



Mekanik Tasarım, Üretim, Testler

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ODTÜ Makina Mühendisliği Bölümü, Ankara

Proje Hedef ve İsterleri

Hedefler:

- Az ataletli ve yüksek direngenlikli uzuv geometrilerinin belirlenmesi
- Normal kısıtlı ve fazla kısıtlı kinematik yapıya sahip iki manipölatör tasarlanarak ve üretilerek aşağıdaki ölçütlere göre kıyaslanması:
 - Enerji verimliliği
 - Dengeleme ve kaideye etki eden sarsma kuvvetleri
 - Konumlama ve tekrarlanabilirlik hassasiyetleri
 - Model karmaşıklığı ve sistem kararlılığı açısından kontrol edilebilirlik
 - Kalibrasyon kolaylığı

Tasarım Ölçütleri:

- 150 mm x 100 mm çalışma alanı
- 5 kg taşıma kapasitesi ve azami 5g ivme
- Konumlama hassasiyeti: $\pm 200 \mu\text{m}$ (dinamik koşullarda)
- Tekrarlanabilirlik: $\pm 100 \mu\text{m}$ (dinamik koşullarda)

Mekanizma Kavramsal Tasarımı

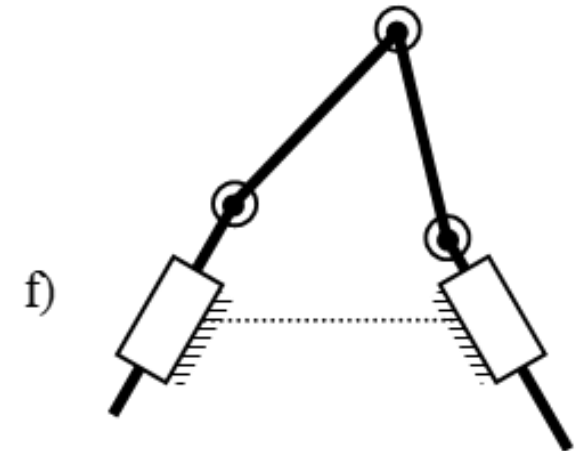
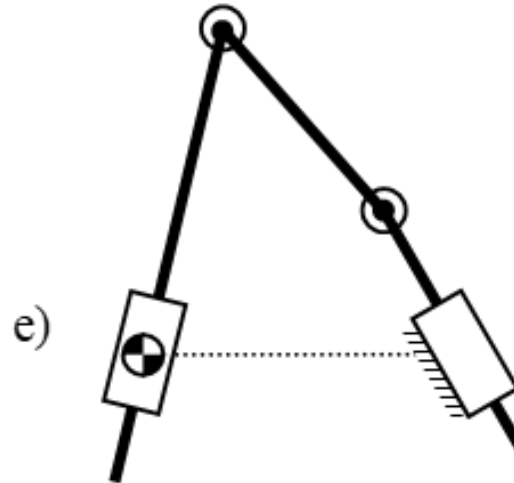
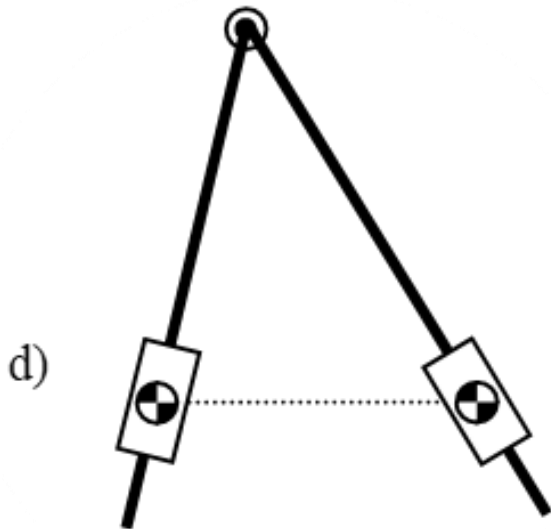
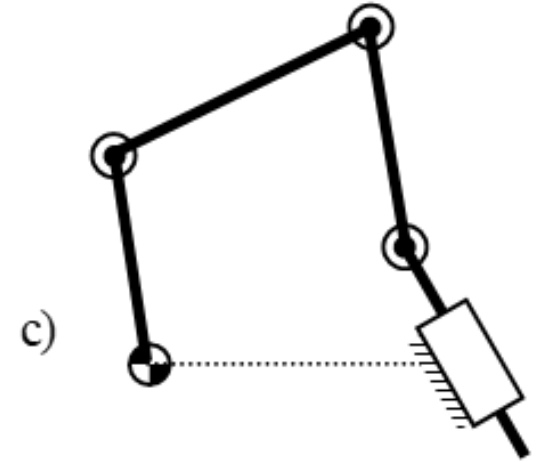
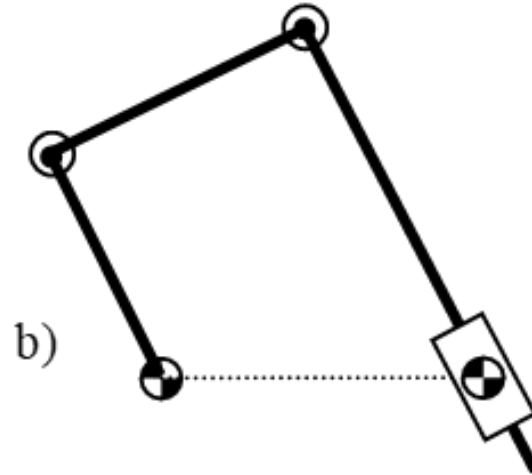
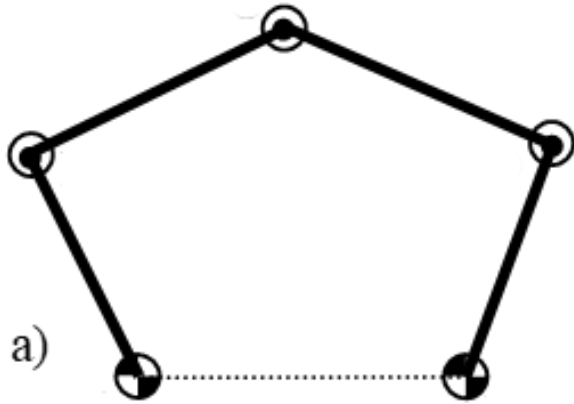
2 Serbestlik Dereceli ($2-s^\circ$) Düzlemsel Mekanizma Alternatifleri

Yalnızca döner (R) ve kayar (P) mafsallardan oluşan, $2-s^\circ$, tek devreli düzlemsel bir mekanizma 5 uzuv ve 5 mafsaldan oluşur. Bir devrede ikiden fazla kayar mafsal kullanılamaz. Bu şekilde 32 farklı mekanizma elde edilebilirse de şu koşullar altında 6 farklı 5-kol mekanizması elde etmek mümkündür:

- Eyleticiler ana gövdeden destekli olmalıdır.
- Varsa, kayar mafsallar aktif (eyletici) olmalıdır.
- Ayna görünümündeki mekanizmalar bir sayılır (ör. RRRPR = RPRRR).
- Hiçbir eyletici mafsal diğerinin yükünü taşımamalıdır.

Mekanizma Kavramsal Tasarımı

Bu şartları sağlayan 5 kol mekanizmaları RRRRR (5R), RRRPR, RRRRP, RPRRP ve PRRRP mekanizmalarıdır:

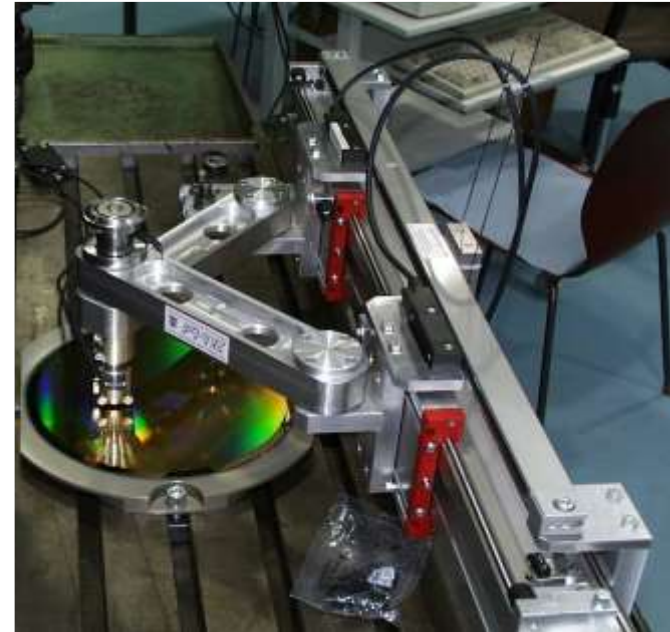


Mekanizma Kavramsal Tasarımı

Çalışma alanı simetrisi, dengeleme ve denetim basitliği nedenleri ile genellikle simetrik yapılar tercih edilmektedir*. RRRRR (5R) ve PRRRP kinematik mimarileri uygulamada sıkça görülmektedir.



DexTAR – ETS, Montreal

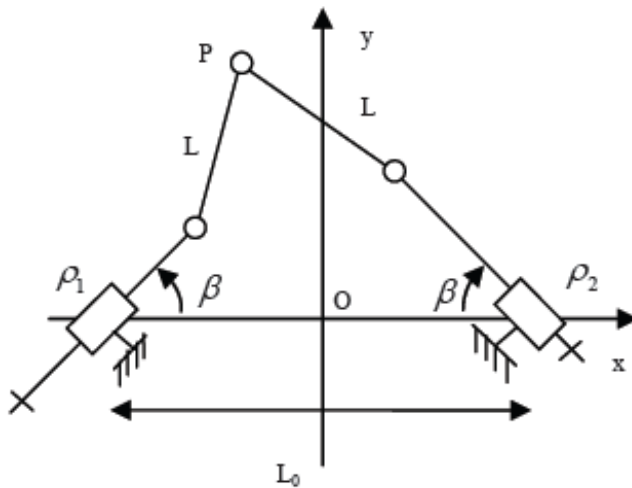


2-s° denetim sistemi -
FHTE, Esslingen

*Sun S, Cheung JWF, Lou Y (2007) A study on five-bar manipulators for semiconductor packaging applications. 2007 IEEE International Conference on Mechatronics and Automation Bildiri Kitabı, 1811-1816.

PRRRP (2-PRR) Mekanizması

Genel yapı ve sıklıkla görülen yapılandırmalar



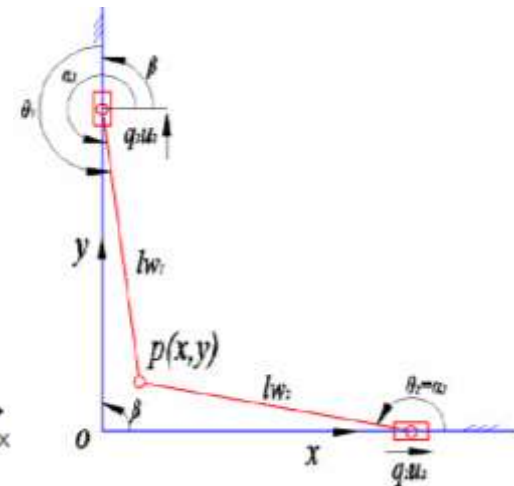
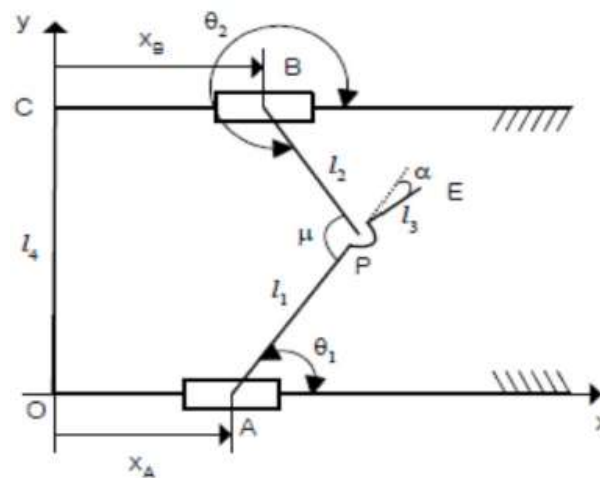
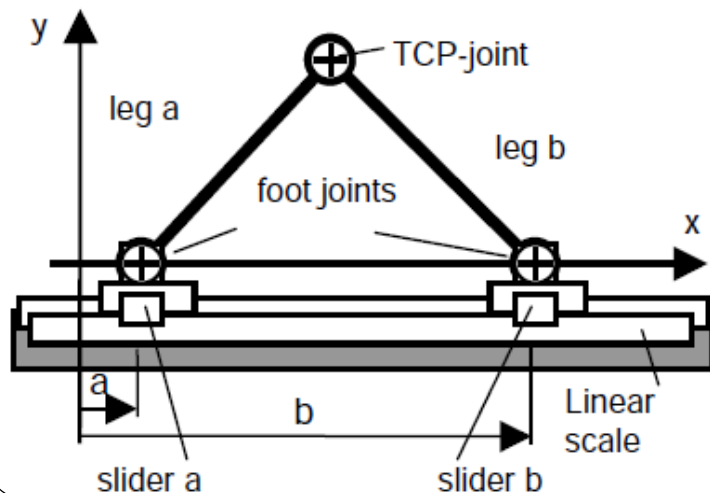
Sun S, Cheung JWF, Lou Y (2007) A study on five-bar manipulators for semiconductor packaging applications. 2007 IEEE International Conference on Mechatronics and Automation Bildiri Kitabı, 1811-1816.

Hanak TR, Zirn O, Ruoff W (2002) 2 DOF Dynamic Accuracy Monitoring for Robot and Machine Tool Manipulators. ASPE's 17th Annual Meeting.

Li J, Liu Y, Sun L (2007) A novel 2-DOF planar parallel robot with high accelerate-high precision. 2007 IEEE International Conference on Robotics and Biomimetics Bildiri Kitabı, 2189-2193

Lee, J. G., Lee, S. R., Lee C. Y., Yang, S. H. (2012). A study on the kinematics of 2-DOF parallel manipulator. Applied Mechanics and Materials, 148-149, 1487-1490.

Lee, J. G., Lee, S. R., Lee C. Y., Yang, S. H. (2012). A study on the kinematics of 2-DOF parallel manipulator. Applied Mechanics and Materials, 148-149, 1487-1490.

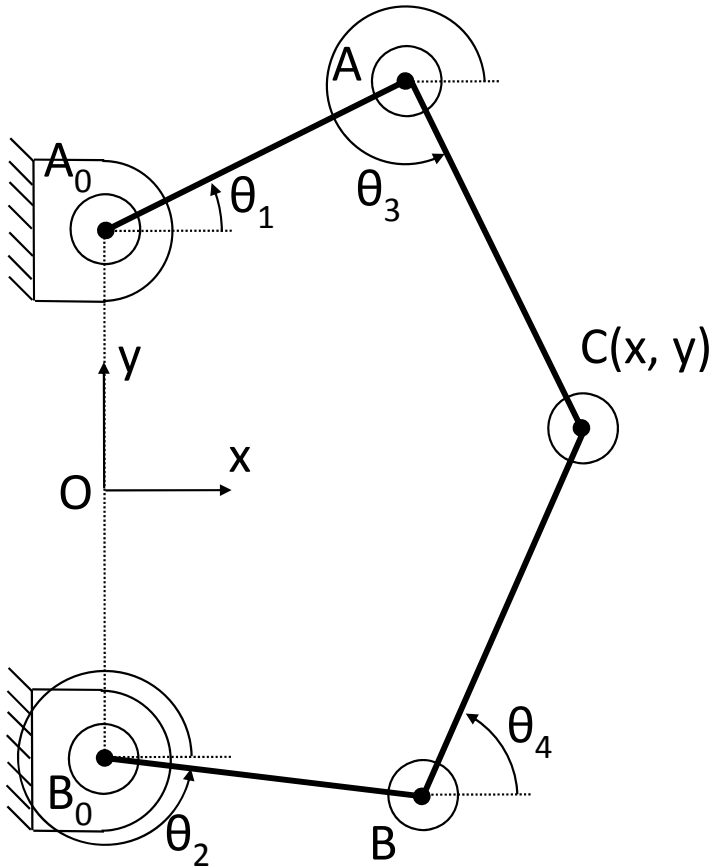


PRRRP Mekanizma Örnek Uygulama

Salvagnini L5 high dynamics fiber laser



RRRRR (5R) (2-RRR) Mekanizması



$$\begin{aligned}
 |OA_0| &= |OB_0| \\
 |A_0B_0| &= a_1 \\
 |A_0A| &= |B_0B| = a_2 \\
 |AC| &= |BC| = a_3
 \end{aligned}$$

Düz kinematik:

$$\overline{OA} = ia_1/2 + a_2 e^{i\theta_1} \quad ; \quad \overline{OB} = -ia_1/2 + a_2 e^{i\theta_2}$$

$$\vec{s} = \overline{AB} = s_x + is_y = -ia_1 + a_2 (e^{i\theta_2} - e^{i\theta_1})$$

$$s_x = a_2 (c\theta_2 - c\theta_1) \quad ; \quad s_y = -a_1 + a_2 (s\theta_2 - s\theta_1)$$

$$s = |\vec{s}| = \sqrt{s_x^2 + s_y^2} \quad ; \quad \phi = \angle \vec{s} = \text{atan2}(s_x, s_y)$$

$$\eta = \widehat{BAC} = \cos^{-1} [(s/2) / a_3]$$

$$\theta_3 = \phi + \eta \quad ; \quad \overline{OC} = \overline{OA} + a_3 e^{i\theta_3}$$

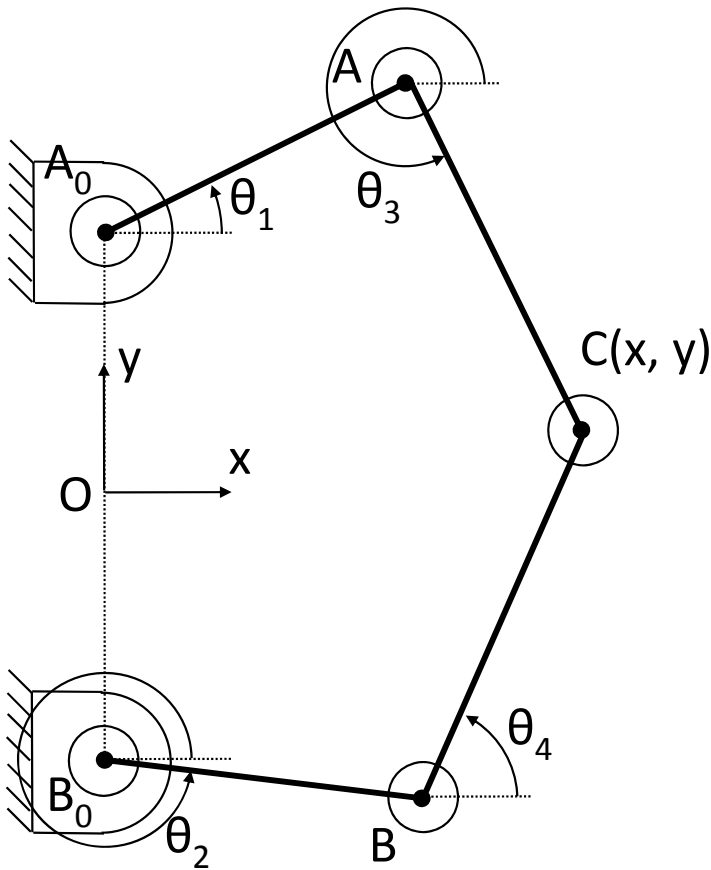
$$\theta_4 = \angle \overline{BC} = \text{atan2} [(\overline{OC} - \overline{OB})_x, (\overline{OC} - \overline{OB})_y]$$

$$\omega_3 = \frac{a_2}{a_3} \frac{-s(\theta_1 - \theta_4)\omega_1 + s(\theta_2 - \theta_4)\omega_2}{s(\theta_3 - \theta_4)}$$

$$\omega_4 = \frac{a_2}{a_3} \frac{-s(\theta_1 - \theta_3)\omega_1 + s(\theta_2 - \theta_3)\omega_2}{s(\theta_3 - \theta_4)}$$

$$v_{cx} + iv_{cy} = ia_2 e^{i\theta_1} \omega_1 + ia_3 e^{i\theta_3} \omega_3$$

RRRRR (5R) (2-RRR) Mekanizması



$$\begin{aligned} |OA_0| &= |OB_0| \\ |A_0B_0| &= a_1 \\ |A_0A| &= |B_0B| = a_2 \\ |AC| &= |BC| = a_3 \end{aligned}$$

Ters kinematik:

$$\vec{s}_1 = \overrightarrow{A_0C} = s_{1x} + s_{1y} = x + i(y - a_1/2)$$

$$s_1 = |\vec{s}_1| = \sqrt{s_{1x}^2 + s_{1y}^2} ; \phi_1 = \angle \vec{s}_1 = \text{atan2}(s_{1x}, s_{1y})$$

$$\eta_1 = \widehat{CA_0A} = \cos^{-1} \left(\frac{a_2^2 + s_1^2 - a_3^2}{2a_2s_1} \right) \Rightarrow \theta_1 = \phi_1 + \eta_1$$

$$\theta_3 = \text{atan2}(s_{1x} - a_2 \cos \theta_1, s_{1y} - a_2 \sin \theta_1)$$

$$\vec{s}_2 = \overrightarrow{B_0C} = s_{2x} + s_{2y} = x + i(y + a_1/2)$$

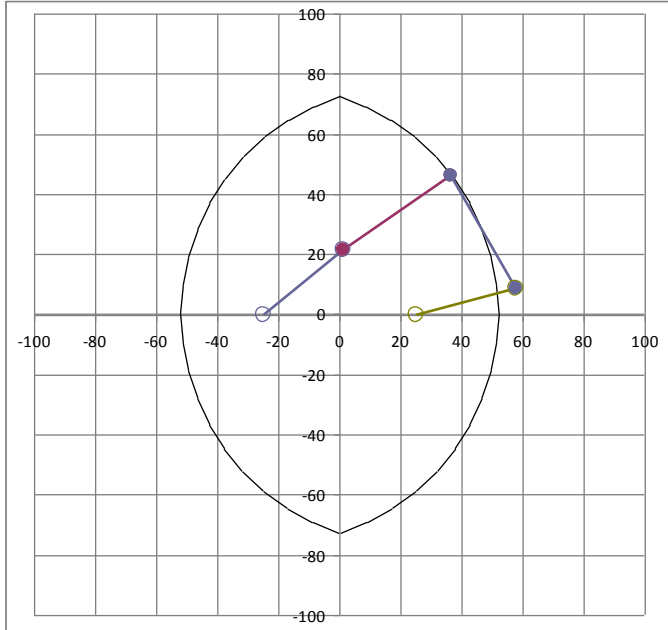
$$s_2 = |\vec{s}_2| = \sqrt{s_{2x}^2 + s_{2y}^2} ; \phi_2 = \angle \vec{s}_2 = \text{atan2}(s_{2x}, s_{2y})$$

$$\eta_2 = \widehat{CB_0B} = \cos^{-1} \left(\frac{a_2^2 + s_2^2 - a_3^2}{2a_2s_2} \right) \Rightarrow \theta_2 = \phi_2 - \eta_2$$

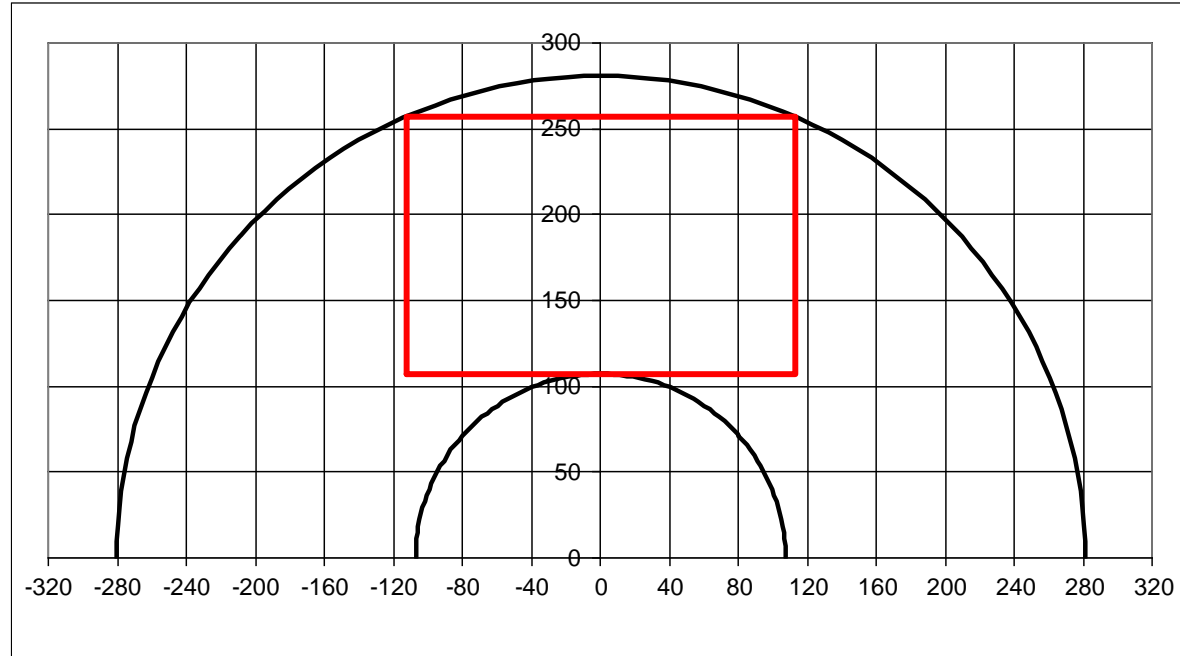
$$\theta_4 = \text{atan2}(s_{2x} - a_2 \cos \theta_2, s_{2y} - a_2 \sin \theta_2)$$

$$\omega_1 = -\frac{c\theta_3 v_{cx} + s\theta_3 v_{cy}}{a_2 s(\theta_1 - \theta_3)} ; \omega_2 = -\frac{c\theta_4 v_{cx} + s\theta_4 v_{cy}}{a_2 s(\theta_2 - \theta_4)}$$

Çalışma alanına göre mekanizma tasarımı



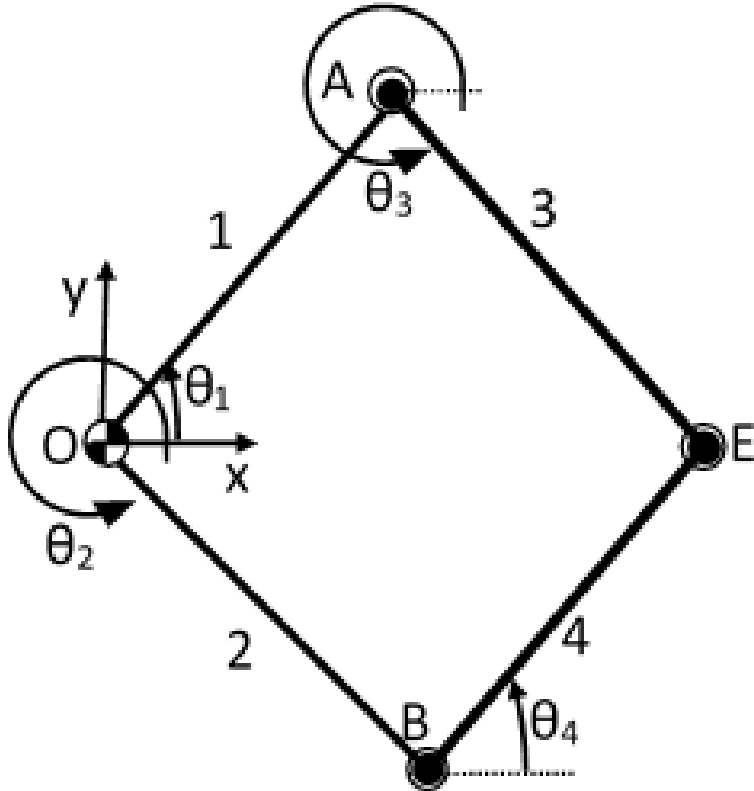
Erişilebilir çalışma alanı



Etkin çalışma alanı (dikdörtgen)

150 mm x 100 mm etkin çalışma alanı için 4 uzuv boyu 150 mm olan çakışık sabit mafsal eksenli 5R mekanizması uygundur.

Mekanizma Kinematığı



Düz kinematik:

$$\theta_3 = \theta_2 ; \theta_4 = \theta_1 ; \omega_3 = \omega_2 ; \omega_4 = \omega_1$$

$$\alpha_3 = \alpha_2 ; \alpha_4 = \alpha_1$$

$$\vec{r}_E = ae^{i\theta_1} + ae^{i\theta_2} ; \vec{v}_E = iae^{i\theta_1}\omega_1 + iae^{i\theta_2}\omega_2$$

$$\vec{a}_E = iae^{i\theta_1}\alpha_1 + iae^{i\theta_2}\alpha_2 - ae^{i\theta_1}\omega_1^2 + ae^{i\theta_2}\omega_2^2$$

Ters kinematik:

$$\vec{s} = \vec{A_0C} = s_x + s_y = x + iy$$

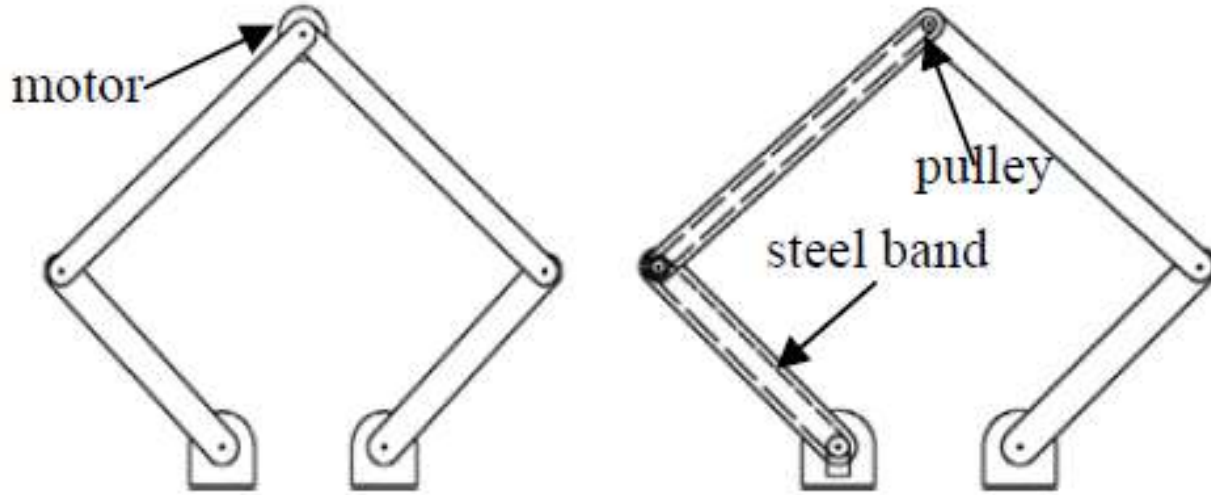
$$s = |\vec{s}| = \sqrt{s_x^2 + s_y^2} ; \phi = \angle \vec{s} = \text{atan2}(s_x, s_y)$$

$$\theta_1 = \phi + \cos^{-1}[s / (2a)] ; \theta_2 = \phi - \cos^{-1}[s / (2a)]$$

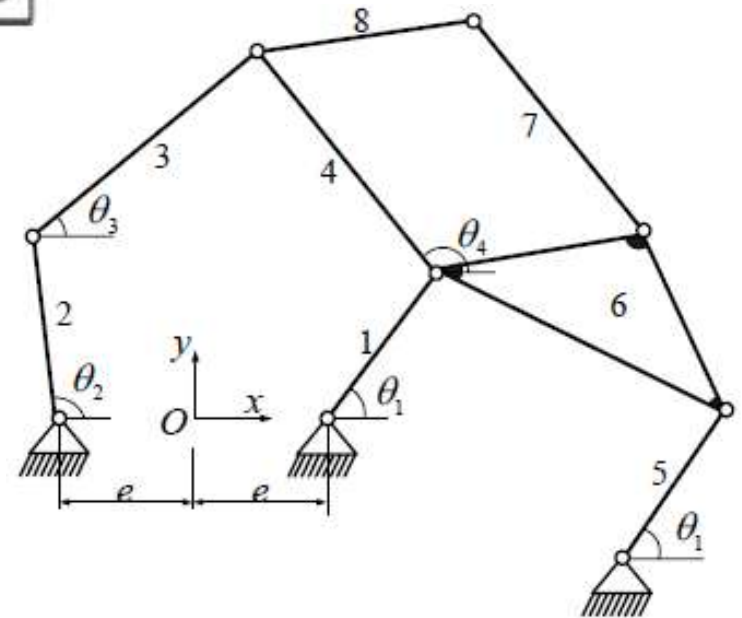
$$\omega_1 = -\frac{c\theta_2 v_{Ex} + s\theta_2 v_{Ey}}{as(\theta_1 - \theta_2)} ; \omega_2 = \frac{c\theta_1 v_{Ex} + s\theta_1 v_{Ey}}{as(\theta_1 - \theta_2)}$$

$$\alpha_1 = \frac{c\theta_2 a_{Ex} + s\theta_2 a_{Ey}}{as(\theta_2 - \theta_1)} + \frac{c(\theta_2 - \theta_1)\omega_1^2 - \omega_2^2}{s(\theta_2 - \theta_1)} \quad \alpha_2 = \frac{c\theta_1 a_{Ex} + s\theta_1 a_{Ey}}{as(\theta_2 - \theta_1)} + \frac{\omega_1^2 - c(\theta_2 - \theta_1)\omega_2^2}{s(\theta_2 - \theta_1)}$$

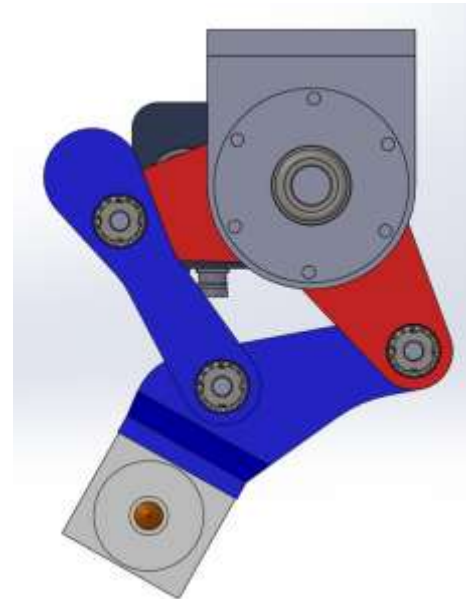
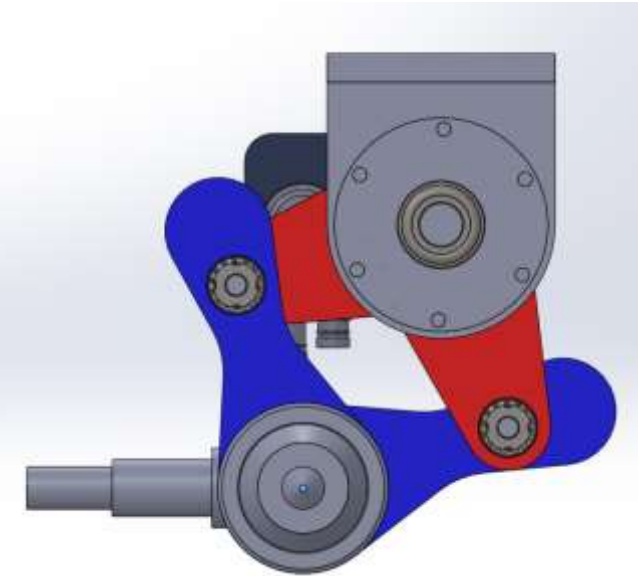
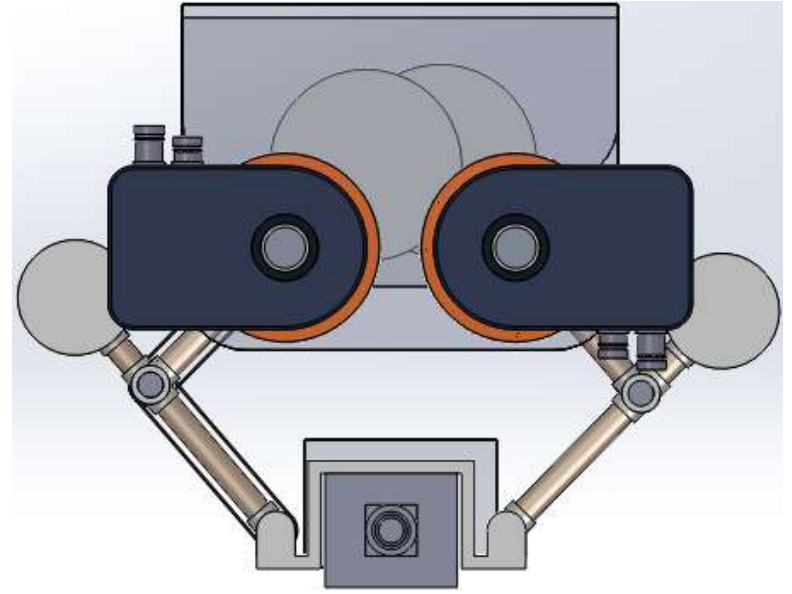
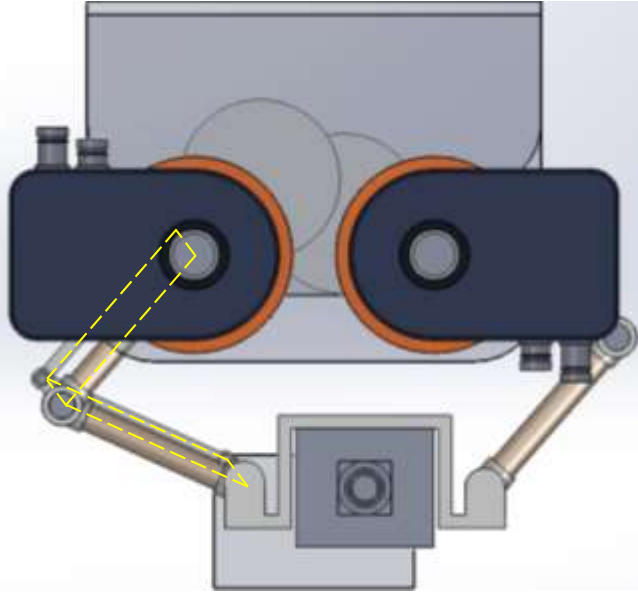
Uç İşlemci Yönelimini Sabit Tutma



- 1) Uç işlemci ekseninde 3. bir motor ve uygun control ile
- 2) Kayış-makara sistemi ile
- 3) Ek paralelkenar devreleri ile

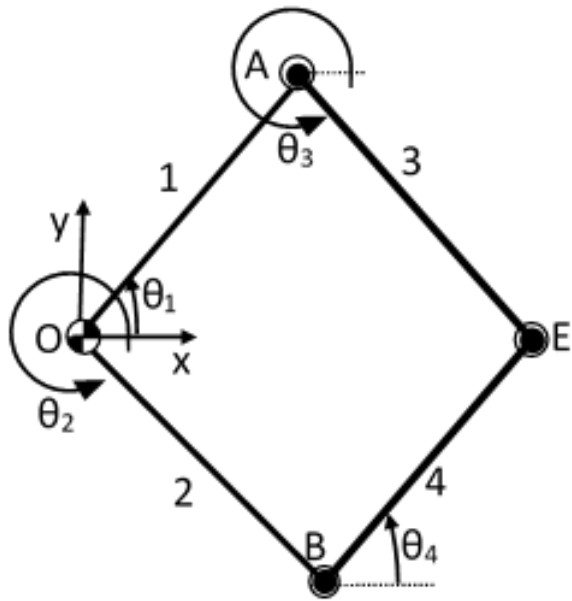


Uç İşlemci Yönelimini Sabit Tutma

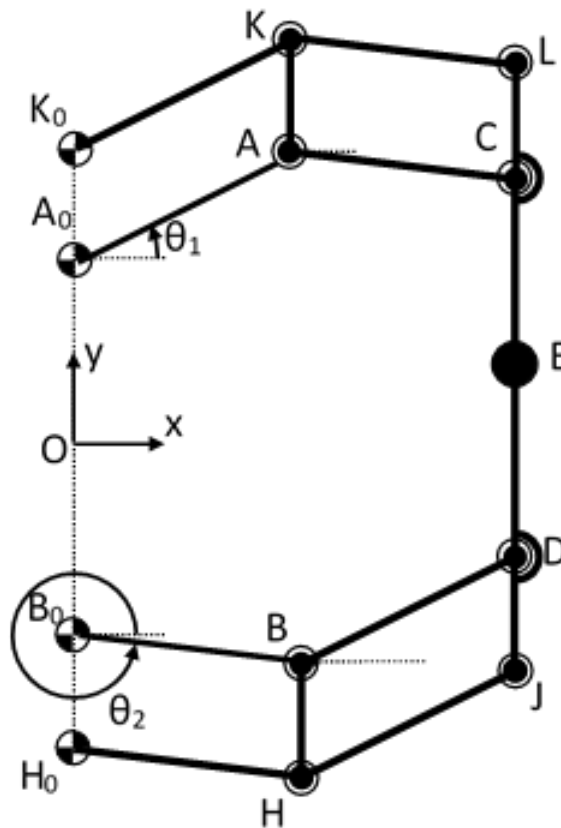


Projedeki Mekanizmalar

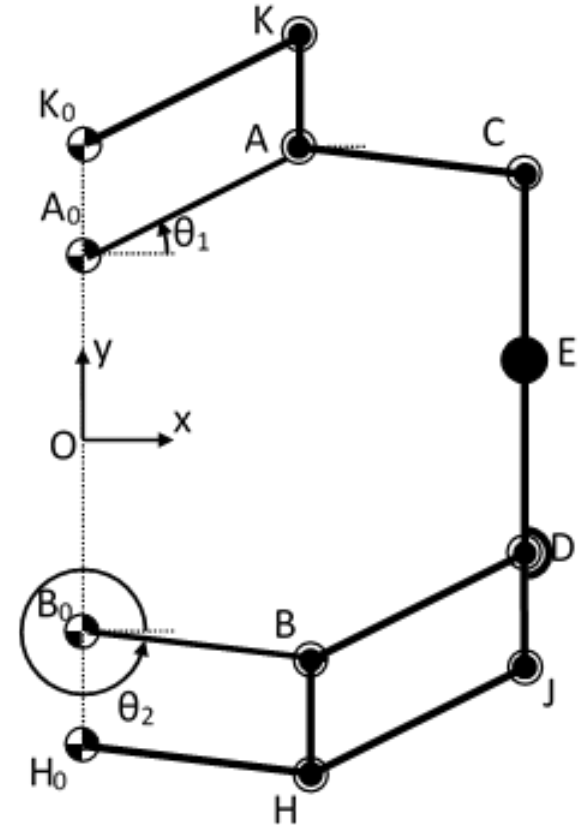
5R
Mekanizması



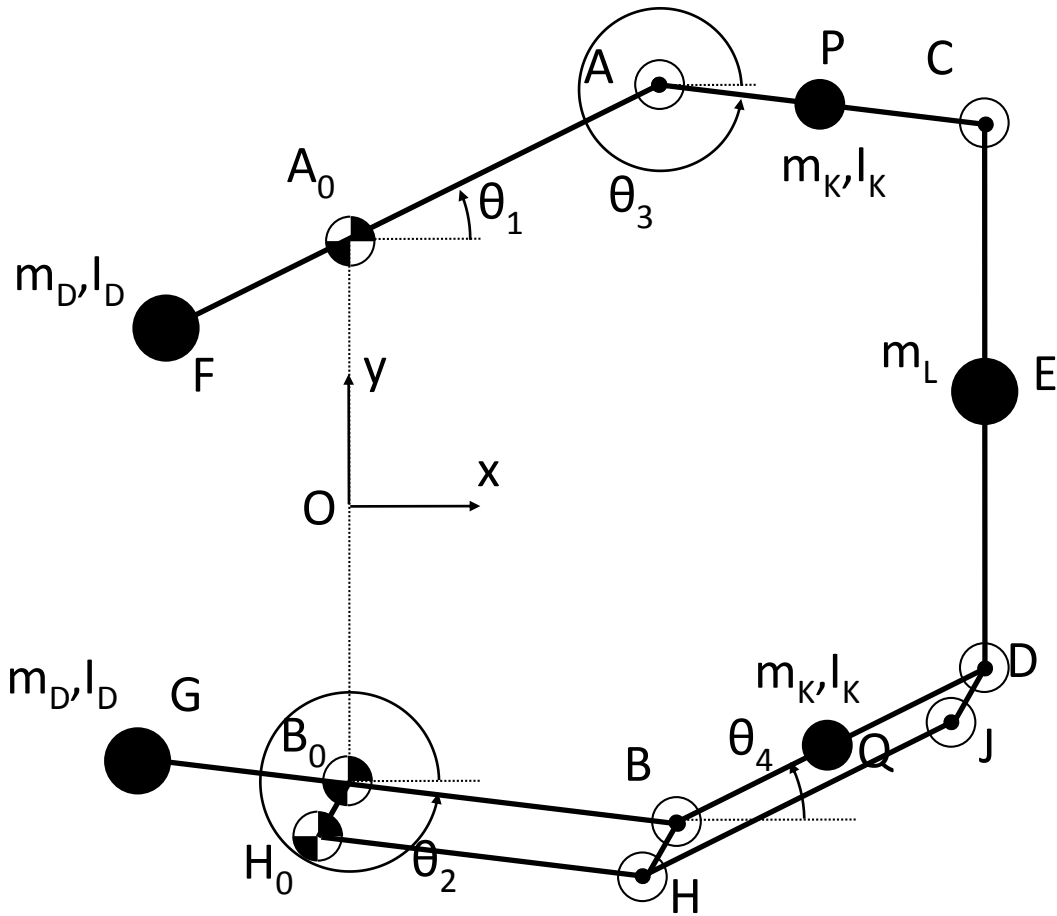
Fazla kısıtlı
mekanizma



Normal kısıtlı
mekanizma



Kuvvet Dengelemesi



$$|OA_0| = |OB_0| = |CE| = |DE| = a/2$$

$$|A_0A| = |B_0B| = |AC| = |BD| = r$$

$$|A_0F| = |B_0G| = p$$

$$|B_0H_0| = |BH| = |DJ|$$

$$\angle A_0B_0H_0 = \angle CDJ$$

Dinamik Analiz – Vektörel Mekaniik

$$F_{13x} = F_{35x} + m_K a_{3x}$$

$$F_{13y} = F_{35y} + m_K a_{3y}$$

$$F_{B4x} = F_{45x} + m_K a_{4x}$$

$$F_{4By} = -F_{45y} - m_K a_{4y}$$

$$F_{01x} = F_{13x} + m_D a_{1x}$$

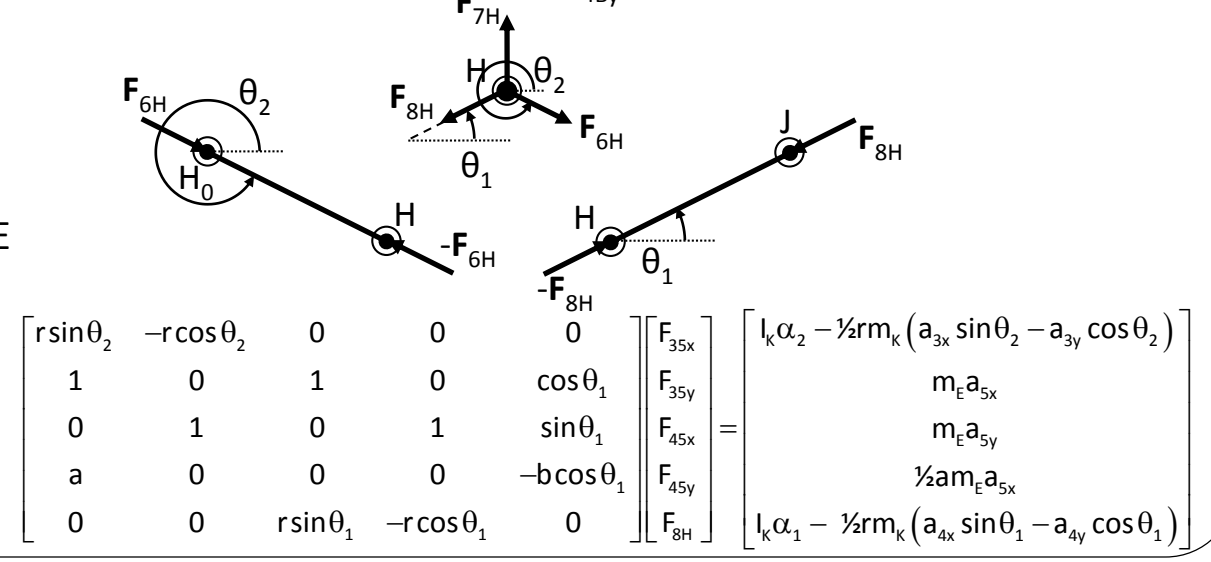
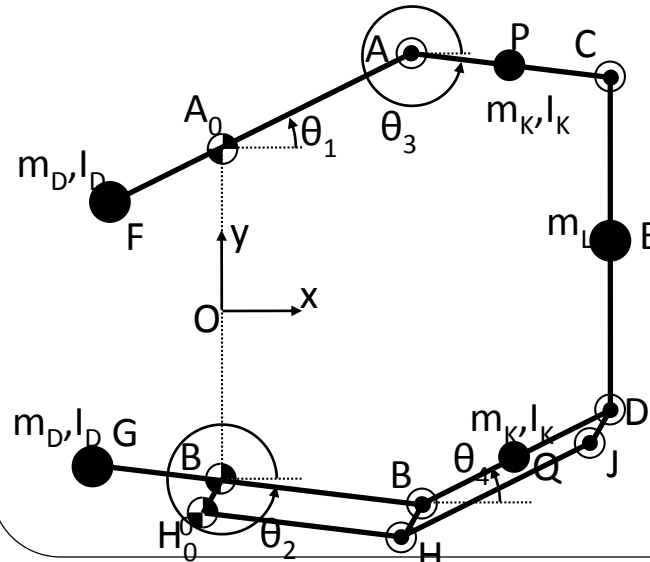
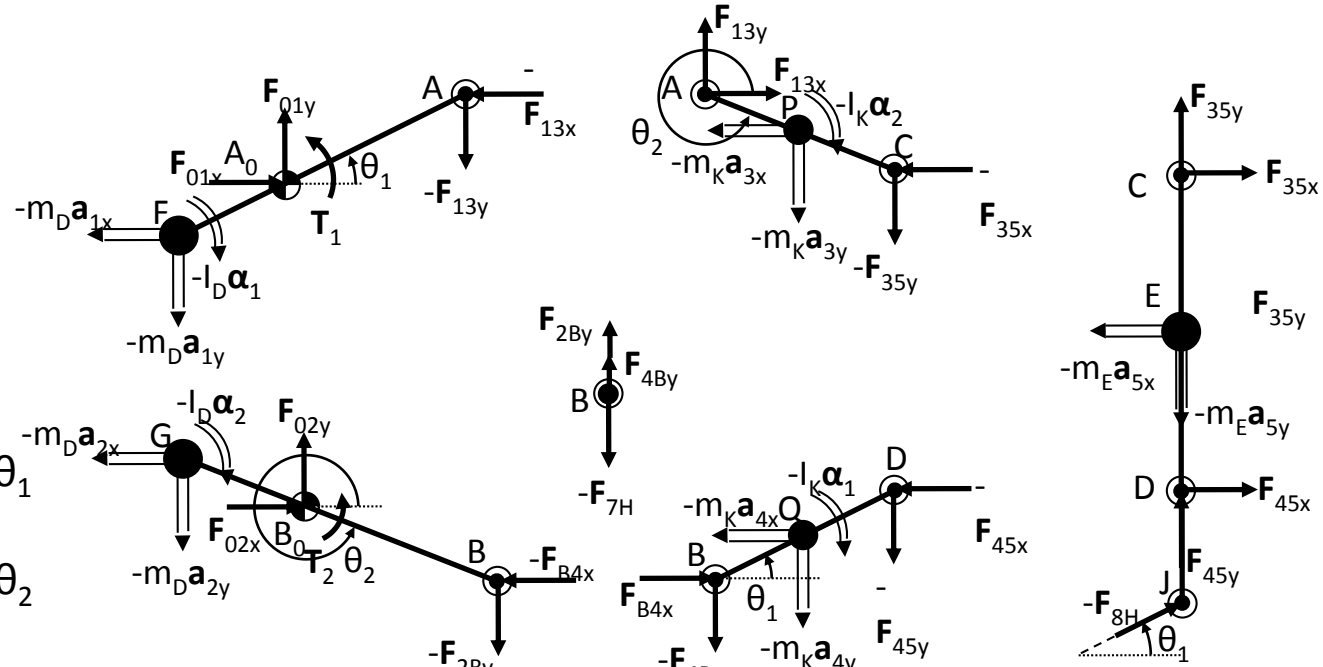
$$F_{01y} = F_{13y} + m_D a_{1y}$$

$$F_{02x} = F_{B4x} + m_D a_{2x}$$

$$F_{02y} = F_{2By} + m_D a_{2y}$$

$$T_1 = I_D \alpha_1 + (pm_D a_{1x} - rF_{13x}) \sin \theta_1 - (pm_D a_{1y} - rF_{13y}) \cos \theta_1$$

$$T_2 = I_D \alpha_2 + (pm_D a_{2x} - rF_{B4x}) \sin \theta_2 - (pm_D a_{2y} - rF_{2By}) \cos \theta_2$$



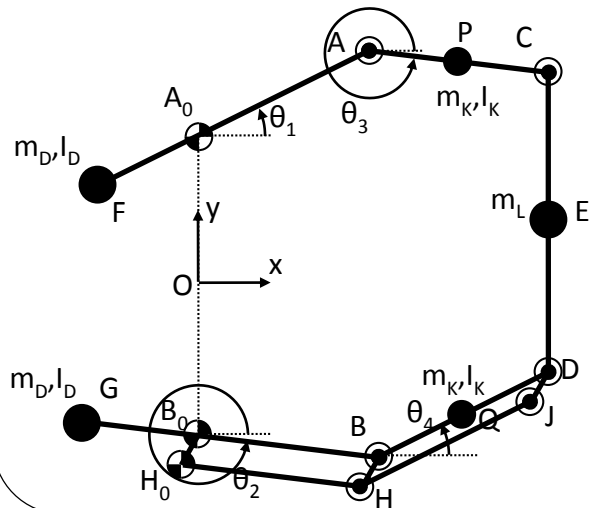
$$\begin{bmatrix} r \sin \theta_2 & -r \cos \theta_2 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & \cos \theta_1 \\ 0 & 1 & 0 & 1 & \sin \theta_1 \\ a & 0 & 0 & 0 & -b \cos \theta_1 \\ 0 & 0 & r \sin \theta_1 & -r \cos \theta_1 & 0 \end{bmatrix} \begin{bmatrix} F_{35x} \\ F_{35y} \\ F_{45x} \\ F_{45y} \\ F_{8H} \end{bmatrix} = \begin{bmatrix} I_K \alpha_2 - \frac{1}{2} r m_K (a_{3x} \sin \theta_2 - a_{3y} \cos \theta_2) \\ m_E a_{5x} \\ m_E a_{5y} \\ \frac{1}{2} a m_E a_{5x} \\ I_K \alpha_1 - \frac{1}{2} r m_K (a_{4x} \sin \theta_1 - a_{4y} \cos \theta_1) \end{bmatrix}$$

Dinamik Analiz – Analitik Mekanik

$$\begin{aligned}
 KE &= \frac{1}{2} \left[m_E v_E^2 + m_K (v_P^2 + v_Q^2) + m_D (v_F^2 + v_G^2) + (I_D + I_K) (\omega_1^2 + \omega_2^2) \right] \\
 &= \frac{1}{2} \left[\left(m_E + \frac{5}{4} m_K \right) r^2 + m_D p^2 + I_D + I_K \right] (\omega_1^2 + \omega_2^2) + (m_E + m_K) r^2 \cos(\theta_1 - \theta_2) \omega_1 \omega_2
 \end{aligned}$$

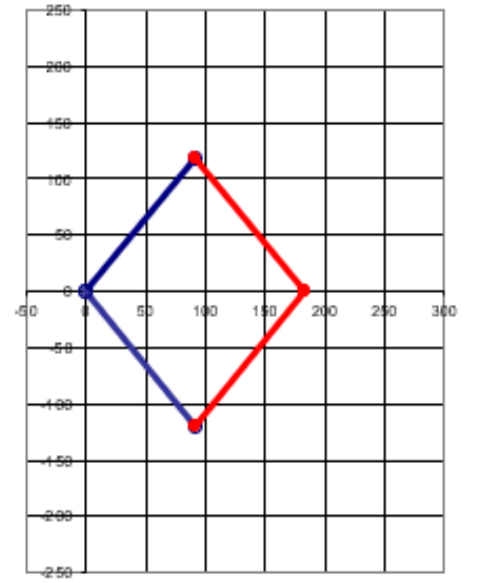
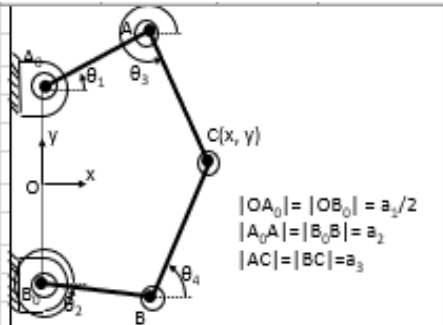
$$T_1 = \frac{d}{dt} \frac{\partial KE}{\partial \omega_1} - \frac{\partial KE}{\partial \theta_1} = \left[\left(m_E + \frac{5}{4} m_K \right) r^2 + m_D p^2 + I_D + I_K \right] \alpha_1 + (m_E + m_K) r^2 \begin{bmatrix} \cos(\theta_1 - \theta_2) \alpha_2 \\ + \sin(\theta_1 - \theta_2) \omega_2^2 \end{bmatrix}$$

$$T_2 = \frac{d}{dt} \frac{\partial KE}{\partial \omega_2} - \frac{\partial KE}{\partial \theta_2} = (m_E + m_K) r^2 \begin{bmatrix} \cos(\theta_1 - \theta_2) \alpha_1 \\ - \sin(\theta_1 - \theta_2) \omega_1^2 \end{bmatrix} + \left[\left(m_E + \frac{5}{4} m_K \right) r^2 + m_D p^2 + I_D + I_K \right] \alpha_2$$



Dinamik Analiz – Excel, Matlab, ADAMS Uygulamaları

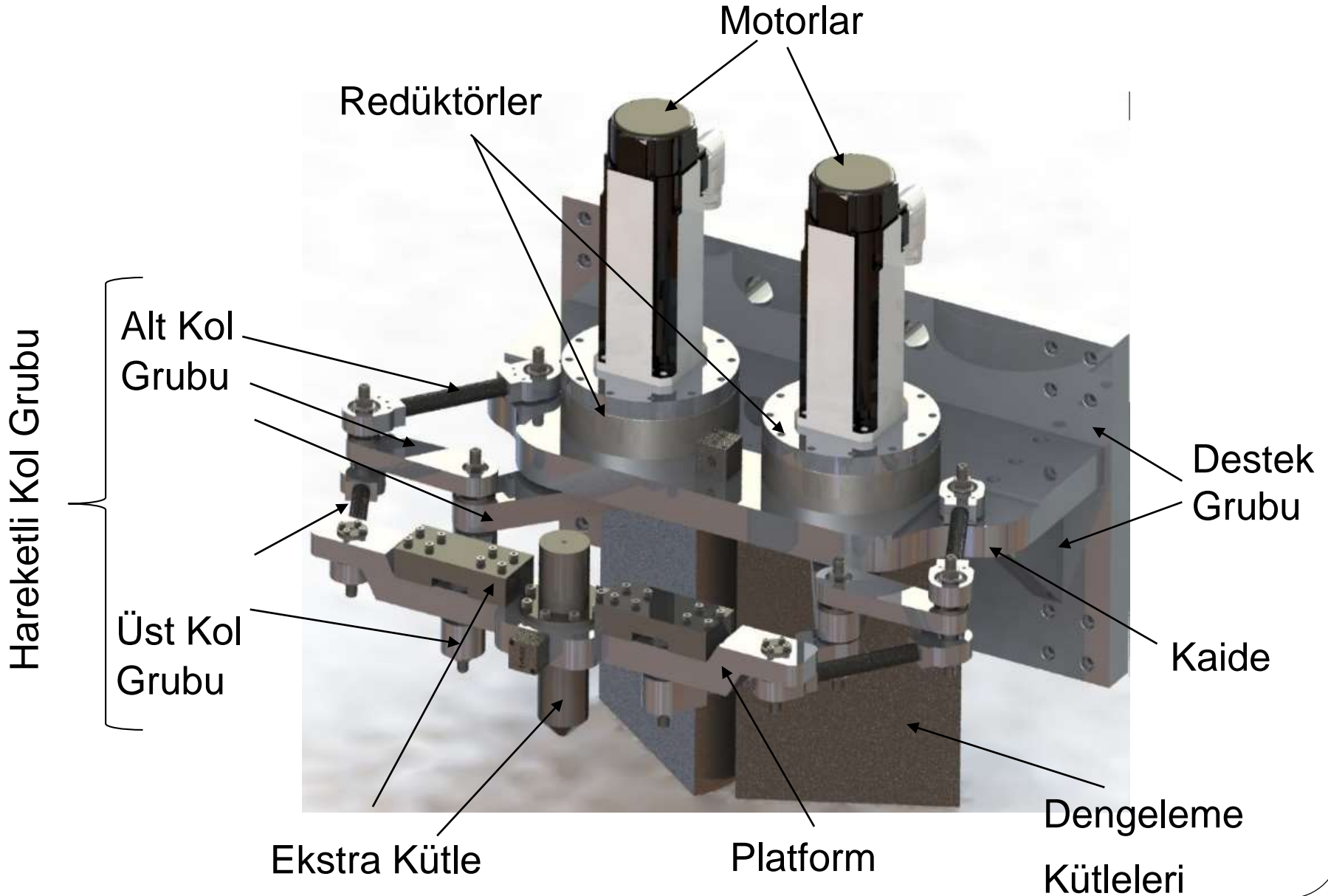
İvme limitleri (g):		Hız limitleri:															
X	1	200	m/dak	3.333333333	m/s												
Y	1	200	m/dak	3.333333333	m/s												
u=x+X	5	100	m/dak	1.666666667	m/s												
v=y+Y	5	100	m/dak	1.666666667	m/s												
Uzuv Boyutları																	
a1	0	mm	g (m/s ²)														
a2	150	mm	9.81														
a3	150	mm	S														
x _C mm	y _C mm	s ₁	φ ₁	η ₁	θ ₁	s ₂	φ ₂	η ₂	θ ₂	θ ₃	θ ₄						
182.132	0	182.132	0	0.918381975	0.918382	182.132	0	0.91838197	-0.918382	5.364803333	0.918382						
V _{Cx} m/dak		V _{Cy} m/dak	V _{Cx} m/s	V _{Cy} m/s	ω ₁ rad/s	ω ₂ rad/s	ω ₁ dev/dak	ω ₂ dev/dak	ω ₃ rad/s	ω ₄ rad/s							
25		0	0.41667	0	-1.747864744	1.747865	-16.69088	16.69088	1.74786474	-1.747865							
a _{Cx} g		a _{Cy} g	a _{Cx} m/s ²	a _{Cy} m/s ²	α ₁ rad/s ²	α ₂ rad/s ²	α ₃ rad/s ²	α ₄ rad/s ²									
3		0	29.43	0	-125.7892907	125.7893	125.7893	-125.7893	125.789291								
Ters kinematik çözümleri kontrol edilmiştir.											0.0187						
YALNIZCA YEŞİL HÜCRELERDEKİ DEĞERLERİ DEĞİŞTİRİNİZ:																	
GERİ KALAN HÜCRELER BAĞIMLIDIR.																	
A ₀ F=B ₀ G=p _{0m1} =p _{0m2}	0.03755	m	A ₀ H ₀ =B ₀ H=DJ=b	0.1	m	p ₁₂ =p ₂₂	0.0187										
A ₀ B ₀ =CD=a	0	m	A ₀ P ₁₁ = B ₀ P ₂₁ =p ₁₁ =p ₂₁	0.05943	m												
a _{1x}	a _{1y}	a _{2x}	a _{2y}	a _{3x}	a _{3y}	a _{4x}	a _{4y}										
16.54947	-10.3457975	16.5495	10.3458	-3.683655	2.958756	-3.683655	-2.958756										
											5.830083	-4.68279	5.830083	4.682793			0.083
MAFSAL KUVVETLERİ																	
-0.119193052	-0.091088	0	0	0	0.707903	F _{12x} N	73.575	F _{12y} N	83.32413	F _{23x} N	0	F _{23y} N	0				
1	0	1	0	0.807108667	147.15	F _{23y} N	-104.0732	F _{34x} N	-110.1678	F _{34y} N	0	F _{45x} N	110.16783				
0	1	0	1	0.794620347	0	F _{45x} N	73.575	F _{45y} N	83.32413	F _{56x} N	0.00043396	F _{56y} N	0.000434				
0	0	0	0	-0.060710867	0	F _{56x} N	104.0732	F _{56y} N	-110.1678	F _{67x} N	-43.2412306	F _{67y} N	43.241231				
0	0	0.11919	-0.09107	0	-0.7079	F _{67x} N	0	F _{67y} N	0	T ₁ N*m	-32.3801957	T ₂ N*m	32.380196				



DİNAMİK ANALİZ:					
m ₁₁ =m ₂₁	1.04642	kg	I ₁₂ =I ₂₂	0.00321	kg*m ²
m ₁₂ =m ₂₂	0.58909	kg	I _{0m1} =I _{0m2}	0.0556534	kg*m ²
m _{0m1} =m _{0m2}	24.276	kg			
m ₅	5	kg			
I ₁₁ =I ₂₁	0.00513	kg*m ²			

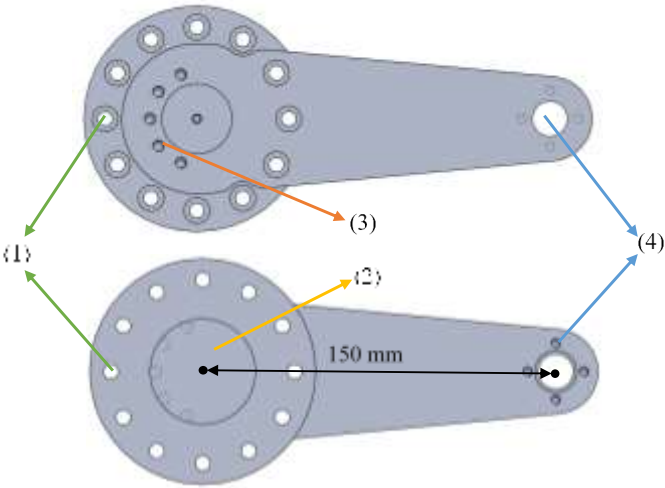
Tork İhtiyacı	
Hareket Denklemlerinden	
T1	-32.15236
T2	32.15236
Motor çıkış gücü:	

Konstrüksiyonel tasarım

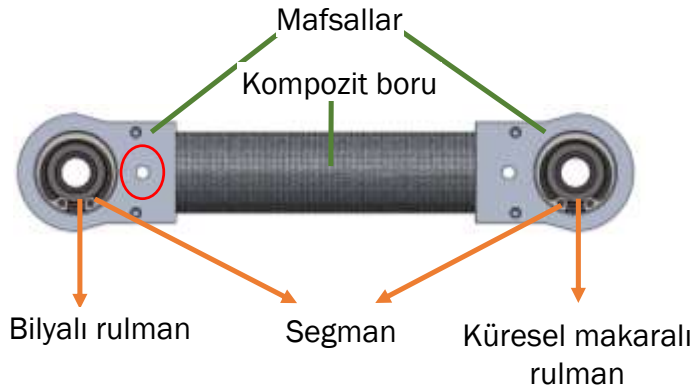
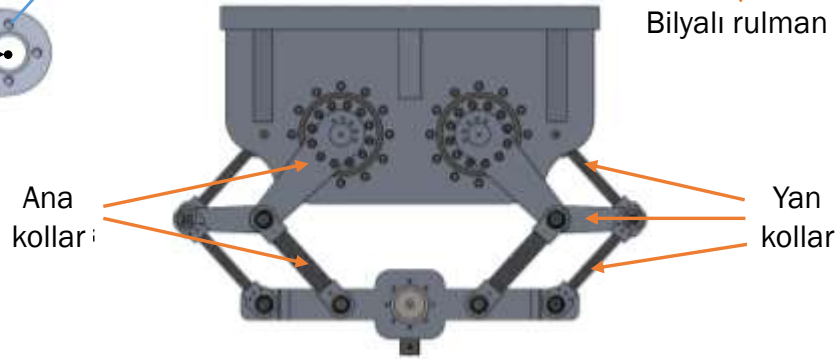
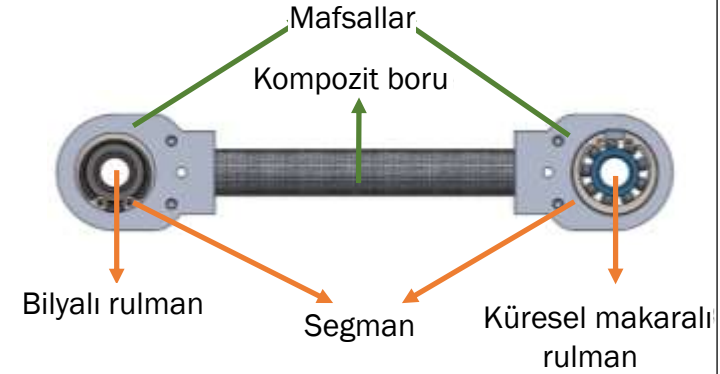


Uzuv ve Mafsallar

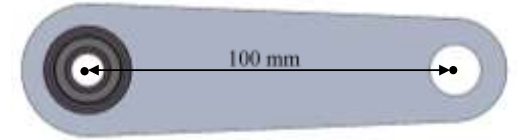
Arka Kollar



Paralel kollar

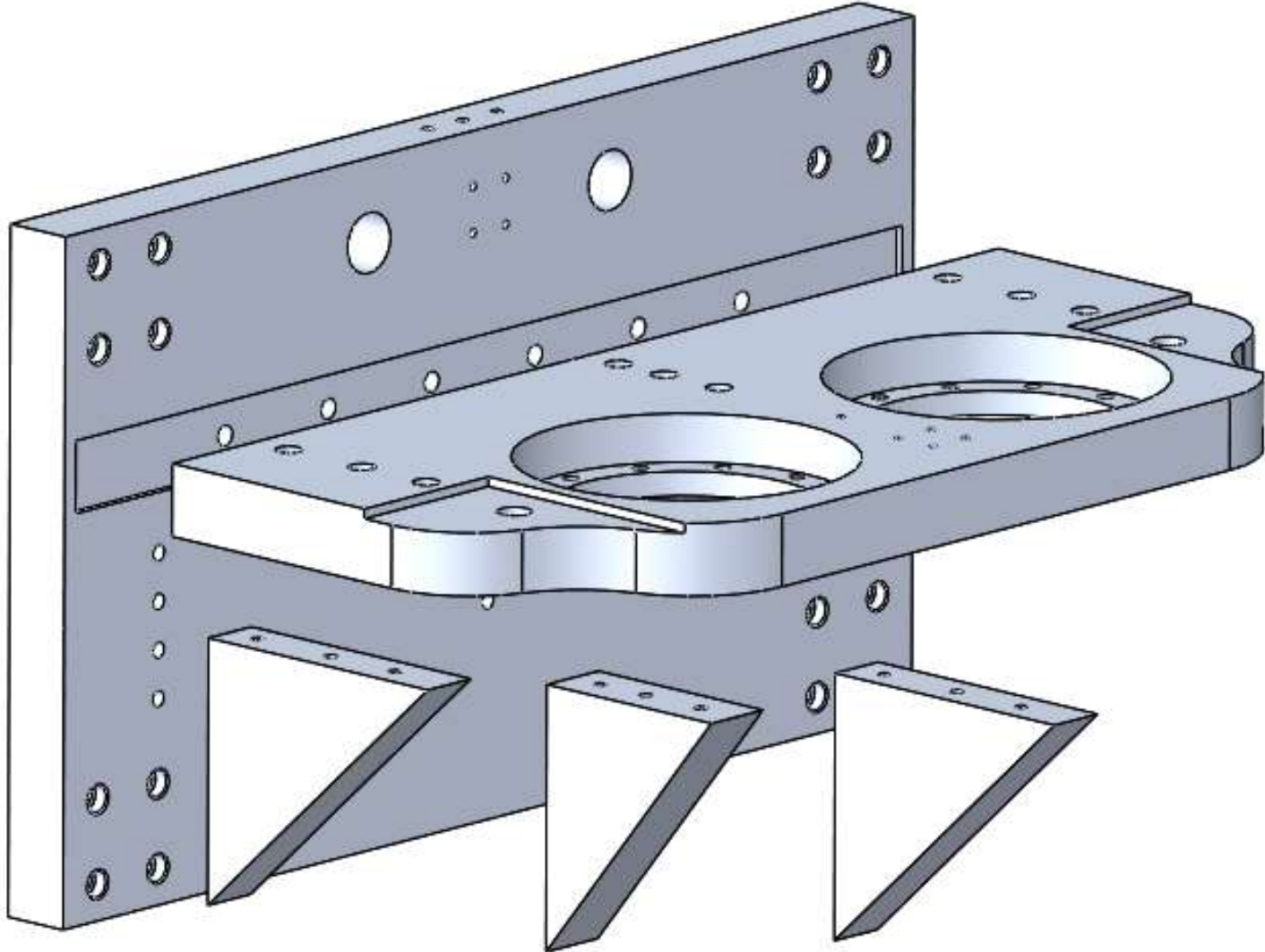


Ön kollar

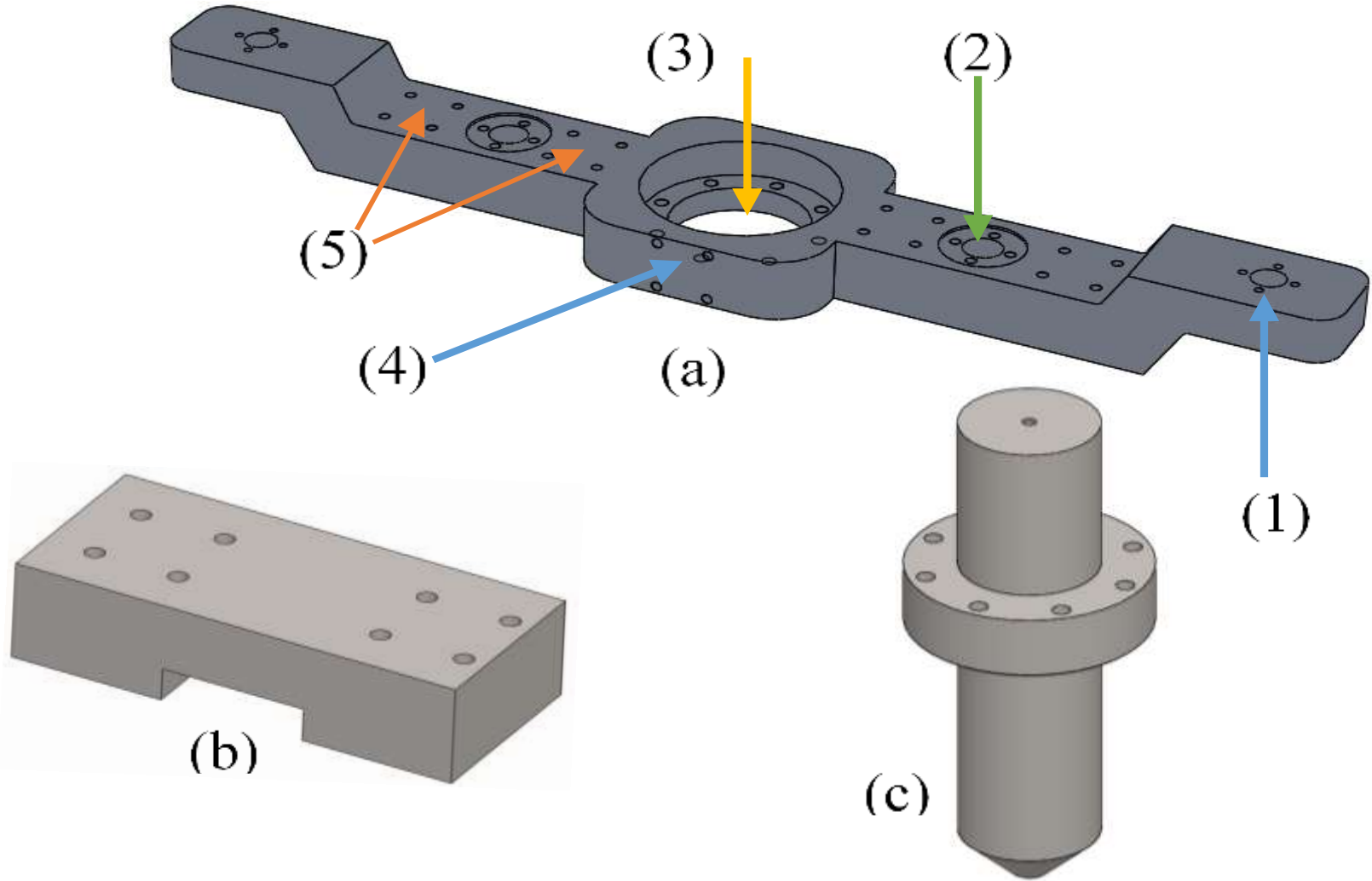


Ara Uzuvlar

Destek Grubu



Platform Grubu



(a) Platform (b) Ek kütleler

(c) Uç işlemci

Motor ve Redüktörler

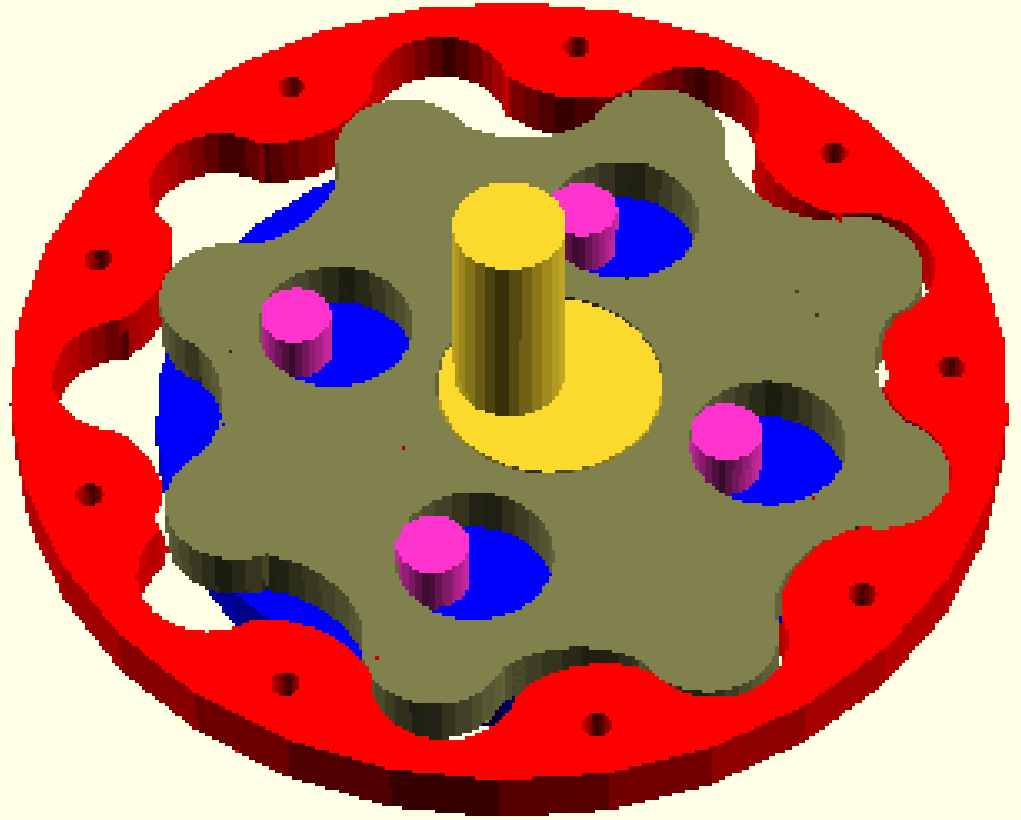


Motor	Anma Momenti (N·m)	Azami Moment (N·m)	Anma hızı (dev/dak)	Azami hız (dev/dak)	Anma gücü (Watt)
Kollmorgen AKM33E	111	164	70	93	1100

Redüktör: Sumimoto Fine Cyclo F1C-A15 (1:59)

Sikloid Redüktörler

- Küçük hacimde yüksek redüksiyon
- Çok küçük boşluk
- Yüksek sürtünme



Lazer kafa

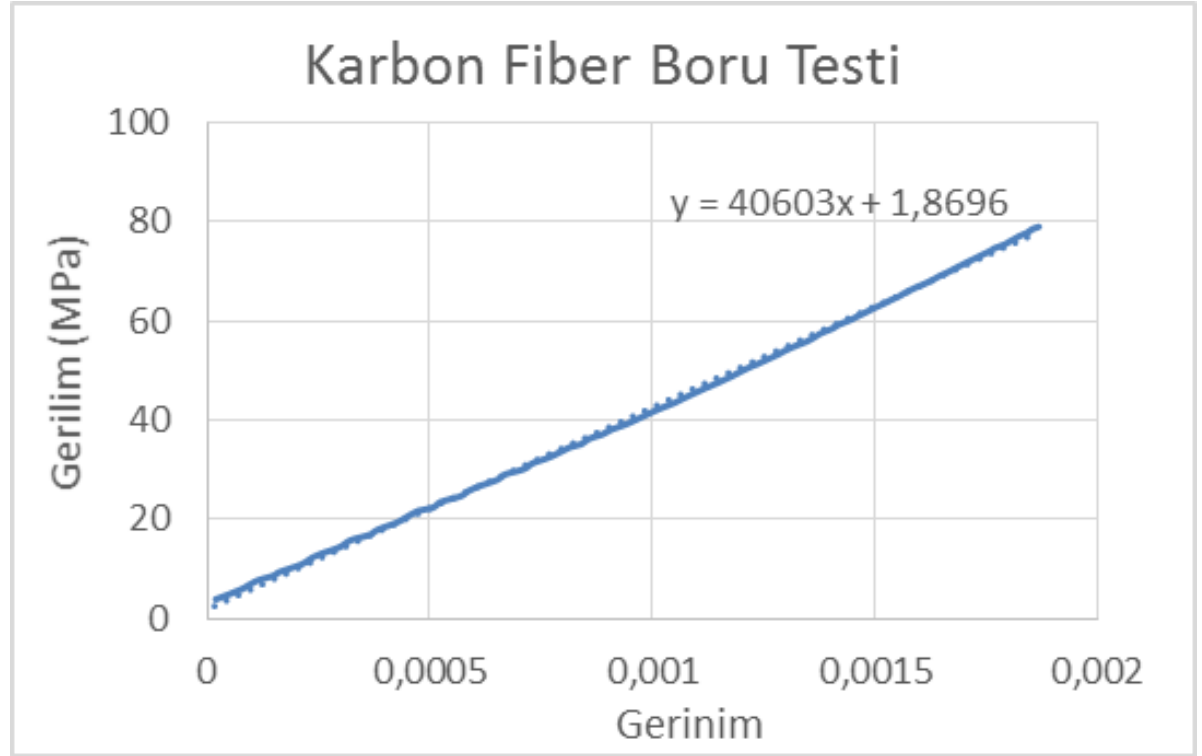


Rezonatör



Denetleyici

Karbon Fiber Boru Testleri



16 / 14 mm dış/iç çapa sahip kompozit borular test edildi. Eksenel lastisite modülü 40.6 GPa olarak bulundu. Yanal elastisite modülü, Poisson oranı, akma mukavemeti ve bu değerlerin eğilme ve kesme yük koşulları için olanları katalogtan hesaplandı:

https://www.hexcel.com/user_area/content_media/raw/Prepreg_Technology.pdf

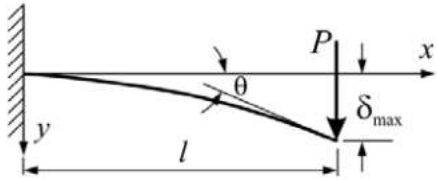
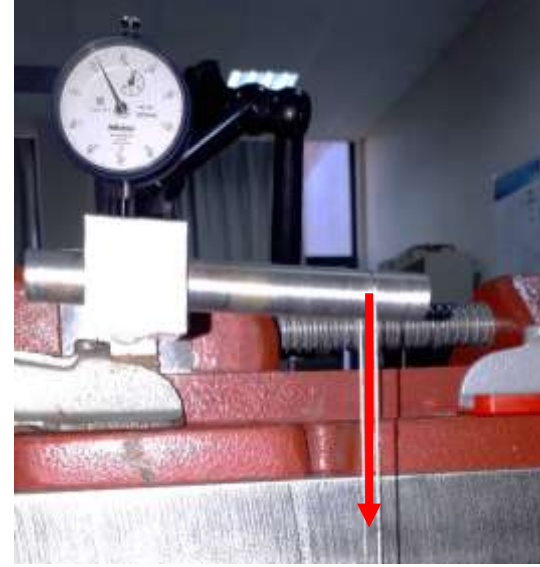
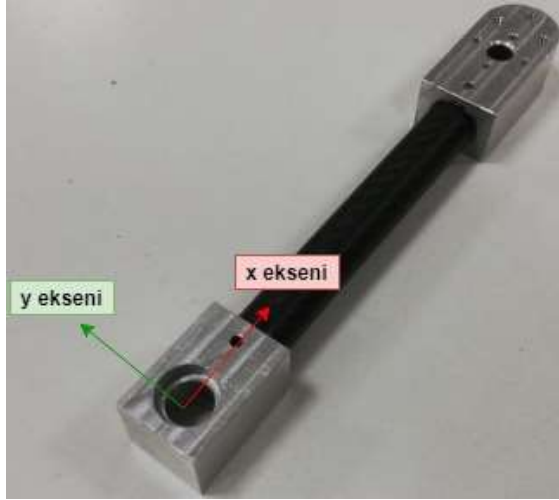
Uzuv Direngenlik Ölçümleri



Faro Prime Ölçüm Kolu

Uzuv örneği bir ucundan sabitlenir. Diğer ucuna bilinen kütleler bağlanarak deplasman ölçülür. Komparatörle sabit kısmın hareketsiz kaldığı teyit edilir. Aksenal yük, eğme yükü, burulma yükü altında çizgisel ve açısal deplasmanlar ölçülür.

Direngenlik Ölçümleri



Eğilme momenti

Yük koşulu

Direngenlik değeri

Eksenel yük (x-ekseni kuvveti)

10400 N/mm

Eğilme momenti (y-ekseni kuvveti)

76 N/mm

Eğilme momenti (y-ekseni kuvveti)

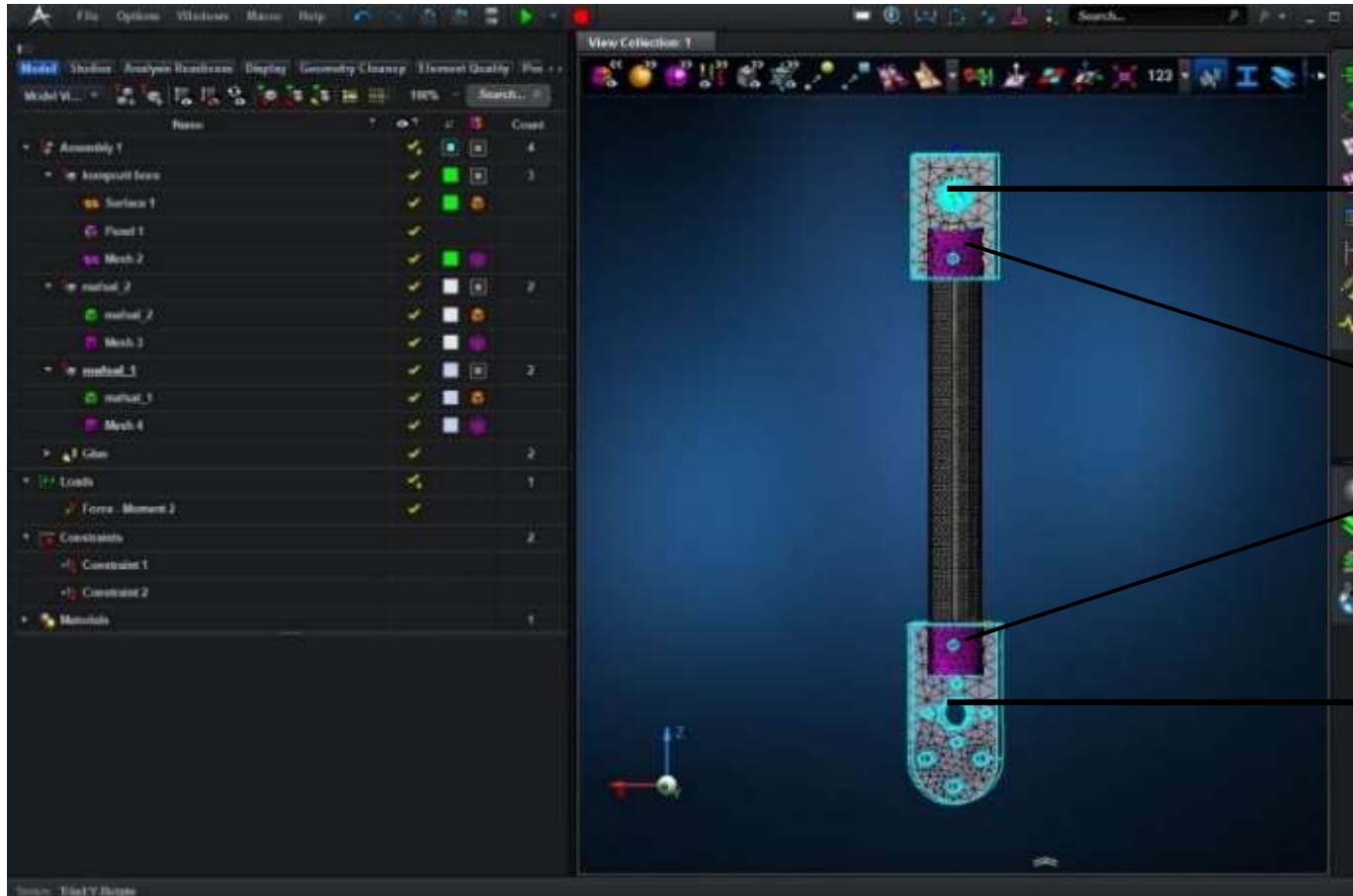
820000 N·mm/rad

Burulma Momenti (x-ekseni momenti)

81000 N·mm/rad

APEX + ADAMS Modelleri Sonlu Eleman Analizleri

Ölçülen/kataloglardan alınan malzeme özellikleri APEX'e girilerek sonlu-eleman modeli, oluşturuldu.



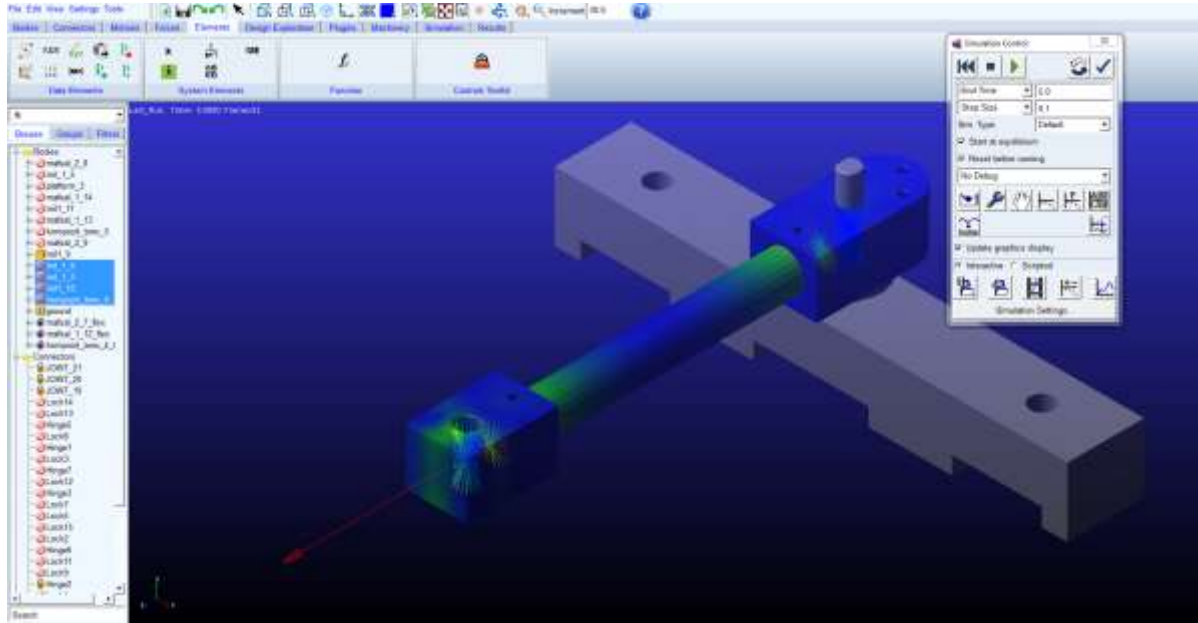
Mafsal-1

Yapıştırıcının
uygulandığı
bölgeler

Mafsal-2

APEX + ADAMS Modelleri Sonlu Eleman Analizleri

Laboratuvarda yapılan testler ADAMS'ta tekrarlanarak model doğrulandı.



Yük koşulu

**Ölçülen direngenlik
değeri**

**Hesaplanan
direngenlik değeri**

Eksenel yük (x-ekseni kuvveti)

10400 N/mm

15500 N/mm

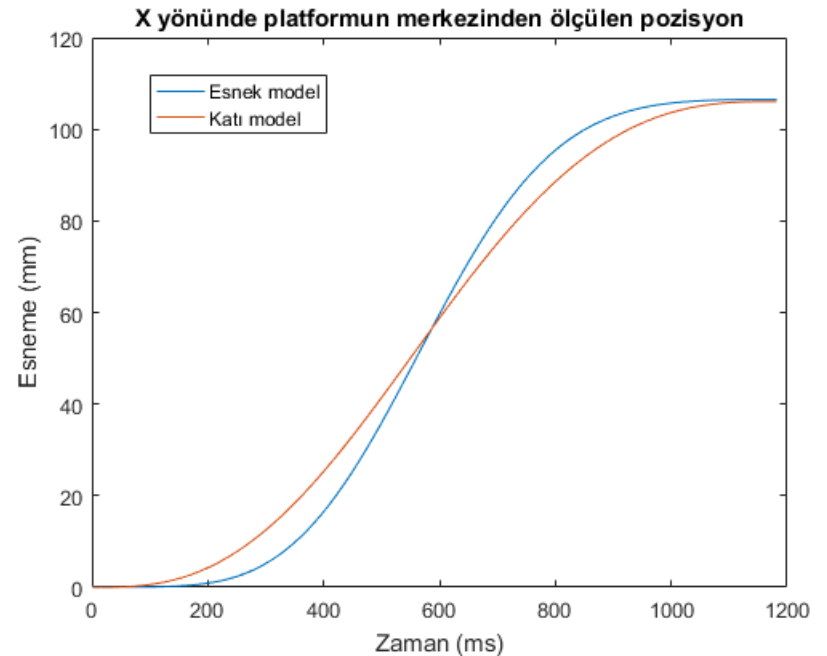
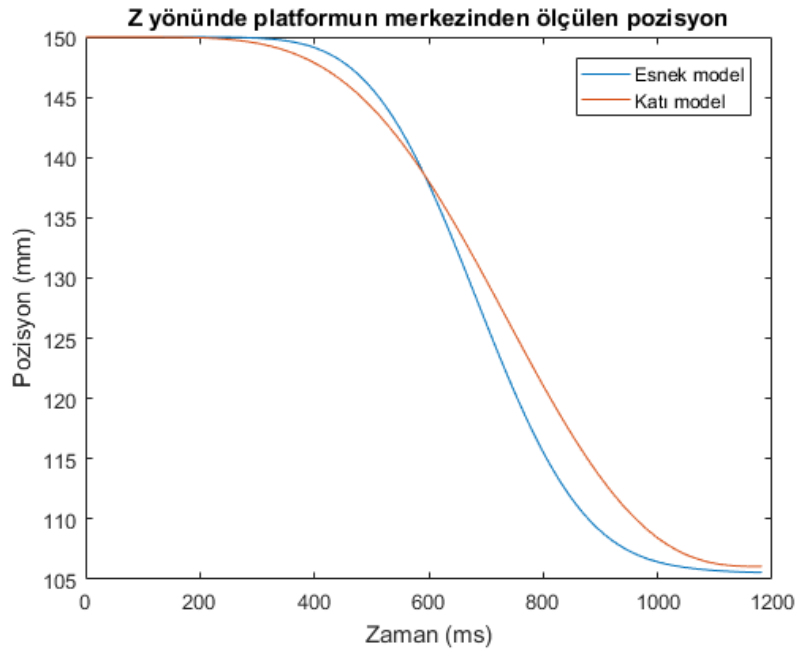
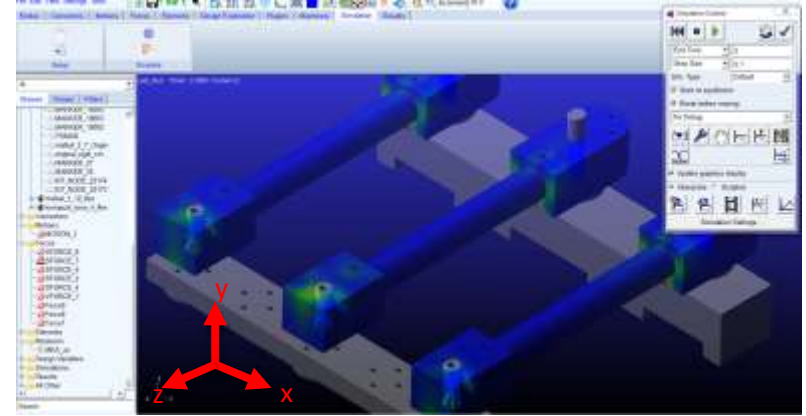
Eğilme momenti (y-ekseni kuvveti)

76 N/mm

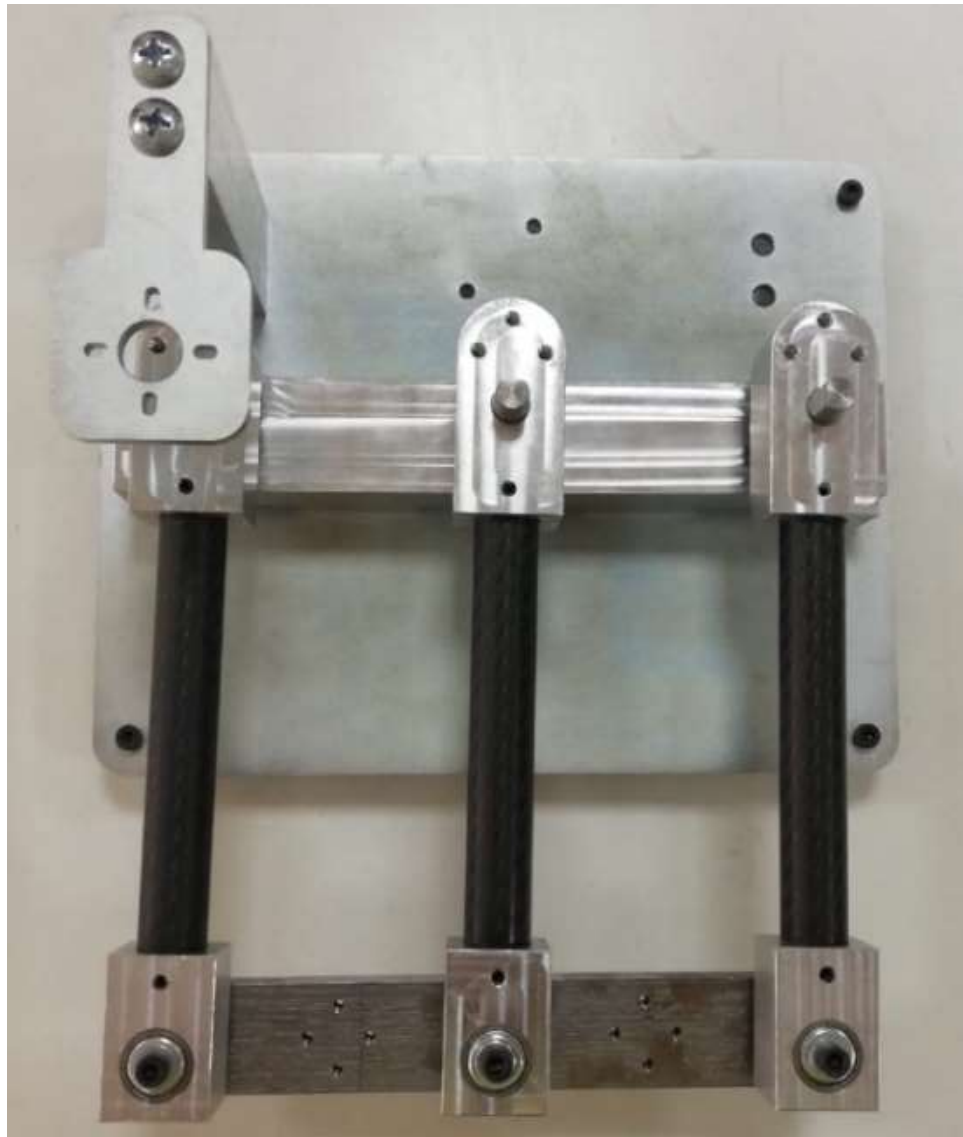
73,8 N/mm

APEX + ADAMS Modelleri Sonlu Eleman Analizleri

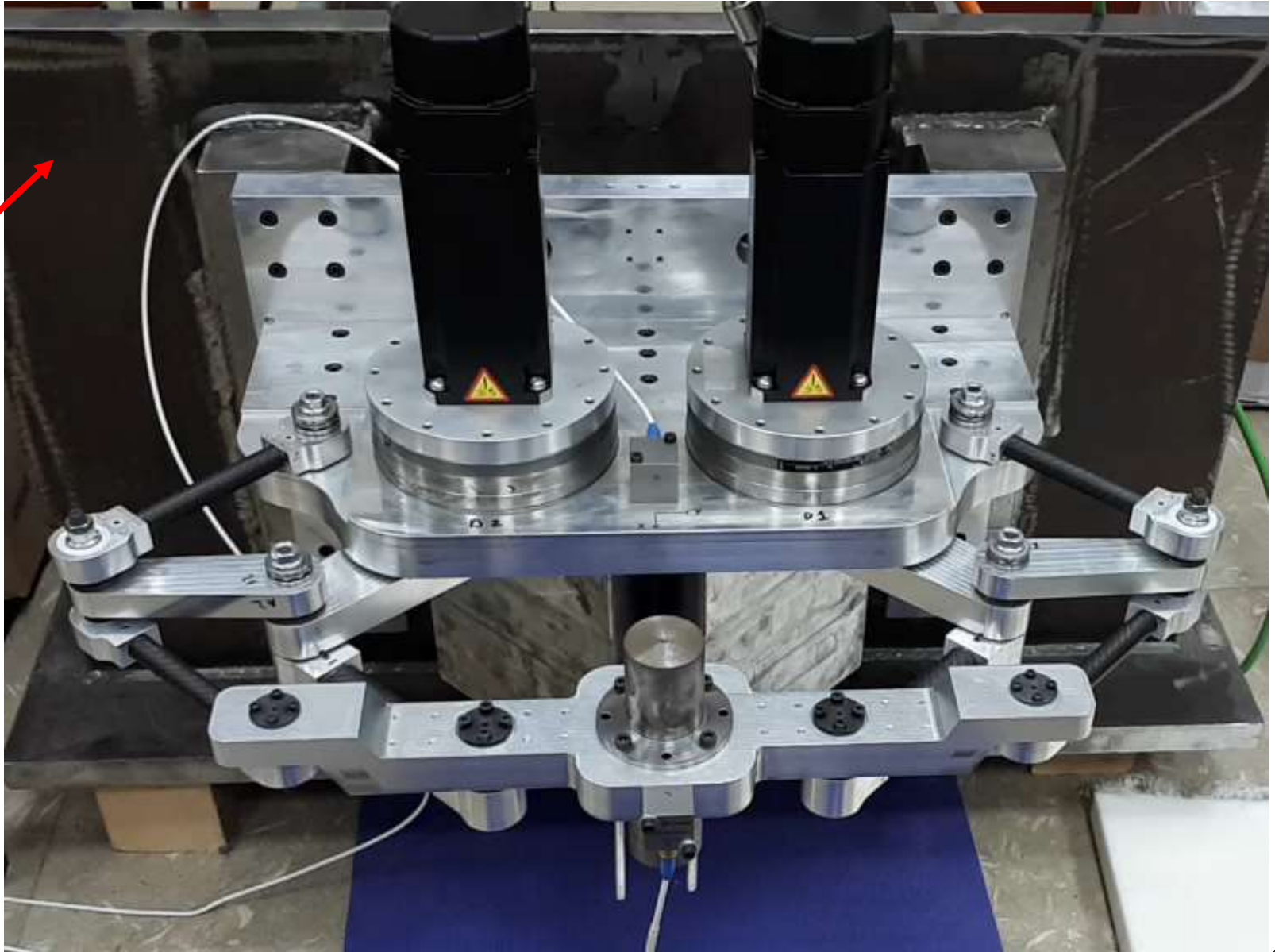
ADAMS'ta katı ve esnek uzuvlu modeller 5 kg uç işlemcinin azami 5g ivmeli hareketi ile benzetimlerle karşılaştırıldı.



Ön Prototip

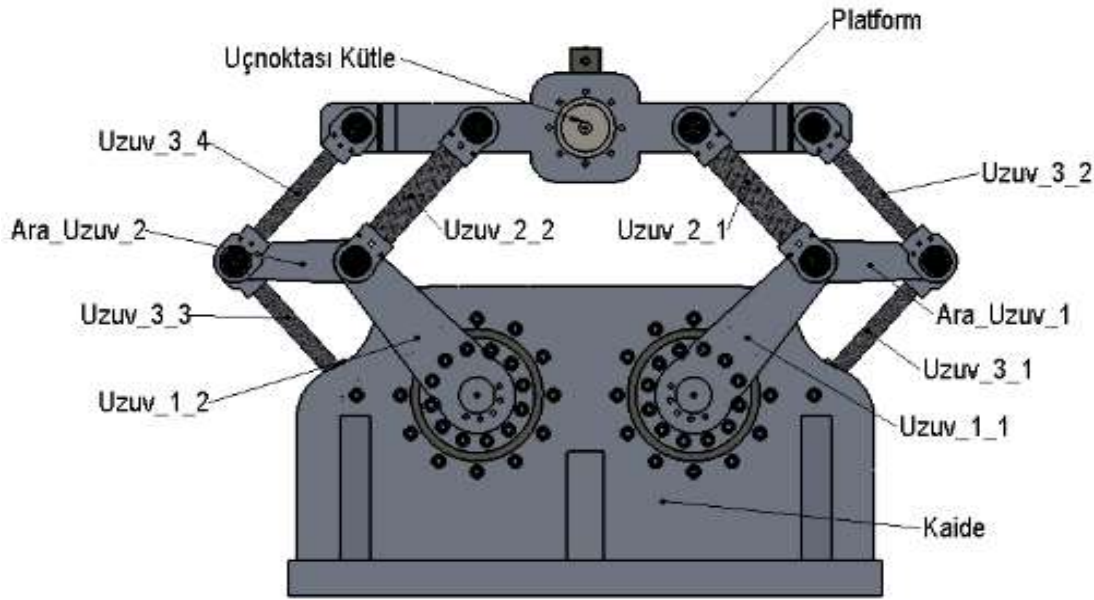


Prototip



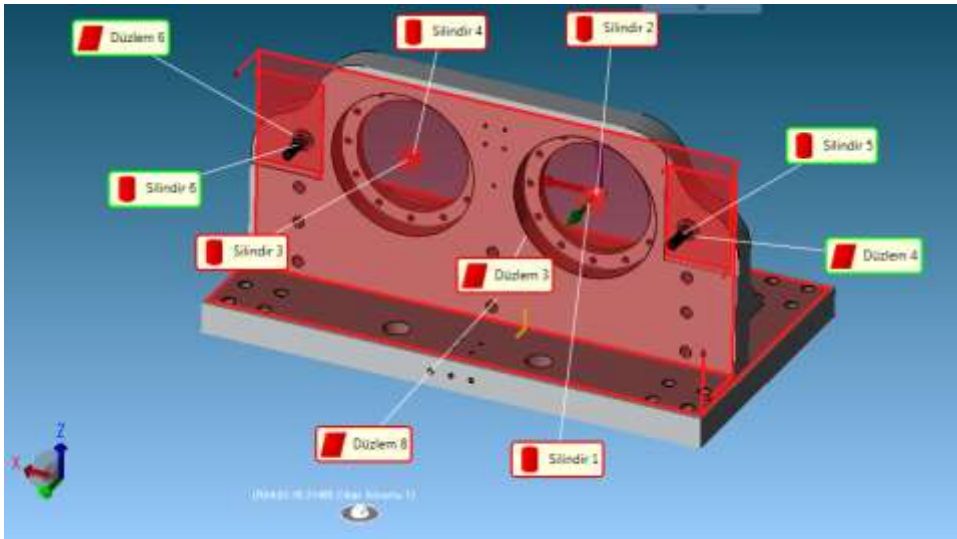
500 kg
kütleli
kaide

Üretim Sonrası Ölçümler



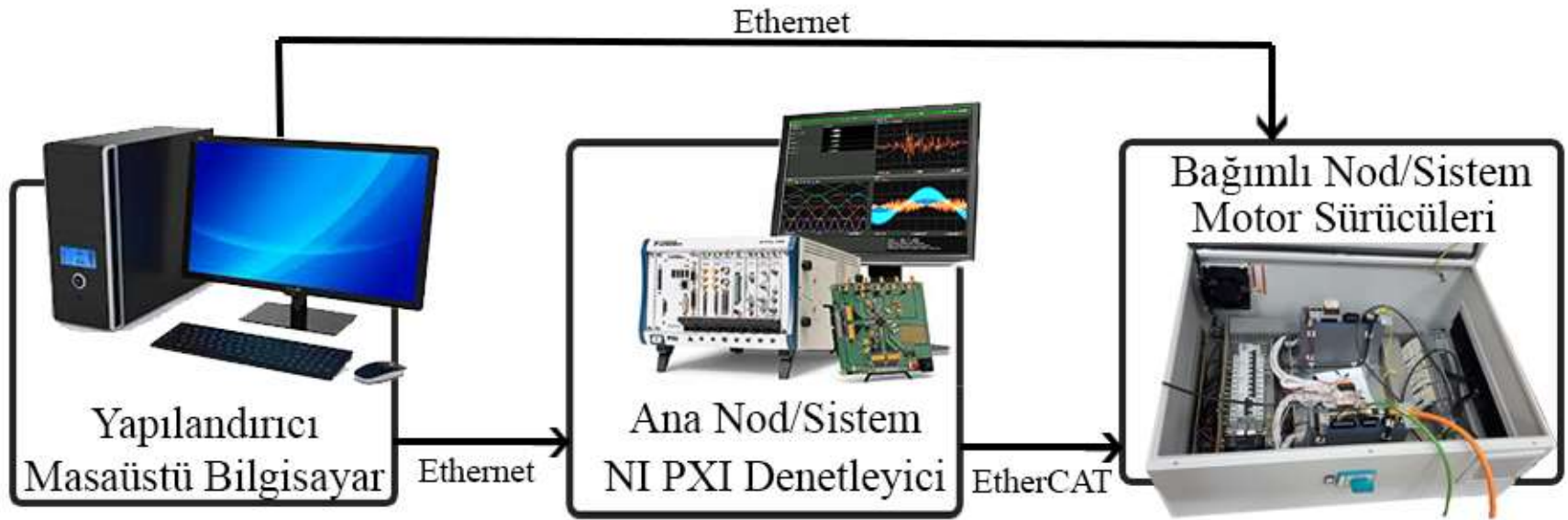
Parça İsmi	Kütle (g)
Uzunluk_1_1	926,5
Uzunluk_1_2	927,4
Uzunluk_2_1	219,2
Uzunluk_2_2	220,0
Uzunluk_3_1	123,5
Uzunluk_3_2	123,1

Parça İsmi	Kütle (g)
Uzunluk_3_3	124,4
Uzunluk_3_4	123,4
Ara_Uzunluk_1	250,9
Ara_Uzunluk_2	251,1
Platform	1451,7
Uç işlemci kütlesi	1869,4



Unsur 1	Unsur 2	Unsurlar arasında mesafe/açı unsur adı	Unsurlar arasında mesafe/açı değeri	Tasarım mesafe/açı değeri
Silindir 4	Silindir 6	Mesafe 3	100,064mm	100mm
Silindir 2	Silindir 4	Mesafe 4	179,949mm	180mm
Silindir 5	Silindir 2	Mesafe 5	99,939mm	100mm
Silindir 3	Silindir 1	Mesafe 6	179,987mm	180mm
Düzlem 3	Düzlem 8	Açı 1	89°59'7,05"	90°

Denetim Sistemi Mimarisi



Yazılımlar: Matlab Simulink + Beckhoff + TwinCAT