UNIVERSITATEA TEHNICĂ DIN CLUJ-NAPOCA
FACULTATEA DE INGINERIE ELECTRICĂ
DEPARTAMENTUL DE MAȘINI ȘI ACȚIONĂRI ELECTRICE

PROIECT DE AN

LA DISCIPLINA

ACȚIONĂRI ELECTRICE

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Coordonator de proiect:
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An universitar
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Modulul 1.
MOTORUL DE CURENT CONTINUU

Date nominale de catalog:

Tipul motorului: 1GF5 144-0FF4 -6VV1

Putere nominală (Rated output), $P_N := 9.8$ [kW]

Viteza nominală (Rated speed), $n_N := 2420$ [rpm]

Tensiune nominală a indusului, $U_{aN} := 420$ [V]

Cuplu nominal la arbore (Rated torque), $M_{arbN} := 38.7$ [Nm]

Curentul nominal din indus (Rated current), $I_{aN} := 28$ [A]

Randamentul (Efficiency): $\eta := 81$ [%]

Rezistența indusului (Armature resistance), $R_a := 1.53$ [Ω]

Inductivitatea indusului (Armature circuit inductance), $L_a := 11.5$ [mH]

Momentul de inerție corespunzător tipului motorului (Moment of inertia), $J := 0.032$ [kgm2]

Puterea nominală a excitației (Field Power approx), $P_{eN} := 0.33$ [kW]

Tensiunea nominală a excitației (Rated field voltage), $U_{eN} := 310$ [V]

Masa: $m := 93$ [kg]

1.1. Calculul datelor principale ale indusului

1.11. Rezistența nominală:

$$R_N := \frac{U_{aN}}{I_{aN}} \qquad R_N := \frac{420}{28} = 15 \quad [\Omega]$$

1.1.2.Viteza unghiulară nominală:

$$\Omega_N := \frac{\pi \cdot n_N}{30} \qquad \Omega_N := \frac{\pi \cdot 2420}{30} = 253.422 \quad [\text{rad/sec}]$$

1.1.3. Constanta motorului la flux nominal:

$$C_N = k \cdot \Psi_N$$

$$C_N := \frac{U_{aN} - R_a \cdot I_{aN}}{\Omega_N} \qquad C_N := \frac{420 - 1.53 \cdot 28}{253.422} = 1.488 \quad [Vs]$$

1.1.4. Cuplul electromagnetic nominal în regim de motor:

$$M_{emN} := C_N \cdot I_{aN} \qquad M_{emN} := 1.488 \cdot 28 = 41.664 \quad [Nm]$$

1.1.5. Cuplul de mers în gol la viteza nominală:

$$M_0 := M_{emN} - M_{arbN} \qquad M_0 := 41.664 - 38.7 = 2.964 \quad [Nm]$$

1.1.6. Curentul de mers în gol la flux nominal:

$$I_{0N} := \frac{M_0}{C_N} \qquad I_{0N} := \frac{2.964}{1.488} = 1.992 \quad [A]$$

Valoarea absolută: $I_{0N} := 2$ [A]

1.1.7. Reactanța circuitului indusului:

$$X_a := L_a \cdot \Omega_N \qquad X_a := 11.5 \cdot 253.422 = 2.914 \cdot 10^3 \quad [\Omega]$$

1.2. Calculul datelor principale ale excitaţiei

Date calculate:

1.1.8. Curentul nominal al excitației:

$$I_{eN} := \frac{P_{eN} \cdot 10^3}{U_{eN}} \qquad I_{eN} := \frac{0.33 \cdot 10^3}{310} = 1.065 \quad [A]$$

1.1.9. Rezistența totală (echivalentă) a excitației:

$$R_e := \frac{{U_{eN}}^2}{P_{eN}} \qquad R_e := \frac{310^2}{0.33} = 2.912 \cdot 10^5 \quad [\Omega]$$

1.3. Ridicarea caracteristicilor mecanice ale mașinii de c.c.

Calculul caracteristicilor naturale:

$$\Omega_1 := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 0}{{C_N}^2} \qquad \Omega_1 := \frac{420}{1.488} - \frac{1.53 \cdot 0}{1.488^2} = 282.258 \quad [rad/sec]$$

$$\Omega_2 := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_0}{C_N^{\,2}} \qquad \Omega_2 := \frac{420}{1.488} - \frac{1.53 \cdot 2.964}{1.488^2} = 280.21 \quad \text{[rad/sec]}$$

$$\Omega_3 := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_{emN}}{C_N^{\,2}} \qquad \Omega_3 := \frac{420}{1.488} - \frac{1.53 \cdot 41.664}{1.488^2} = 253.468 \quad \text{[rad/sec]}$$

$$\Omega_4 := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{C_N^{\,2}} \qquad \Omega_4 := \frac{420}{1.488} - \frac{1.53 \cdot 62.496}{1.488^2} = 239.073 \quad \text{[rad/sec]}$$

Tabelul 1. Calculul caracteristicii naturale

M (Nm)	M = 0	M = M0	M = M emN	M = 1.5MemN
Ω (rad/s)	282.258	280.21	253.468	239.073

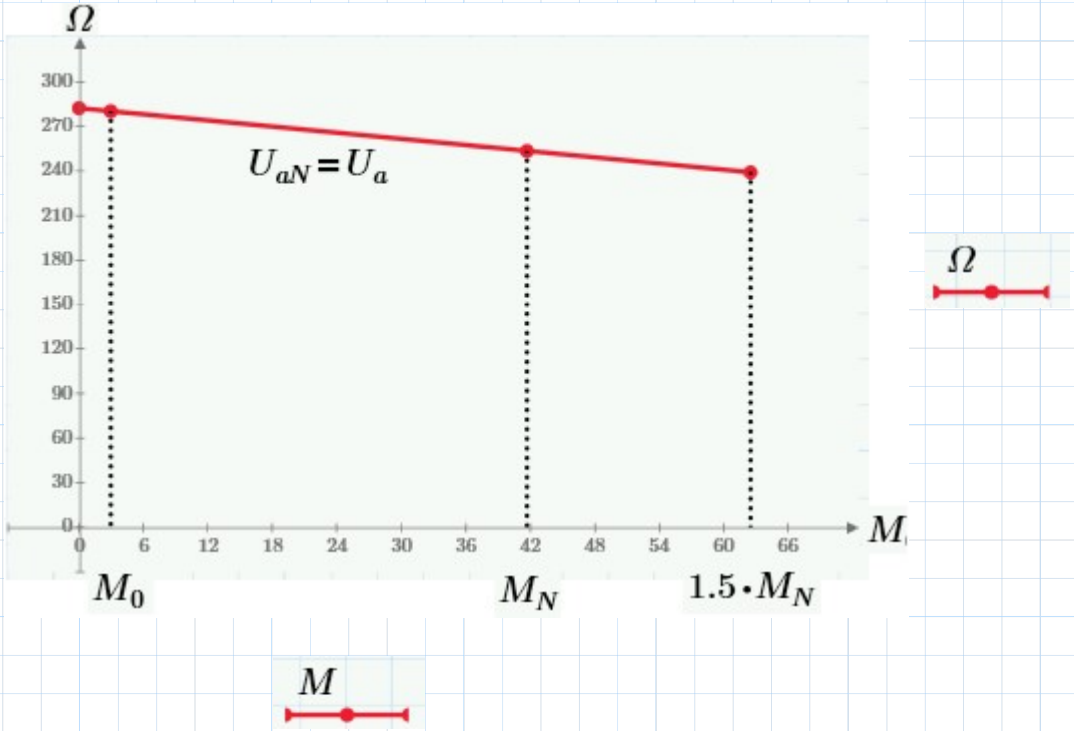


Fig. 1. Caracteristica mecanică naturală a motorului de curent continuu

Caracteristicile artificiale obținute prin modificarea tensiunii de alimentare a indusului. (Ua = var.)

Calculul caracteristicilor la variația tensiunii de alimentare a indusului :

Pentru: $U_a = U_{aN}$

$$\Omega_{11} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 0}{{C_N}^2} \qquad \Omega_{11} := \frac{420}{1.488} - \frac{1.53 \cdot 0}{1.488^2} = 282.258 \quad \text{[rad/sec]}$$

$$\Omega_{21} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_0}{{C_N}^2} \qquad \Omega_{21} := \frac{420}{1.488} - \frac{1.53 \cdot 2.964}{1.488^2} = 280.21 \quad \text{[rad/sec]}$$

$$\Omega_{31} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_{emN}}{{C_N}^2} \qquad \Omega_{31} := \frac{420}{1.488} - \frac{1.53 \cdot 41.664}{1.488^2} = 253.468 \quad \text{[rad/sec]}$$

$$\Omega_{41} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{{C_N}^2} \qquad \Omega_{41} := \frac{420}{1.488} - \frac{1.53 \cdot 62.496}{1.488^2} = 239.073 \quad \text{[rad/sec]}$$

Pentru: $U_a = 0.75 \cdot U_{aN}$

$$\Omega_{12} := \frac{0.75 \cdot U_{aN}}{C_N} - \frac{R_a \cdot 0}{{C_N}^2} \qquad \Omega_{12} := \frac{0.75 \cdot 420}{1.488} - \frac{1.53 \cdot 0}{1.488^2} = 211.694 \quad \text{[rad/sec]}$$

$$\Omega_{22} := \frac{0.75 \cdot U_{aN}}{C_N} - \frac{R_a \cdot M_0}{{C_N}^2} \qquad \Omega_{22} := \frac{0.75 \cdot 420}{1.488} - \frac{1.53 \cdot 2.964}{1.488^2} = 209.645 \quad \text{[rad/sec]}$$

$$\Omega_{32} := \frac{0.75 \cdot U_{aN}}{C_N} - \frac{R_a \cdot M_{emN}}{{C_N}^2} \qquad \Omega_{32} := \frac{0.75 \cdot 420}{1.488} - \frac{1.53 \cdot 41.664}{1.488^2} = 182.903 \quad \text{[rad/sec]}$$

$$\Omega_{42} := \frac{0.75 \cdot U_{aN}}{C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{{C_N}^2} \qquad \Omega_{42} := \frac{0.75 \cdot 420}{1.488} - \frac{1.53 \cdot 62.496}{1.488^2} = 168.508 \quad \text{[rad/sec]}$$

Pentru: $U_a = 0.5 \cdot U_{aN}$

$$\Omega_{13} := \frac{0.5 \cdot U_{aN}}{C_N} - \frac{R_a \cdot 0}{{C_N}^2} \qquad \Omega_{13} := \frac{0.5 \cdot 420}{1.488} - \frac{1.53 \cdot 0}{1.488^2} = 141.129 \quad \text{[rad/sec]}$$

$$\Omega_{23} := \frac{0.5 \cdot U_{aN}}{C_N} - \frac{R_a \cdot M_0}{{C_N}^2} \qquad \Omega_{23} := \frac{0.5 \cdot 420}{1.488} - \frac{1.53 \cdot 2.964}{1.488^2} = 139.081 \quad \text{[rad/sec]}$$

$$\Omega_{33} := \frac{0.5 \cdot U_{aN}}{C_N} - \frac{R_a \cdot M_{emN}}{{C_N}^2} \qquad \Omega_{33} := \frac{0.5 \cdot 420}{1.488} - \frac{1.53 \cdot 41.664}{1.488^2} = 112.339 \quad \text{[rad/sec]}$$

$$\Omega_{43} := \frac{0.5 \cdot U_{aN}}{C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{{C_N}^2} \qquad \Omega_{43} := \frac{0.5 \cdot 420}{1.488} - \frac{1.53 \cdot 62.496}{1.488^2} = 97.944 \quad \text{[rad/sec]}$$

Pentru: $U_a = 0.25 \cdot U_{aN}$

$$\Omega_{14} := \frac{0.25 \cdot U_{aN}}{C_N} - \frac{R_a \cdot 0}{C_N{}^2} \qquad \Omega_{14} := \frac{0.25 \cdot 420}{1.488} - \frac{1.53 \cdot 0}{1.488^2} = 70.565 \quad \text{[rad/sec]}$$

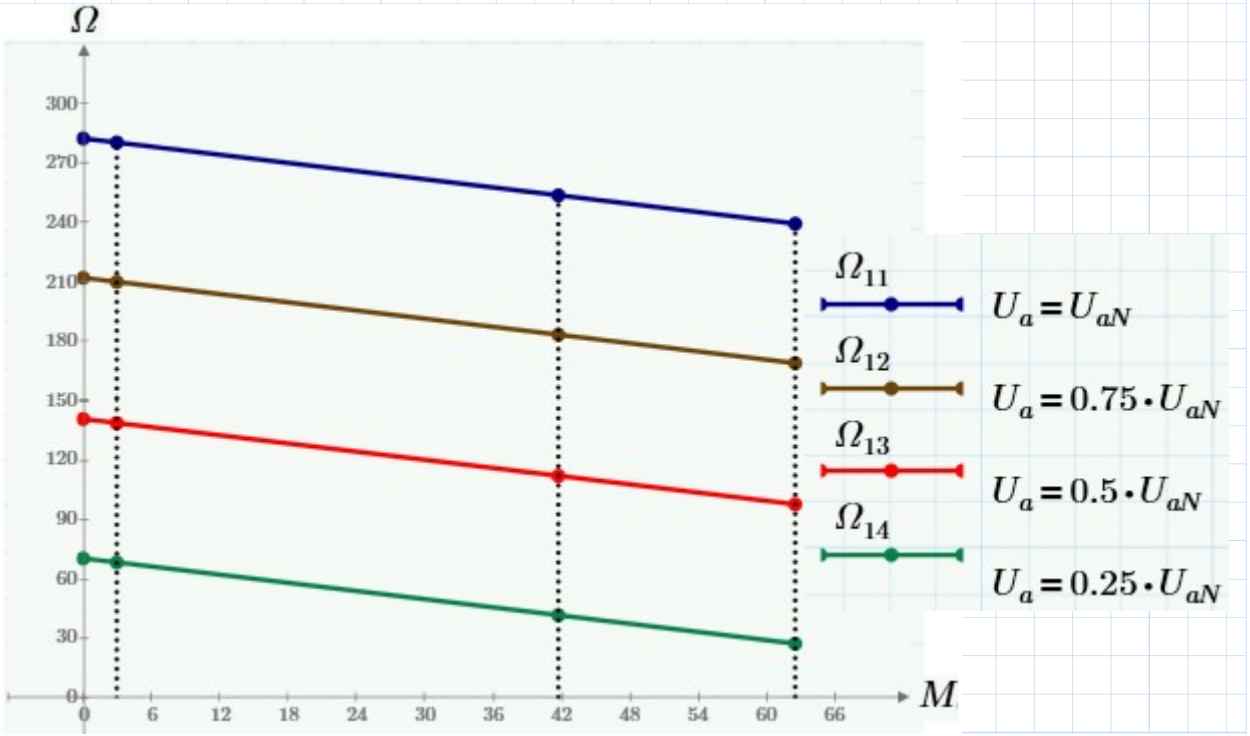
$$\Omega_{24} := \frac{0.25 \cdot U_{aN}}{C_N} - \frac{R_a \cdot M_0}{C_N{}^2} \qquad \Omega_{24} := \frac{0.25 \cdot 420}{1.488} - \frac{1.53 \cdot 2.964}{1.488^2} = 68.516 \quad \text{[rad/sec]}$$

$$\Omega_{34} := \frac{0.25 \cdot U_{aN}}{C_N} - \frac{R_a \cdot M_{emN}}{C_N{}^2} \qquad \Omega_{34} := \frac{0.25 \cdot 420}{1.488} - \frac{1.53 \cdot 41.664}{1.488^2} = 41.774 \quad \text{[rad/sec]}$$

$$\Omega_{44} := \frac{0.25 \cdot U_{aN}}{C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{C_N{}^2} \qquad \Omega_{44} := \frac{0.25 \cdot 420}{1.488} - \frac{1.53 \cdot 62.496}{1.488^2} = 27.379 \quad \text{[rad/sec]}$$

Tabelul 2. Calculul caracteristicilor la variația tensiunii de alimentare a indusului

	Caracteristica naturală Ua= UaN	Caracteristica la Ua=0.75 UaN	Caracteristica la Ua =0.5 UaN	Caracteristica la Ua =0.25 UaN
M (Nm)	**Ω (rad/s)**	**Ω (rad/s)**	**Ω (rad/s)**	**Ω (rad/s)**
M = 0	282.258	211.694	141.129	70.565
M = M0 =	280.21	209.645	139.081	68.516
M = MemN =	253.468	182.903	112.339	41.774
M = 1.5MemN=	239.073	168.508	97.944	27.379



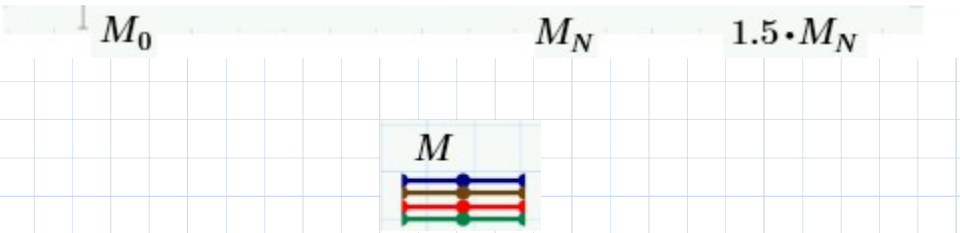


Fig. 2. Caracteristicile mecanice artificiale a motorului de curent continuu la variația tensiunii de alimentare a indusului

Caracteristicile artificiale obținute prin modificarea fluxului de excitație ($k \cdot \Psi = var$)

Calculul caracteristicilor la variația fluxului de excitație

Pentru: $\Psi = \Psi_N = C_N$

$$\Omega_{11} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 0}{C_N{}^2} \qquad \Omega_{11} := \frac{420}{1.488} - \frac{1.53 \cdot 0}{1.488^2} = 282.258 \quad \text{[rad/sec]}$$

$$\Omega_{21} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_0}{C_N{}^2} \qquad \Omega_{21} := \frac{420}{1.488} - \frac{1.53 \cdot 2.964}{1.488^2} = 280.21 \quad \text{[rad/sec]}$$

$$\Omega_{31} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_{emN}}{C_N{}^2} \qquad \Omega_{31} := \frac{420}{1.488} - \frac{1.53 \cdot 41.664}{1.488^2} = 253.468 \quad \text{[rad/sec]}$$

$$\Omega_{41} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{C_N{}^2} \qquad \Omega_{41} := \frac{420}{1.488} - \frac{1.53 \cdot 62.496}{1.488^2} = 239.073 \quad \text{[rad/sec]}$$

Pentru: $\Psi = 0.85 \cdot \Psi_N = 0.85 \cdot C_N$

$$\Omega_{12} := \frac{U_{aN}}{0.85 \cdot C_N} - \frac{R_a \cdot 0}{(0.85 \cdot C_N)^2} \qquad \Omega_{12} := \frac{420}{0.85 \cdot 1.488} - \frac{1.53 \cdot 0}{(0.85 \cdot 1.488)^2} = 332.068 \quad \text{[rad/sec]}$$

$$\Omega_{22} := \frac{U_{aN}}{0.85 \cdot C_N} - \frac{R_a \cdot M_0}{(0.85 \cdot C_N)^2} \qquad \Omega_{22} := \frac{420}{0.85 \cdot 1.488} - \frac{1.53 \cdot 2.964}{(0.85 \cdot 1.488)^2} = 329.233 \quad \text{[rad/sec]}$$

$$\Omega_{32} := \frac{U_{aN}}{0.85 \cdot C_N} - \frac{R_a \cdot M_{emN}}{(0.85 \cdot C_N)^2} \qquad \Omega_{32} := \frac{420}{0.85 \cdot 1.488} - \frac{1.53 \cdot 41.664}{(0.85 \cdot 1.488)^2} = 292.22 \text{ [rad/sec]}$$

$$\Omega_{42} := \frac{U_{aN}}{0.85 \cdot C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{(0.85 \cdot C_N)^2} \qquad \Omega_{42} := \frac{420}{0.85 \cdot 1.488} - \frac{1.53 \cdot 62.496}{(0.85 \cdot 1.488)^2} = 272.296 \text{ [rad/sec]}$$

Pentru: $\Psi = 0.75 \cdot \Psi_N = 0.75 \cdot C_N$

$$\Omega_{13} := \frac{U_{aN}}{0.75 \cdot C_N} - \frac{R_a \cdot 0}{(0.75 \cdot C_N)^2} \qquad \Omega_{13} := \frac{420}{0.75 \cdot 1.488} - \frac{1.53 \cdot 0}{(0.75 \cdot 1.488)^2} = 376.344 \text{ [rad/sec]}$$

$$\Omega_{23} := \frac{U_{aN}}{0.75 \cdot C_N} - \frac{R_a \cdot M_0}{(0.75 \cdot C_N)^2} \qquad \Omega_{23} := \frac{420}{0.75 \cdot 1.488} - \frac{1.53 \cdot 2.964}{(0.75 \cdot 1.488)^2} = 372.703 \text{ [rad/sec]}$$

$$\Omega_{33} := \frac{U_{aN}}{0.75 \cdot C_N} - \frac{R_a \cdot M_{emN}}{(0.75 \cdot C_N)^2} \qquad \Omega_{33} := \frac{420}{0.75 \cdot 1.488} - \frac{1.53 \cdot 41.664}{(0.75 \cdot 1.488)^2} = 325.161 \text{ [rad/sec]}$$

$$\Omega_{43} := \frac{U_{aN}}{0.75 \cdot C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{(0.75 \cdot C_N)^2} \qquad \Omega_{43} := \frac{420}{0.75 \cdot 1.488} - \frac{1.53 \cdot 62.496}{(0.75 \cdot 1.488)^2} = 299.57 \text{ [rad/sec]}$$

Pentru: $\Psi = 0.6 \cdot \Psi_N = 0.6 \cdot C_N$

$$\Omega_{14} := \frac{U_{aN}}{0.6 \cdot C_N} - \frac{R_a \cdot 0}{(0.6 \cdot C_N)^2} \qquad \Omega_{14} := \frac{420}{0.6 \cdot 1.488} - \frac{1.53 \cdot 0}{(0.6 \cdot 1.488)^2} = 470.43 \text{ [rad/sec]}$$

$$\Omega_{24} := \frac{U_{aN}}{0.6 \cdot C_N} - \frac{R_a \cdot M_0}{(0.6 \cdot C_N)^2} \qquad \Omega_{24} := \frac{420}{0.6 \cdot 1.488} - \frac{1.53 \cdot 2.964}{(0.6 \cdot 1.488)^2} = 464.741 \text{ [rad/sec]}$$

$$\Omega_{34} := \frac{U_{aN}}{0.6 \cdot C_N} - \frac{R_a \cdot M_{emN}}{(0.6 \cdot C_N)^2} \qquad \Omega_{34} := \frac{420}{0.6 \cdot 1.488} - \frac{1.53 \cdot 41.664}{(0.6 \cdot 1.488)^2} = 390.457 \text{ [rad/sec]}$$

$$\Omega_{44} := \frac{U_{aN}}{0.6 \cdot C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{(0.6 \cdot C_N)^2} \qquad \Omega_{44} := \frac{420}{0.6 \cdot 1.488} - \frac{1.53 \cdot 62.496}{(0.6 \cdot 1.488)^2} = 350.47 \text{ [rad/sec]}$$

Tabelul 3. Calculul caracteristicilor la variația fluxului de excitație

	Caracteristica naturală $k\Psi = k\Psi_n = C_N$	Caracteristica la $k\Psi = 0.85k\Psi_n = 0.85 \cdot C_N$	Caracteristica la $k\Psi = 0.75k\Psi_n = 0.75 \cdot C_N$	Caracteristica la $k\Psi = 0.6k\Psi_n = 0.6 \cdot C_N$
M (Nm)	**Ω (rad/s)**	**Ω (rad/s)**	**Ω (rad/s)**	**Ω (rad/s)**
M = 0	282.258	332.068	376.344	470.43
M = M0 =	280.21	329.233	372.703	464.741
M = MemN =	253.468	292.22	325.161	390.457
M = 1.5MemN=	239.073	272.296	299.57	350.47

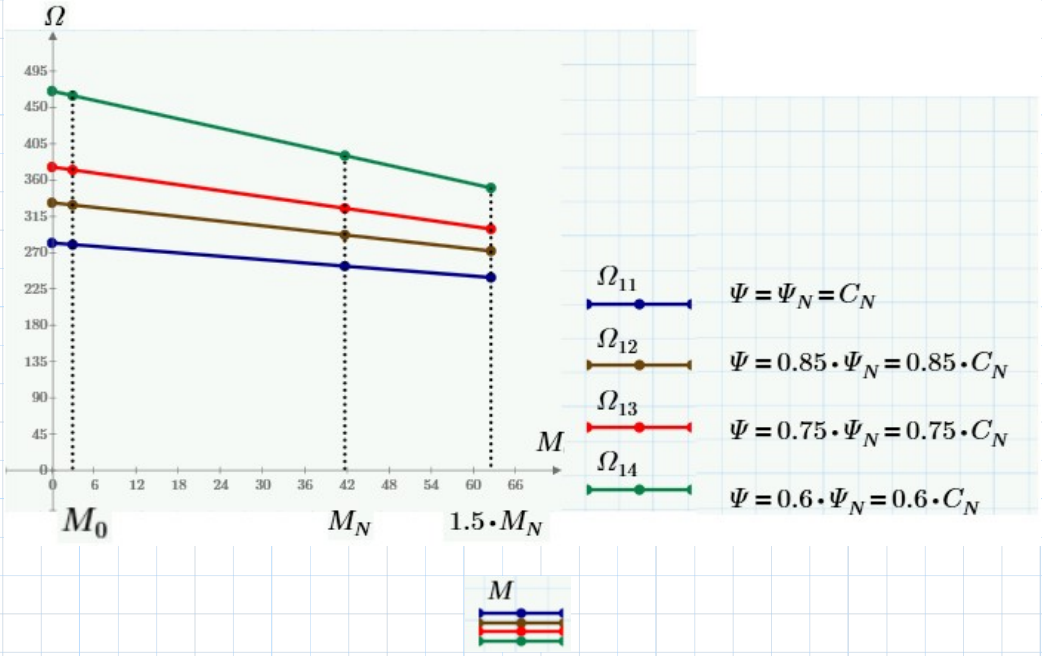


Fig. 3. Caracteristicile mecanice artificiale a motorului de curent continuu la variația fluxului de excitație

Caracteristicile artificiale obținute prin modificarea rezistenței circuitului indusului: Ra = var.

Calculul caracteristicilor la variația rezistenței circuitului indusului:

Pentru: $R_{tot} = R_a$

$$\Omega_{11} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 0}{C_N^{\,2}} \qquad \Omega_{11} := \frac{420}{1.488} - \frac{1.53 \cdot 0}{1.488^2} = 282.258 \quad \text{[rad/sec]}$$

$$\Omega_{21} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_0}{C_N^{\,2}} \qquad \Omega_{21} := \frac{420}{1.488} - \frac{1.53 \cdot 2.964}{1.488^2} = 280.21 \quad \text{[rad/sec]}$$

$$\Omega_{31} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot M_{emN}}{C_N^{\,2}} \qquad \Omega_{31} := \frac{420}{1.488} - \frac{1.53 \cdot 41.664}{1.488^2} = 253.468 \quad \text{[rad/sec]}$$

$$\Omega_{41} := \frac{U_{aN}}{C_N} - \frac{R_a \cdot 1.5 \cdot M_{emN}}{C_N^{\,2}} \qquad \Omega_{41} := \frac{420}{1.488} - \frac{1.53 \cdot 62.496}{1.488^2} = 239.073 \quad \text{[rad/sec]}$$

Pentru: $R_{tot} = 1.5 \cdot R_a$

$$\Omega_{12} := \frac{U_{aN}}{C_N} - \frac{1.5 \cdot R_a \cdot 0}{C_N^{\,2}} \qquad \Omega_{12} := \frac{420}{1.488} - \frac{1.5 \cdot 1.53 \cdot 0}{1.488^2} = 282.258 \quad \text{[rad/sec]}$$

$$\Omega_{22} := \frac{U_{aN}}{C_N} - \frac{1.5 \cdot R_a \cdot M_0}{C_N^{\,2}} \qquad \Omega_{22} := \frac{420}{1.488} - \frac{1.5 \cdot 1.53 \cdot 2.964}{1.488^2} = 279.186 \quad \text{[rad/sec]}$$

$$\Omega_{32} := \frac{U_{aN}}{C_N} - \frac{1.5 \cdot R_a \cdot M_{emN}}{C_N^{\,2}} \qquad \Omega_{32} := \frac{420}{1.488} - \frac{1.5 \cdot 1.53 \cdot 41.664}{1.488^2} = 239.073 \quad \text{[rad/sec]}$$

$$\Omega_{42} := \frac{U_{aN}}{C_N} - \frac{1.5 \cdot R_a \cdot 1.5 \cdot M_{emN}}{C_N^{\,2}} \qquad \Omega_{42} := \frac{420}{1.488} - \frac{1.5 \cdot 1.53 \cdot 62.496}{1.488^2} = 217.48 \quad \text{[rad/sec]}$$

Pentru: $R_{tot} = 2 \cdot R_a$

$$\Omega_{13} := \frac{U_{aN}}{C_N} - \frac{2 \cdot R_a \cdot 0}{C_N^{\,2}} \qquad \Omega_{13} := \frac{420}{1.488} - \frac{2 \cdot 1.53 \cdot 0}{1.488^2} = 282.258 \quad \text{[rad/sec]}$$

$$\Omega_{23} := \frac{U_{aN}}{C_N} - \frac{2 \cdot R_a \cdot M_0}{C_N^{\,2}} \qquad \Omega_{23} := \frac{420}{1.488} - \frac{2 \cdot 1.53 \cdot 2.964}{1.488^2} = 278.162 \quad \text{[rad/sec]}$$

$$\Omega_{33} := \frac{U_{aN}}{C_N} - \frac{2 \cdot R_a \cdot M_{emN}}{C_N{}^2} \qquad \Omega_{33} := \frac{420}{1.488} - \frac{2 \cdot 1.53 \cdot 41.664}{1.488^2} = 224.677 \quad \text{[rad/sec]}$$

$$\Omega_{43} := \frac{U_{aN}}{C_N} - \frac{2 \cdot R_a \cdot 1.5 \cdot M_{emN}}{C_N{}^2} \qquad \Omega_{43} := \frac{420}{1.488} - \frac{2 \cdot 1.53 \cdot 62.496}{1.488^2} = 195.887 \quad \text{[rad/sec]}$$

Tabelul 4. Calculul caracteristicilor la variația rezistenței circuitului indusului

	Caracteristica naturală Rtot = Ra	Caracteristica la Rtot=1.5Ra	Caracteristica la Rtot=2Ra
M (Nm)	**Ω (rad/s)**	**Ω (rad/s)**	**Ω (rad/s)**
M = 0	282.258	282.258	282.258
M = M0 =	280.21	279.186	278.162
M = MemN =	253.468	239.073	224.677
M = 1.5MemN=	239.073	217.48	195.887

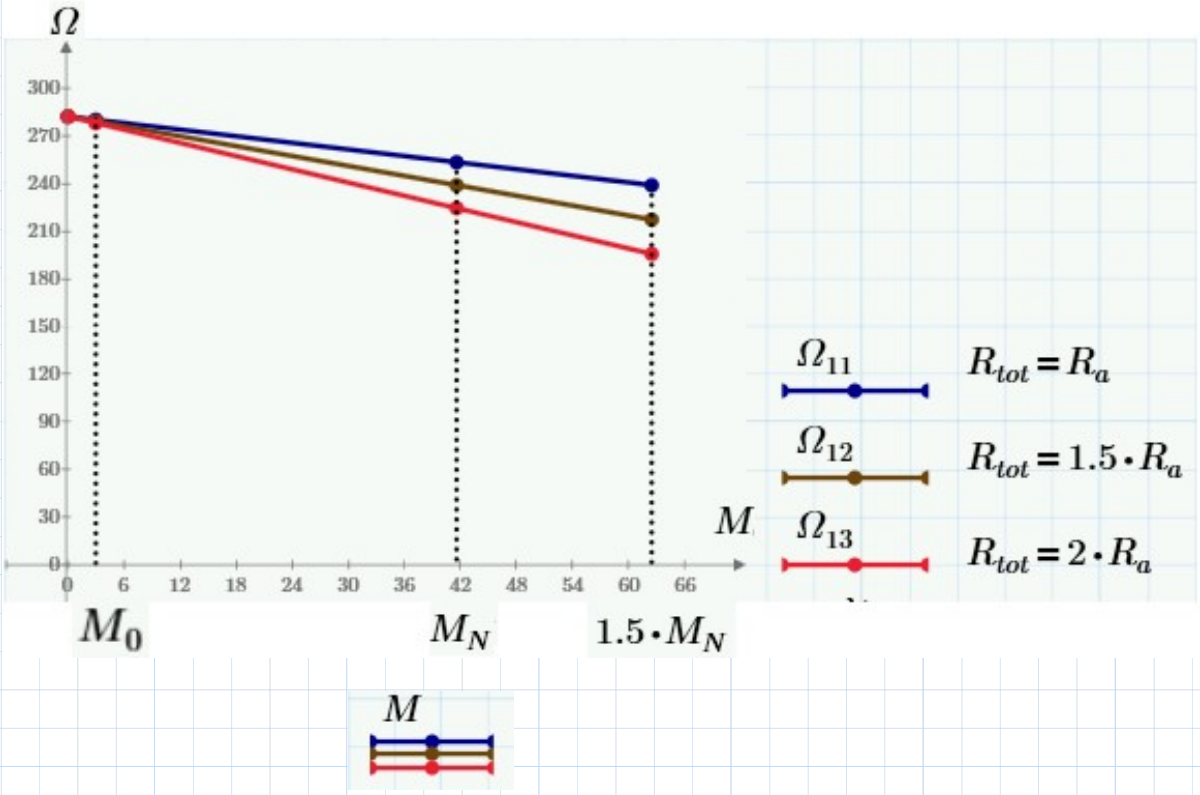


Fig. 4. Caracteristicile mecanice artificiale a motorului de curent continuu la variația rezistenței circuitului indusului

Ridicarea caracteristicilor de viteză unghiulară, curent și cuplu în regim tranzitoriu

1.5. Ridicarea caracteristicilor de viteză unghiulară, curent și cuplu în regim tranzitoriu

Constanta de timp electromecanică pentru caracteristica naturală

$$T_{emN} := J \cdot \frac{R_a}{C_N^{\,2}} \qquad (1.5.1)$$

$$T_{emN} := 0.032 \cdot \frac{1.53}{1.488^2} = 0.022 \qquad (s)$$

1.5.1. Ridicarea caracteristicilor mecanice statice a motorului respectiv a sarcinii mecanice

a) Caracteristica mecanică statică a motorului de c.c.

$$U_a := 0.2 \cdot U_{aN} \qquad \text{(Conform Fig. 1.5.2)}$$

$$U_a := 0.2 \ 420 = 84$$

$$\Omega_1 := \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot 0 \qquad \Omega_1 := \frac{84}{1.488} - \frac{1.53}{1.488^2} \cdot 0 = 56.452 \quad \text{[rad/sec]}$$

$$\Omega_2 := \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot M_0 \qquad \Omega_2 := \frac{84}{1.488} - \frac{1.53}{1.488^2} \cdot 2.964 = 54.403 \quad \text{[rad/sec]}$$

$$\Omega_3 := \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot 0.75 \cdot M_{emN} \qquad \Omega_3 := \frac{84}{1.488} - \frac{1.53}{1.488^2} \cdot 31.248 = 34.859 \quad \text{[rad/sec]}$$

$$\Omega_4 := \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot M_{emN} \qquad \Omega_4 := \frac{84}{1.488} - \frac{1.53}{1.488^2} \cdot 41.664 = 27.661 \quad \text{[rad/sec]}$$

M (Nm)	**M = 0**	**M = M0**	**M = Mr = 0.75MemN**	**M = Mr = Me**
Ω (rad/s)	56.452	54.403	34.859	27.661

b) Caracteristica mecanică a sarcinii

$$M_r := 0.75 \ M_{emN} = 31.248$$

$$\Omega := \begin{bmatrix} 56.452 \\ 54.403 \\ 34.859 \\ 27.661 \end{bmatrix} \qquad M := \begin{bmatrix} 0 \\ 2.964 \\ 31.248 \\ 41.664 \end{bmatrix} \qquad \Omega_r := \begin{bmatrix} 31.248 \\ 31.248 \\ 0 \end{bmatrix}$$

$$M_r := \begin{bmatrix} 31.248 \\ 31.248 \\ 0 \end{bmatrix} \qquad \Omega_1 := \begin{bmatrix} 60 \\ 0 \end{bmatrix} \qquad M_{r1} := \begin{bmatrix} 34.859 \\ 34.859 \\ 34.859 \end{bmatrix}$$

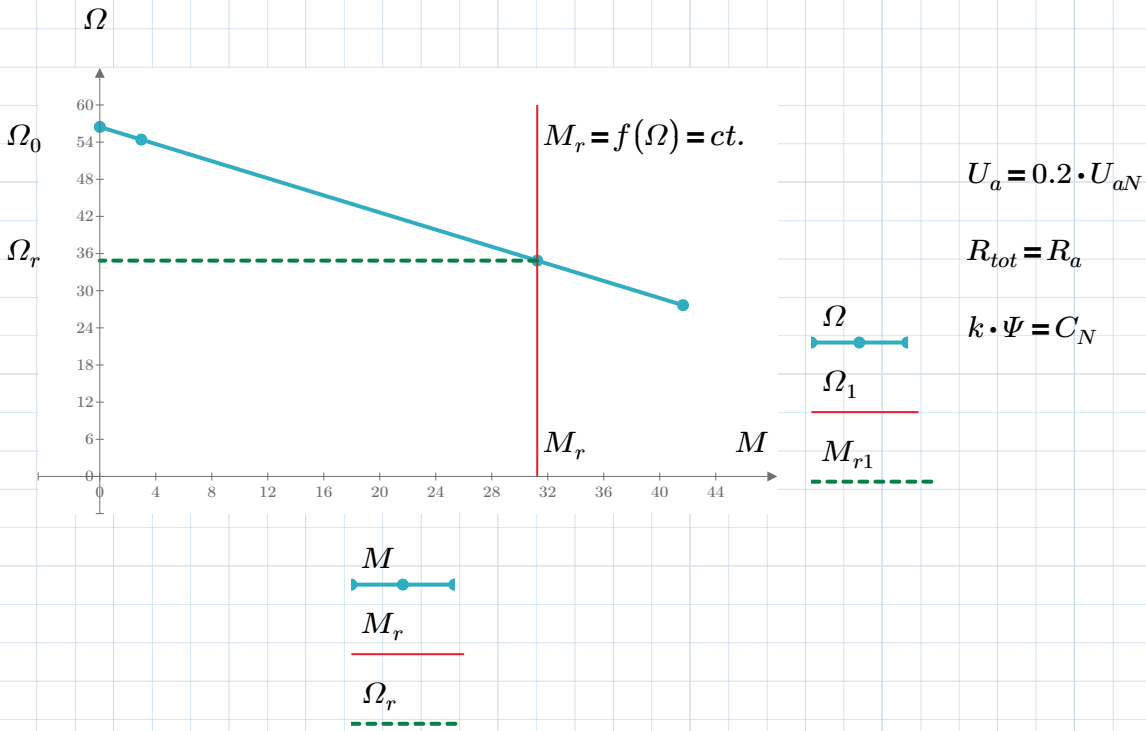


Figura 1.5.1. Reprezentarea caracteristicilor mecanice a motorului M=f(Ω) și a sarcinii Mr = f(Ω)

Viteza de mers în gol pe caracteristică pentru Ua=0.2UaN:

$$U_a := 0.2 \cdot U_{aN} \qquad U_a := 0.2 \ 420 = 84 \quad [V]$$

$$\Omega_0 := \frac{U_a}{C_N} \qquad (1.5.3)$$

$$\Omega_0 := \frac{84}{1.488} = 56.452 \qquad [rad/sec]$$

Căderea de viteză unghiulară datorată cuplului rezistent

$$M_r := 0.75\ M_{emN}$$

$$M_r := 0.75 \cdot 41.664 = 31.248 \qquad \text{[Nm]}$$

$$\Delta\Omega := \frac{R_a}{C_N^{\,2}} \cdot M_r \qquad (1.5.4)$$

$$\Delta\Omega := \frac{1.53}{1.488^2} \cdot 31.248 = 21.593 \qquad \text{[rad/sec]}$$

Viteza unghiulară în punctul de funcționare (viteza de regim stabilizat):

$$\Omega_r := \Omega_0 - \Delta\Omega \qquad (1.5.5)$$

$$\Omega_r := 56.452 - 21.593 = 34.859 \qquad \text{[rad/sec]}$$

1.5.2. Reprezentarea evoluției în timp a vitezei unghiulare a motorului pe durata pornirii

$$\Omega_i := 0 \qquad T_{em} := T_{emN}$$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{\frac{-t}{T_{em}}}\right) + \Omega_i$$

Tabelul 1.5.1

t	0	$0.2T_{emN}$	$0.4T_{emN}$	$0.7T_{emN}$	T_{emN}	$1.5T_{emN}$	$2T_{emN}$	$2.5T_{emN}$	$3T_{emN}$	$4T_{emN}$	$5T_{emN}$
$\Omega(t$	0	5.795	11.70	17.23	22.03	27.08	30.14	31.99	33.12	34.22	34.63

$$T_{em} = 0.022$$

$$t := 0$$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0}{0.022}\right)}\right) + 0 = 0 \qquad \text{[rad/sec]}$$

$$t := 0.2 \cdot T_{emN} = 0.004$$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.004}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.004}{0.022}\right)}\right) + 0 = 5.795 \qquad \text{[rad/sec]}$$

$t := 0.4 \cdot T_{emN} = 0.009$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.009}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.009}{0.022}\right)}\right) + 0 = 11.704 \quad \text{[rad/sec]}$$

$t := 0.7 \cdot T_{emN} = 0.015$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.015}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.015}{0.022}\right)}\right) + 0 = 17.231 \quad \text{[rad/sec]}$$

$t := T_{emN} = 0.022$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.022}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.022}{0.022}\right)}\right) + 0 = 22.035 \quad \text{[rad/sec]}$$

$t := 1.5 \cdot T_{emN} = 0.033$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.033}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.033}{0.022}\right)}\right) + 0 = 27.081 \quad \text{[rad/sec]}$$

$t := 2 \cdot T_{emN} = 0.044$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.044}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.044}{0.022}\right)}\right) + 0 = 30.141 \quad \text{[rad/sec]}$$

$t := 2.5 \cdot T_{emN} = 0.055$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.055}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.055}{0.022}\right)}\right) + 0 = 31.998 \quad \text{[rad/sec]}$$

$t := 3 \cdot T_{emN} = 0.066$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.066}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.066}{0.022}\right)}\right) + 0 = 33.123 \quad \text{[rad/sec]}$$

$t := 4 \cdot T_{emN} = 0.088$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.088}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.088}{0.022}\right)}\right) + 0 = 34.221 \quad \text{[rad/sec]}$$

$t := 5 \cdot T_{emN} = 0.111$

$$\Omega(t) := (\Omega_0 - \Omega_i - \Delta\Omega) \cdot \left(1 - e^{-\left(\frac{0.111}{T_{em}}\right)}\right) + \Omega_i$$

$$\Omega(t) := (56.452 - 0 - 21.593) \cdot \left(1 - e^{-\left(\frac{0.111}{0.022}\right)}\right) + 0 = 34.635 \quad \text{[rad/sec]}$$

$\Omega_r = 34.859$

$$\Omega_r := \begin{bmatrix} 34.859 \\ 34.859 \\ 34.859 \end{bmatrix} \qquad \Omega_1 := \begin{bmatrix} 34.859 \\ 34.859 \\ 0 \end{bmatrix}$$

$$t_1 := \begin{bmatrix} 0 \\ 0.111 \\ 0.111 \end{bmatrix} \qquad t_2 := \begin{bmatrix} 0 \\ 0.022 \\ 0 \end{bmatrix}$$

$$\Omega(t) := \begin{bmatrix} 0 \\ 5.795 \\ 11.704 \\ 17.231 \\ 22.035 \\ 27.081 \\ 30.141 \\ 31.998 \\ 33.123 \\ 34.221 \\ 34.635 \end{bmatrix} \qquad t := \begin{bmatrix} 0 \\ 0.004 \\ 0.009 \\ 0.015 \\ 0.022 \\ 0.033 \\ 0.044 \\ 0.055 \\ 0.066 \\ 0.088 \\ 0.111 \end{bmatrix}$$

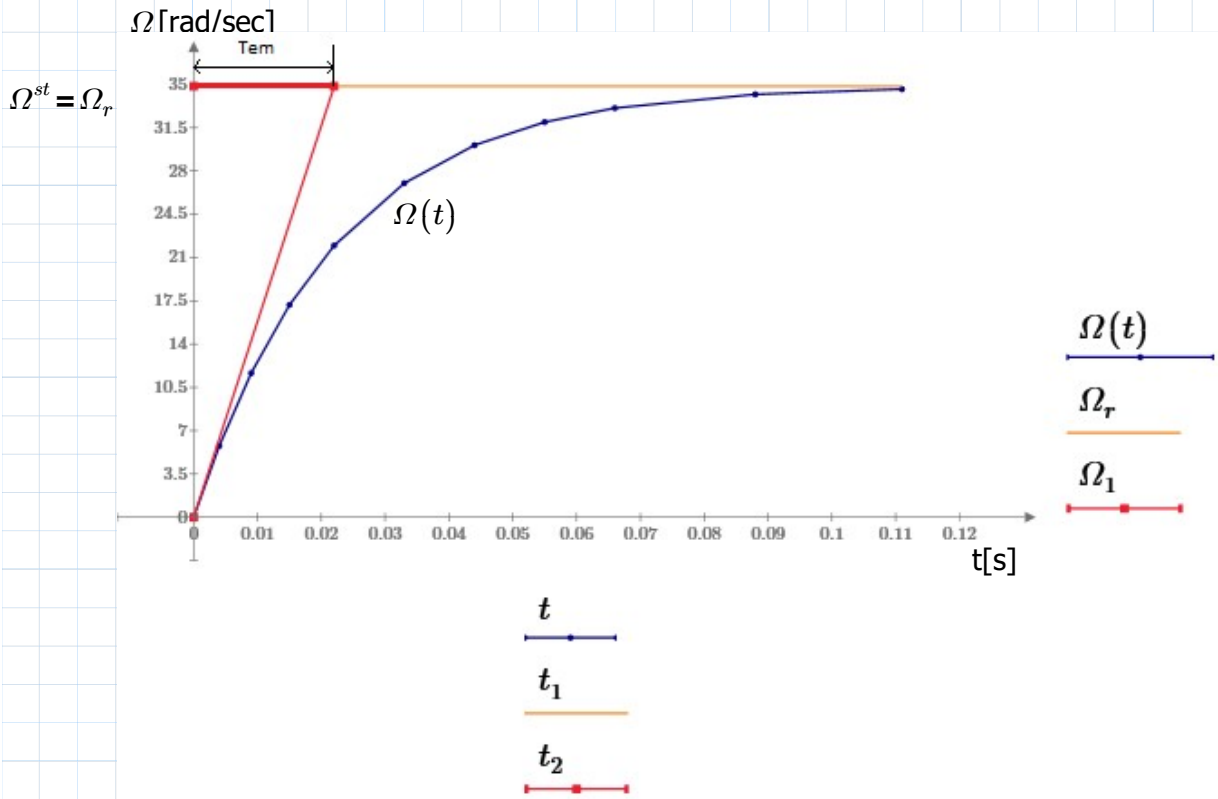


Figura 1.5.2. Evoluția în timp a vitezei unghiulare pe durata pornirii motorului

1.5.3. Reprezentarea evoluției în timp a curentului indusului pe durata pornirii

- Curentul în regim stabilizat corespunzător cuplului rezistent Mr = 0.75MemN este:

$$M_r := 0.75 \cdot M_{emN}$$

$$M_r := 0.75 \cdot 41.664 = 31.248 \quad [Nm]$$

$$I_r := \frac{M_r}{C_N} \qquad (1.5.7)$$

$$I_r := \frac{31.248}{1.488} = 21 \quad [A]$$

- Curentul inițial la momentul t = 0

$$U_a := 0.2 \cdot U_{aN}$$

$$U_a := 0.2 \cdot 420 = 84 \quad [V]$$

$$I_i := \frac{U_a - C_N \cdot \Omega_i}{R_a} \qquad (1.5.8)$$

$$I_i := \frac{84 - 1.488 \cdot 0}{1.53} = 54.902 \quad [A]$$

Se va ridica caracteristica de variație a curentului la pornire ia(t) conform expresiei:

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{t}{T_{em}}\right)} + I_r \qquad (1.5.9)$$

indicând pe grafic și valoarea de regim stabilizat a curentului (Ir) conform Fig. 1.6.4.

Tabelul 1.5.2

t	0	$0.2T_{emN}$	$0.4T_{emN}$	$0.7T_{emN}$	T_{emN}	$1.5T_{emN}$	$2T_{emN}$	$2.5T_{emN}$	$3T_{emN}$	$4T_{emN}$	$5T_{emN}$
$i(t)$	54.9	49.29	43.56	38.19	33.53	28.61	25.63	23.81	22.71	21.63	21.22

$t := 0$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0}{0.022}\right)} + 21 = 54.902 \quad [A]$$

$t := 0.2 \cdot T_{emN} = 0.004$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.004}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.004}{0.022}\right)} + 21 = 49.266 \quad [A]$$

$t := 0.4 \cdot T_{emN} = 0.009$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.009}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.009}{0.022}\right)} + 21 = 43.52 \quad [A]$$

$t := 0.7 \cdot T_{emN} = 0.015$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.015}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.015}{0.022}\right)} + 21 = 38.144 \quad [A]$$

$t := T_{emN} = 0.022$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.022}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.022}{0.022}\right)} + 21 = 33.472 \quad [A]$$

$t := 1.5 \cdot T_{emN} = 0.033$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.033}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.033}{0.022}\right)} + 21 = 28.565 \quad [A]$$

$t := 2 \cdot T_{emN} = 0.044$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.044}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.044}{0.022}\right)} + 21 = 25.588 \quad [A]$$

$t := 2.5 \cdot T_{emN} = 0.055$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.055}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.055}{0.022}\right)} + 21 = 23.783 \quad [A]$$

$t := 3 \cdot T_{emN} = 0.066$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.066}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.066}{0.022}\right)} + 21 = 22.688 \quad [A]$$

$t := 4 \cdot T_{emN} = 0.088$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.088}{T_{em}}\right)} + I_r$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.088}{0.022}\right)} + 21 = 21.621 \quad [A]$$

$t := 5 \cdot T_{emN} = 0.111$

$$i_a(t) := (I_i - I_r) \cdot e^{-\left(\frac{0.111}{T_{em}}\right)} + I_r = 21.224$$

$$i_a(t) := (54.902 - 21) \cdot e^{-\left(\frac{0.111}{0.022}\right)} + 21 = 21.218 \quad [A]$$

$$i_a(t) := \begin{bmatrix} 54.902 \\ 49.266 \\ 43.52 \\ 38.144 \\ 33.472 \\ 28.565 \\ 25.588 \\ 23.783 \\ 22.688 \\ 21.621 \\ 21.218 \end{bmatrix} \quad t := \begin{bmatrix} 0 \\ 0.004 \\ 0.009 \\ 0.015 \\ 0.022 \\ 0.033 \\ 0.044 \\ 0.055 \\ 0.066 \\ 0.088 \\ 0.111 \end{bmatrix}$$

i_a[A]

$I_r = 21$

$$I_r := \begin{bmatrix} 21 \\ 21 \\ 21 \end{bmatrix}$$

$$t_1 := \begin{bmatrix} 0.111 \\ 0.111 \\ 0 \end{bmatrix}$$

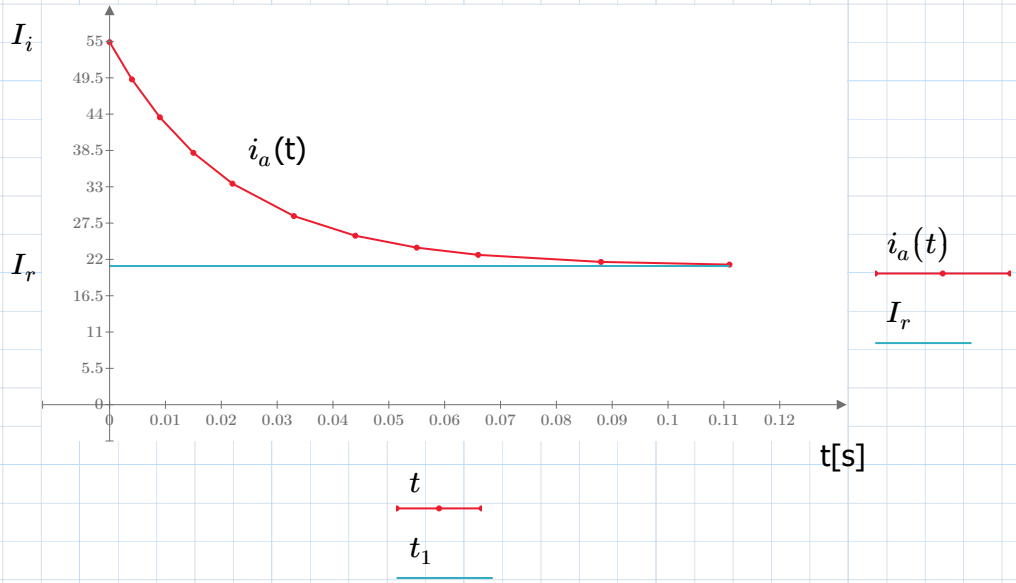


Figura 1.5.3. Evoluția în timp a curentului indusului durata pornirii motorului

1.5.4. Reprezentarea evoluției în timp a cuplurilor pe durata pornirii

a) Calculul și reprezentarea cuplului motor pe durata pornirii.
Cuplul inițial la pornire:

$$M_i := C_N \cdot I_i \qquad (1.5.10)$$

$$M_i := 1.488 \cdot 54.902 = 81.694 \quad [Nm]$$

Cuplul motorului în funcție de timp se reprezintă pe baza expresiei:

$$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{t}{T_{em}}\right)} + M_r \qquad (1.5.11)$$

b) Caracteristica cuplului rezistent
Se va reprezenta caracteristica cuplului rezistent constant pentru (orizontala trasată la Mr = $0.75 M_N$)

$$M_N := M_{emN}$$

$$M_r := 0.75 \cdot M_N$$

$$M_r := 0.75 \cdot 41.664 = 31.248 \quad [Nm]$$

c) Calculul și reprezentarea evoluției în timp a cuplului dinamic pe durata pornirii
Pe baza ecuației de mișcare, cuplul dinamic rezultă:

$$M_j(t) := M(t) - M_r(t) \qquad (1.5.12)$$

Tabelul 1.5.3

t	0	$0.2T_{em}$	$0.4T_{em}$	$0.7T_{em}$	T_{emN}	$1.5T_{em}$	$2T_{emN}$	$2.5T_{em}$	$3T_{emN}$	$4T_{emN}$	$5T_{emN}$
$M(t)$	81.70	73.35	64.83	56.85	49.90	42.59	38.14	35.44	33.80	32.19	31.58
Mj (t)	50.45	42.10	33.58	25.59	18.64	11.33	6.89	4.19	2.54	0.94	0.33

$t := 0$

$$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0}{T_{em}}\right)} + M_r$$

$$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0}{0.022}\right)} + 31.248 = 81.694 \quad [Nm]$$

$$M_j(t) := M(t) - M_r(t)$$

$$M_j(t) := 81.709 - 0.75 \cdot 41.672 = 50.455 \quad [Nm]$$

$t := 0.2 \cdot T_{emN} = 0.004$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.004}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.004}{0.022}\right)} + 31.248 = 73.307$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 73.357 - 0.75 \cdot 41.672 = 42.103$ [Nm]

$t := 0.4 \cdot T_{emN} = 0.009$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.009}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.009}{0.022}\right)} + 31.248 = 64.757$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 64.834 - 0.75 \cdot 41.672 = 33.58$ [Nm]

$t := 0.7 \cdot T_{emN} = 0.015$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.015}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.015}{0.022}\right)} + 31.248 = 56.758$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 56.851 - 0.75 \cdot 41.672 = 25.597$ [Nm]

$t := T_{emN} = 0.022$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.022}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.022}{0.022}\right)} + 31.248 = 49.806$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 49.903 - 0.75 \cdot 41.672 = 18.649$ [Nm]

$t := 1.5 \cdot T_{emN} = 0.033$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.033}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.033}{0.022}\right)} + 31.248 = 42.504$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 42.592 - 0.75 \cdot 41.672 = 11.338$ [Nm]

$t := 2 \cdot T_{emN} = 0.044$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.044}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.044}{0.022}\right)} + 31.248 = 38.075$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 38.147 - 0.75 \cdot 41.672 = 6.893$ [Nm]

$t := 2.5 \cdot T_{emN} = 0.055$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.055}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.055}{0.022}\right)} + 31.248 = 35.389$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 35.444 - 0.75 \cdot 41.672 = 4.19$ [Nm]

$t := 3 \cdot T_{emN} = 0.066$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.066}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.066}{0.022}\right)} + 31.248 = 33.76$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 33.802 - 0.75 \cdot 41.672 = 2.548$ [Nm]

$t := 4 \cdot T_{emN} = 0.088$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.088}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.088}{0.022}\right)} + 31.248 = 32.172$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 32.195 - 0.75 \cdot 41.672 = 0.941$ [Nm]

$t := 5 \cdot T_{emN} = 0.111$

$M(t) := (M_i - M_r) \cdot e^{-\left(\frac{0.111}{T_{em}}\right)} + M_r$

$M(t) := (81.694 - 31.248) \cdot e^{-\left(\frac{0.111}{0.022}\right)} + 31.248 = 31.573$ [Nm]

$M_j(t) := M(t) - M_r(t)$

$M_j(t) := 31.586 - 0.75 \cdot 41.672 = 0.332$ [Nm]

$$M(t) := \begin{bmatrix} 81.694 \\ 73.307 \\ 64.757 \\ 56.758 \\ 49.806 \\ 42.504 \\ 38.075 \\ 35.389 \\ 33.76 \\ 32.172 \\ 31.573 \end{bmatrix} \quad M_j(t) := \begin{bmatrix} 50.455 \\ 42.103 \\ 33.58 \\ 25.597 \\ 18.649 \\ 11.338 \\ 6.893 \\ 4.19 \\ 2.548 \\ 0.941 \\ 0.332 \end{bmatrix} \quad t := \begin{bmatrix} 0 \\ 0.004 \\ 0.009 \\ 0.015 \\ 0.022 \\ 0.033 \\ 0.044 \\ 0.055 \\ 0.066 \\ 0.088 \\ 0.111 \end{bmatrix}$$

$M_r = 31.248$

$$M_r := \begin{bmatrix} 31.248 \\ 31.248 \\ 31.248 \end{bmatrix}$$

$$t_1 := \begin{bmatrix} 0.111 \\ 0.111 \\ 0 \end{bmatrix}$$

Caracteristicile se vor reprezenta pe intervalul t = (0 ... 5 Tem) pe baza valorilor calculate din tabelul 1.5.3.

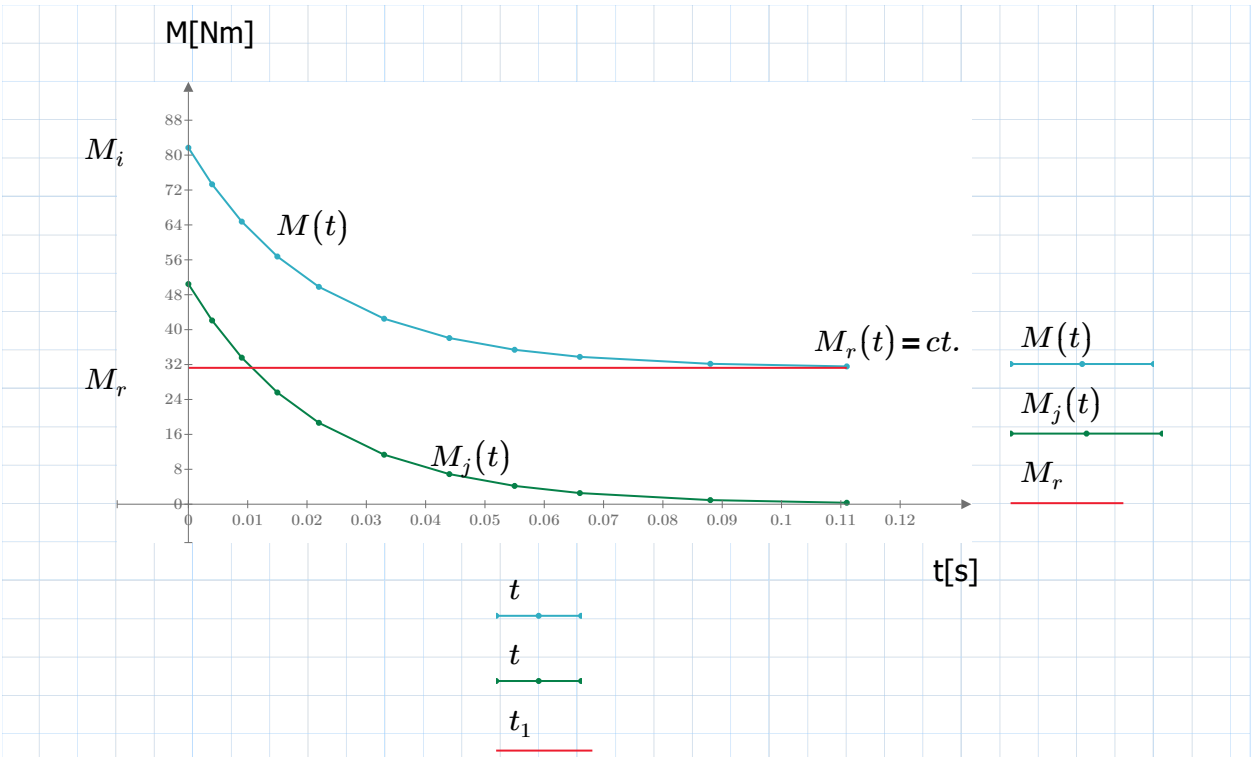


Figura 1.5.4. Evoluția în timp a cuplurilor pe durata pornirii motorului

1.6. Calculul și reprezentarea punctelor de funcționare pe caracteristica M.C.C. la cuplu rezistent liniar variabil în raport cu viteza

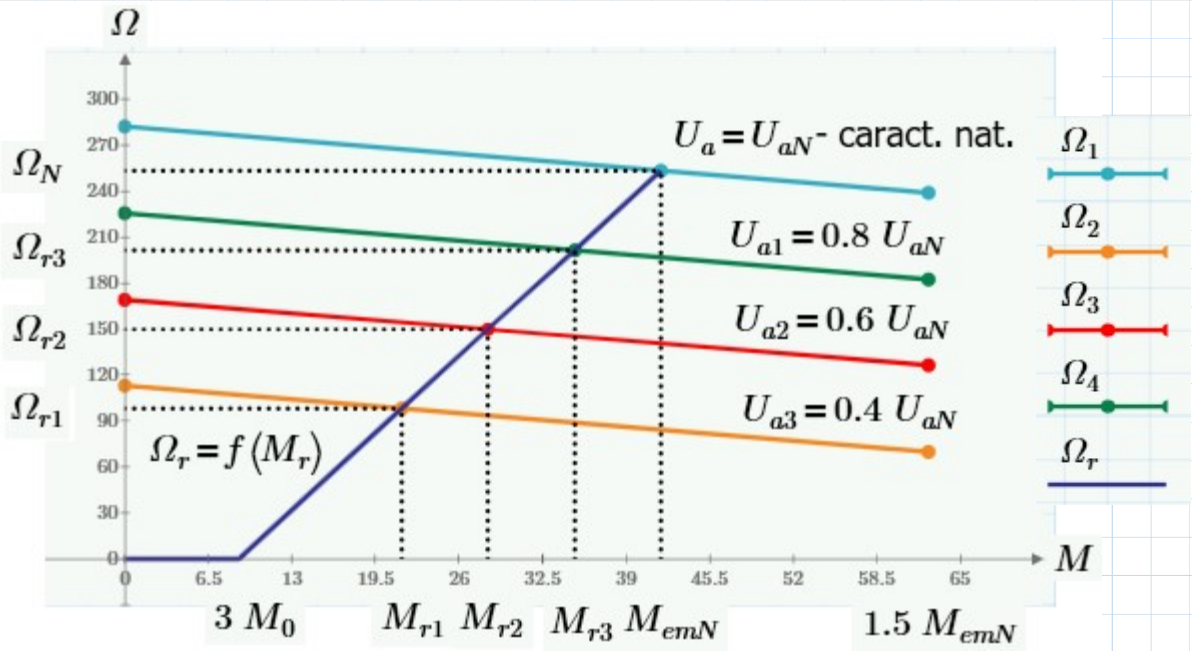


Fig. 1.6.1 Caracteristicile motorului și caracteristica sarcinii cu variație liniară în raport cu viteza.

1.6.1. Deducerea coordonatelor punctului de funcționare.

Se consideră expresia caracteristicii **motorului de curent continuu:**

$$\Omega = \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot M \qquad (1.6.1)$$

Exprimând cuplul din această expresie, rezultă:

$$M = \frac{U_a \cdot C_N}{R_a} - \frac{C_N^{\,2}}{R_a} \cdot \Omega \qquad (1.6.2)$$

$$M_r = M_r(ct) + M_r(\Omega) \qquad (1.6.3)$$

$$M_r(\Omega) := 3 \cdot M_0 + (M_{emN} - 3 \cdot M_0) \cdot \frac{\Omega_r}{\Omega_N}$$

<u>Pentru a calcula coordonatele unui punct de funcționare se procedează în felul următor:</u>

$$\Omega_r := \frac{U_a \cdot C_N - 3 \cdot R_a \cdot M_0}{(M_{emN} - 3 \cdot M_0) \cdot R_a + C_N^{\,2} \cdot \Omega_N} \cdot \Omega_N \qquad (1.6.5)$$

$$M_r := 3 \cdot M_0 + (M_{emN} - 3 \cdot M_0) \cdot \frac{\Omega_r}{\Omega_N} \qquad (1.6.6)$$

1.6.2. Calculul punctelor de funcționare pe caracteristica motorului

a) Motorul funcționează pe caracteristica naturală, definită prin: R_a, C_N respectiv:

$$U_a := U_{aN} = 420$$

$$M_r := M_{emN} = 41.664$$

$$\Omega_r := \Omega_N = 253.422$$

b) Motorul funcționează pe caracteristica definită prin R_a, C_N respectiv:

$$U_a := 0.4 \cdot U_{aN} = 168$$

$$\Omega_{r1} := \frac{U_a \cdot C_N - 3 \cdot R_a \cdot M_0}{\left(M_{emN} - 3 \cdot M_0\right) \cdot R_a + {C_N}^2 \cdot \Omega_N} \cdot \Omega_N$$

$$\Omega_{r1} := \frac{168 \cdot 1.488 - 3 \cdot 1.53 \cdot 2.964}{\left(41.664 - 3 \cdot 2.964\right) \cdot 1.53 + 1.488^2 \cdot 253.422} \cdot 253.422 = 98.001$$

$$M_{r1} := 3 \cdot M_0 + \left(M_{emN} - 3 \cdot M_0\right) \cdot \frac{\Omega_{r1}}{\Omega_N}$$

$$M_{r1} := 3 \cdot 2.964 + \left(41.664 - 3 \cdot 2.964\right) \cdot \frac{98.001}{253.422} = 21.565$$

c) Motorul funcționează pe caracteristica definită prin R_a, C_N respectiv:

$$U_a := 0.6 \cdot U_{aN} = 252$$

$$\Omega_{r2} := \frac{U_a \cdot C_N - 3 \cdot R_a \cdot M_0}{\left(M_{emN} - 3 \cdot M_0\right) \cdot R_a + {C_N}^2 \cdot \Omega_N} \cdot \Omega_N$$

$$\Omega_{r2} := \frac{252 \cdot 1.488 - 3 \cdot 1.53 \cdot 2.964}{\left(41.664 - 3 \cdot 2.964\right) \cdot 1.53 + 1.488^2 \cdot 253.422} \cdot 253.422 = 149.822$$

$$M_{r2} := 3 \cdot M_0 + \left(M_{emN} - 3 \cdot M_0\right) \cdot \frac{\Omega_{r2}}{\Omega_N}$$

$$M_{r2} := 3 \cdot 2.964 + \left(41.664 - 3 \cdot 2.964\right) \cdot \frac{149.822}{253.422} = 28.267$$

d) Motorul funcționează pe caracteristica definită prin R_a, C_N respectiv:

$$U_a := 0.8 \cdot U_{aN} = 336$$

$$\Omega_{r3} := \frac{U_a \cdot C_N - 3 \cdot R_a \cdot M_0}{\left(M_{emN} - 3 \cdot M_0\right) \cdot R_a + {C_N}^2 \cdot \Omega_N} \cdot \Omega_N$$

$$\Omega_{r3} := \frac{336 \cdot 1.488 - 3 \cdot 1.53 \cdot 2.964}{\left(41.664 - 3 \cdot 2.964\right) \cdot 1.53 + 1.488^2 \cdot 253.422} \cdot 253.422 = 201.643$$

$$M_{r3} := 3 \cdot M_0 + \left(M_{emN} - 3 \cdot M_0\right) \cdot \frac{\Omega_{r3}}{\Omega_N}$$

$$M_{r3} := 3 \cdot 2.964 + (41.664 - 3 \cdot 2.964) \cdot \frac{201.643}{253.422} = 34.968$$

1.6.3. Ridicarea caracteristicilor

Caracteristicile motorului $\Omega = f(M)$ pe **baza expresiei (1.6.1.)**

a. Caracteristica naturală în punctele calculate conform Tabelului 1.6.1.

Tabelul 1.6.1

M (Nm)	**M = 0**	**M = M emN =41.664**	**M = 1.5MemN =62.496**
Ω (rad/s)	282.258	253.468	239.073

$$U_a := U_{aN} = 420$$

Pentru M = 0

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N{}^2} \cdot 0$$

$$\Omega := \frac{420}{1.488} - \frac{1.53}{1.488^2} \cdot 0 = 282.258$$

Pentru M = M_{emN}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N{}^2} \cdot M_{emN}$$

$$\Omega := \frac{420}{1.488} - \frac{1.53}{1.488^2} \cdot 41.664 = 253.468$$

Pentru M = 1.5 M_{emN}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N{}^2} \cdot 1.5 \cdot M_{emN}$$

$$\Omega := \frac{420}{1.488} - \frac{1.53}{1.488^2} \cdot 1.5 \cdot 41.664 = 239.073$$

b) Caracteristica artificială la Ua = 0.4UaN în punctele calculate conform Tabelului 1.6.2.

$$U_a := 0.4 \cdot U_{aN}$$

$$U_a := 0.4 \cdot 420 = 168$$

Tabelul 1.6.2

M (Nm)	**M = 0**	**Mr1** = 21.565	**1.5MemN** = 62.496
Ω (rad/s)	112.903	98.002	69.718

$$U_a := 0.4 \cdot U_{aN} = 168$$

$$U_a := 0.4 \cdot 420 = 168$$

Pentru M = 0

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N{}^2} \cdot 0$$

$$\Omega := \frac{168}{1.488} - \frac{1.53}{1.488^2} \cdot 0 = 112.903$$

Pentru M = M_{r1}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N{}^2} \cdot M_{r1}$$

$$\Omega := \frac{168}{1.488} - \frac{1.53}{1.488^2} \cdot 21.565 = 98.002$$

Pentru M = 1.5 M_{emN}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N{}^2} \cdot 1.5\ M_{emN}$$

$$\Omega := \frac{168}{1.488} - \frac{1.53}{1.488^2} \cdot 62.496 = 69.718$$

c) Caracteristica artificială la Ua = 0.6UaN în punctele calculate conform Tabelului 1.6.3.

$$U_a := 0.6 \cdot U_{aN}$$

$$U_a := 0.6 \cdot 420 = 252$$

Tabelul 1.6.3

M (Nm)	M = 0	Mr2 = 28.267	1.5MemN = 62.496
Ω (rad/s)	169.355	149.822	126.169

$$U_a := 0.6 \cdot U_{aN} = 252$$

$$U_a := 0.6 \cdot 420 = 252$$

Pentru M = 0

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{{C_N}^2} \cdot 0$$

$$\Omega := \frac{252}{1.488} - \frac{1.53}{1.488^2} \cdot 0 = 169.355$$

Pentru M = M_{r2}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{{C_N}^2} \cdot M_{r2}$$

$$\Omega := \frac{252}{1.488} - \frac{1.53}{1.488^2} \cdot 28.267 = 149.822$$

Pentru M = 1.5 M_{emN}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{{C_N}^2} \cdot 1.5\ M_{emN}$$

$$\Omega := \frac{252}{1.488} - \frac{1.53}{1.488^2} \cdot 62.496 = 126.169$$

d) Caracteristica artificială la Ua = 0.8UaN în punctele calculate conform Tabelului 1.6.4.

Tabelul 1.6.4

M (Nm)	M = 0	Mr3 = 34.968	1.5MemN = 62.496
Ω (rad/s)	225.806	201.643	182.621

$$U_a := 0.8 \cdot U_{aN}$$

$$U_a := 0.8 \cdot 420 = 336$$

Pentru M = 0

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot 0$$

$$\Omega := \frac{336}{1.488} - \frac{1.53}{1.488^2} \cdot 0 = 225.806$$

Pentru M = M_{r3}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot M_{r3}$$

$$\Omega := \frac{336}{1.488} - \frac{1.53}{1.488^2} \cdot 34.968 = 201.643$$

Pentru M = 1.5 M_{emN}

$$\Omega := \frac{U_a}{C_N} - \frac{R_a}{C_N^{\,2}} \cdot 1.5\ M_{emN}$$

$$\Omega := \frac{336}{1.488} - \frac{1.53}{1.488^2} \cdot 62.496 = 182.621$$

Caracteristica sarcinii

Se completează tabelul 1.6.5 pe baza valorilor calculate în subcapitolul 1.6.2.

Se ridică caracteristica Ω*r=f(Mr)* pe baza tabelului 1.6.5.

Tabelul 1.6.4

Mr (Nm)	**Mr = 0**	**3M0 =** 8.892	**Mr1 =** 21.565	**Mr2 =** 28.267	**Mr3 =** 34.968	**MemN =** 41.664
Ωr (rad/s)	*Ωr= 0*	*Ωr= 0*	*Ωr1 =* 98.001	*Ωr2 =* 149.822	*Ωr3 =* 201.643	*ΩN =* 253.422