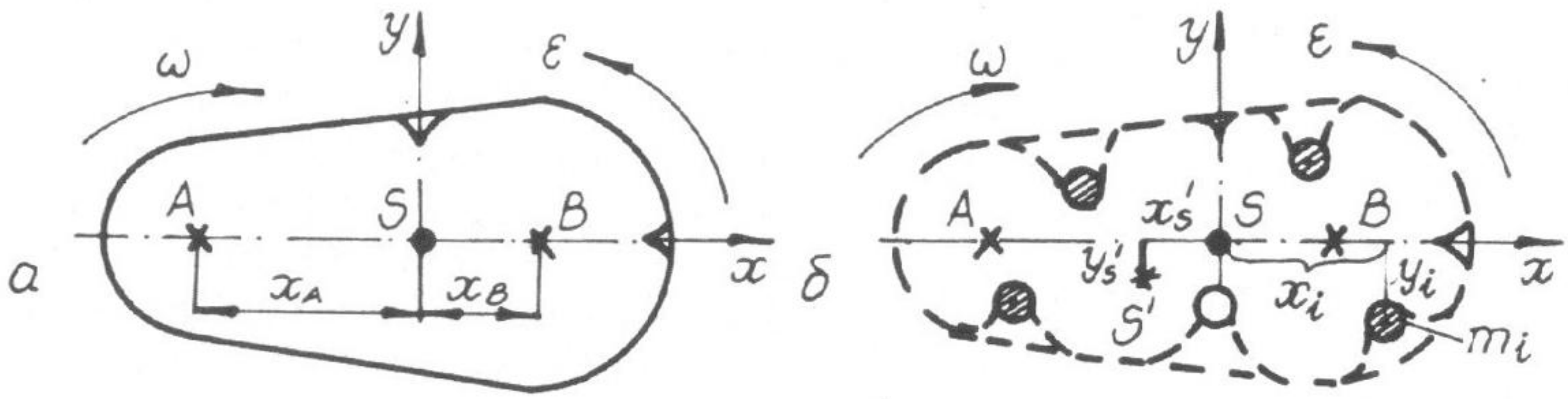
Уравновесяване на масови сили

Точкови модели

Точкови модели на звена и механизми. В теоретичната механика се доказва, че при общо равнинно движение на всяка звено (тяло) разпределените по цялото равнинно сечение на звеното елементарни инерционни сили се редуцират спрямо масовия център до една динама $\vec{\Phi}, \vec{M}_\Phi$. И също, че всяка равнинна система сили се редуцира в общия случай до една динама. Оттук следва, че равнинната система от безкрайно много елементарни инерционни сили на звеното може да се замени с други системи сили, еквивалентни на нея по отношение на резултантната динама. За практически цели е удобно еквивалентната система да има ограничен брой крайни по големина инерционни сили.



$$\vec{\Phi} = -m\vec{a}_s$$

$$\vec{M}_{\Phi} = -J_s\vec{\varepsilon}$$

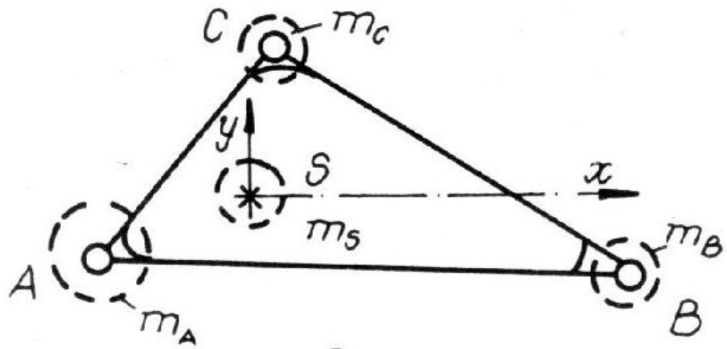
$$\vec{\Phi}' = -m'\vec{a}'_s; \quad m'x'_s = \sum_{i=1}^{k} m_i x_i; \quad m'y'_s = \sum_{i=1}^{k} m_i y_i,$$

$$\sum_{i=1}^{k} m_i = m; \quad \sum_{i=1}^{k} m_i x_i = 0; \quad \sum_{i=1}^{k} m_i y_i = 0.$$

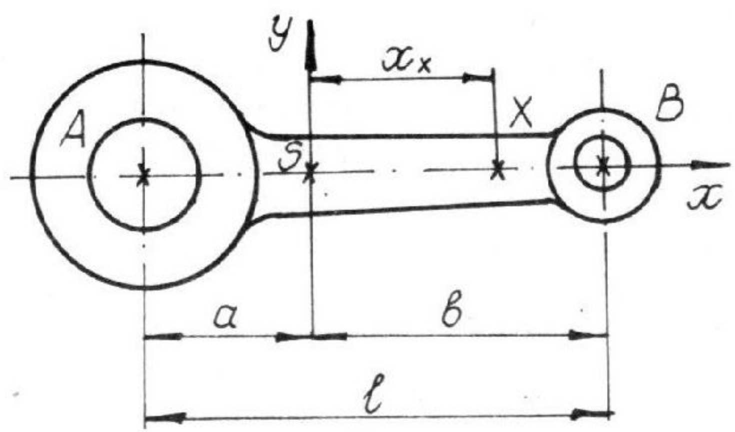
$$M'_{\Phi} = -J'_s \varepsilon = -\varepsilon \sum_{i=1}^{k} m_i (x_i^2 + y_i^2).$$

$$\sum_{i=1}^{k} m_i (x_i^2 + y_i^2) = J_s$$

$$E = m\frac{V_s^2}{2} + J_s\frac{\omega^2}{2}.$$



а



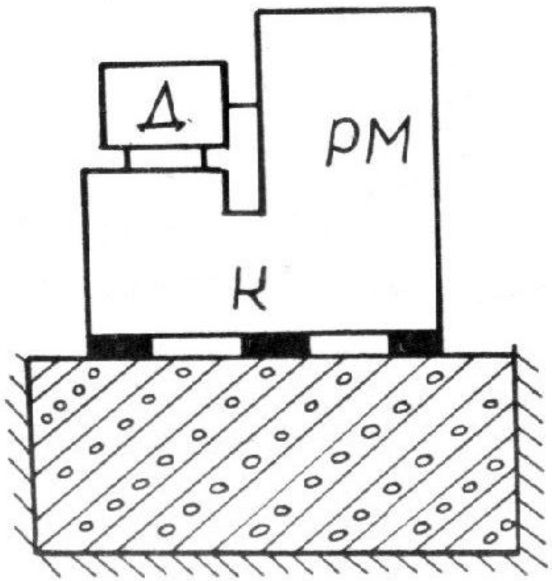
б

$$\begin{cases} m_A + m_s + m_B = m \\ -m_A a + m_B b = 0 \\ m_A a^2 + m_B b^2 = J_s = m i_s^2 . \end{cases}$$

$$m_A = \frac{J_s}{al}; \quad m_B = \frac{J_s}{bl}; \quad m_s = m - \frac{J_s}{ab} = m\left(1 - \frac{i_s^2}{ab}\right).$$

$$m_{AS} = m_S \frac{b}{l}; \quad m_{BS} = m_S \frac{a}{l}.$$

$$m_A = m\frac{b}{l}; \quad m_B = m\frac{a}{l}.$$



Цел на уравновесяването и условия за уравновесеност

$$\Phi_{\Sigma x} = 0; \Phi_{\Sigma y} = 0; \Phi_{\Sigma z} = 0; M^{\Phi}_{\Sigma x} = 0; M^{\Phi}_{\Sigma y} = 0; M^{\Phi}_{\Sigma z} = 0.$$

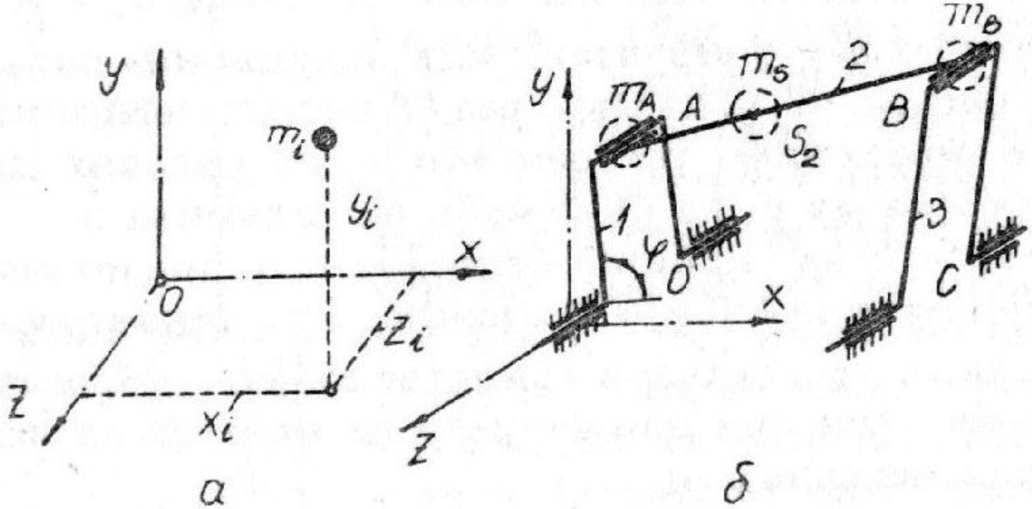
$$\Sigma \vec{F}_i = m\vec{a}_s = -\vec{\Phi}_{\Sigma}.$$

$$x_s = \text{const}; \; y_s = \text{const}; \; z_s = \text{const}.$$

$$\frac{d}{dt}K_x = M_x^{F_i}; \ \frac{d}{dt}K_y = M_y^{F_i}; \ \frac{d}{dt}K_z = M_z^{F_i}.$$

Векторната производна на главния момент на кол. на движение е равна на главния момент на външните сили.

$$K_x = \text{const}; \quad K_y = \text{const}; \quad K_z = \text{const}.$$



$$\left| \begin{aligned} K_x &= \Sigma m_i z_i V_{yi} = \Sigma m_i z_i \frac{dy_i}{dt} = \frac{dy_i}{dt} \Sigma m_i z_i y_i = \frac{d}{dt} J_{yz} \\ K_y &= \Sigma m_i z_i V_{xi} = \Sigma m_i z_i \frac{dx_i}{dt} = \frac{d}{dt} \Sigma m_i z_i x_i = \frac{d}{dt} J_{xz}. \end{aligned} \right.$$

$$K_x = \frac{d}{dt} Jyz = \text{const}; \quad K_y = \frac{d}{dt} Jxz = \text{const}.$$

$$Jyz = C_1 t + D_1; \quad Jxz = C_2 t + D_2,$$

$$Jxz = \text{const}; \quad Jyz = \text{const}$$

$$x_s = \text{const}; y_s = \text{const}; Jxz = \text{const}; Jyz = \text{const}.$$

Уравновесяване на равнинни механизми

$$\begin{vmatrix} m_{0_1} + m_{A_1} m_1; \; m_{0_1}.\overline{OS}_1 = m_{A_1}.\overline{AS}_1; \\ m_{A_2} + m_{b_2} = m_2; \; m_{A_2}.\overline{AS}_2 = m_{b_2}.\overline{BS}_2; \\ m_{B_3} = m_3. \end{vmatrix}$$

$$m_{0_1}, m_A = m_{A_1} + m_{A_2} \quad \text{и} \quad m_B = m_{B_2} + m_3,$$

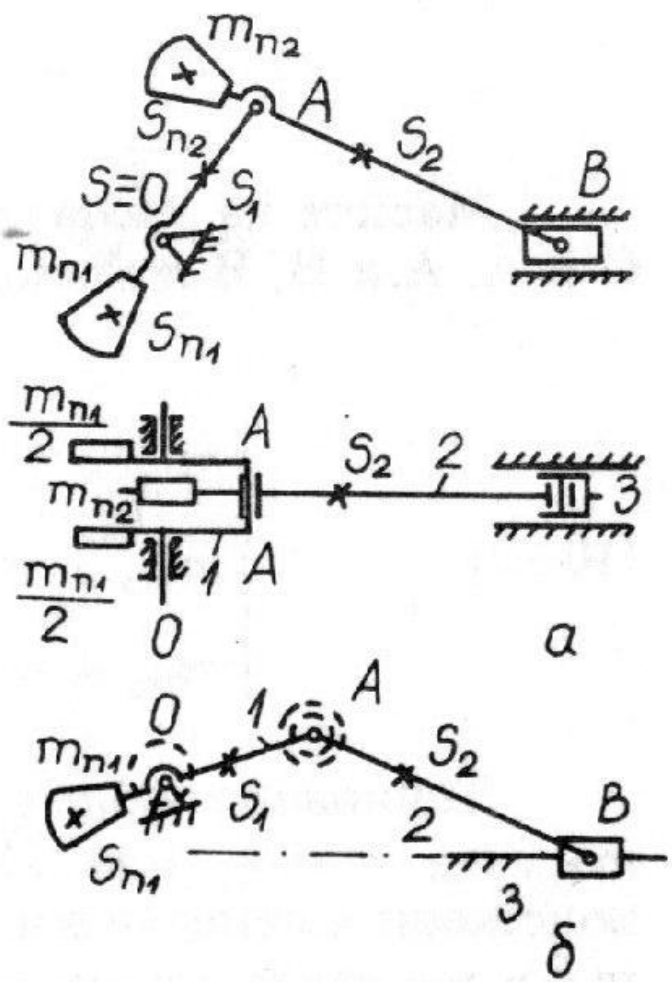
$$m_{\text{п}_2}.\overline{AS}_{\text{п}_2} = m_B \overline{AB}$$

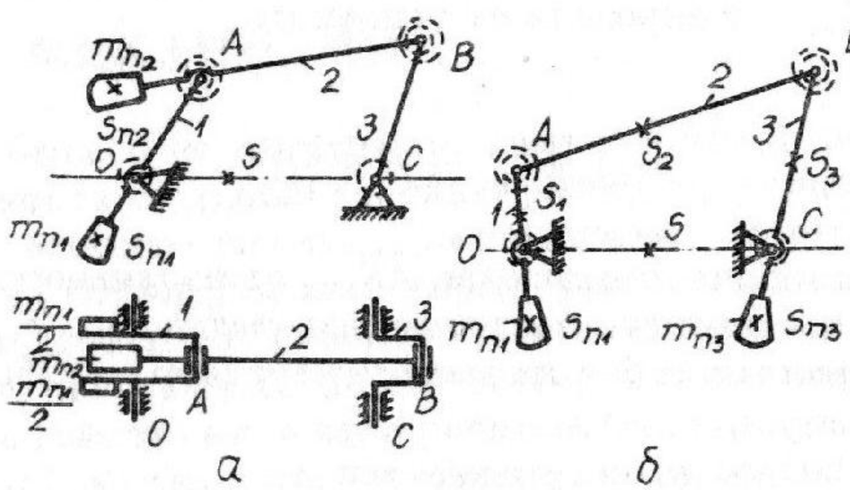
$$m_A^{\Sigma} = m_B + m_A + m_{\text{п}_2}$$

$$m_{\text{п}_1} \overline{OS}_{\text{п}_1} = m_A^{\Sigma} \overline{OA}.$$

$$m_0^{\Sigma} = m_{\text{п}_1} + m_{O_1} + m_A^{\Sigma}$$

$$= m_1 + m_2 + m_3 + m_{\text{п}_1} + m_{\text{п}_2}.$$





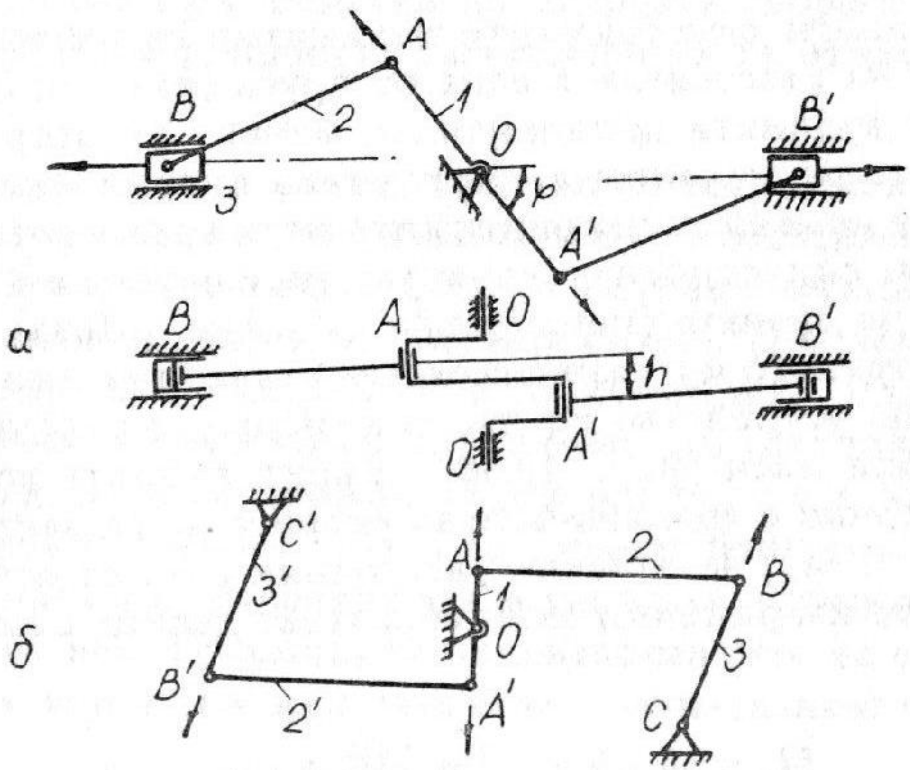
$$\left|\begin{array}{ll} m_{O_1} + m_{A_1} = m_1; & m_{O_1}.\overline{OS}_1 = m_{A_1}.\overline{AS}_1; \\ m_{A_2} + m_{B_2} = m_2; & m_{A2}.\overline{AS}_2 = m_{B_2}.\overline{BS}_2; \\ m_{B_3} + m_{C_3} = m_3; & m_{B_3}.\overline{BS}_3 = m_{C_3}.\overline{CS}_3. \end{array}\right.$$

$$m_{п_1}.\overline{OS}_{п_1} = m_A.\overline{OA}; m_{п_3}.\overline{CS}_{п_3} = m_B.\overline{CB}.$$

$$m_O^{\Sigma} = m_{п_1} + m_{O_1} + m_A; \;\; m_C^{\Sigma} = m_{п_3} + m_{C_3} + m_B.$$

$$m_0^{\Sigma}.\overline{OS} = m_C^{\Sigma}(\overline{OC} - \overline{OS}).$$

$$m^{\Sigma} = m_0^{\Sigma} + m_C^{\Sigma} = m_1 + m_2 + m_3 + m_{\Pi_1} + m_{\Pi_3}.$$



A
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1
O
B′
3
φ
A′
а
B
A
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C′
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3′
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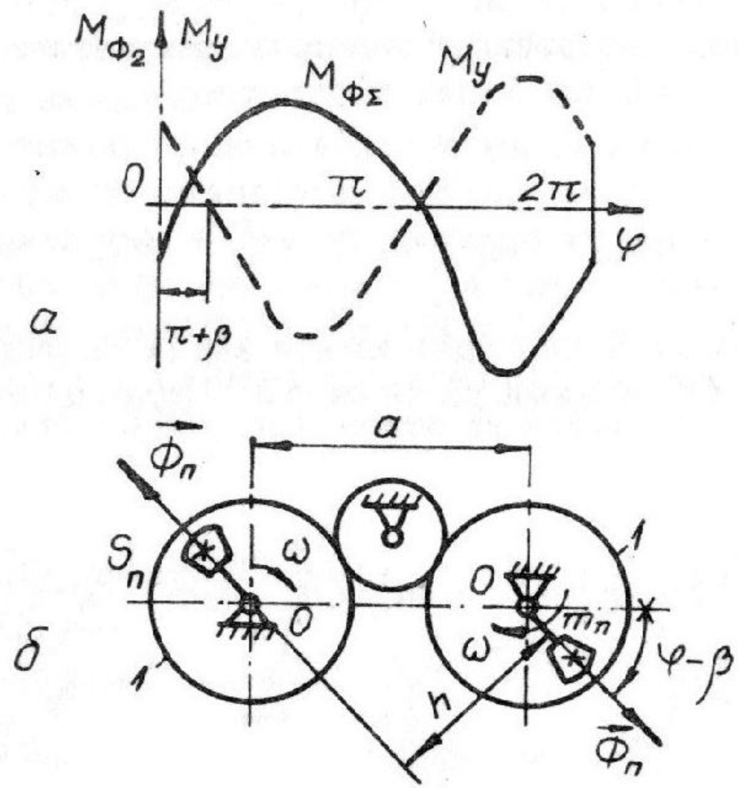
B′
2′
A′
C



$$M_y = Ф_{\text{п}} h = \omega^2 m_{\text{п}} \overline{OS}_{\text{п}} a \sin(\varphi - \beta).$$

Уравновесяване на ротори

$$d\Phi^n = \rho\omega^2 dm; \qquad d\Phi^t = \rho\epsilon dm.$$

$$\begin{aligned}
d\Phi_x &= \omega^2\rho\cos\alpha dm - \epsilon\rho\sin\alpha dm = \omega^2 x dm - \epsilon y dm,\\
d\Phi_y &= \omega^2\rho\sin\alpha dm + \epsilon\rho\cos\alpha dm = \omega^2 y dm + \epsilon x dm,\\
d\Phi_z &= 0,\\
dM_x &= d\Phi_y z = \omega^2 yz dm + \epsilon xz dm,\\
dM_y &= -d\Phi_x z = -\omega^2 xz dm + \epsilon yz dm,\\
dM_z &= d\Phi_x y - d\Phi_y x = -\epsilon(x^2 + y^2) dm.
\end{aligned}$$

$$
\left|
\begin{aligned}
&d\Phi_x = \omega^2 \rho \cos\alpha dm - \epsilon\rho\sin\alpha dm = \omega^2 x dm - \epsilon y dm,\\
&d\Phi_y = \omega^2 \rho \sin\alpha dm + \epsilon\rho\cos\alpha dm = \omega^2 y dm + \epsilon x dm,\\
&d\Phi_z = 0,\\
&dM_x = d\Phi_y z = \omega^2 yz dm + \epsilon xz dm,\\
&dM_y = -d\Phi_x z = -\omega^2 xz dm + \epsilon yz dm,\\
&dM_z = d\Phi_x y - d\Phi_y x = -\epsilon(x^2 + y^2) dm.
\end{aligned}
\right.
$$

$$
\Phi = \sqrt{\Phi x^2 + \Phi y^2} = m\sqrt{x_s^2 + y_s^2}\ \sqrt{\omega^4 + \epsilon^2} = m\rho_s\sqrt{\omega^4 + \epsilon^2},
$$

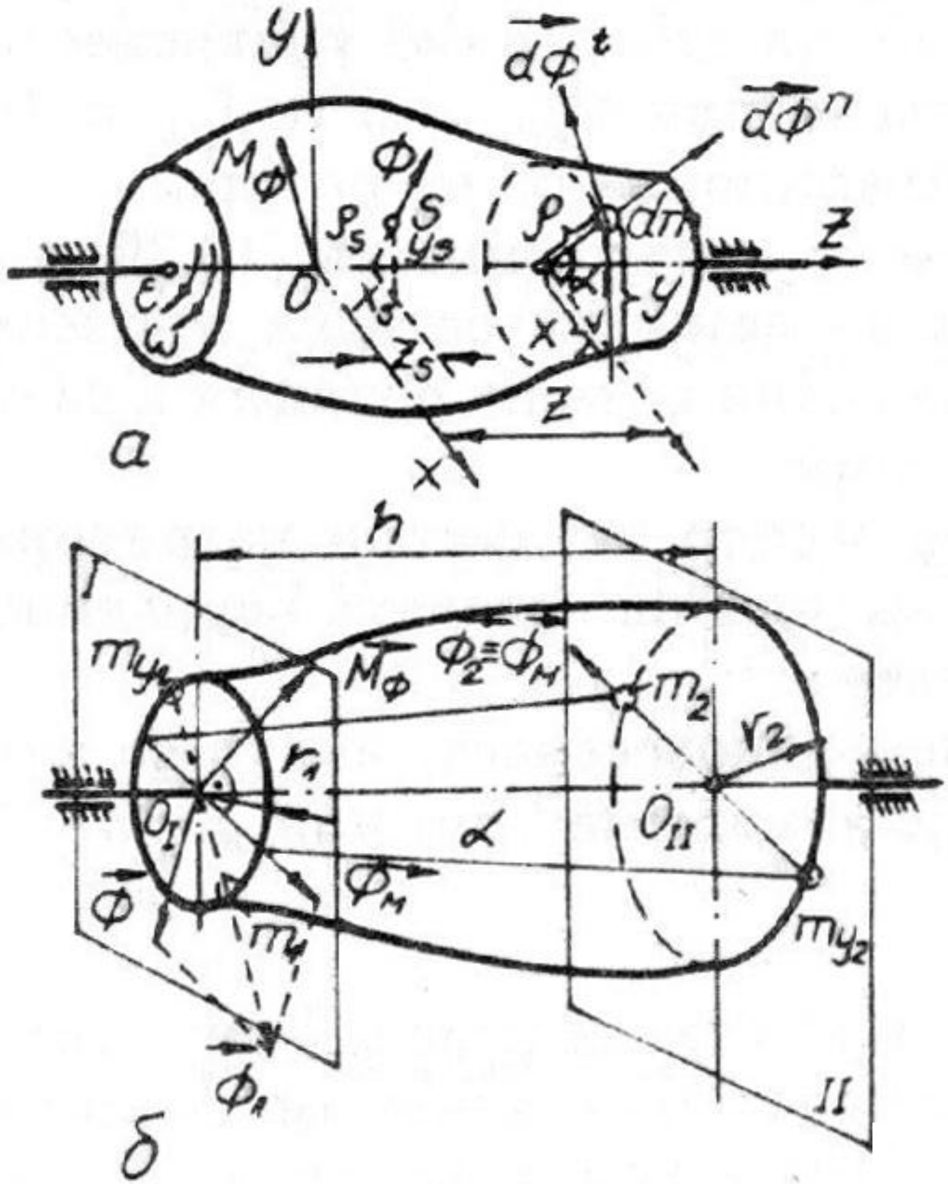
$$
M_\Phi = \sqrt{M_x^2 + M_y^2} = \sqrt{J_{xz}^2 + J_{yz}^2}\sqrt{\omega^4 + \epsilon^2},
$$

$$
\Phi = 0 \qquad \text{и} \qquad M_\Phi = 0.
$$

$$\Delta_c = m\rho_s = \frac{G}{g}\rho_s.$$

$$\Delta_g = J_{\rho z} = \sqrt{J_{xz}^2 + J_{yz}^2}.$$

$$\Delta_c = m\rho_s = 0 \qquad \text{и} \qquad \Delta_g = \sqrt{J_{xz}^2 + J_{yz}^2} = 0.$$

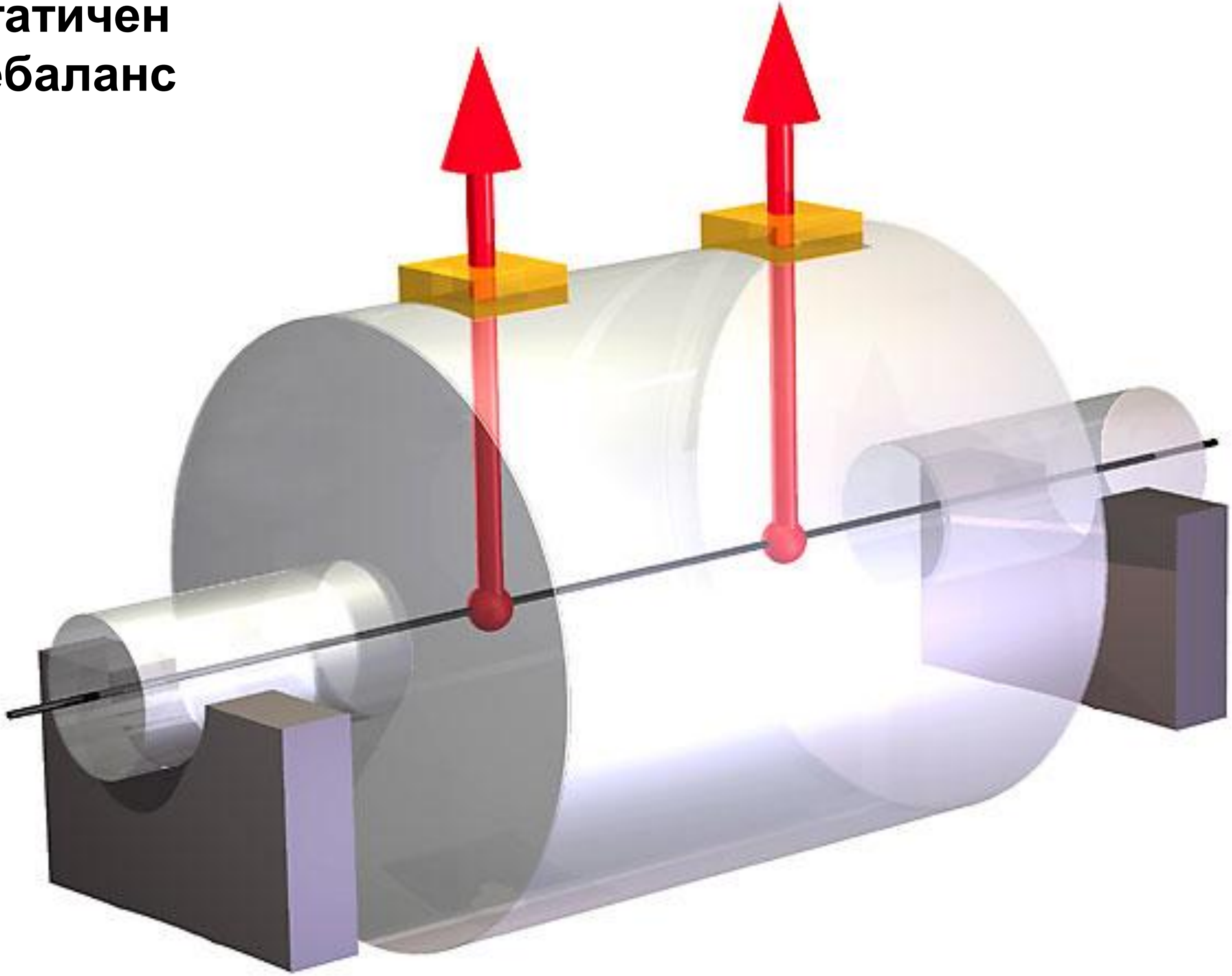


$$\Phi_M = \frac{M_\Phi}{h},$$

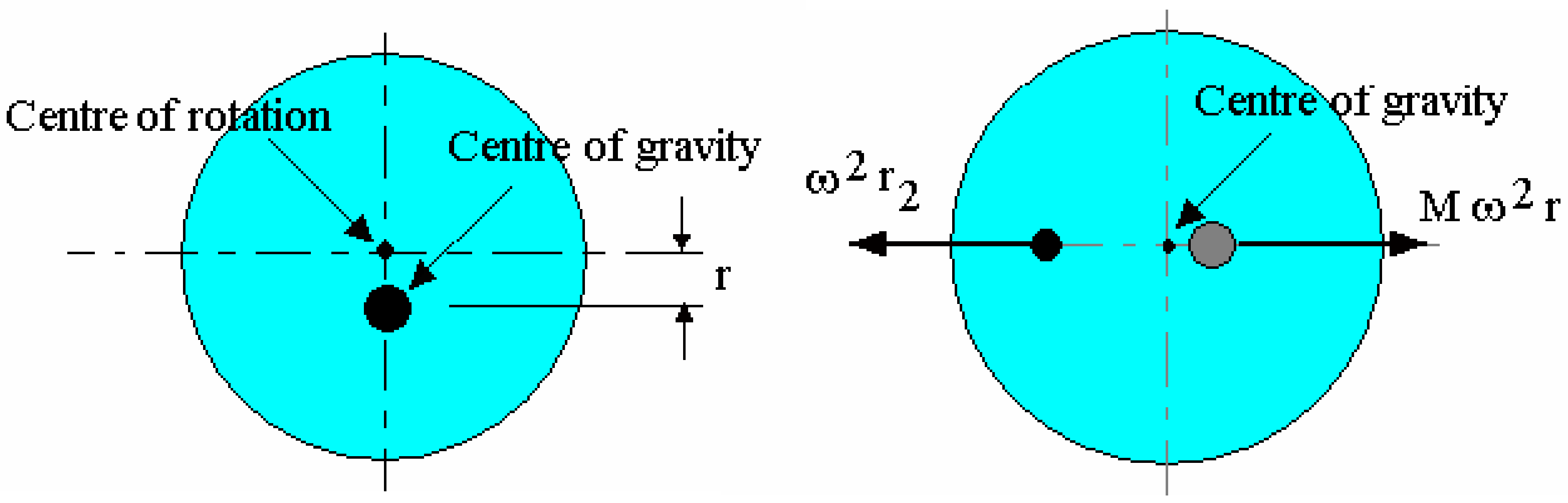
$$\vec{\Phi}_1 = \vec{\Phi} + \vec{\Phi}_M.$$

$$m_1 \equiv m_{y1} = \frac{|\vec{\Phi}_1|}{r_1\omega^2}; \quad m_2 \equiv m_{y2} = \frac{|\vec{\Phi}_2|}{r_2\omega^2},$$

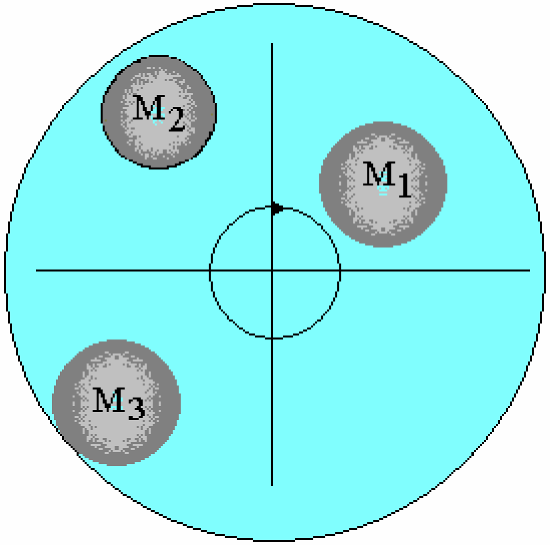
Статичен дебаланс

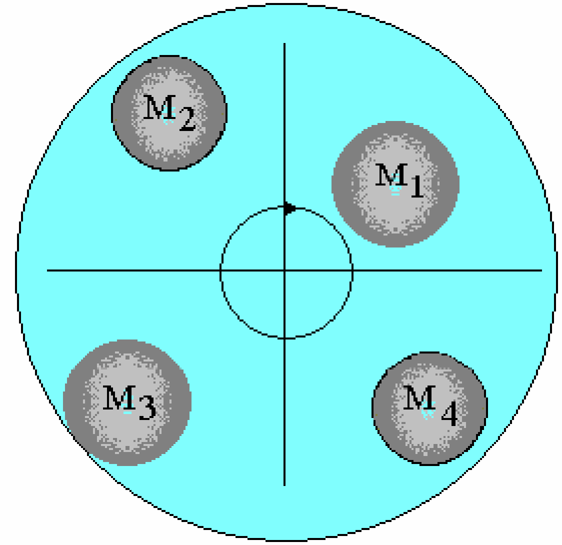


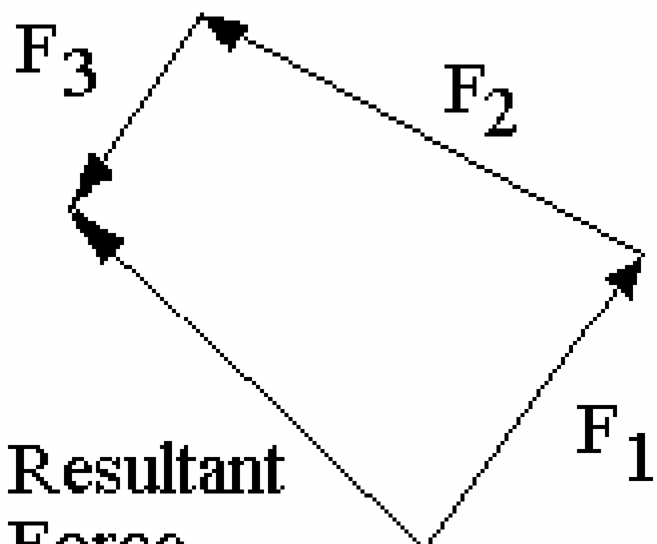
Статичен дебаланс

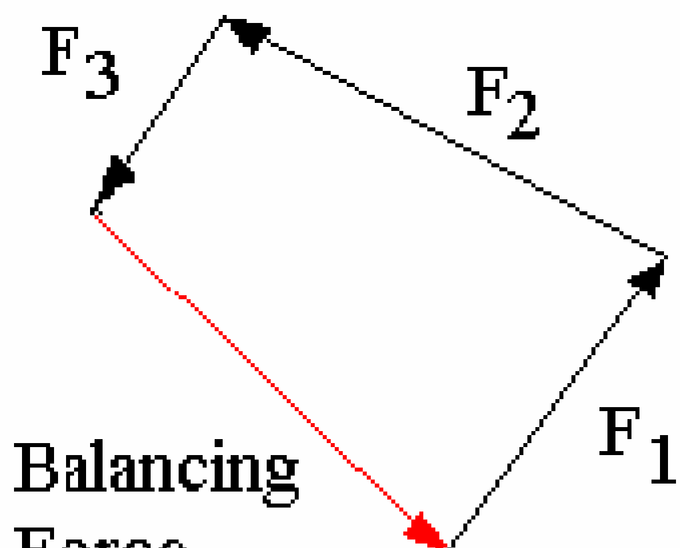


Статичен дебаланс и отстраняване

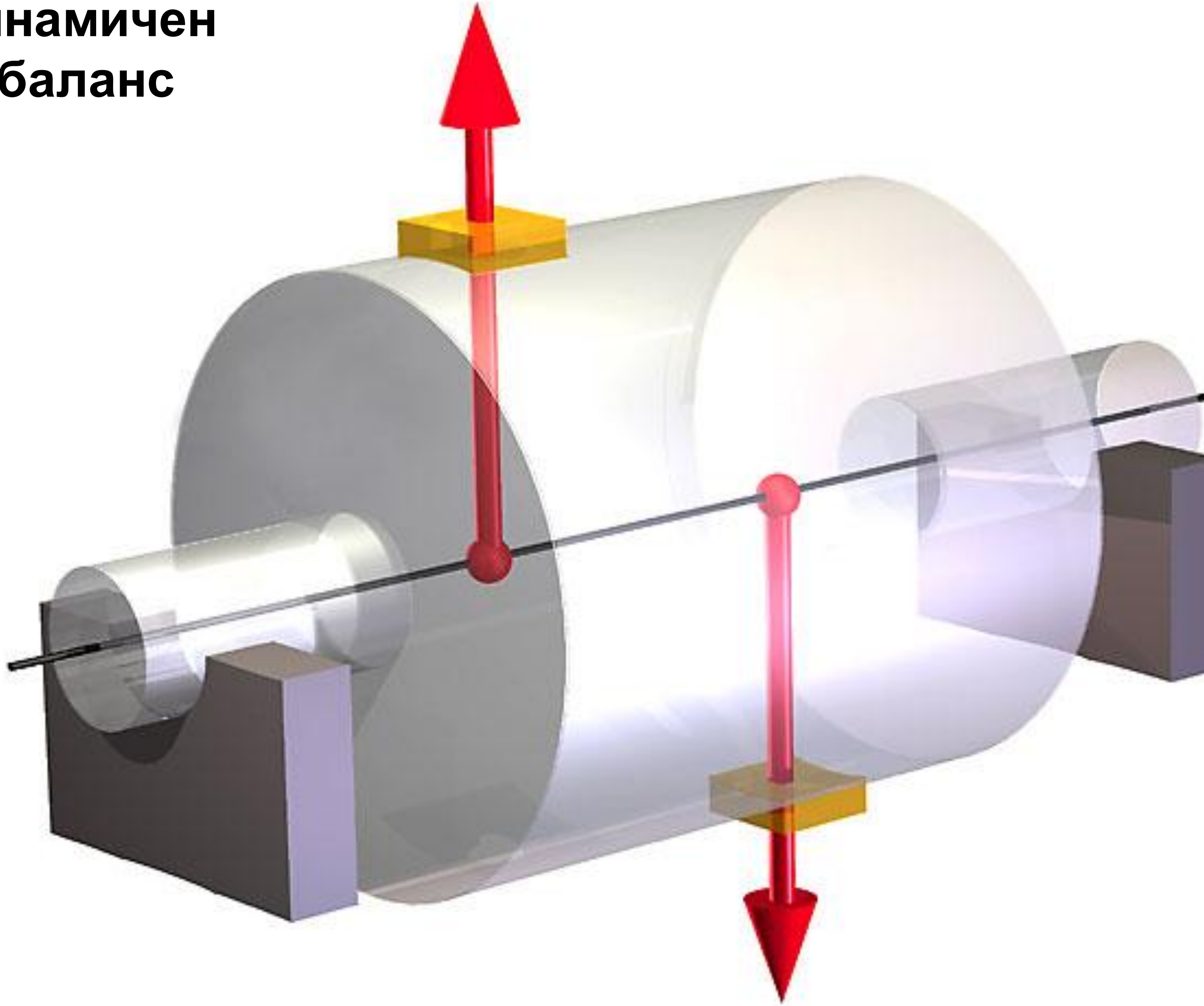




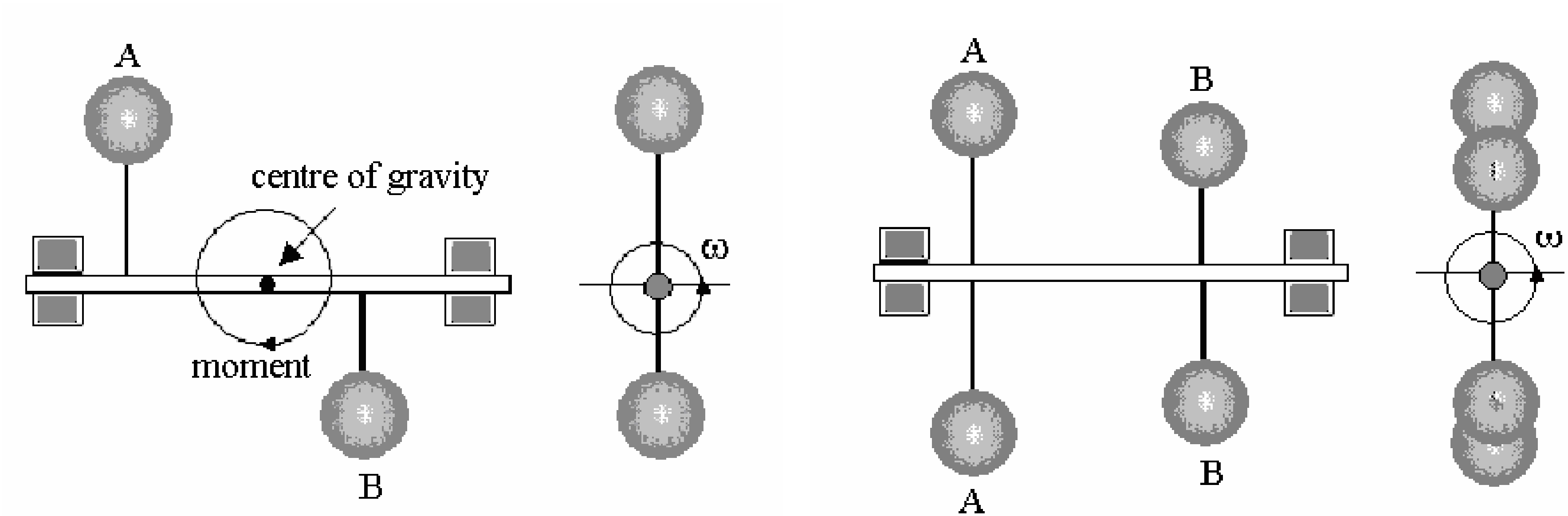




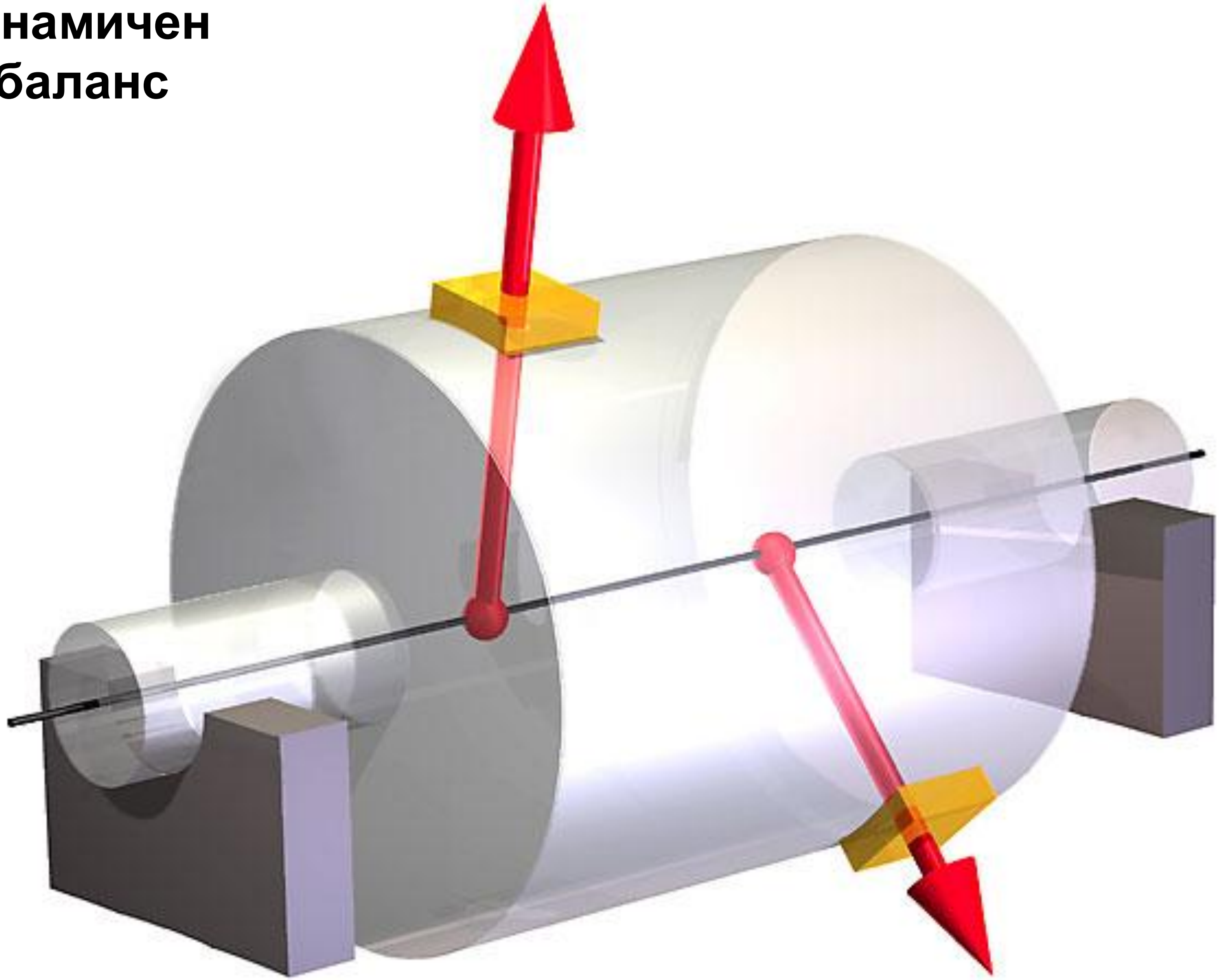
Динамичен дебаланс

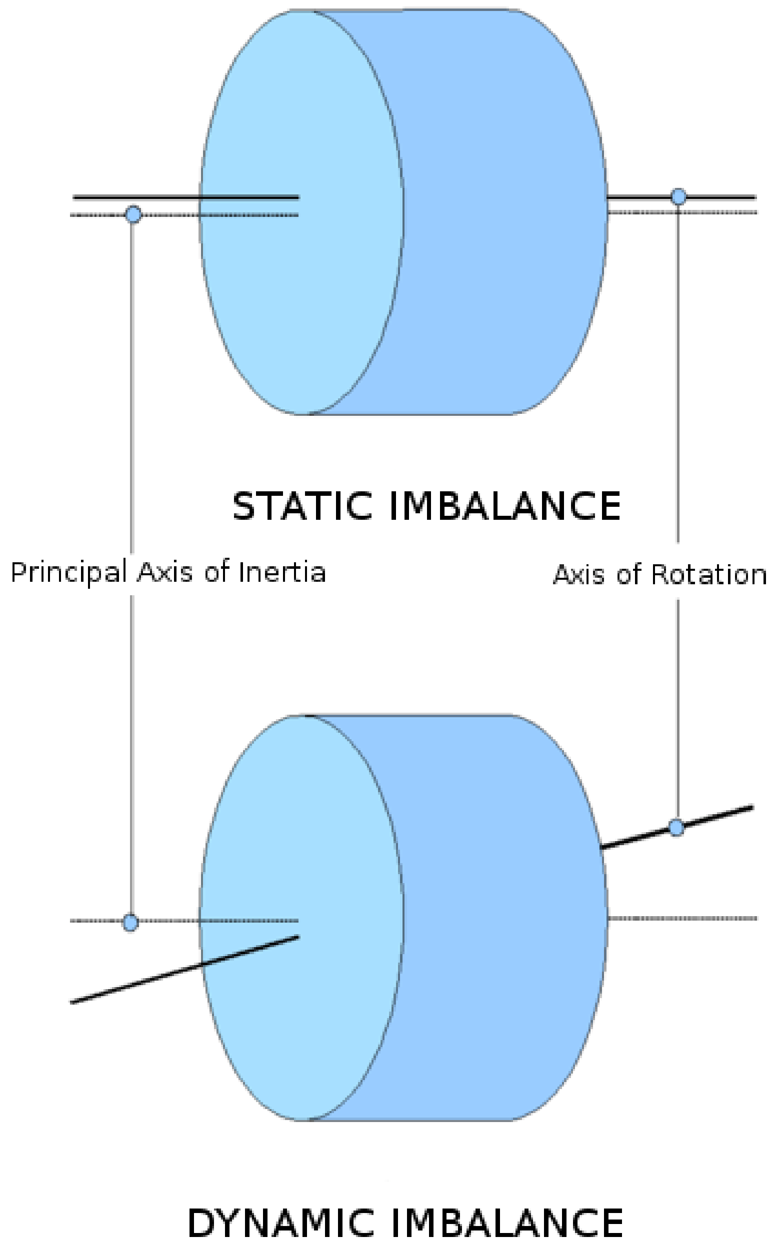


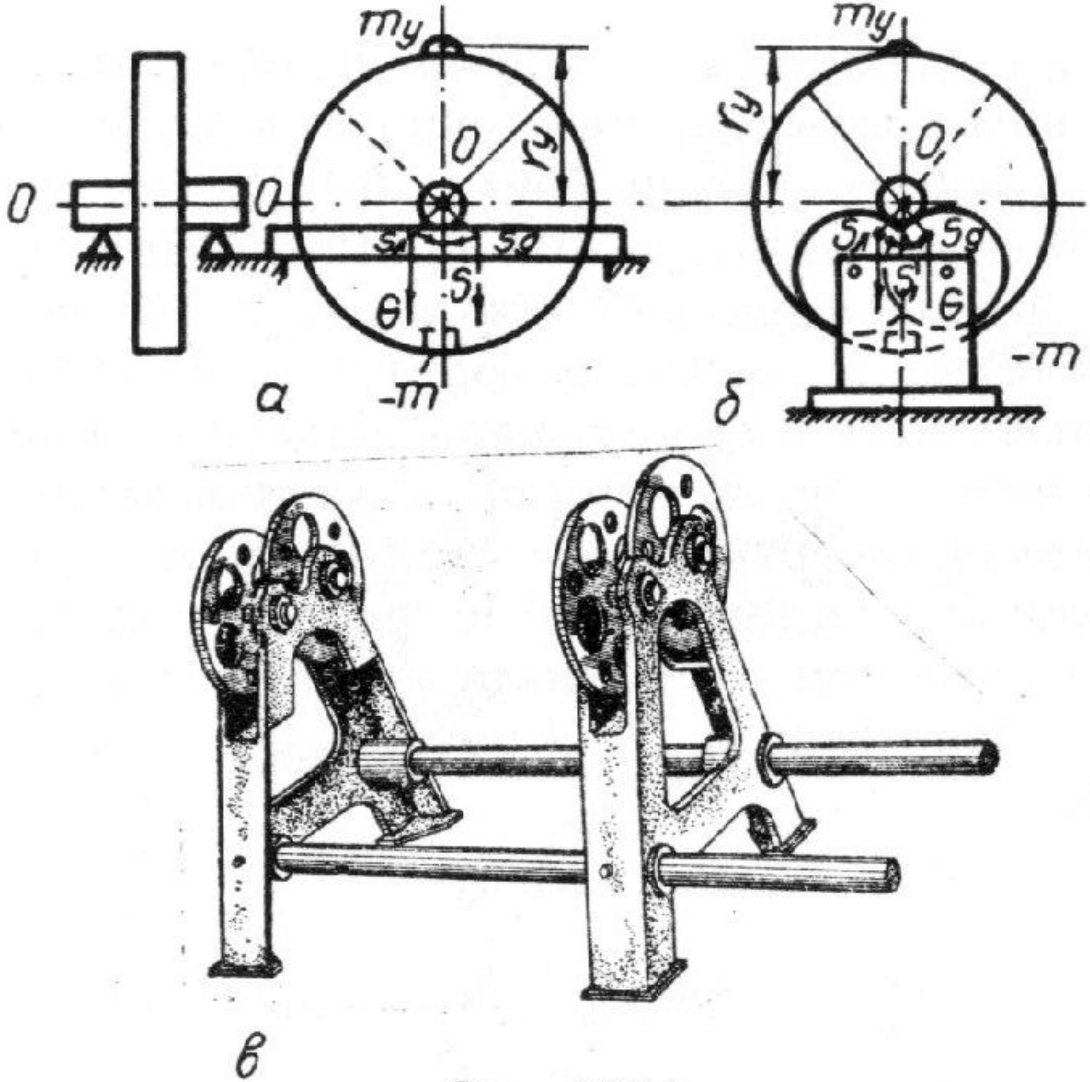
Маси в различни равнини



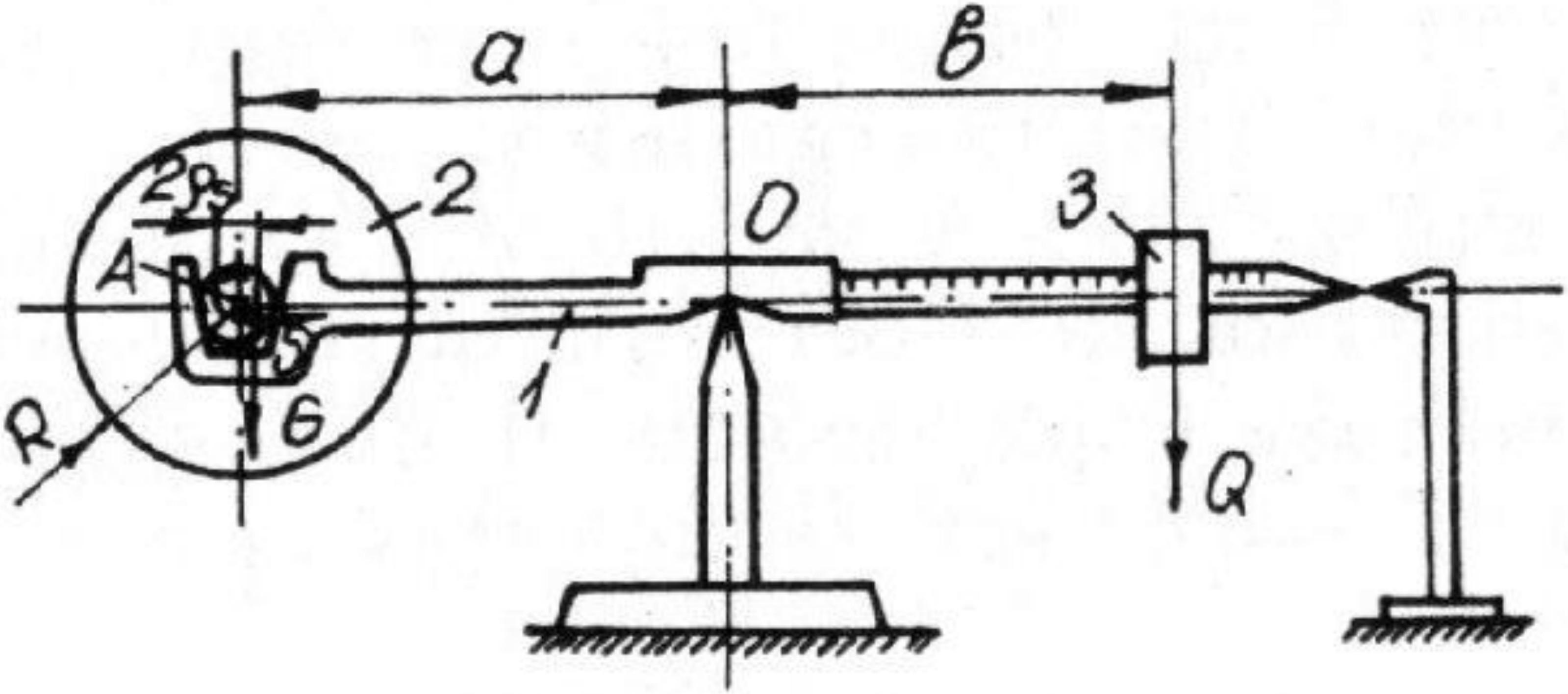
Динамичен дебаланс




STATIC IMBALANCE
Principal Axis of Inertia
Axis of Rotation
DYNAMIC IMBALANCE



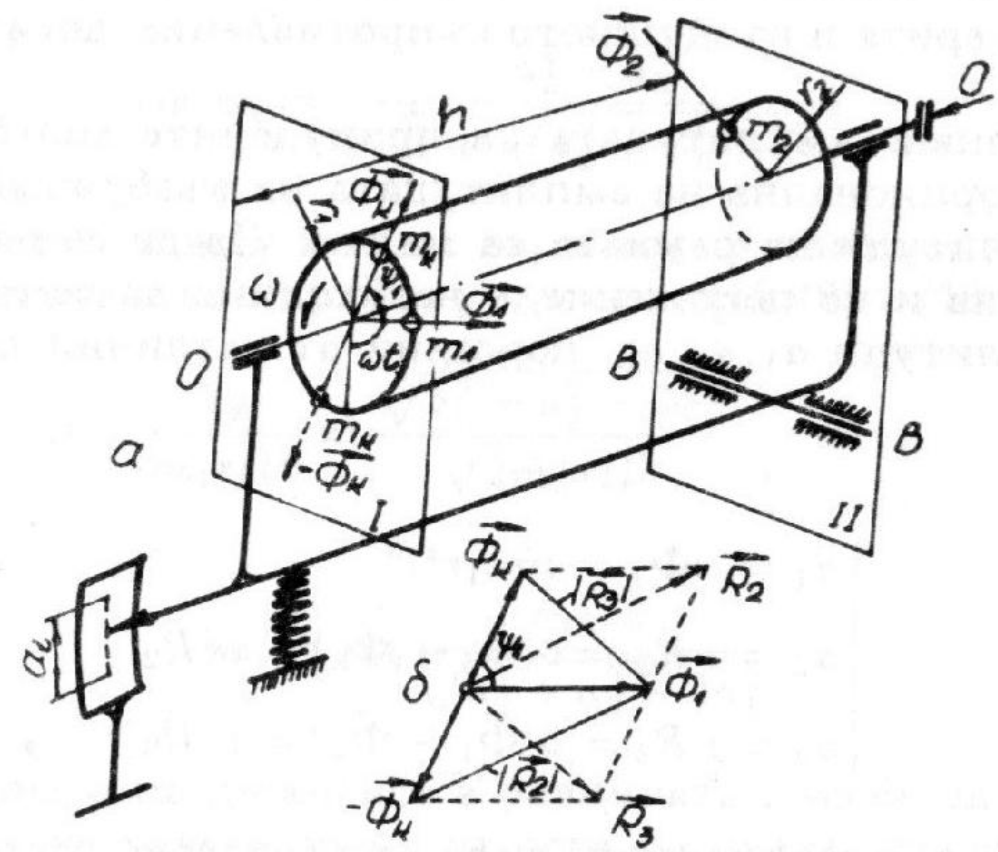
Фиг. 10.14



$$
\left|\begin{array}{l}
M_{yp}^{\max} = Qb_{\max} = G(a + \rho_s), \\
M_{yp}^{\min} = Qb_{\min} = G(a - \rho_s).
\end{array}\right.
$$

$$\Delta_c = \frac{G}{g}\rho_s = \frac{Q}{2g}(b_{\max} - b_{\min})$$

$$m_y = -m = \frac{\Delta_c}{R}.$$



$$
\left|
\begin{aligned}
a_1 &= \nu \Phi_1 = \nu m_1 r \Omega^2 \\
a_2 &= \nu R_2 = \nu |\vec{\Phi}_1 + \vec{\Phi}_k| = \nu |\vec{R}_2| \\
a_3 &= \nu R_3 = \nu |\vec{\Phi}_1 - \vec{\Phi}_k| = \nu |\vec{R}_3|
\end{aligned}
\right.
$$

$$
\left|
\begin{aligned}
R_3^2 &= \Phi_1^2 + \Phi_k^2 - 2\Phi_1 \Phi_k \cos \psi_1, \\
R_2^2 &= \Phi_1^2 + \Phi_k^2 - 2\Phi_1 \Phi_k \cos(\pi - \psi_1).
\end{aligned}
\right.
$$

$$\Phi_k = \frac{1}{\sqrt{2}}\sqrt{R_2^2 + R_3^2 - 2\Phi_1^2} = \frac{1}{\sqrt{2}}\sqrt{\frac{a_2^2}{\nu^2} + \frac{a_3^2}{\nu^2} - 2\frac{a_1^2}{\nu^2}};$$

$$\Phi_k = m_k r \Omega^2$$

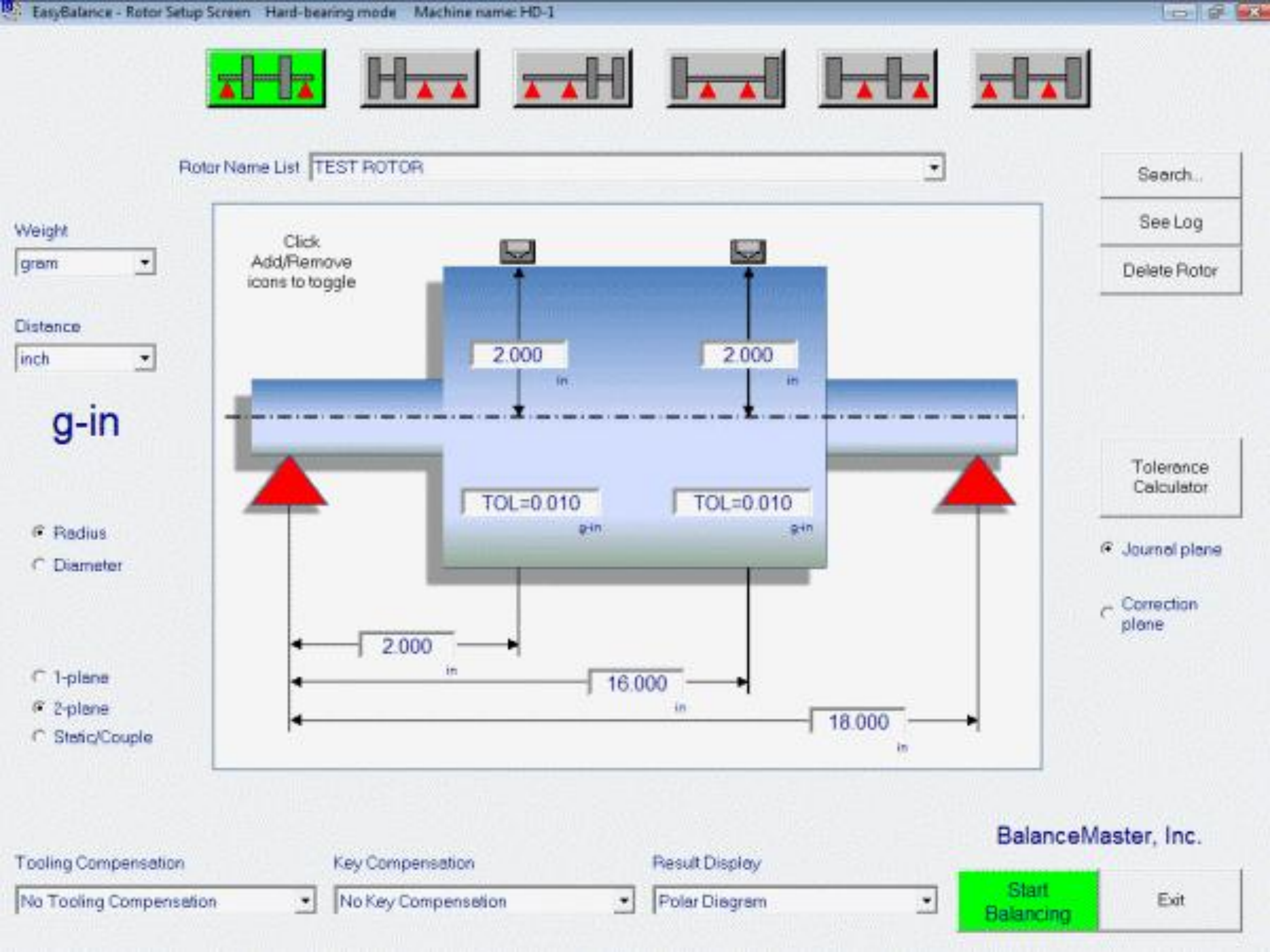
$$\cos\psi_1 = \frac{\Phi_1^2 + \Phi_k^2 - R_3^2}{2\Phi_1\Phi_k} = \frac{R_2^2 - R_3^2}{2\sqrt{2}\,\Phi_1\sqrt{R_2^2 + R_3^2 - 2\Phi_1^2}}.$$

$$\cos\psi_1 = \frac{a_2^2 - a_3^2}{2\sqrt{2}\,a_1\sqrt{a_2^2 + a_3^2 - 2a_1^2}}$$

$$\nu = \frac{a_1}{m_1 r \Omega^2} = \frac{\sqrt{a_2^2 + a_3^2 - 2a_1^2}}{\sqrt{2} m_k r \Omega^2}.$$

$$m_1 = m_k \frac{a_1\sqrt{2}}{\sqrt{a_2^2 + a_3^2 - 2a_1^2}}.$$

$$m_{y1} r_{y1} = m_1 r.$$


EasyBalance - Rotor Setup Screen Hard-bearing mode Machine name: HD-1
Rotor Name List
TEST ROTOR
Search..
See Log
Delete Rotor
Weight
gram
Distance
inch
g-in
Click Add/Remove icons to toggle
2.000
in
2.000
in
TOL=0.010
g-in
TOL=0.010
g-in
Radius
Diameter
1-plane
2-plane
Static/Couple
2.000
in
16.000
in
18.000
in
Tolerance Calculator
Journal plane
Correction plane
BalanceMaster, Inc.
Tooling Compensation
No Tooling Compensation
Key Compensation
No Key Compensation
Result Display
Polar Diagram
Start Balancing
Exit