TECHNICKÁ UNIVERZITA V LIBERCI
Fakulta mechatroniky, informatiky a mezioborových studií

Electric drives

Lecture 3 – D.C. Brush Motor

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evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Projekt ESF CZ.1.07/2.2.00/28.0050
Modernizace didaktických metod a inovace výuky technických předmětů.

Advantages and disadvantages

- Continuous speed control
- Accurate torque, velocity and position regulation

- Commutation
- Brushes
- Signification
- More exacting servicing

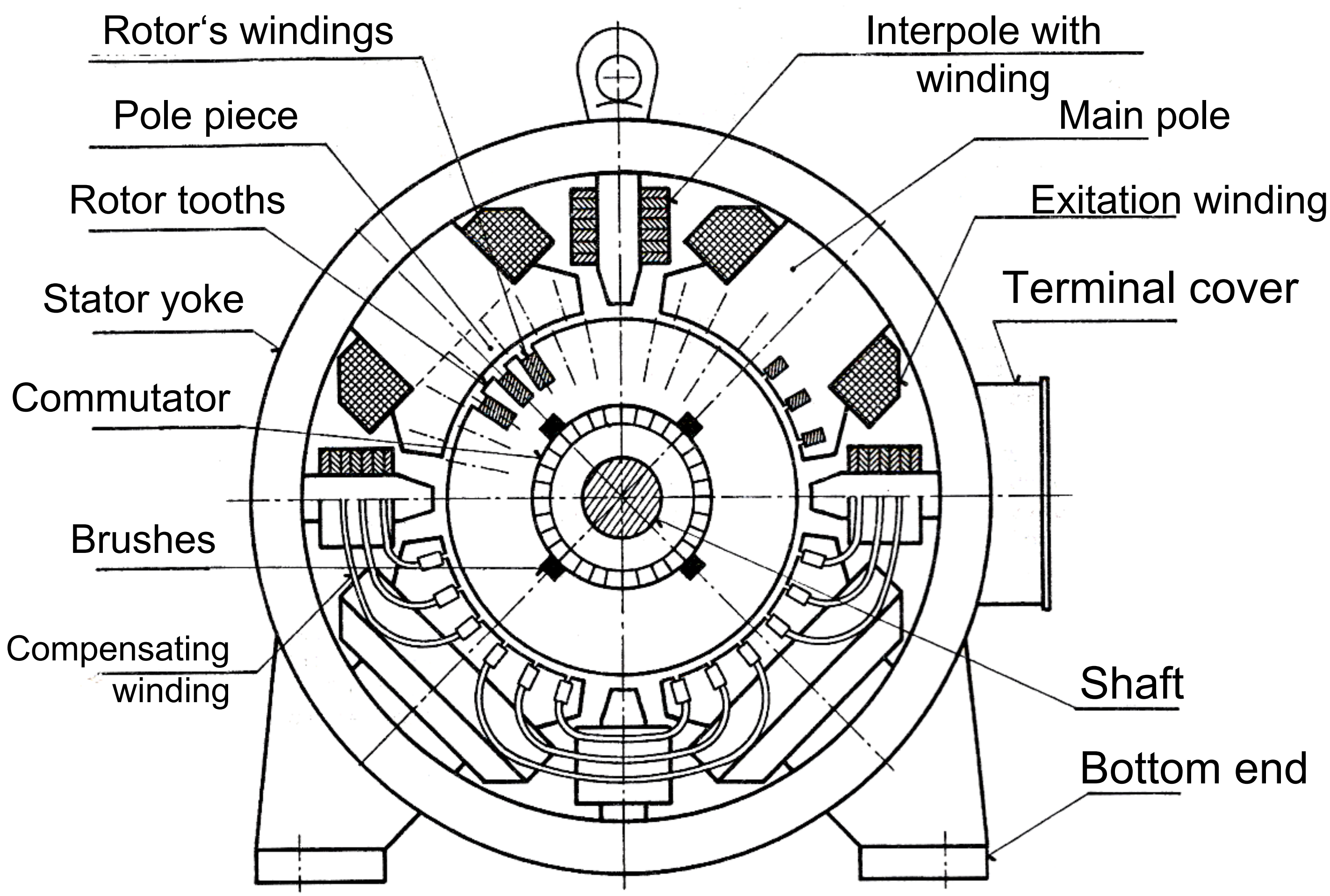
On account of presence of commutation and brushes are these motors replace by electronic commutator machines.

Usage in praxis

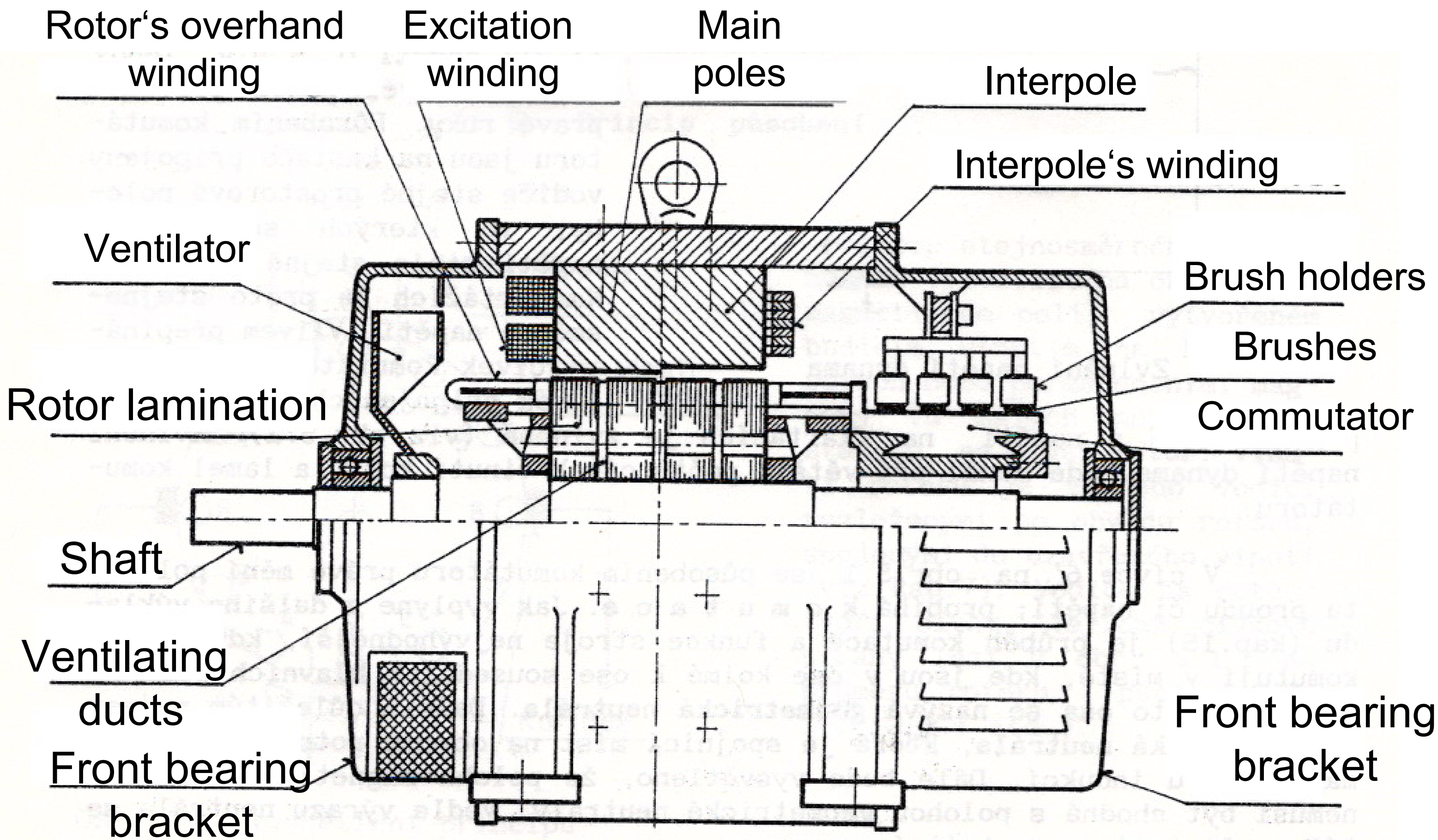
- D.C brush motor has gigantic substitution in praxis
- Winding engines
- Rolling mills
- Heavy industry – in the applications with heavy masses, where is necessary continuous speed control

Construction

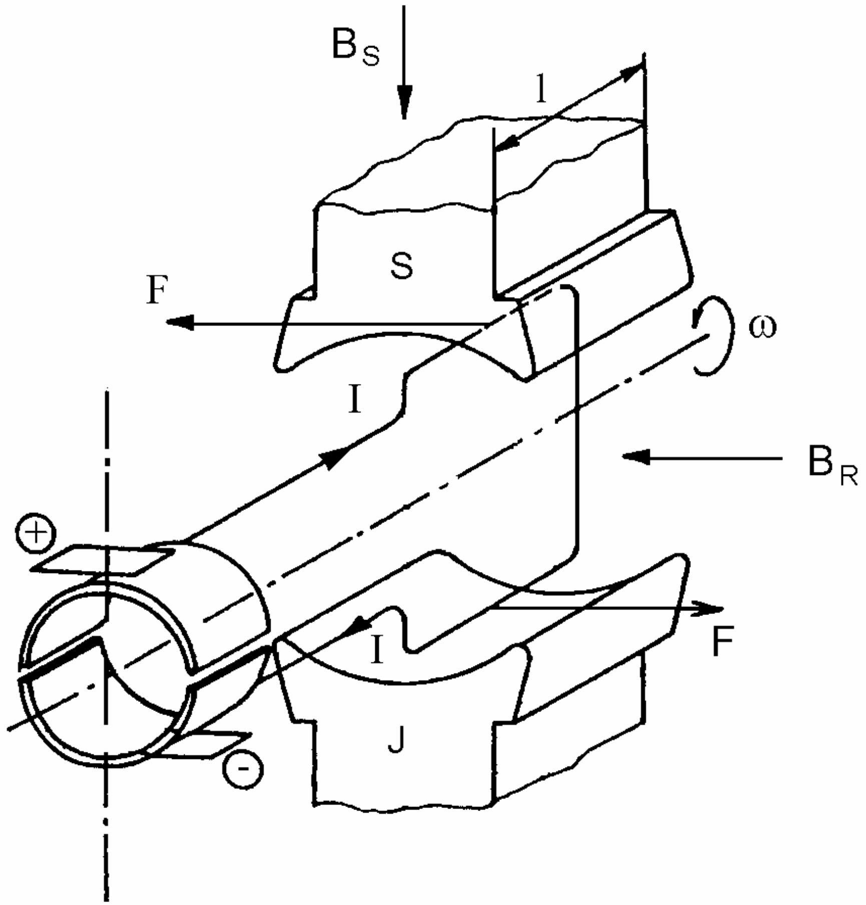
Introduction
Construction
Principle
Induced voltage
Torque
Model
Start up
Breaking
Control



Construction



Motor and dynamo principle



Size of induced voltage

- Size of induced voltage D.S. motor is deduced from induced voltage i one wire

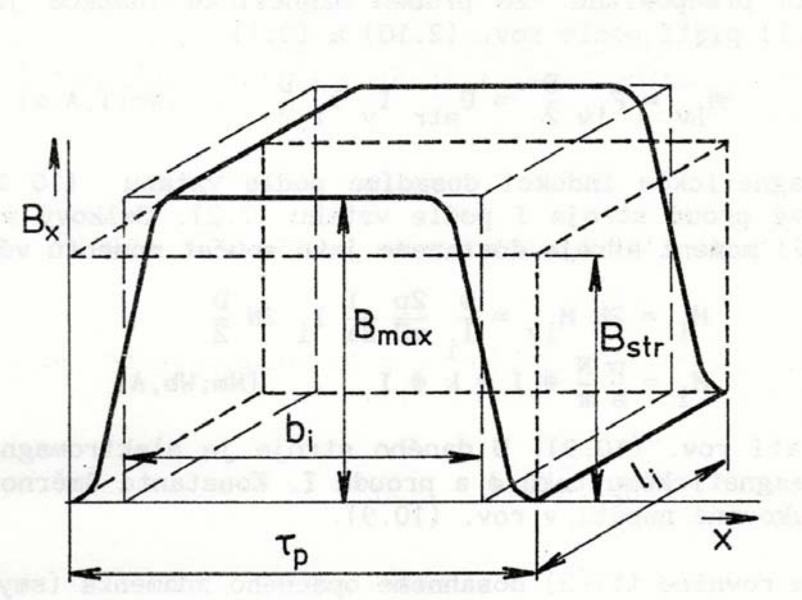
$$U_{iv} = B_x \cdot l_i \cdot v$$

B_x – Magnetic inductance in the place x on rotor circumference

l_i – Active wire lenght

v – Wire velocity

Size of induced voltage



$$\Phi = l_i \cdot \int_0^{\tau_p} B_x dx = B_{avg} \cdot l_i \cdot \tau_p = B_{mas} \cdot l_i \cdot b_i$$

$$B_{avg} = \frac{\Phi}{l_i \cdot \tau_p} = \frac{\Phi}{l_i} \frac{2p}{\pi \cdot D}$$

$$v = \omega \frac{D}{2}$$

Size of induced voltage

- Machine has 2N wires connected to 2a parallel branches
- The whole machine voltage is done by multiplying one wire voltage by number of wires in one parallel branches

$$U_i = \frac{\Phi}{l_i}\frac{2p}{\pi D}\cdot l_i \cdot \omega_m \cdot \frac{D}{2}\cdot\frac{2N}{2a} = \frac{pN}{a\pi}\cdot\Phi\cdot\omega_m = k\cdot\Phi\cdot\omega_m$$

Electromagnetic torque

- For size of electromagnetic torque M, which posses on one wire in on rotor, we use equation:

$$M_{iw} = F_{iw} \cdot \frac{D}{2} = B_{avg} . I_w \cdot l_i \cdot \frac{D}{2}$$

$$I_w = \frac{I}{2a}$$

$$B_{avg} = \frac{\Phi}{l_i} \cdot \frac{2p}{\pi D}$$

- The whole electromagnetic torque is sume of all wires 2N

Electromagnetic torque

$$M_i = 2N \cdot M_{iw} = \frac{\Phi}{l_i} \cdot \frac{2p}{\pi D} \cdot \frac{I}{2a} \cdot l_i \cdot 2N \frac{D}{2} =$$

$$= \frac{p}{a} \cdot \frac{N}{\pi} \cdot \Phi \cdot I = k \cdot \Phi \cdot I$$

pole number

winding number

$$k = \frac{p}{a} \cdot \frac{N}{\pi}$$

branches number

Types of D.C. motors

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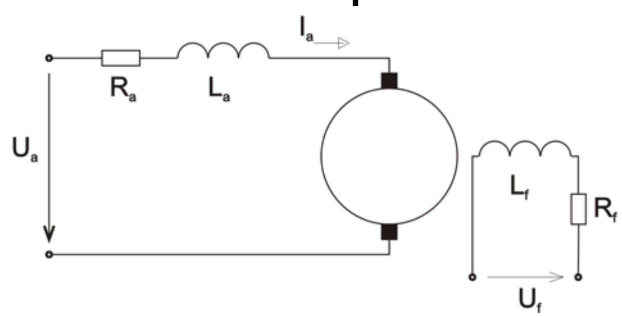
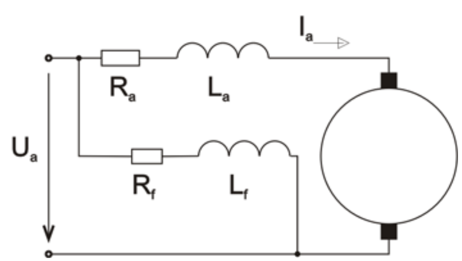
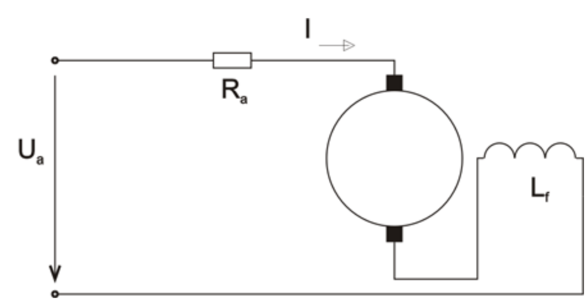
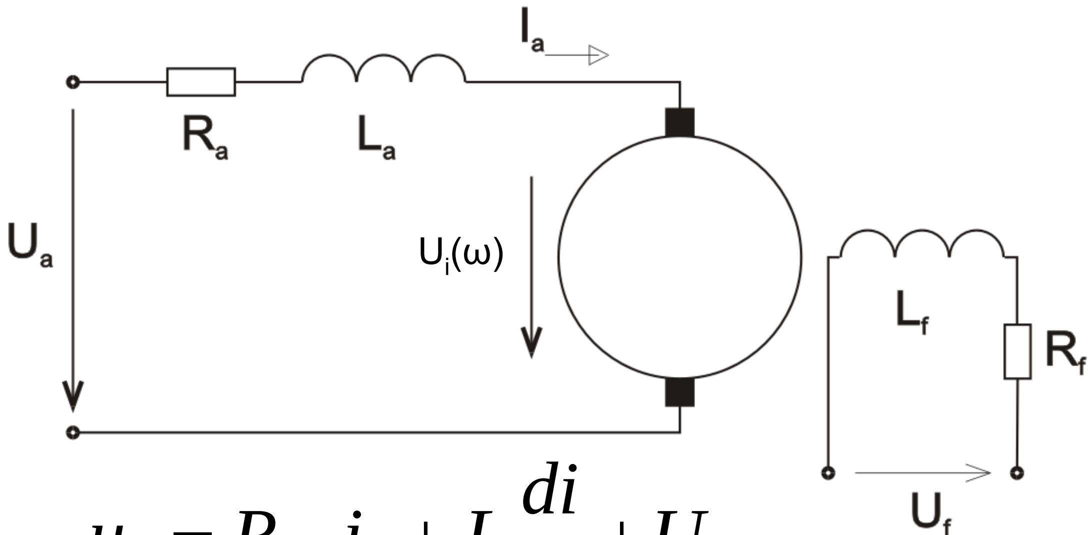
- D.C. brush motors with separate excitation
- D.C. brush motors with series excitation
- D.C. brush motors with parallel excitation







Mathematical description of D.C brush motor with external excitation



$$u_a = R_a \cdot i_a + L\frac{di}{dt} + U_i$$

$$U_i = k \cdot \Phi \cdot \omega$$

$$M_i - M_z = J\frac{da}{dt}$$

$$M_i = k \cdot \Phi \cdot i_a$$

Mathematical description of D.C brush motor with external excitation

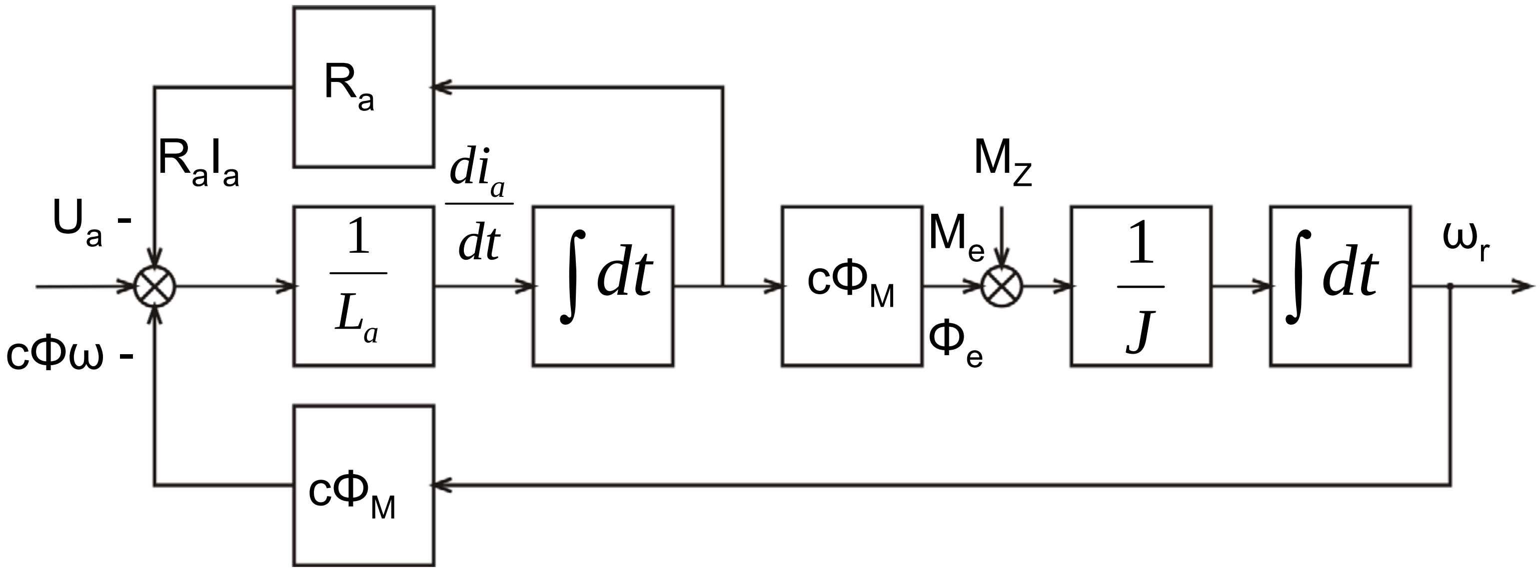
$$u_a = R_a \cdot i_a + L\frac{di_a}{dt} + c\Phi\omega$$

$$L\frac{di_a}{dt} = u_a - R_a i_a - c\Phi\omega$$

$$\frac{di_a}{dt} = \frac{1}{L_a}\left[u_a - R_a i_a - c\Phi\omega\right]$$

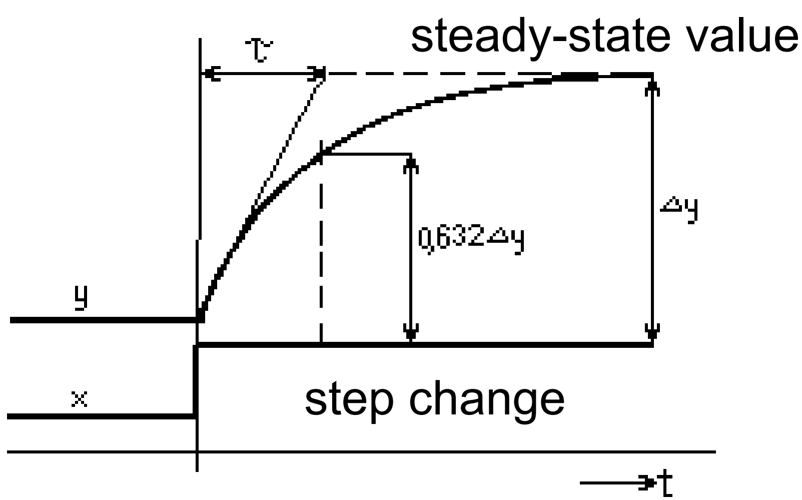
$$i_a = \frac{1}{L_a}\int\left[u_a - R_a i_a - c\Phi\omega\right]$$

Mathematical model of D.C brush motor with external excitation



How to get the parameters for model?

- J – from D‘alambert‘s principle, from the free slow-down stop
- R_a – by measuring from armature cicuit
- L_a – from voltage step change and from I – curve



D.C. brush motor starting

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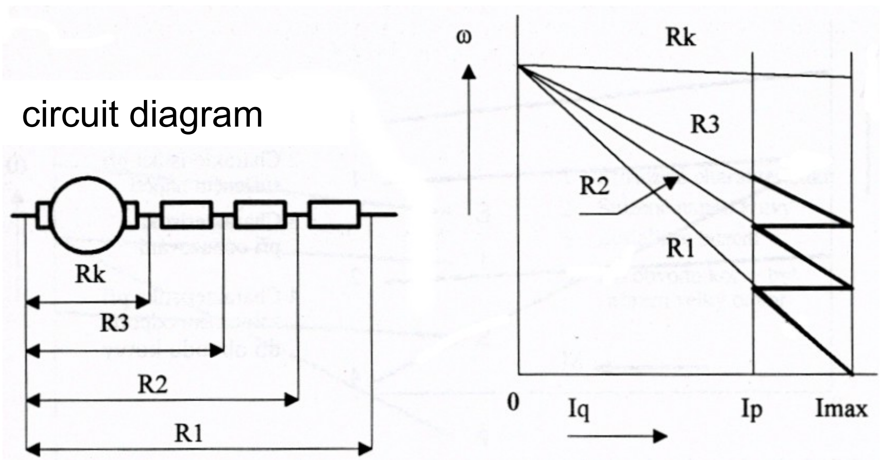
- Resistance starting



Starting resistance proposal

$$R_1 = \frac{U}{I_{MAX}}$$

$$\frac{R_1}{R_2} = \frac{R_2}{R_3} = \frac{R_3}{Rq} = \ldots = \frac{Rm}{Rq} = \frac{\operatorname{Im}ax}{I_p} = g$$

$$R_1 = g^m \cdot R_q \to R_2 = g^{m-1} \cdot R_q \to R_3 = g^{m-2} R_q$$

$$R_1 = \frac{U}{I_{\max}} = g^m \cdot R_q \to m = \frac{\log \frac{U_q}{R_q I_{\max}}}{\log g}$$

D.C. brush motor breaking

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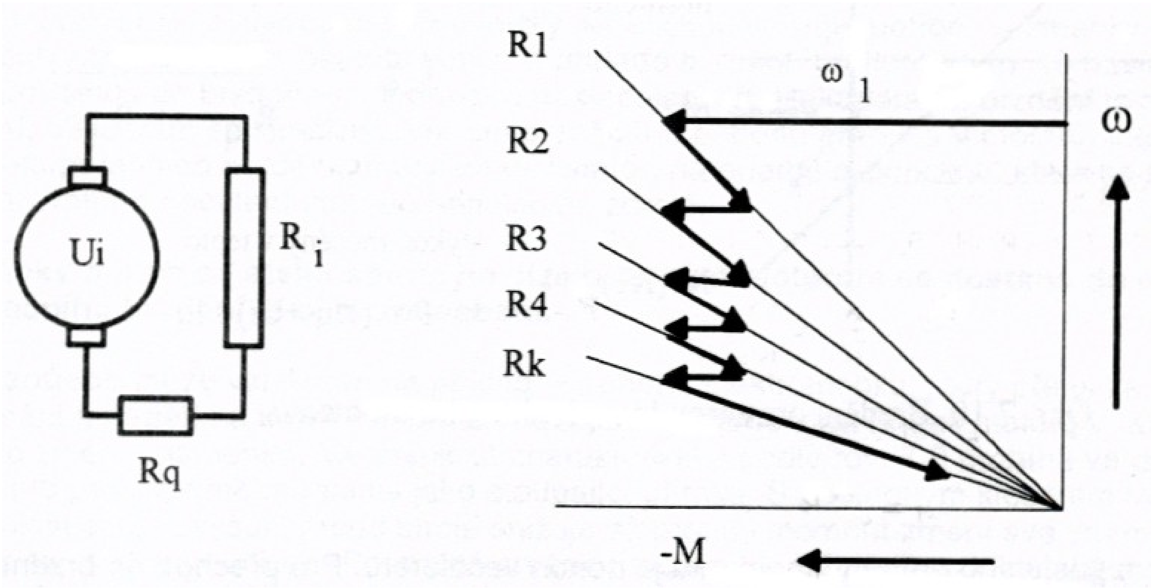
- Breaking to the armature resistor

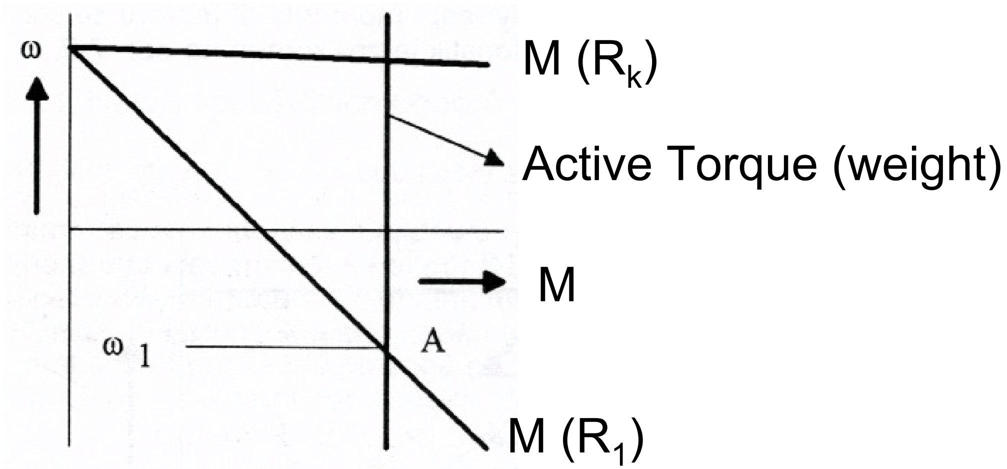


$$0 = (R_a + R_B) \cdot I_a + k\Phi\omega \rightarrow \omega = \frac{R_a + R_B}{k\Phi} I_a$$

$$\omega = \frac{R_a + R_B}{(c\Phi)^2} \cdot M$$

D.C. brush motor breaking

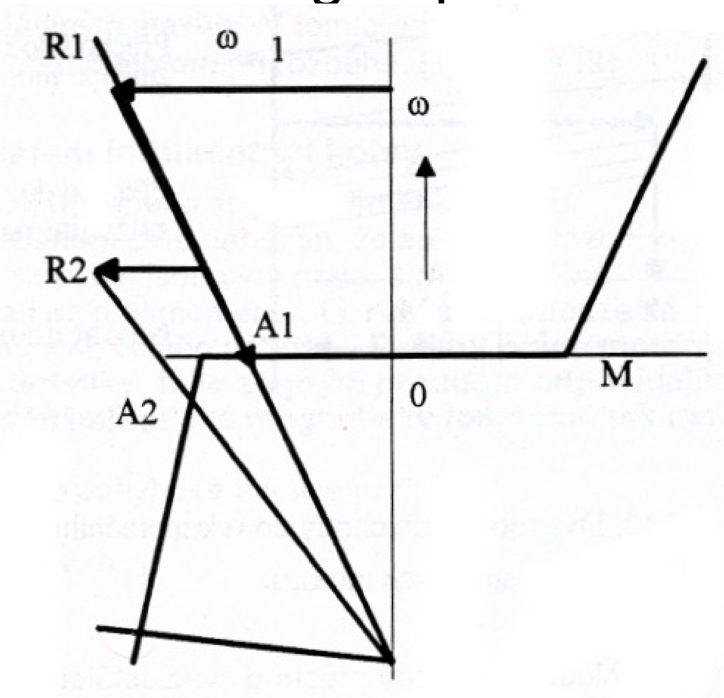
- counter-current braking at active torque



$$I = \frac{U + U_i}{R_a + R_1}$$

D.C. brush motor breaking

- counter-current braking at passive torque



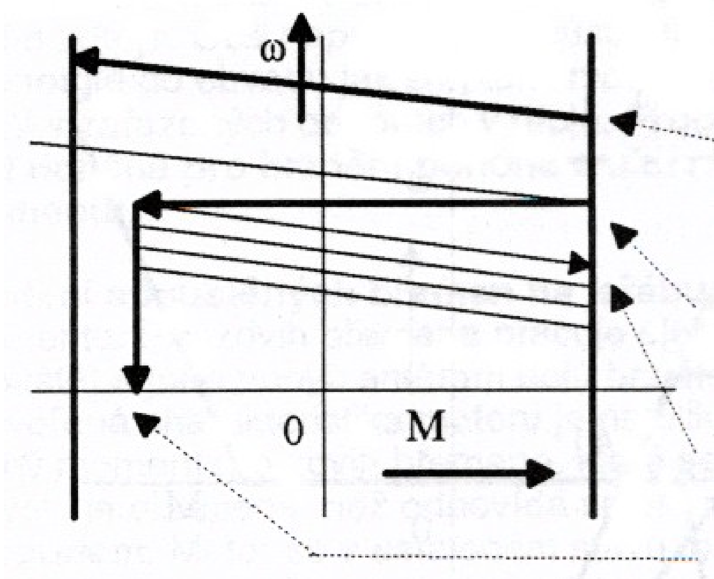
R1 – mechanical characteristic

A1 – steady state after breaking, motor stands still

A2 – drive run in the motor mode with reversal

D.C. brush motor breaking

- regenerative braking



Crossing to the regenerative braking by the changing of the torque and velocity increasing

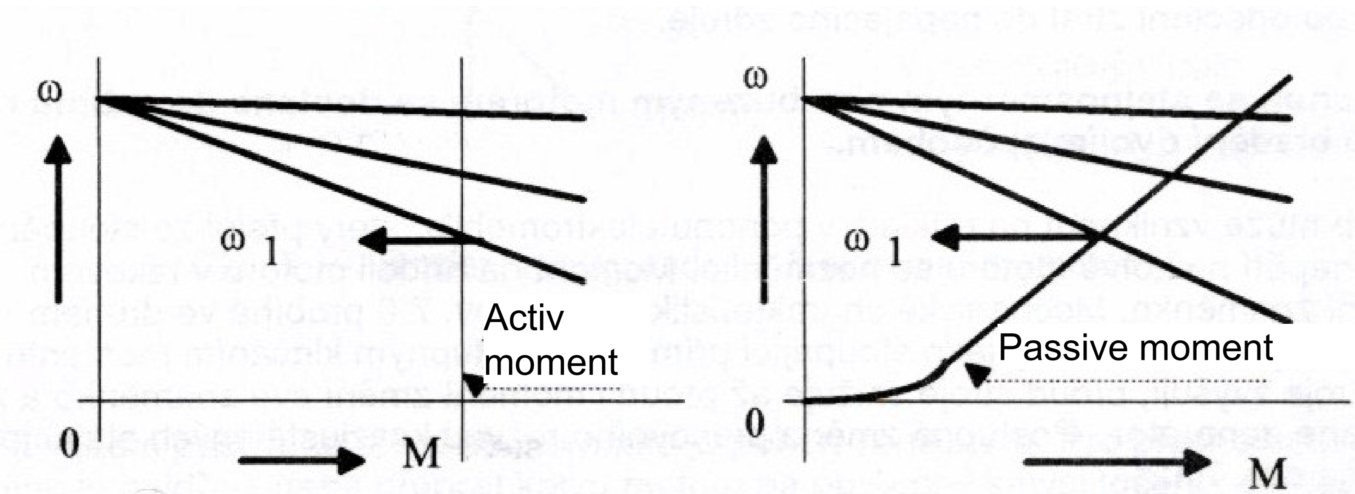
Crossing to the regenerative braking by the decreasing of the suplying voltage

Return to the motor operation

Recuperation breaking by the voltage decreasing

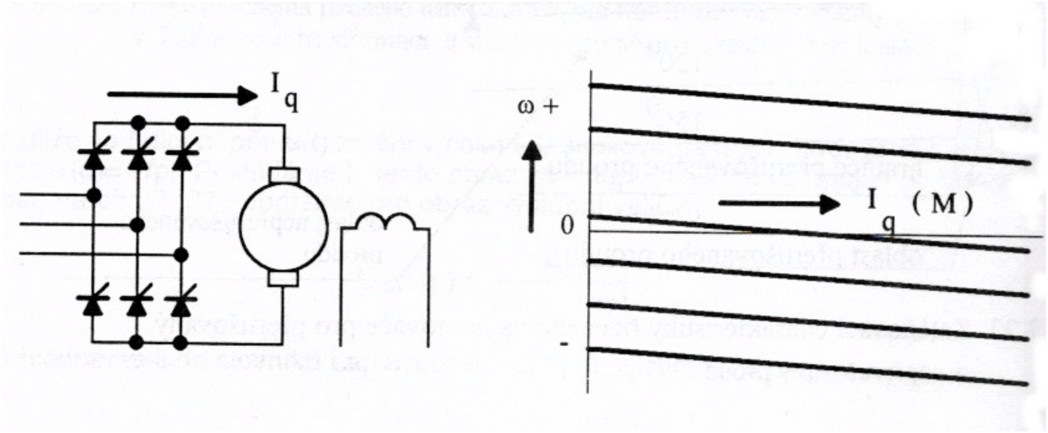
D.C. brush motor velocity control

- Control with resistance in the armature circuit



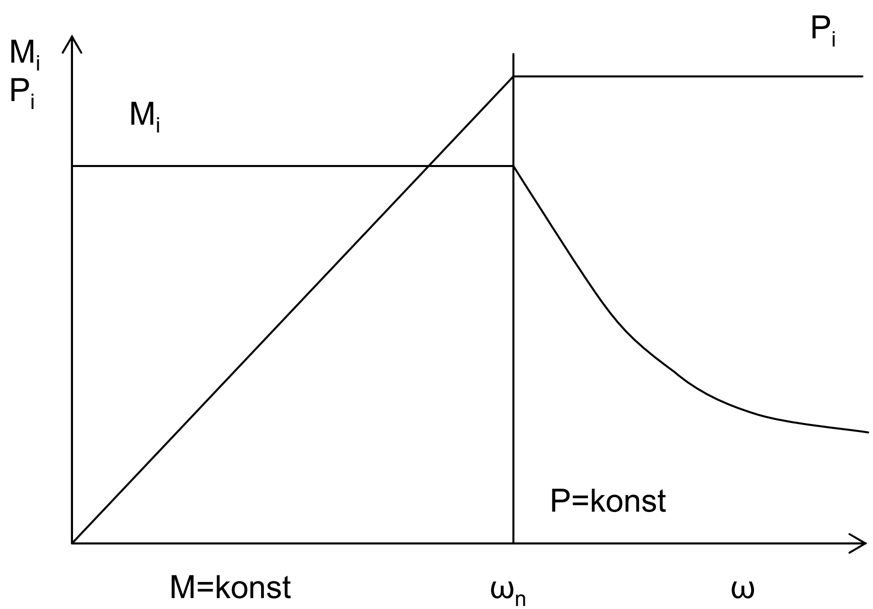
D.C. brush motor velocity control

- Speed velocity by the armature voltage



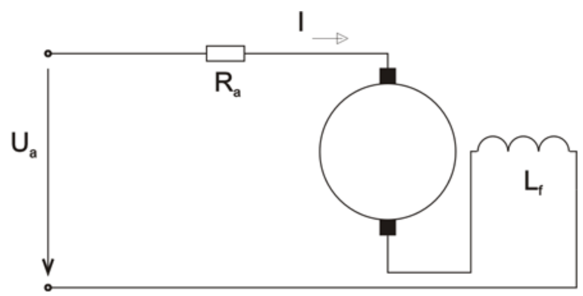
D.C. brush motor velocity control

- Speed velocity by exitation voltage
- (Beware of torque drop)



D.C. brush series motor

Mathematical model



Unlinear system equation

$$u_a = R_a \cdot i_a + L_f \frac{di_a}{dt} + u_i$$

$$J \frac{d\omega}{dt} = M - M_z$$

$$u_i = k\Phi\omega = k \cdot c \cdot i_a \cdot \omega$$

$$M = k\Phi i_a = k \cdot c \cdot i_a^2$$

Static charakteristics

1) $\omega(I_a)$

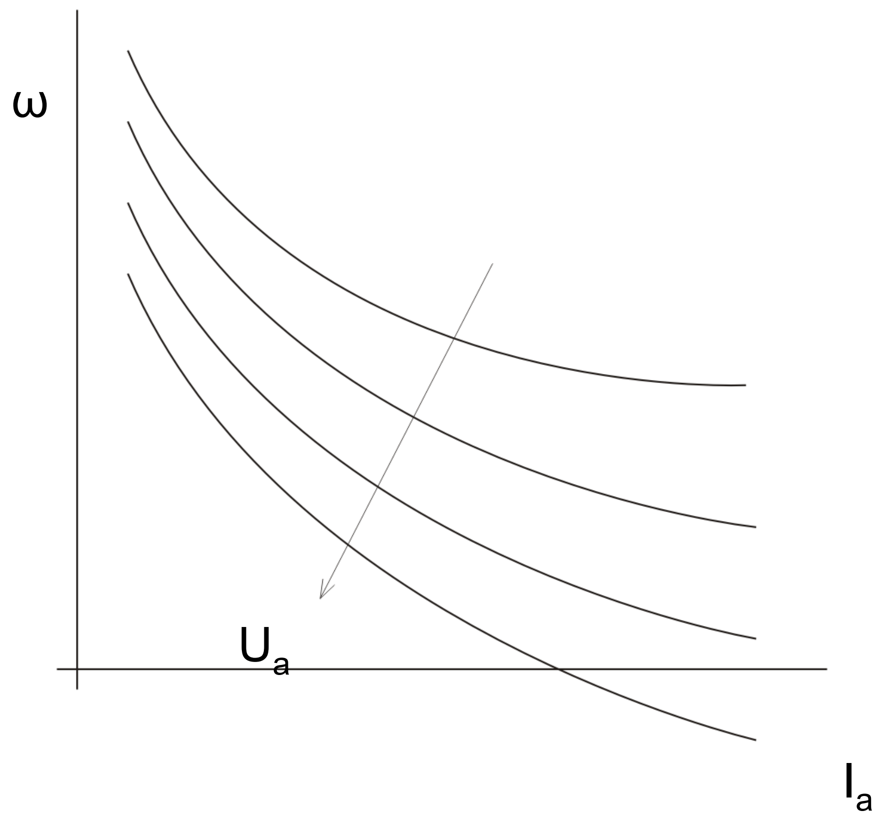
$$\text{if } \frac{d}{dt} = 0$$

$$U_a = R_a \cdot I_a + k \cdot C \cdot I_a \cdot \omega$$

$$\Rightarrow \omega = \frac{U_a - R_a \cdot I_a}{k \cdot C \cdot I_a} = \frac{U_a}{k \cdot C \cdot I_a} - \frac{R_a}{k \cdot C}$$

D.C. brush series motor

Speed charakteristic ω = f(I)

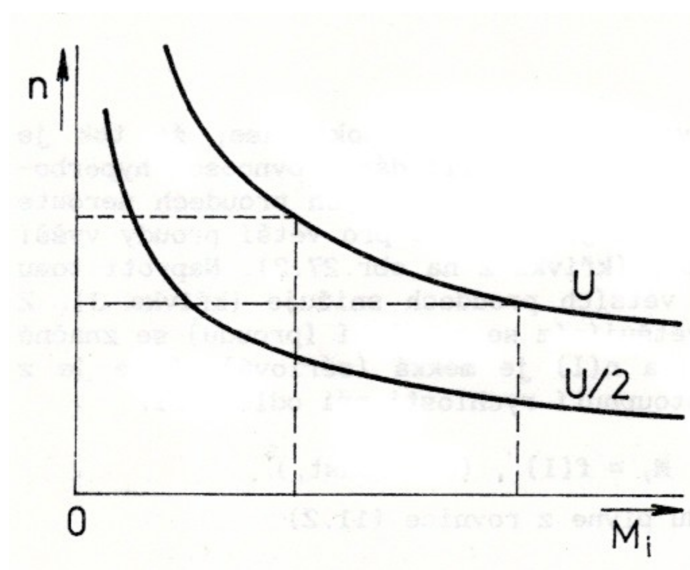


D.C. brush series motor

- Mechanical charakteristic n = f(M)

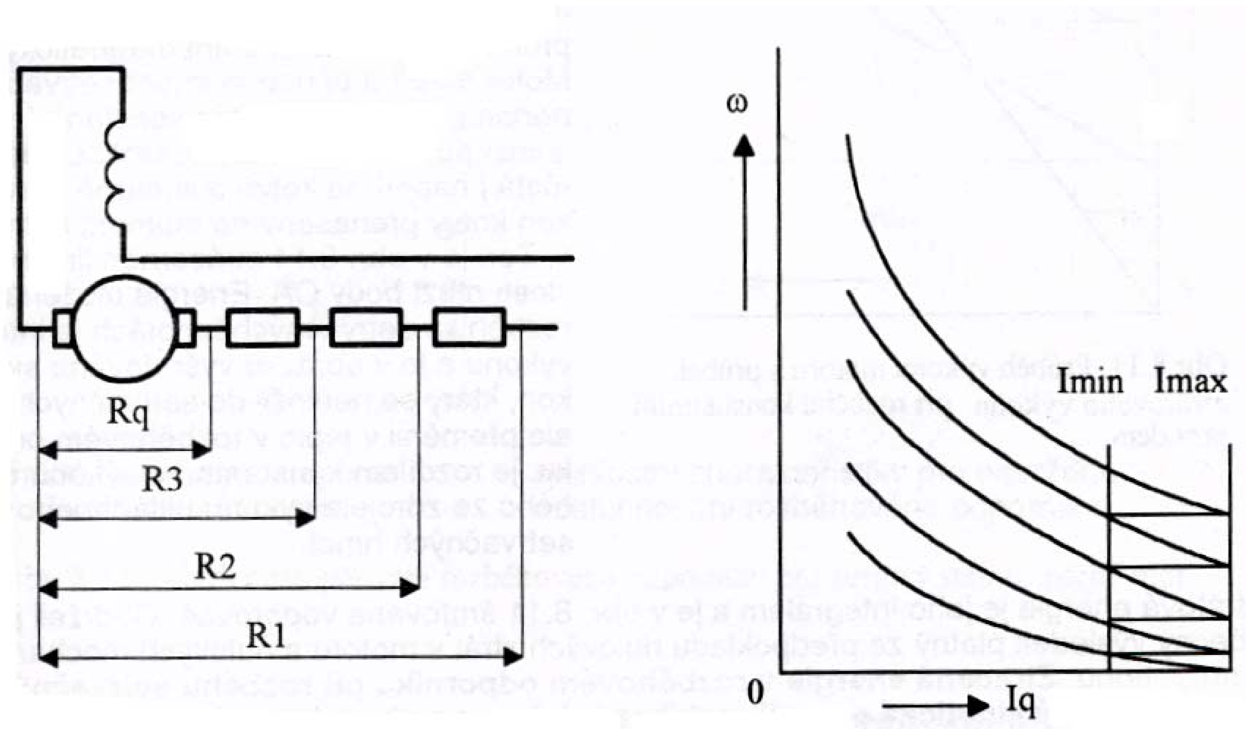
$$M = k \cdot C \cdot I^2 \Rightarrow I_a = \sqrt{\frac{M}{kC}}$$

$$\omega = \frac{U_a}{k \cdot C \cdot \sqrt{\frac{M}{kC}}} - \frac{R_a}{kC} = \frac{U_a}{\sqrt{kC \cdot M}} - \frac{R_a}{kC}$$



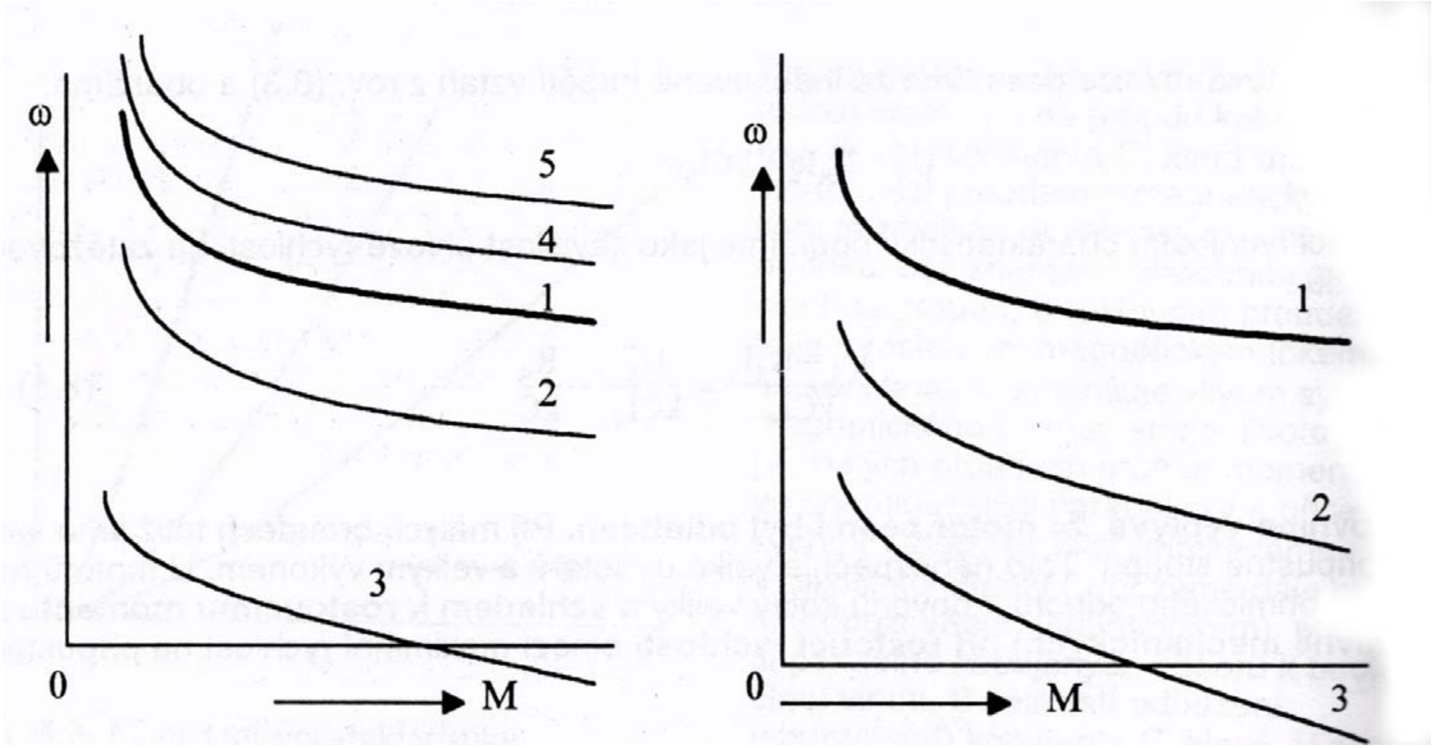
D.C. brush series motor

- Anchor resistance starting



D.C. brush series motor

- Mechanical characteristics



D.C. brush series motor

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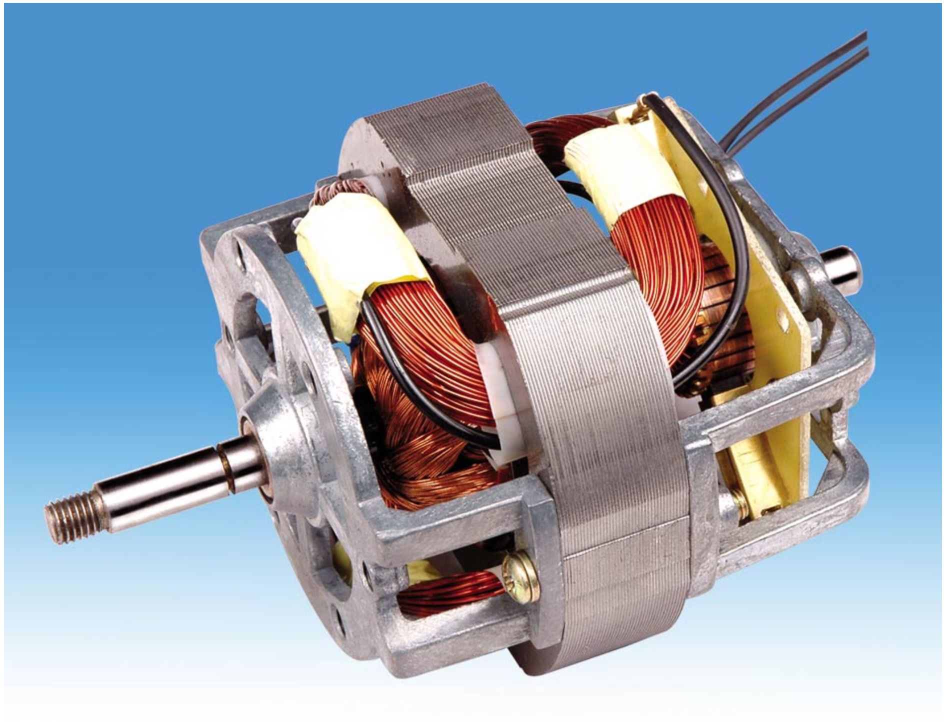
- Recuperation‘s breaking
- A.C Brush series(universal) motor



Thank you for your attention

Tento materiál vznikl v rámci projektu ESF CZ.1.07/2.2.00/28.0050
Modernizace didaktických metod a inovace výuky technických předmětů,
který je spolufinancován Evropským sociálním fondem a státním rozpočtem ČR.