta_{15} - s_{35}\ddot{\theta}_{15}\cos\theta_{15} + \ddot{s}_{16} = -a_1\dot{\theta}_{12}^2\sin\theta_{12} + 2\dot{s}_{35}\dot{\theta}_{15}\cos\theta_{15} - s_{35}\dot{\theta}_{15}^2\sin\theta_{15}$$

$$\begin{bmatrix} \cos\theta_{15} & -s_{34}\sin\theta_{15} & 0 & 0 \\ \sin\theta_{15} & s_{34}\cos\theta_{15} & 0 & 0 \\ 0 & -s_{35}\sin\theta_{15} & \cos\theta_{15} & 0 \\ 0 & -s_{35}\cos\theta_{15} & -\sin\theta_{15} & 1 \end{bmatrix} \begin{bmatrix} \ddot{s}_{34} \\ \ddot{\theta}_{15} \\ \ddot{s}_{35} \\ \ddot{s}_{16} \end{bmatrix} = \begin{bmatrix} -a_1\dot{\theta}_{12}^2\cos\theta_{12} + 2\dot{s}_{34}\dot{\theta}_{15}\sin\theta_{15} + s_{34}\dot{\theta}_{15}^2\cos\theta_{15} \\ -a_1\dot{\theta}_{12}^2\sin\theta_{12} - 2\dot{s}_{34}\dot{\theta}_{15}\cos\theta_{15} + s_{34}\dot{\theta}_{15}^2\sin\theta_{15} \\ a_1\dot{\theta}_{12}^2\cos\theta_{12} + 2\dot{s}_{35}\dot{\theta}_{15}\sin\theta_{15} + s_{35}\dot{\theta}_{15}^2\cos\theta_{15} \\ -a_1\dot{\theta}_{12}^2\sin\theta_{12} + 2\dot{s}_{35}\dot{\theta}_{15}\cos\theta_{15} - s_{35}\dot{\theta}_{15}^2\sin\theta_{15} \end{bmatrix}$$

$$\begin{bmatrix} \ddot{s}_{34} \\ \ddot{\theta}_{15} \\ \ddot{s}_{35} \\ \ddot{s}_{16} \end{bmatrix} = \begin{bmatrix} 0.4342 \\ -1.9171 \\ 1.4672 \\ 0.8538 \end{bmatrix}$$



# İvme Analizi Bilgisayar Uygulaması I

---

%Verilenler

```
alfa12=0;
```

```
d=[-a1*w12^2*cos(q12)+2*L(1)*L(2)*sin(q15)+s34*L(2)^2*cos(q15);  
    -a1*w12^2*sin(q12)-2*L(1)*L(2)*cos(q15)+s34*L(2)^2*sin(q15);  
    a1*w12^2*cos(q12)+2*L(3)*L(2)*sin(q15)+s35*L(2)^2*cos(q15);  
    -a1*w12^2*sin(q12)+2*L(3)*L(2)*cos(q15)-s35*L(2)^2*sin(q15)];
```

```
Ac=A\d;
```

```
disp('dd(s34) ivme');disp(Ac(1))
```

```
disp('dd(q15) açýsal ivme');disp(Ac(2))
```

```
disp('dd(s35) ivme');disp(Ac(3))
```

```
disp('dd(s16) ivme');disp(Ac(4))
```

dd(s34) ivme

-0.3208

dd(q15) açýsal ivme

-0.1147

dd(s35) ivme

0.7391

dd(s16) ivme

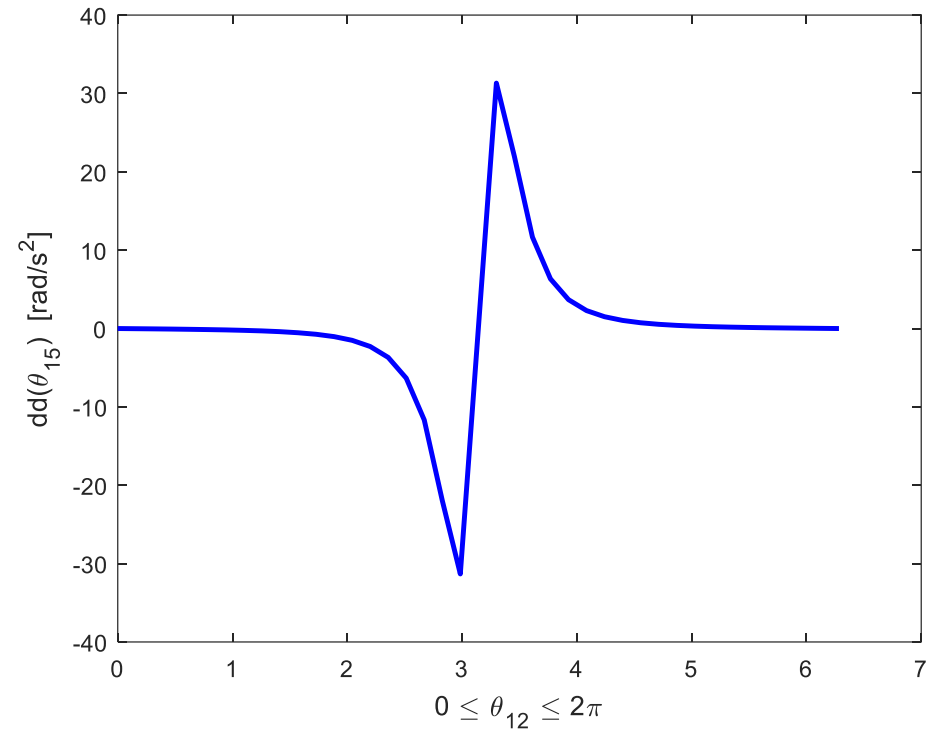
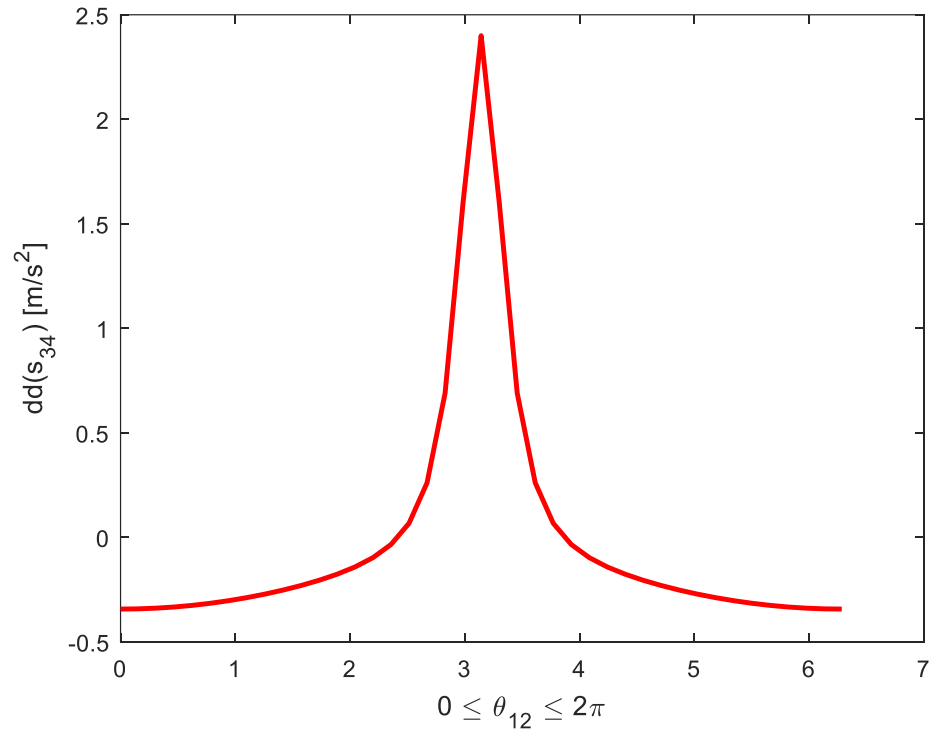
0.1728

# İvme Analizi Bilgisayar Uygulaması II

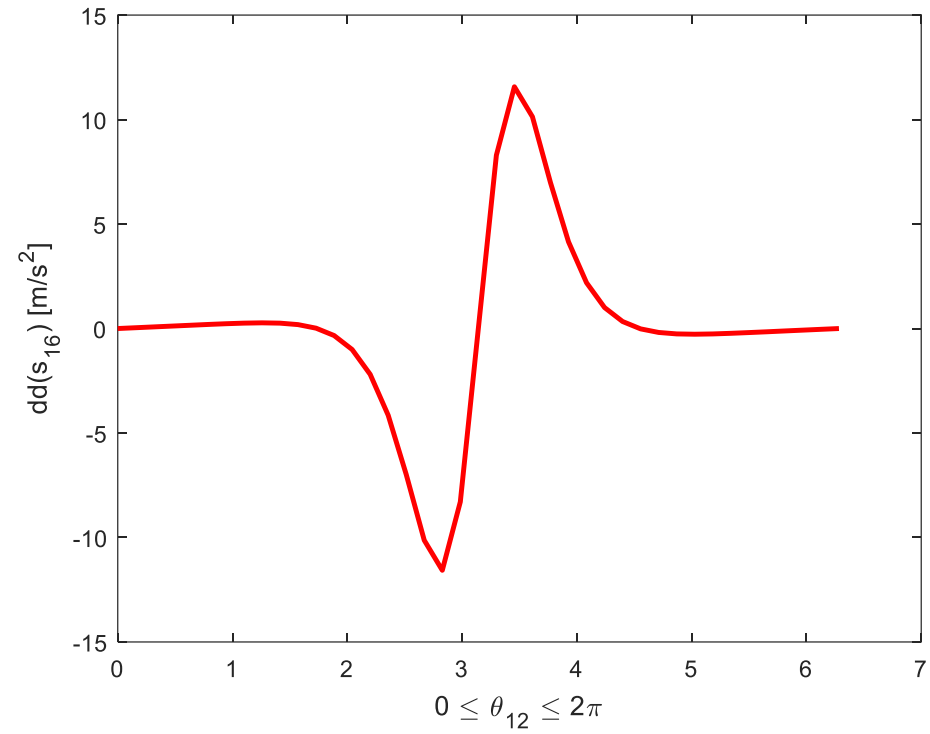
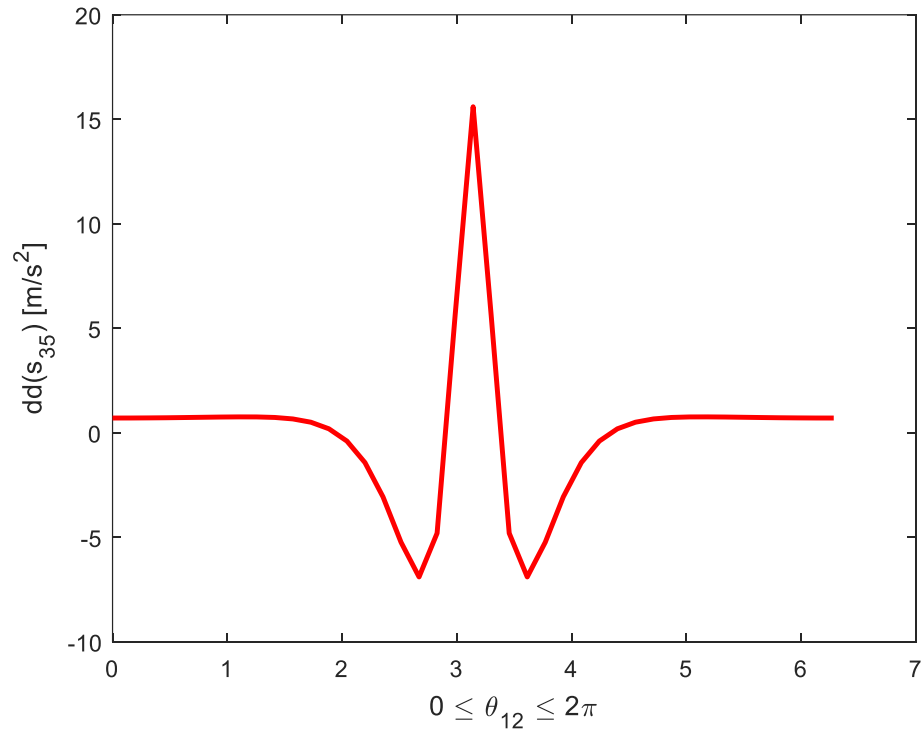
---

```
alfa12=0;
for i=1:length(q12)
A=[cos(q15(i)) -s34(i)*sin(q15(i)) 0 0;
   sin(q15(i)) s34(i)*cos(q15(i)) 0 0;
   0 -s35(i)*sin(q15(i)) cos(q15(i)) 0;
   0 -s35(i)*cos(q15(i)) -sin(q15(i)) 1];
d=[-a1*w12^2*cos(q12(i))+2*L(1,i)*L(2,i)*sin(q15(i))+s34(i)*L(2,i)^2*cos(q15(i));
   -a1*w12^2*sin(q12(i))-2*L(1,i)*L(2,i)*cos(q15(i))+s34(i)*L(2,i)^2*sin(q15(i));
   a1*w12^2*cos(q12(i))+2*L(3,i)*L(2,i)*sin(q15(i))+s35(i)*L(2,i)^2*cos(q15(i));
   -a1*w12^2*sin(q12(i))+2*L(3,i)*L(2,i)*cos(q15(i))-s35(i)*L(2,i)^2*sin(q15(i))];
Ac(:,i)=A\d;
end;
figure;
plot(q12,Ac(1,:), 'linewidth',2, 'color',[1 0 0]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('dd(s_{34}) [m/s^2]')
figure;
plot(q12,Ac(2,:), 'linewidth',2, 'color',[0 0 1]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('dd(\theta_{15}) [rad/s^2]')
figure;
plot(q12,Ac(3,:), 'linewidth',2, 'color',[1 0 0]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('dd(s_{35}) [m/s^2]')
figure;
plot(q12,Ac(4,:), 'linewidth',2, 'color',[1 0 0]);xlabel('0 \leq \theta_{12} \leq 2\pi');ylabel('dd(s_{16}) [m/s^2]')
```

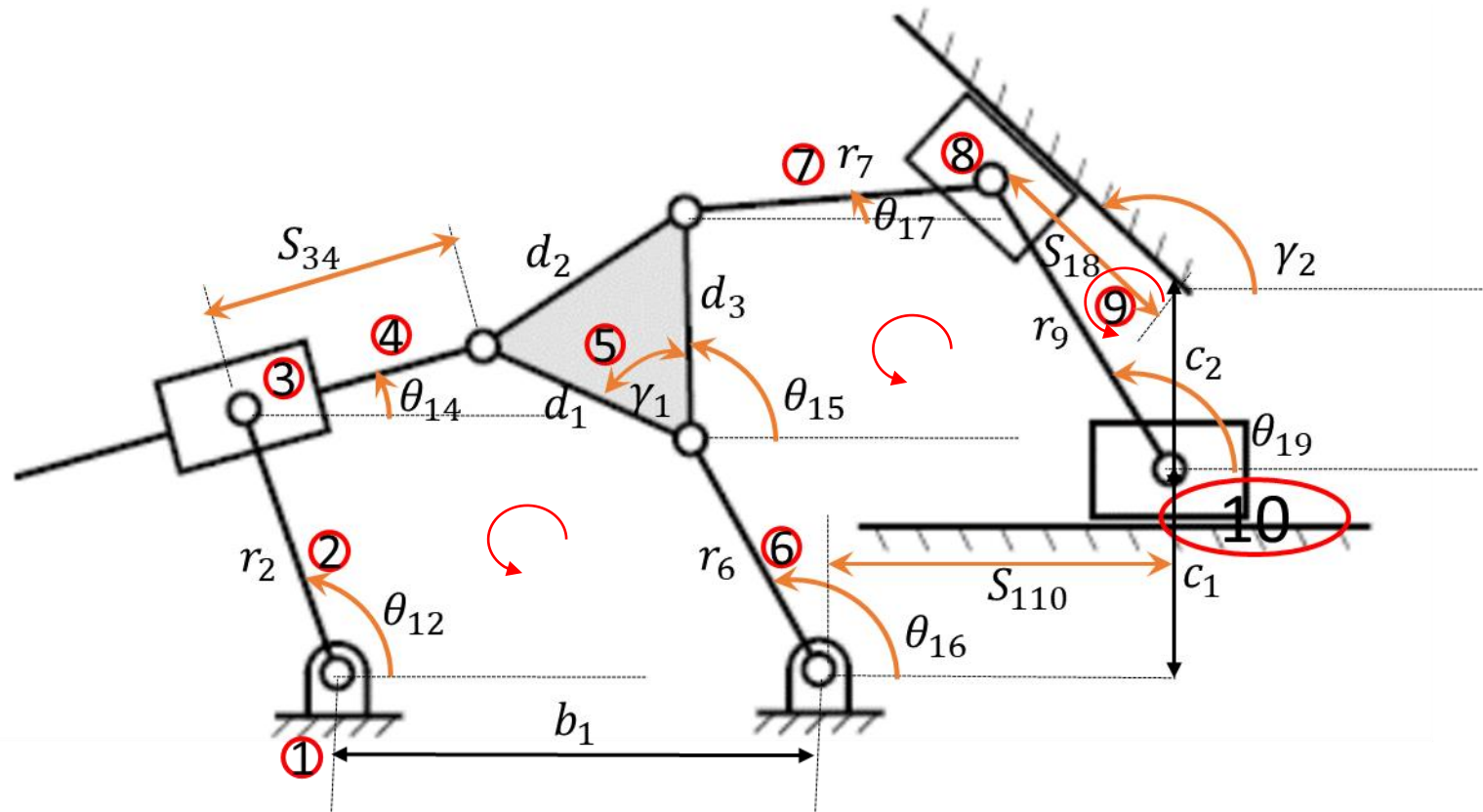
# İvme Değişkenleri Grafikleri



# İvme Değişkenleri Grafikleri



# Örnek 2



# Serbestlik Derecesi Analizi

---

$$F = \lambda(l - j - 1) + \sum_{i=1}^j f_i$$

$$F = 3(10 - 12 - 1) + 12 = 3$$

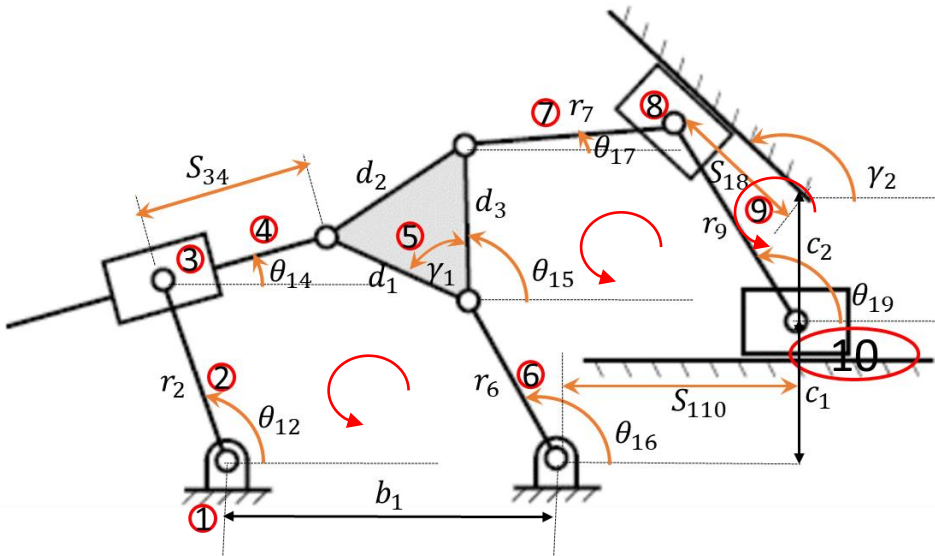
Mekanizmanın bağımsız mafsal değişkenleri;  $\theta_{12}, \theta_{16}, \theta_{15}, \theta_{14}, \theta_{17}, \theta_{19}, S_{34}, S_{110}, S_{18}$

Üç bağımsız devre var;

6 skaler denklem elde edilir. Dolayısıyla 9 mafsal değişkeninden 3'ünün verilmiş olması gerekir. Başka bir deyişle serbestlik derecesi kadar değişkenin biliniyor olması gerekir.

$\theta_{12}, \theta_{16}$  ve  $S_{110}$  verilmiş diğer mafsal değişkenlerini bulunuz.

# Devre Denklemleri



$$b_1 + r_6 e^{i\theta_{16}} + d_1 e^{i(\gamma_1 + \theta_{15})} = r_2 e^{i\theta_{12}} + s_{34} e^{i\theta_{14}}$$

$$r_6 e^{i\theta_{16}} + d_3 e^{i\theta_{15}} + r_7 e^{i\theta_{17}} = c_1 i + s_{110} + r_9 e^{i\theta_{19}}$$

$$r_9 e^{i\theta_{19}} = c_2 i + s_{18} e^{i\gamma_2}$$

$\theta_{12}$ ,  $\theta_{16}$  ve  $s_{110}$  verilmiş diğer mafsal değişkenlerini bulunuz.

$$b_1 = 0.75; c_1 = 0.20; c_2 = 0.25; d_1 = d_2 = d_3 = 0.3;$$

$$r_2 = 0.40; r_6 = 0.35; r_7 = 0.45; r_9 = 0.5$$

$$\theta_{12} = 110^\circ; \theta_{16} = 120^\circ; s_{110} = 0.65 \text{ m};$$

$$\gamma_1 = 60^\circ; \gamma_2 = 135^\circ;$$

$$\dot{\theta}_{12} = 2 \frac{\text{rad}}{\text{s}}; \dot{\theta}_{16} = 3 \text{ rad/s}; \dot{s}_{110} = 0.25 \text{ m/s};$$

# Devre Denklemlerinin Skaler Formu

---

$$b_1 + r_6 e^{i\theta_{16}} + d_1 e^{i(\gamma_1 + \theta_{15})} = r_2 e^{i\theta_{12}} + s_{34} e^{i\theta_{14}}$$

$$r_6 e^{i\theta_{16}} + d_3 e^{i\theta_{15}} + r_7 e^{i\theta_{17}} = c_1 i + s_{110} + r_9 e^{i\theta_{19}}$$

$$r_9 e^{i\theta_{19}} = c_2 i + s_{18} e^{i\gamma_2}$$

$$b_1 + r_6 \cos\theta_{16} + d_1 \cos(\gamma_1 + \theta_{15}) = r_2 \cos\theta_{12} + s_{34} \cos\theta_{14}$$

$$b_1 + r_6 \sin\theta_{16} + d_1 \sin(\gamma_1 + \theta_{15}) = r_2 \sin\theta_{12} + s_{34} \sin\theta_{14}$$

$$r_6 \cos\theta_{16} + d_3 \cos\theta_{15} + r_7 \cos\theta_{17} = s_{110} + r_9 \cos\theta_{19}$$

$$r_6 \sin\theta_{16} + d_3 \sin\theta_{15} + r_7 \sin\theta_{17} = c_1 + r_9 \sin\theta_{19}$$

$$r_9 \cos\theta_{19} = s_{18} \cos(\gamma_2)$$

$$r_9 \sin\theta_{19} = c_2 + s_{18} \sin(\gamma_2)$$



# KA için skaler denklemlerin çözümü

---

İlk dört denklemde bilinmeyen sayısı denklem sayısından fazla bu nedenle son iki denklemi kullanarak çözüme başlamalıyız. Her iki denklemin karesini alıp taraf tarafa toplayalım.

$$r_9 \cos \theta_{19} = s_{18} \cos(\gamma_2) \Rightarrow r_9^2 \cos^2 \theta_{19} = s_{18}^2 \cos^2 \gamma_2$$

$$r_9 \sin \theta_{19} = c_2 + s_{18} \sin(\gamma_2) \Rightarrow r_9^2 \sin^2 \theta_{19} = c_2^2 + s_{18}^2 \sin^2 \gamma_2 + 2c_2 s_{18} \sin \gamma_2$$

$$r_9^2 = c_2^2 + s_{18}^2 + 2c_2 s_{18} \sin \gamma_2 \Rightarrow s_{18}^2 + 2c_2 s_{18} \sin \gamma_2 + c_2^2 - r_9^2 = 0$$

$$\theta_{19} = \text{atan2}(c_2 + s_{18} \sin(\gamma_2), s_{18} \cos(\gamma_2))$$

$$s_{18} = 0.2909; \theta_{19} = 114.2952^\circ$$

# Bilgisayarla konum analizi

---

```
clc;
close all;
%Verilenler
b1=0.75;c1=0.20;c2=0.25;d1=0.3;d2=0.3;d3=0.3;
r2=0.4;r6=0.35;r7=0.45;r9=0.5;
g1=60*pi/180;g2=135*pi/180;
q12=80*pi/180;
q16=120*pi/180;
s110=0.65;
%s18'in çözümü;
C=c2^2-r9^2;
B=2*c2*sin(g2);
A=1;
Delta=B^2-4*A*C;
s18=(-B+sqrt(Delta))/2/A;
q19=atan2((c2+s18*sin(g2)),(s18*cos(g2)));
```

# KA için skaler denklemlerin çözümü

---

$$d_3 \cos \theta_{15} + r_7 \cos \theta_{17} = s_{110} + r_9 \cos \theta_{19} - r_6 \cos \theta_{16}$$

$$d_3 \sin \theta_{15} + r_7 \sin \theta_{17} = c_1 + r_9 \sin \theta_{19} - r_6 \sin \theta_{16}$$

$$0.3 \cos \theta_{15} = 0.6193 - 0.45 \cos \theta_{17} \Rightarrow 0.3^2 \cos^2 \theta_{15} = 0.6193^2 + 0.45^2 \cos^2 \theta_{17} - 0.5574 \cos \theta_{17}$$

$$0.3 \sin \theta_{15} = 0.3526 - 0.45 \sin \theta_{17} \Rightarrow 0.3^2 \sin^2 \theta_{15} = 0.3526^2 + 0.45^2 \sin^2 \theta_{17} - 0.3173 \sin \theta_{17}$$

Denklemleri taraf tarafa toplarsak;

$$0.3^2 = 0.6193^2 + 0.3526^2 + 0.45^2 - 0.5574 \cos \theta_{17} - 0.3173 \sin \theta_{17}$$

$$0.5574 \cos \theta_{17} + 0.3173 \sin \theta_{17} = 0.6204$$

# Bilgisayarla Konum Analizi

---

```
k1=[s110+r9*cos(q19)-r6*cos(q16);c1+r9*sin(q19)-r6*sin(q16)];
C=k1(1)^2+k1(2)^2+r7^2-d3^2;
A=k1(1)*r7^2;B=k1(2)*r7^2;
D=sqrt(A^2+B^2);
fi=atan2(B,A);
q17=fi-acos(C/D);
q15=atan2(k1(2)-r7*sin(q17),k1(1)-r7*cos(q17));
k2=[b1+r6*cos(q16)+d1*cos(g1+q15)-r2*cos(q12);
    b1+r6*sin(q16)+d1*sin(g1+q15)-r2*sin(q12)];
q14=atan2(k2(2),k2(1));
s34=k2(2)/sin(q14);
```

# KA için skaler denklemlerin çözümü

---

$$0.5574\cos\theta_{17} + 0.3173\sin\theta_{17} = 0.6204$$

Hatırlatma;  $A\cos\theta + B\sin\theta = C$  denkleminin çözümü

1. Yöntem;  $\tan\left(\frac{\theta}{2}\right) = t \Rightarrow \sin\theta = \frac{2t}{1+t^2}$  ;  $\cos\theta = \frac{1-t^2}{1+t^2}$

2. Yöntem;  $D = \sqrt{A^2 + B^2}$  ;  $\tan\phi = \frac{B}{A} \Rightarrow \phi = \tan^{-1}\frac{B}{A}$  ;

$$C = D\cos(\theta - \phi); \theta = \phi \pm \cos^{-1}\frac{C}{D}$$

$$D = \sqrt{A^2 + B^2} = \sqrt{0.5574^2 + 0.3173^2} = 0.6414$$

$$\tan\phi = \frac{0.3173}{0.5574} \Rightarrow \phi = \tan^{-1}\left(\frac{0.3173}{0.5574}\right) = 29.65^\circ$$

$$\theta_{17} = \phi \pm \cos^{-1}\frac{C}{D} = 29.65^\circ \pm \cos^{-1}\frac{0.6204}{0.6414} = 29.65^\circ \pm 14.70^\circ = 44.35^\circ \text{ yada } 14.95^\circ$$

# KA için skaler denklemlerin çözümü

---

$$\theta_{17} = 44.35^0 \text{ yada } 14.95^0$$

$$\text{Eğer } \theta_{17} = 44.35^0$$

$$0.3\cos\theta_{15} = 0.6193 - 0.45\cos\theta_{17} \Rightarrow \cos\theta_{15} = 0.9917$$

$$0.3\sin\theta_{15} = 0.3526 - 0.45\sin\theta_{17} \Rightarrow \sin\theta_{15} = 0.038$$

$$\theta_{15} = \tan^{-1}\left(\frac{0.038}{0.9917}\right) = 2.19^0$$

$$\text{Eğer } \theta_{17} = 14.95^0$$

$$0.3\cos\theta_{15} = 0.6193 - 0.45\cos\theta_{17} \Rightarrow \cos\theta_{15} = 0.615$$

$$0.3\sin\theta_{15} = 0.3526 - 0.45\sin\theta_{17} \Rightarrow \sin\theta_{15} = 0.788$$

$$\theta_{15} = \tan^{-1}\left(\frac{0.788}{0.615}\right) = 52.04^0$$

# KA için skaler denklemlerin çözümü

---

$$\theta_{17} = 14.95^0 \text{ ve } \theta_{15} = 52.04^0$$

$$b_1 + r_6 \cos \theta_{16} + d_1 \cos(\gamma_1 + \theta_{15}) = r_2 \cos \theta_{12} + s_{34} \cos \theta_{14}$$

$$b_1 + r_6 \sin \theta_{16} + d_1 \sin(\gamma_1 + \theta_{15}) = r_2 \sin \theta_{12} + s_{34} \sin \theta_{14}$$

$$b_1 + r_6 \cos \theta_{16} + d_1 \cos(\gamma_1 + \theta_{15}) - r_2 \cos \theta_{12} = s_{34} \cos \theta_{14}$$

$$b_1 + r_6 \sin \theta_{16} + d_1 \sin(\gamma_1 + \theta_{15}) - r_2 \sin \theta_{12} = s_{34} \sin \theta_{14}$$

$$\tan \theta_{14} = \frac{\sin \theta_{14}}{\cos \theta_{14}} \Rightarrow \theta_{14} = \tan^{-1} \frac{b_1 + r_6 \sin \theta_{16} + d_1 \sin(\gamma_1 + \theta_{15}) - r_2 \sin \theta_{12}}{b_1 + r_6 \cos \theta_{16} + d_1 \cos(\gamma_1 + \theta_{15}) - r_2 \cos \theta_{12}} = 57.9025^0$$

$$s_{34} = 1.1277 \text{ m}$$

# Örnek 2 Hız Analizi

---

Denklemleri bilinmeyen parametreler bir tarafta toplanacak şekilde düzenliyoruz . Böylece türev alma sonunda denklemleri düzenlemek daha kolay olacaktır.

$$b_1 + r_6 \cos\theta_{16} - r_2 \cos\theta_{12} = s_{34} \cos\theta_{14} - d_1 \cos(\gamma_1 + \theta_{15})$$

$$b_1 + r_6 \sin\theta_{16} - r_2 \sin\theta_{12} = s_{34} \sin\theta_{14} - d_1 \sin(\gamma_1 + \theta_{15})$$

$$r_6 \cos\theta_{16} - s_{110} = r_9 \cos\theta_{19} - d_3 \cos\theta_{15} - r_7 \cos\theta_{17}$$

$$r_6 \sin\theta_{16} = c_1 + r_9 \sin\theta_{19} - d_3 \sin\theta_{15} - r_7 \sin\theta_{17}$$

$$0 = s_{18} \cos(\gamma_2) - r_9 \cos\theta_{19}$$

$$0 = c_2 + s_{18} \sin(\gamma_2) - r_9 \sin\theta_{19}$$



# Örnek 2 Hız Analizi

---

Denklemlerin türevlerini alıyoruz.

$$b_1 - r_6 \dot{\theta}_{16} \sin \theta_{16} + r_2 \dot{\theta}_{12} \sin \theta_{12} = \dot{s}_{34} \cos \theta_{14} - s_{34} \dot{\theta}_{14} \sin \theta_{14} + d_1 \dot{\theta}_{15} \sin(\gamma_1 + \theta_{15})$$

$$b_1 + r_6 \dot{\theta}_{16} \cos \theta_{16} - r_2 \dot{\theta}_{12} \cos \theta_{12} = \dot{s}_{34} \sin \theta_{14} + s_{34} \dot{\theta}_{14} \cos \theta_{14} - d_1 \dot{\theta}_{15} \cos(\gamma_1 + \theta_{15})$$

$$-r_6 \dot{\theta}_{16} \sin \theta_{16} - \dot{s}_{110} = -r_9 \dot{\theta}_{19} \sin \theta_{19} + d_3 \dot{\theta}_{15} \sin \theta_{15} + r_7 \dot{\theta}_{17} \sin \theta_{17}$$

$$r_6 \dot{\theta}_{16} \cos \theta_{16} = r_9 \dot{\theta}_{19} \cos \theta_{19} - d_3 \dot{\theta}_{15} \cos \theta_{15} - r_7 \dot{\theta}_{17} \cos \theta_{17}$$

$$0 = \dot{s}_{18} \cos(\gamma_2) + r_9 \dot{\theta}_{19} \sin \theta_{19}$$

$$0 = \dot{s}_{18} \sin(\gamma_2) - r_9 \dot{\theta}_{19} \cos \theta_{19}$$

# Örnek 2 Hız Analizi

$$\begin{bmatrix}
 \cos\theta_{14} & -s_{34}\sin\theta_{14} & d_1\sin(\gamma_1 + \theta_{15}) & 0 & 0 & 0 \\
 \sin\theta_{14} & s_{34}\cos\theta_{14} & -d_1\cos(\gamma_1 + \theta_{15}) & 0 & 0 & 0 \\
 0 & 0 & d_3\sin\theta_{15} & r_7\sin\theta_{17} & -r_9\sin\theta_{19} & 0 \\
 0 & 0 & -d_3\cos\theta_{15} & -r_7\cos\theta_{17} & r_9\cos\theta_{19} & 0 \\
 0 & 0 & 0 & 0 & r_9\sin\theta_{19} & \cos(\gamma_2) \\
 0 & 0 & 0 & 0 & -r_9\cos\theta_{19} & \sin(\gamma_2)
 \end{bmatrix}
 \begin{bmatrix}
 \dot{s}_{34} \\
 \dot{\theta}_{14} \\
 \dot{\theta}_{15} \\
 \dot{\theta}_{17} \\
 \dot{\theta}_{19} \\
 \dot{s}_{18}
 \end{bmatrix}
 =
 \begin{bmatrix}
 b_1 - r_6\dot{\theta}_{16}\sin\theta_{16} + r_2\dot{\theta}_{12}\sin\theta_{12} \\
 b_1 + r_6\dot{\theta}_{16}\cos\theta_{16} - r_2\dot{\theta}_{12}\cos\theta_{12} \\
 -r_6\dot{\theta}_{16}\sin\theta_{16} - \dot{s}_{110} \\
 r_6\dot{\theta}_{16}\cos\theta_{16} \\
 0 \\
 0
 \end{bmatrix}$$

# Bilgisayarla Hız Analizi

---

`%Verilenler`

```
dq12=2;dq16=3;ds110=0.25;
```

```
A=[cos(q14) -s34*sin(q14) d1*sin(g1+q15) 0 0 0;  
    sin(q14) s34*cos(q14) -d1*cos(g1+q15) 0 0 0;  
    0 0 d3*sin(q15) r7*sin(q17) -r9*sin(q19) 0;  
    0 0 -d3*cos(q15) -r7*cos(q17) r9*cos(q19) 0;  
    0 0 0 0 r9*sin(q19) cos(g2);  
    0 0 0 0 -r9*cos(q19) sin(g2)];
```

```
b=[b1-r6*dq16*sin(q16)+r2*dq12*sin(q12);  
    b1+r6*dq16*cos(q16)-r2*dq12*cos(q12);  
    -r6*dq16*sin(q16)-ds110;  
    r6*dq16*cos(q16);0;0];
```

```
K=[s34;q14;q15;q17;q19;s18]
```

```
V=A\b
```

# Hız analizi sonucu elde edilen matrisin çözümü

---

A = 0.3866 -0.9372 0.2781 0 0 0  
0.9222 0.3929 0.1126 0 0 0  
0 0 0.2366 0.1161 -0.4557 0  
0 0 -0.1845 -0.4348 -0.2057 0  
0 0 0 0 0.4557 -0.7071  
0 0 0 0 0.2057 0.7071

b = 0.6285

0.0861

-1.1593

-0.5250

0

0

# Sonuç

---

$$\begin{bmatrix} \dot{s}_{34} \\ \dot{\theta}_{14} \\ \dot{\theta}_{15} \\ \dot{\theta}_{17} \\ \dot{\theta}_{19} \\ \dot{s}_{18} \end{bmatrix} = \begin{bmatrix} 1.7888 \\ -1.9910 \\ -6.9377 \\ 4.1516 \\ 0 \\ 0 \end{bmatrix}$$