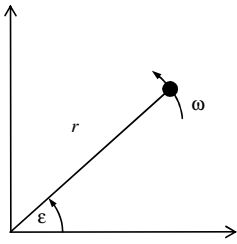



Univerza na Ljubljani  
Fakulteta za elektrotehniko





---

Mehatronika – Vanja Ambrožič

1

---

---

---

---

---

---


---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

$$n [\text{vrt/min}] = 60 f [\text{vrt/s}] = \frac{60}{2\pi} \omega [\text{rad s}^{-1}]$$

$$\text{npr. } 3000 [\text{vrt/min}] = 50 f [\text{vrt/s}] = 314 \omega [\text{rad s}^{-1}]$$



---

Mehatronika – Vanja Ambrožič

2

---

---

---

---

---


---

---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

<p><b>Premo gibanje</b></p> <p><math>x [m]</math></p> <p><math>v = \frac{dx}{dt}</math></p> <p><math>a = \frac{dv}{dt} = \frac{d^2x}{dt^2}</math></p>	<p><math>v = r \cdot \omega</math></p>	<p><b>Rotacijsko gibanje (dvodimenzionalno)</b></p> <p><math>\varepsilon [rad]</math></p> <p><math>\omega = \frac{d\varepsilon}{dt}</math></p> <p><math>\alpha = \frac{d\omega}{dt} = \frac{d^2\varepsilon}{dt^2}</math></p>
---	--	--



---

Mehatronika – Vanja Ambrožič

3

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za inženjirstvo

**Premo gibanje** **Rotacijsko gibanje**

$$\mathbf{M} = \mathbf{r} \times \mathbf{F} = r \cdot F \cdot \sin \theta$$

$F = ma = m \frac{dv}{dt} = m \frac{d^2x}{dt^2}$  **Dinamični navor**

$$M = J\alpha = J \frac{d\omega}{dt} = J \frac{d^2\varepsilon}{dt^2}$$

$$P_{\text{mech}} = Fv = \frac{M}{r} r\omega = M\omega$$

Mehatronika – Vanja Ambrožič 4

---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za inženjirstvo

$$F = m\ddot{x} + \gamma\dot{x} + Kx = ma + \gamma + Kx$$

m – masa  
 $\gamma$  – trenje  
 K – konstanta vzmeti

$$M = J\ddot{\varepsilon} + \Gamma\dot{\varepsilon} + \mu\varepsilon = J\alpha + \Gamma\omega + \mu\varepsilon$$

J – vztrajnostni moment  
 $\Gamma$  – rotacijsko trenje  
 $\mu$  – torzijska konstanta

Mehatronika – Vanja Ambrožič 5

---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za inženjirstvo

**Reduktor**

Prestavno razmerje:

$$g_r = \frac{R}{r} = \frac{v}{\Omega} = \frac{\omega}{\Omega} = \frac{P}{M_r} = \frac{M_R}{M_r}$$

R,  $\Omega$  – večji zobnik  
 r,  $\omega$  – manjši zobnik

prestava	$g_r$
1	2.97:1
2	2.07:1
3	1.43:1
4	1.00:1
5	0.84:1
6	0.56:1
Vzvr.	3.28:1

Mehatronika – Vanja Ambrožič 6

---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

### Planetni gonilnik

Mehatronika – Vanja Ambrožič

7

---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

### Značilne navorne karakteristike bremen

$M_{br} = k$   
 $P_{br} = M_{br} \cdot \omega = k \cdot \omega$

Delovni stroji, ki opravljajo dela dviganja, trenja ali preoblikovanja: dvigala, vozila z majhno hitrostjo, obdelovalni stroji, transportni trakovi, industrijski pogoni z valji.

Mehatronika – Vanja Ambrožič

8

---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

### Značilne navorne karakteristike bremen

$M_{br} = k \cdot \omega^2$   
 $P_{br} = M_{br} \cdot \omega = k \cdot \omega^3$

Zračni ali tekočinski upor: ventilatorji, centrifugalne črpalke, mešalniki, ladijski vijaki.

Mehatronika – Vanja Ambrožič

9

---

---

---

---

---

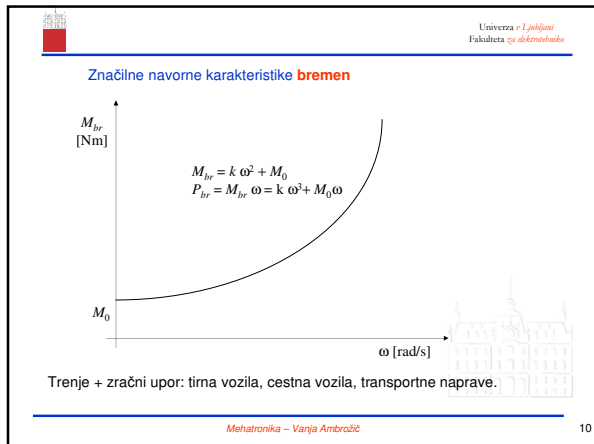
---

---

---

---

---




---

---

---

---

---

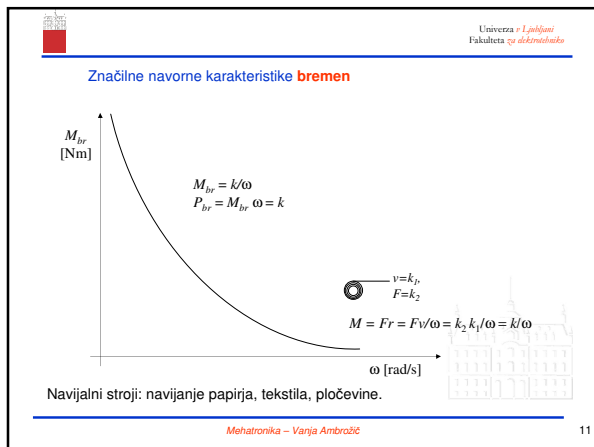
---

---

---

---

---




---

---

---

---

---

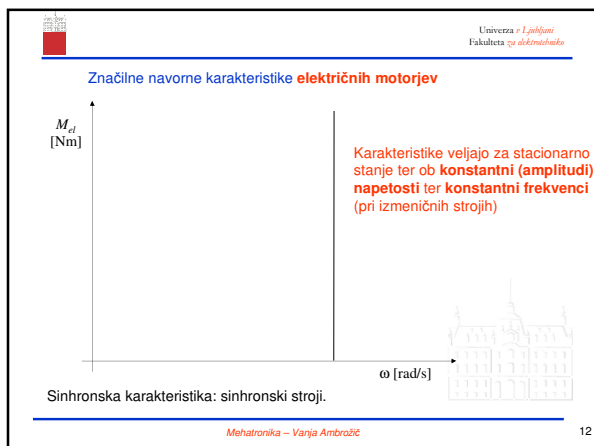
---

---

---

---

---




---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

**Značilne navorne karakteristike električnih motorjev**

$M_{el}$  [Nm]

$\omega$  [rad/s]

Trda karakteristika: asinhronski stroji, komutatorski stroji z vzporednim vzbujanjem

Mehatronika – Vanja Ambrožič

13

---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

**Značilne navorne karakteristike električnih motorjev**

$M_{el}$  [Nm]

$\omega$  [rad/s]

Mehka karakteristika: komutatorski stroji z zaporednim vzbujanjem

Mehatronika – Vanja Ambrožič

14

---

---

---

---

---

---

---

---

---

---

Univerza na Ljubljani  
Fakulteta za elektrotehniko

**Dinamično stanje** ( $\omega = \text{var.} \rightarrow \alpha \neq 0, M_d \neq 0$ )

$$M_{el} = M_{br} + \underbrace{M_d}_{J \frac{d\omega}{dt}} \quad \left( M_d = J\alpha = J \frac{d\omega}{dt} = J \frac{d^2\theta}{dt^2} \right)$$

**Stacionarno stanje** ( $\omega = \text{const.} \rightarrow \alpha = 0, M_d = 0$ )

$$M_{el} = M_{br}$$

Mehatronika – Vanja Ambrožič

15

---

---

---

---

---

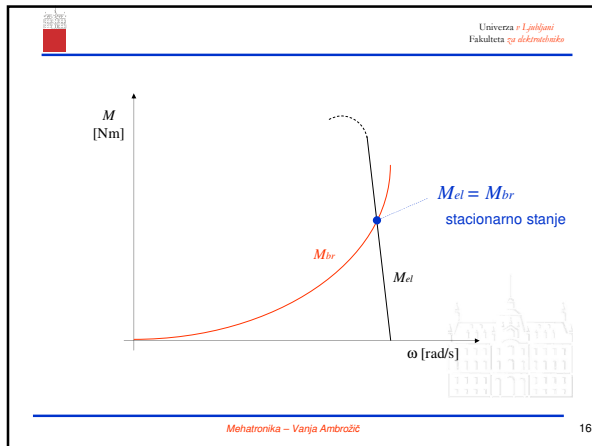
---

---

---

---

---




---

---

---

---

---

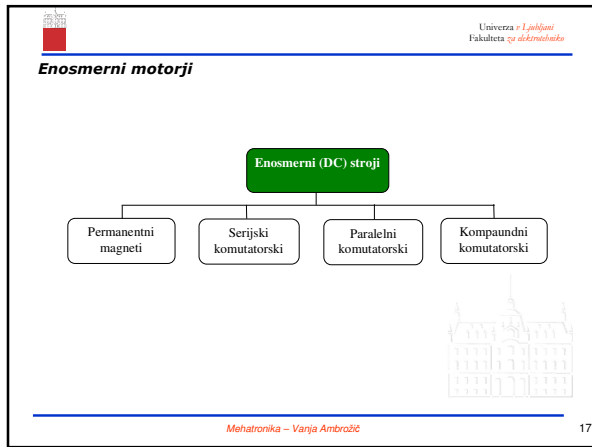
---

---

---

---

---




---

---

---

---

---

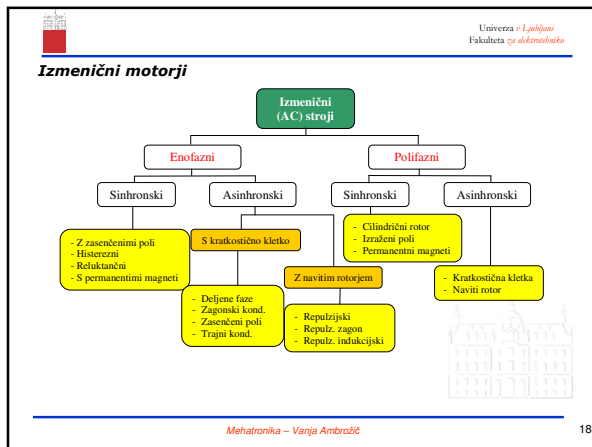
---

---

---

---

---




---

---

---

---

---

---

---

---

---

---

**Sila na aktivni vodnik v magnetnem polju** Univerza *Ljubljana*  
Fakulteta *za elektrotehniko*

$$\vec{F} = (\vec{l} \times \vec{B}) i$$

*Mehatronika – Vanja Ambrožič* 19

---

---

---

---

---

---

---

---

---

---

**Komutatorski motorji** Univerza *Ljubljana*  
Fakulteta *za elektrotehniko*

$$\begin{aligned} \vec{M}_{el} &= 2 \cdot (\vec{r} \times \vec{F}) = 2 \cdot (\vec{r} \times (\vec{l} \times \vec{B})) = 2 \cdot (\vec{l}(\vec{r} \cdot \vec{B}) - \vec{B}(\vec{r} \cdot \vec{l})) = \\ &= 2\vec{l}(rB \cos \theta) = 2\vec{l}_{en} l \left( r \frac{\Phi}{A} \right) \cos \theta = 2\vec{l}_{en} l \left( r \frac{\Phi}{2rl} \right) i \cos \theta = \vec{l}_{en} \Phi i \cos \theta. \end{aligned}$$

*Mehatronika – Vanja Ambrožič* 20

---

---

---

---

---

---

---

---

---

---

**Komutatorski motorji** Univerza *Ljubljana*  
Fakulteta *za elektrotehniko*

*Mehatronika – Vanja Ambrožič* 21

---

---

---

---

---

---

---

---

---

---

**Komutatorski motorji**

Univerza na Ljubljani  
Fakulteta za elektrotehniko

Mehanika – Vanja Ambrožič

22

---

---

---

---

---

---

---

---

---

---

**Enosmerni komutatorski motorji**

Univerza na Ljubljani  
Fakulteta za elektrotehniko

$$u_a = R_a i_a + L_a \frac{di_a}{dt} + e$$

$$e = k_e \psi_{vc} \omega$$

$$M_{el} = k_M \psi_{vc} i_a$$

$$J \frac{d\omega}{dt} = M_{el} - M_{br}$$

Mehanika – Vanja Ambrožič

23

---

---

---

---

---

---

---

---

---

---

**Enosmerni komutatorski motorji**

Univerza na Ljubljani  
Fakulteta za elektrotehniko

$$T \frac{dy(t)}{dt} + y(t) = k \cdot x(t)$$

Mehanika – Vanja Ambrožič

24

---

---

---

---

---

---

---

---

---

---



**Enosmerni komutatorski motorji - regulacija** Univerza *Ljubljana*  
Fakulteta *za elektrotehniko*

*Mehatronika – Vanja Ambrožič*

25

---

---

---

---

---

---

---

---

---

---

**Koračni motorji** Univerza *Ljubljana*  
Fakulteta *za elektrotehniko*

- Trajni magnet na rotorju
- Navitja (lahko različno število, npr. 3) na statorju
- Navitja napajamo z bipolarnimi enosmernimi napetostmi (pošiljamo tokove)

*Mehatronika – Vanja Ambrožič*

26

---

---

---

---

---

---

---

---

---

---

**Koračni motorji** Univerza *Ljubljana*  
Fakulteta *za elektrotehniko*

**Oblike tokov pri koračnem motorju**

*Mehatronika – Vanja Ambrožič*

27

---

---

---

---

---


---

---

---

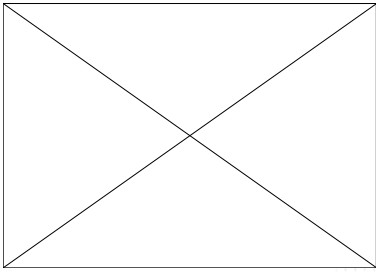
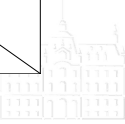
---

---


Univerza na Ljubljani  
Fakulteta za elektrotehniko

---

**Koračni motorji**


---

28

*Mehatronika – Vanja Ambrožič*

---

---

---


---

---

---

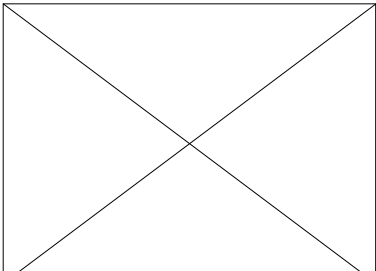
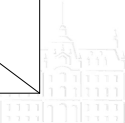
---

---


Univerza na Ljubljani  
Fakulteta za elektrotehniko

---

**Brezkrtični enosmerni motor (BLDC)**


---

29

*Mehatronika – Vanja Ambrožič*

---

---

---


---

---

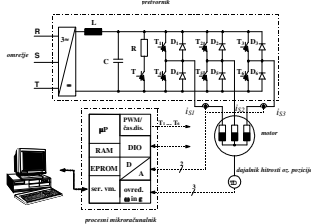

---

---

---


Univerza na Ljubljani  
Fakulteta za elektrotehniko

---


---

30

*Mehatronika – Vanja Ambrožič*

---

---

---

---

---

---

---

---