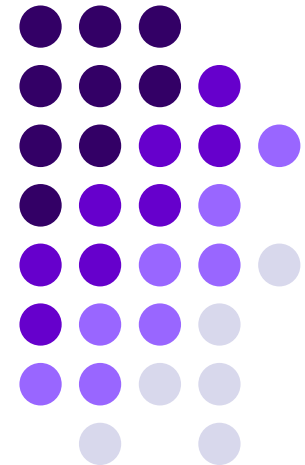
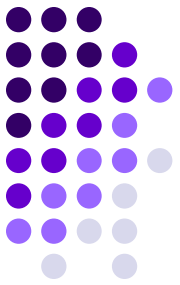


Senzori si traductoare

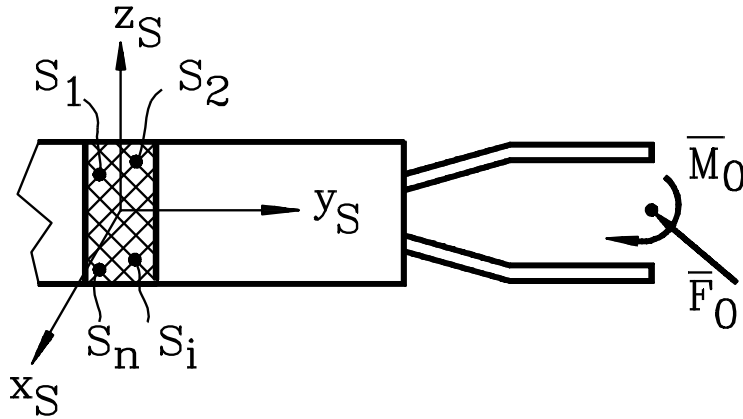




Cuprins 9

Modelul matematic al senzorului de forta tensorezistiv
Forma elementului elastic
Frecventa proprie a elementului elastic
Structuri elastic complexe
Rigiditatea elementului elastic
Constructia senzorului de forta tensorezistiv

Modelul matematic al elementului senzorial tensorezistiv

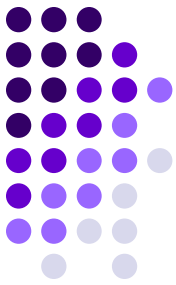


- Senzor tensometric
- S_i – semnalele din puncte de masurare

$$[Y] = f([X], [P]) \left\{ \begin{array}{l} [X]^T = [F_x, F_y, F_z, M_x, M_y, M_z] \\ [P] \text{ - factorii perturbatori} \\ [Y]^T = [Y_1, Y_2, \dots, Y_n] \end{array} \right.$$

$$[Y] = [\Psi] \cdot [X]$$

Matricea de masurare



$$[S]_{nx1} = [B]_{nx6} \cdot \{[F], [M]\}_{6x1}^T$$

[B] - matrice de cuplare

$$[B] = \begin{bmatrix} B_{11} & 0 & \dots & 0 \\ 0 & B_{22} & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & B_{66} \end{bmatrix} \quad \text{Cazul ideal – matrice diagonala}$$

$$\{[F], [M]\}_{6x1}^T = [A]_{6xn} \cdot [S]_{nx1}$$

[A] - matricea de decuplare

$$[A] = [B^T \cdot B]^{-1} \cdot B^T$$

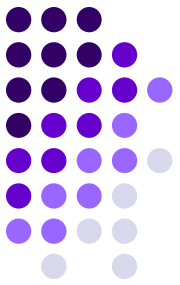
Pseudo-inversa $[A]$ trebuie să verifice condițiile Moore-Penrose

$$[B] \cdot [A] \cdot [B] = [B]$$

$$[A] \cdot [B] \cdot [A] = [A]$$

$$([A] \cdot [B])^T = [A] \cdot [B]$$

$$([B] \cdot [A])^T = [B] \cdot [A]$$



$$F_i = A_{i1} \cdot S_1 + A_{i2} \cdot S_2 + \dots + A_{in} \cdot S_n$$

Sensibilitatea la perturbatii

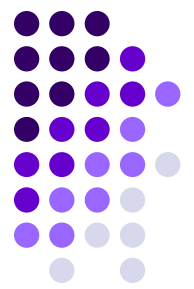
$$K = \|M\| \cdot \|M^{-1}\|$$

Numărul de condiționare.

$$K = \left| \frac{\lambda_{\max}}{\lambda_{\min}} \right| \geq 1$$

Valoarea singulară minimă a matricii de cuplare normalizate

Forma elementului elastic



Forma elementului elastic + locul de aplicare a TER:

- sarcina nominală;
- sensibilitate;
- liniaritate;
- histereză etc.

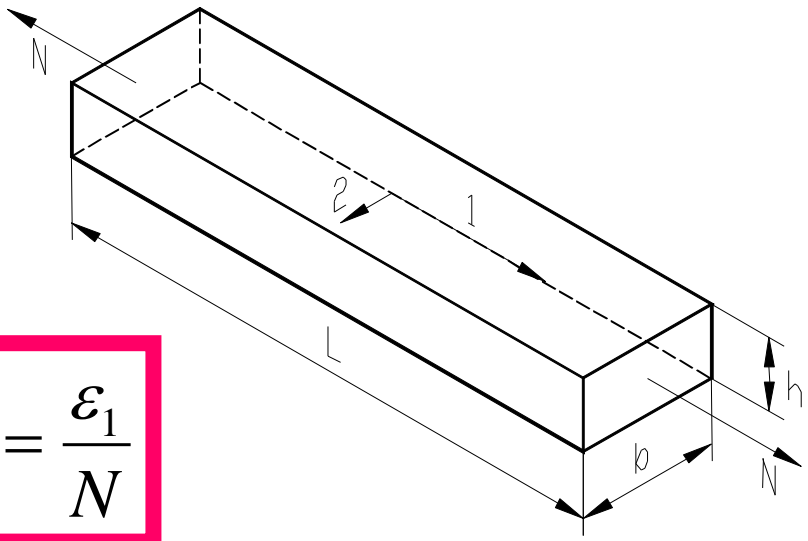
• *Bara dreaptă sollicitată axial*

$$\varepsilon_1 = \frac{N}{Ebh}$$

$$\varepsilon_2 = -\mu\varepsilon_1$$

$$K = \frac{Ebh}{L}$$

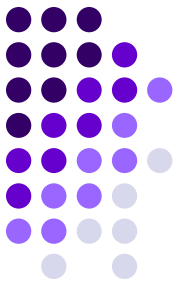
$$S_{1m} = \frac{\varepsilon_1}{N}$$



$$\sigma = \frac{F}{A}$$

$$\varepsilon = \frac{\sigma}{E}$$

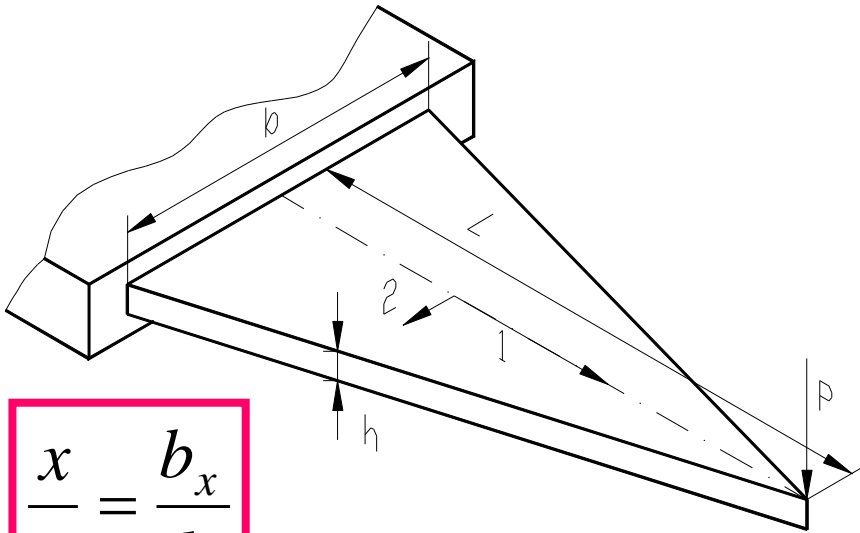
• **Bara de egală rezistență la încovoiere**



$$\sigma = \frac{M_i}{W_z} = \frac{6P \cdot L}{b \cdot h^2}$$

$$f = \int_x \frac{M_i \cdot \bar{M}_i}{EI_z} dx$$

$$K = \frac{P}{f}$$



$$\frac{x}{L} = \frac{b_x}{b}$$

$$\varepsilon_1 = \frac{6PL}{Ebh^2}$$

$$\varepsilon_2 = -\mu\varepsilon_1$$

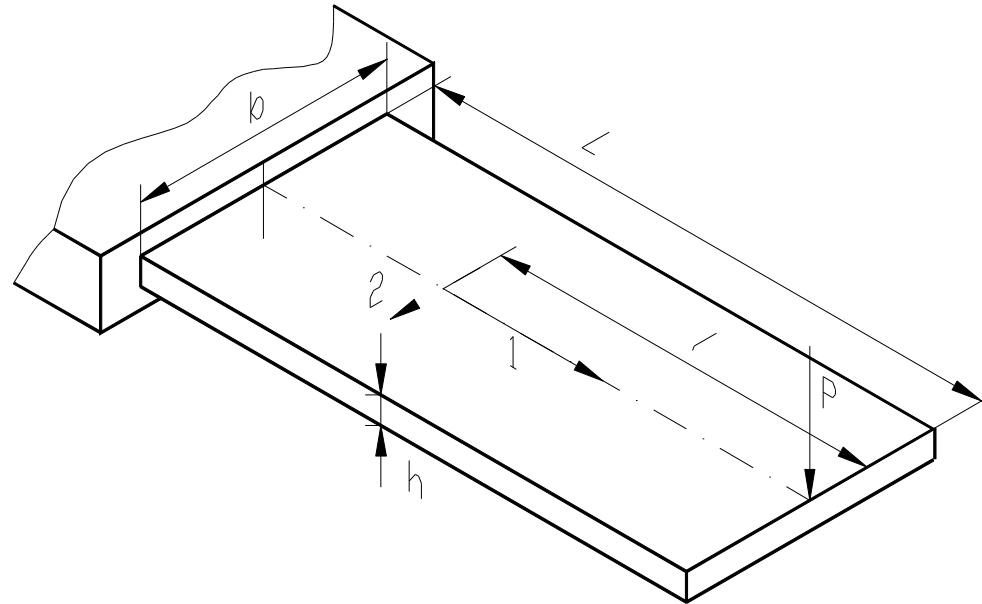
$$K = \frac{Ebh^3}{6L^3}$$

•Bară dreaptă în consolă solicitată la încovoiere

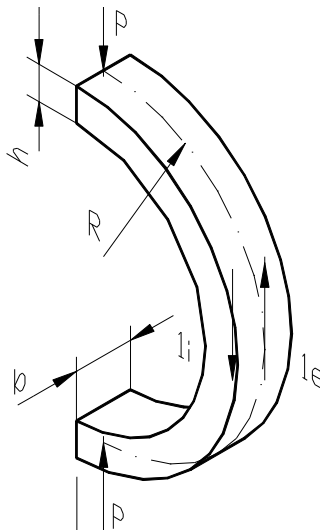
$$\varepsilon_1 = \frac{6PL}{Ebh^2}$$

$$\varepsilon_2 = -\mu\varepsilon_1$$

$$K = \frac{Ebh^3}{4L^3}$$



•Bară curbă (semi-inel)



$$\varepsilon_{1i} = -\frac{P}{Ebh} \cdot \left(1 + \frac{2R}{h} \cdot \frac{6R-h}{2R-h} \right)$$

$$\varepsilon_{1e} = \frac{P}{Ebh} \cdot \left(-1 + \frac{2R}{h} \cdot \frac{6R+h}{2R+h} \right)$$

$$K = \frac{Ebh^3}{6\pi R^3}$$

•Bară cotită solicitată la încovoiere

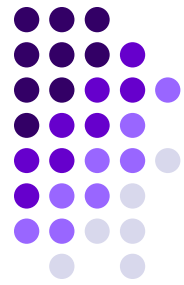
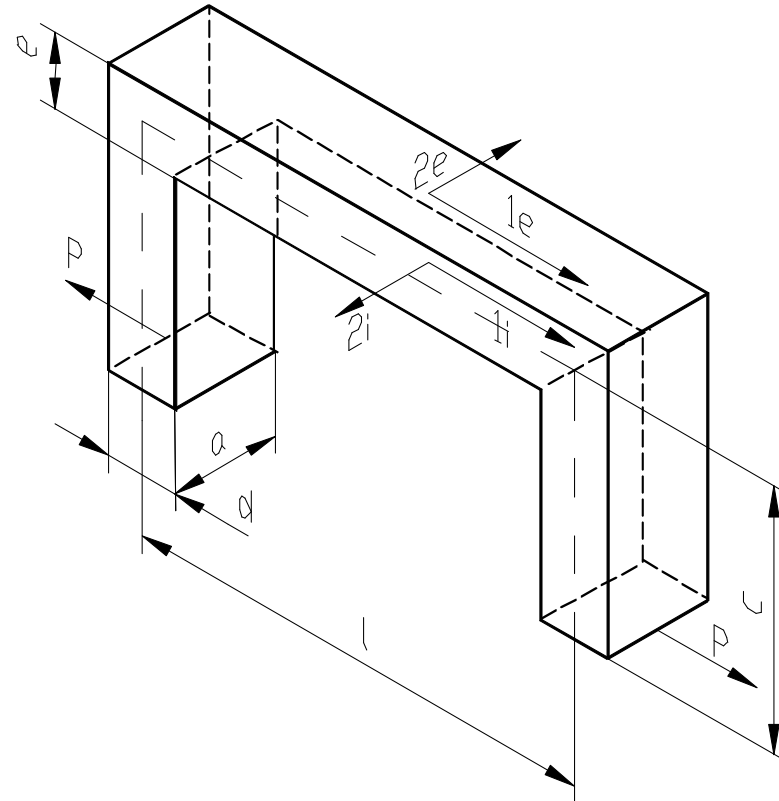
$$\varepsilon_{1i} = \frac{P}{Eae} \cdot \left(\frac{6c}{e} + 1 \right)$$

$$\varepsilon_{2i} = -\mu\varepsilon_{1i}$$

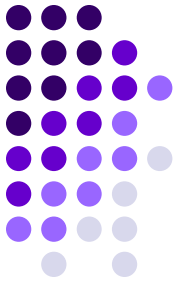
$$\varepsilon_{1e} = -\frac{P}{Eae} \cdot \left(\frac{6c}{e} - 1 \right)$$

$$\varepsilon_{2e} = -\mu\varepsilon_{1e}$$

$$K = \frac{Ea}{4c^2 \cdot \left(\frac{2c}{d^3} + \frac{3l}{e^3} \right)}$$



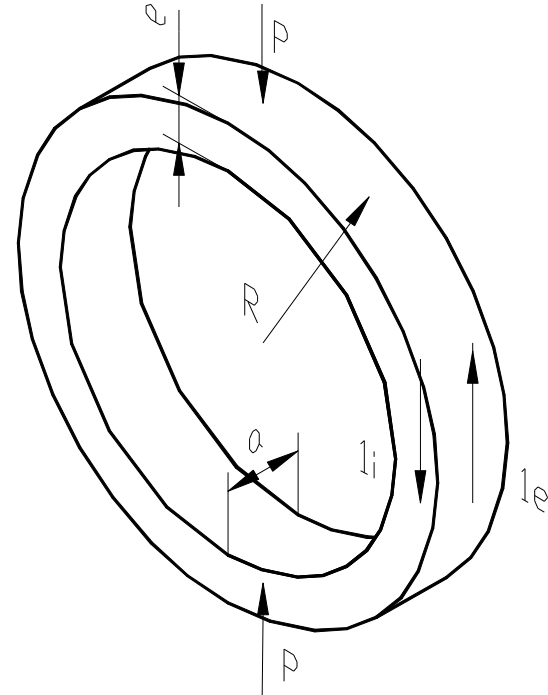
•Bară inel circular



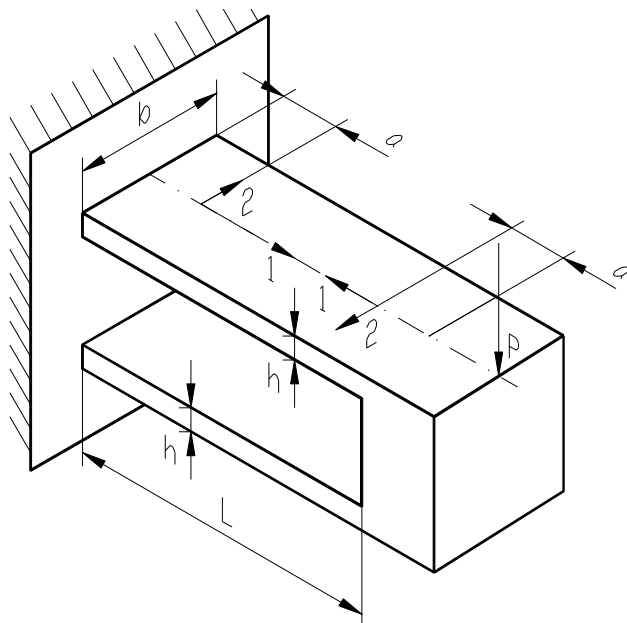
$$\varepsilon_{1e} = \frac{P}{2Eae} \cdot \left[1 - \frac{3R}{e} \cdot \left(1 - \frac{2}{\pi} \right) \right]$$

$$\varepsilon_{1i} = \frac{P}{2Eae} \cdot \left[1 + \frac{3R}{e} \cdot \left(1 - \frac{2}{\pi} \right) \right]$$

$$K = \frac{Eae^3}{12 \cdot \left(\frac{\pi}{4} - \frac{2}{\pi} \right) \cdot R^3}$$



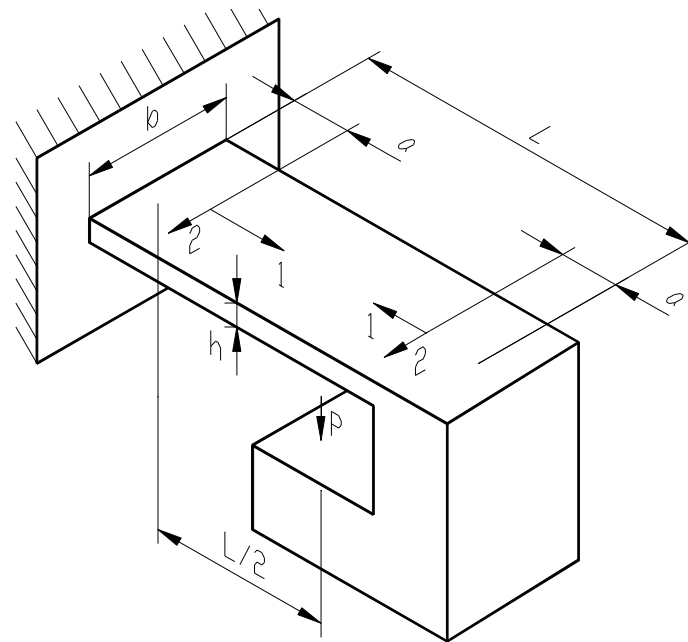
• Cadru plan solicitat la încovoiere
 • Bară cotită încastrată la un capăt



$$\varepsilon_1 = \frac{3P \cdot (L - 2a)}{2Ebh^2}$$

$$\varepsilon_2 = -\mu\varepsilon_1$$

$$K = \frac{2Ebh^3}{L^3}$$

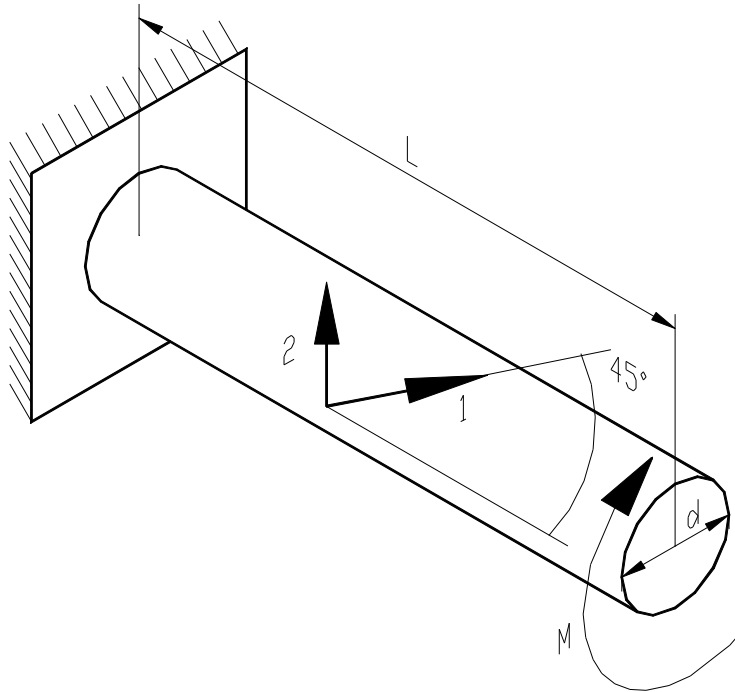
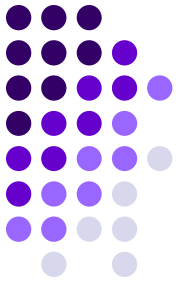


$$\varepsilon_1 = \frac{3P \cdot (L - 2a)}{Ebh^2}$$

$$\varepsilon_2 = -\mu\varepsilon_1$$

$$K = \frac{Ebh^3}{L^3}$$

• **Bară de secțiune circulară solicitată la răsucire**

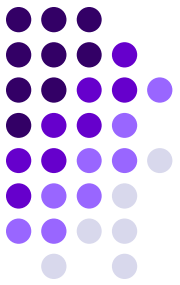


$$\tau = \frac{M_t}{W_p} = \frac{16M_t}{\pi d^3}$$

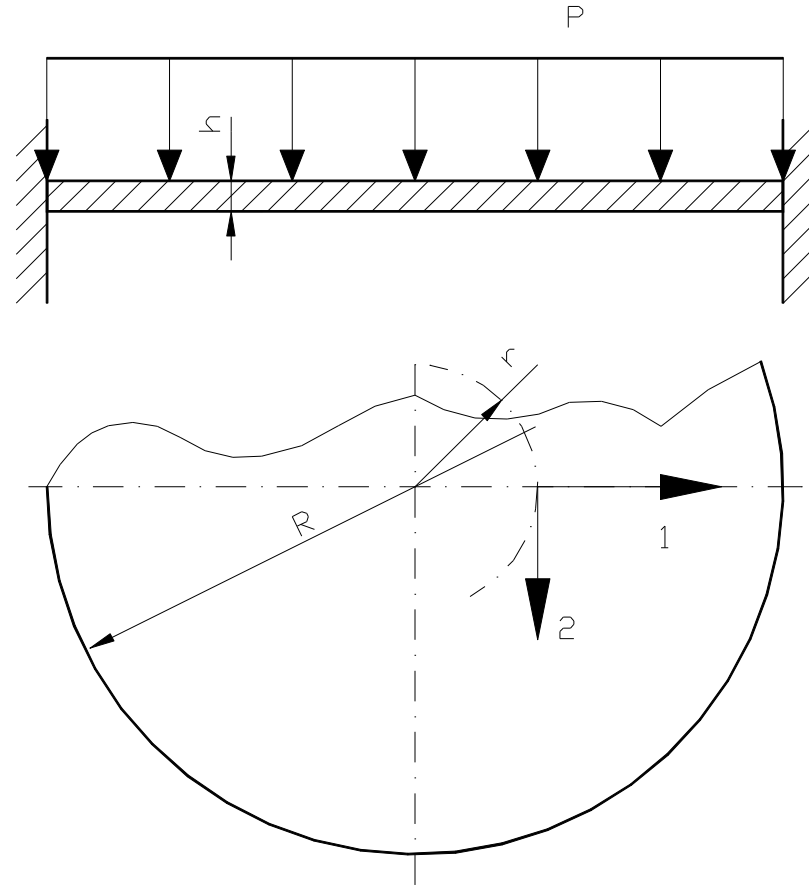
$$\varepsilon_1 = \frac{8M}{\pi G d^3}$$

$$\varepsilon_2 = -\mu \varepsilon_1$$

$$K = \frac{\pi G d^4}{32L}$$



• **Placa plană circulară încadrată**



$$\varepsilon_1 = \frac{3p \cdot (1 - \mu^2)}{8Eh^2} \cdot (R^2 - 3r^2)$$

$$\varepsilon_2 = \frac{3p \cdot (1 - \mu^2)}{8Eh^2} \cdot (R^2 - r^2)$$

$$K = \frac{16\pi Eh^3}{3 \cdot (1 - \mu^2) \cdot R^2}$$

Frecventa proprie a elementului elastic

$$f = \frac{1}{2\pi} \sqrt{\frac{K}{m}}$$

- rigiditatea elementului elastic
- masa elementului elastic

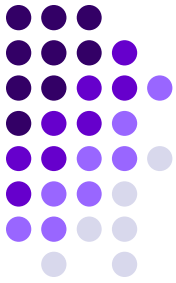
$$f = \frac{1}{4.89\pi} \sqrt{\frac{Ebh^3}{L^3m}} = \frac{1}{4.89\pi} \cdot \frac{h}{L^2} \cdot \sqrt{\frac{E}{\rho}}$$

Element elastic
tringhiular

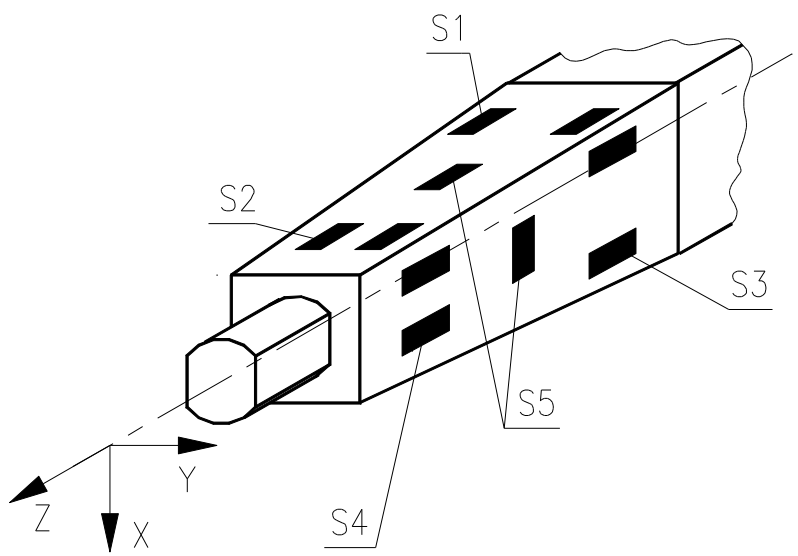
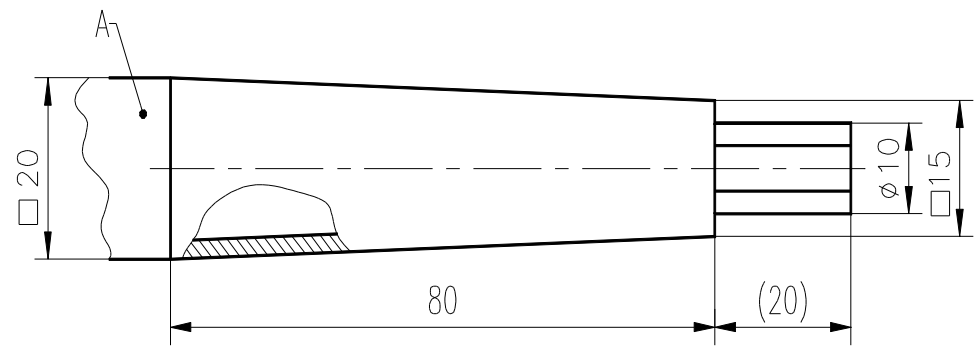
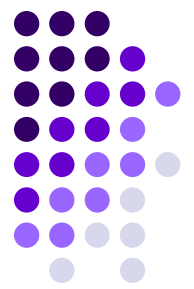
$$f = \frac{1}{4\pi} \cdot \sqrt{\frac{Ebh^3}{L^3m}} = \frac{1}{4\pi} \cdot \frac{h}{L^2} \cdot \sqrt{\frac{E}{\rho}}$$

Element elastic
dreptunghiular

Indice de calitate al
materialului

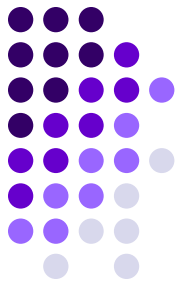


Exemplu de element elastic si matricea de decuplare



$$\begin{bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & a_{13} & 0 & 0 & 0 \\ 0 & a_{22} & 0 & a_{24} & 0 & 0 \\ 0 & 0 & 0 & 0 & a_{35} & 0 \\ 0 & a_{42} & 0 & a_{44} & 0 & 0 \\ a_{51} & 0 & a_{53} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{66} \end{bmatrix} \cdot \begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{bmatrix}$$

Structuri elastice complexe

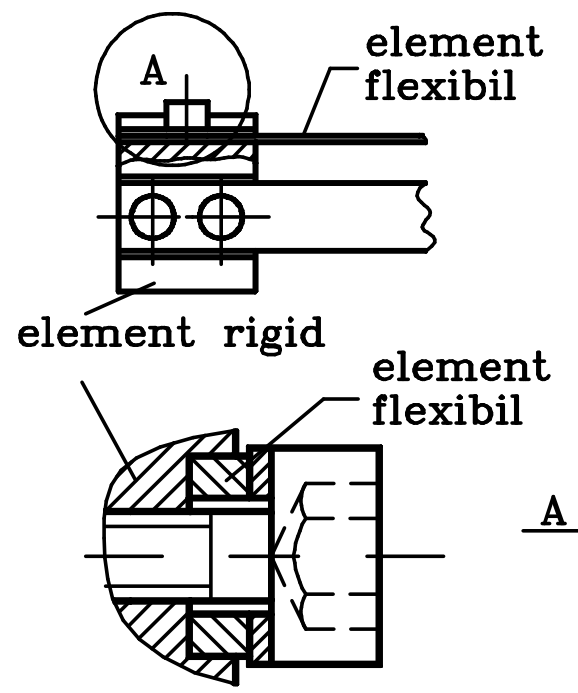
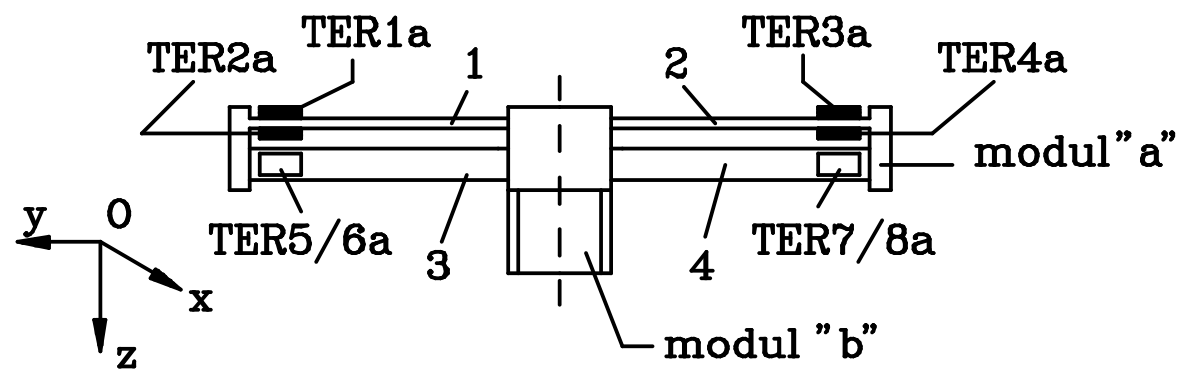
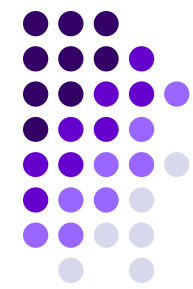


AutoCAD - FIGURA31

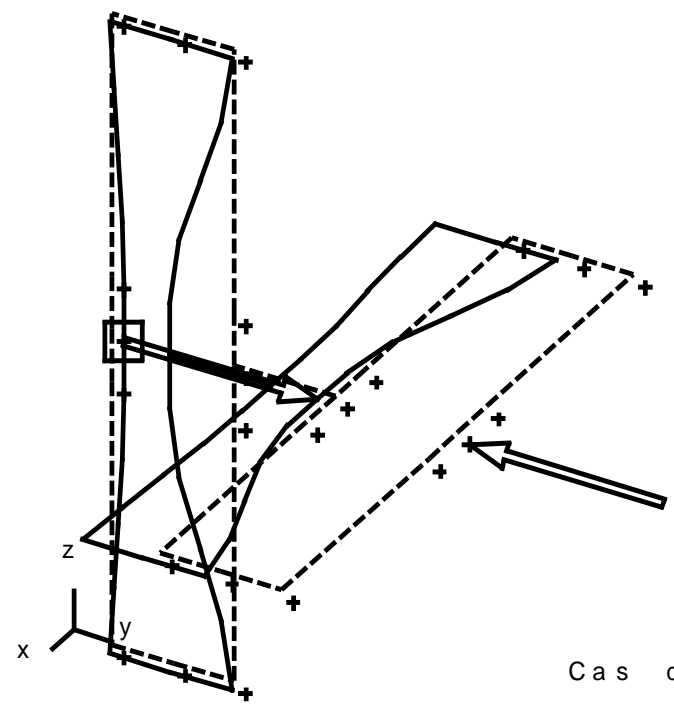
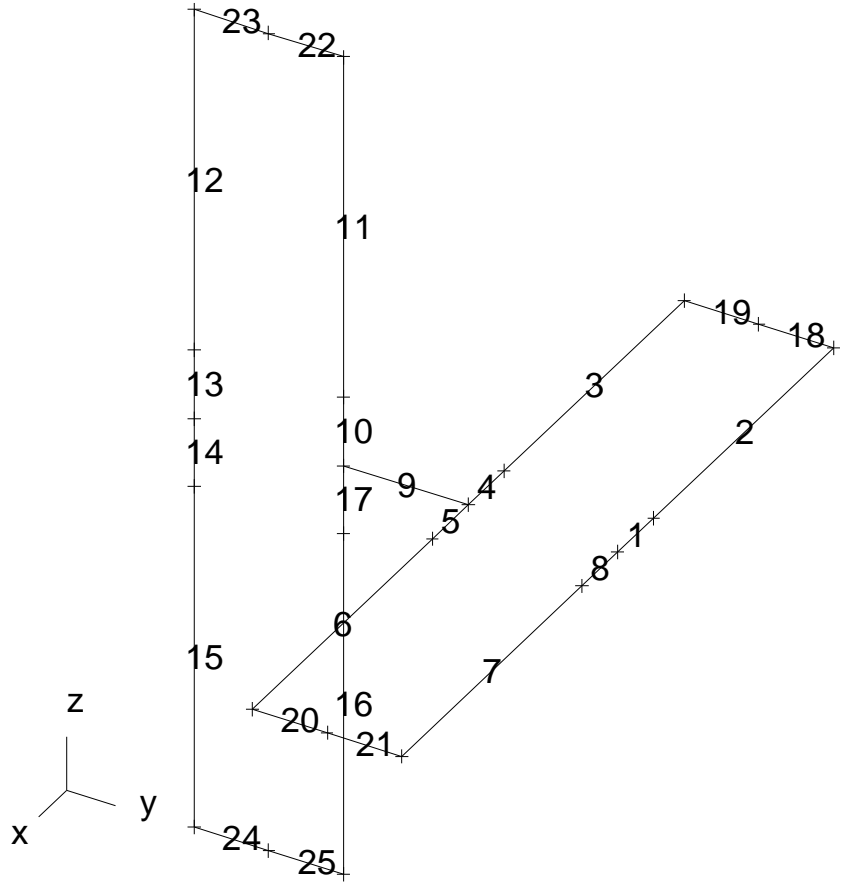
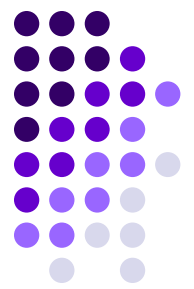
File Edit ELEM. SIMPLE MATERIALE Help

Layer AXE O S P 62.0, -53.5

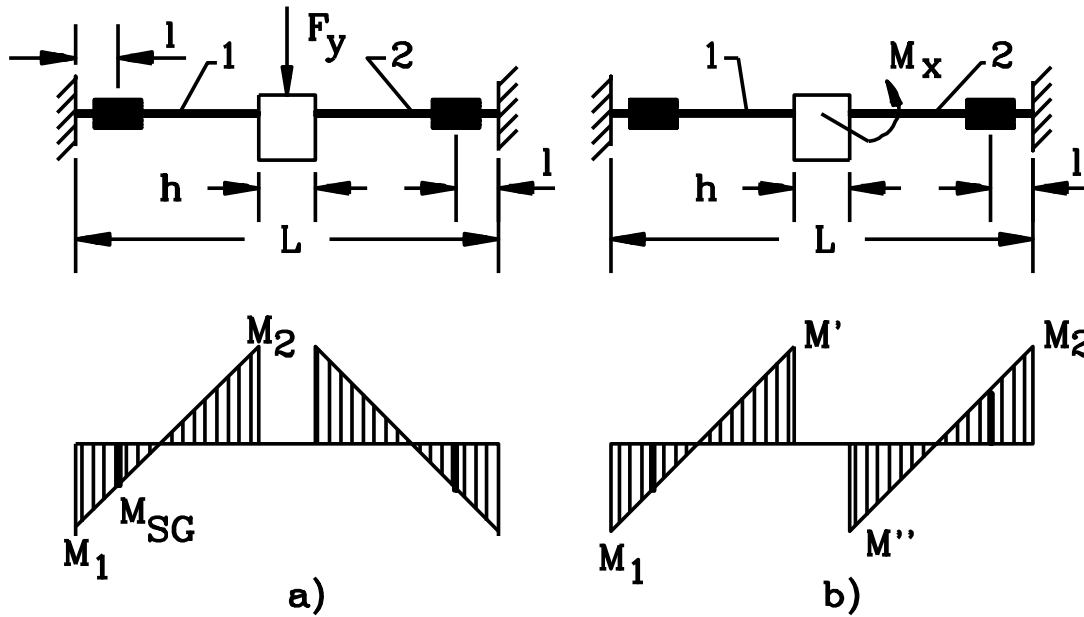
Regenerating drawing.
 Hiding lines: done 100%
 Command:



Calculul starii de solicitare



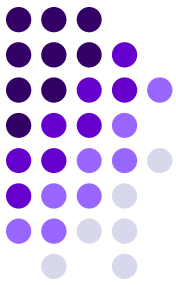
Cas de ch.



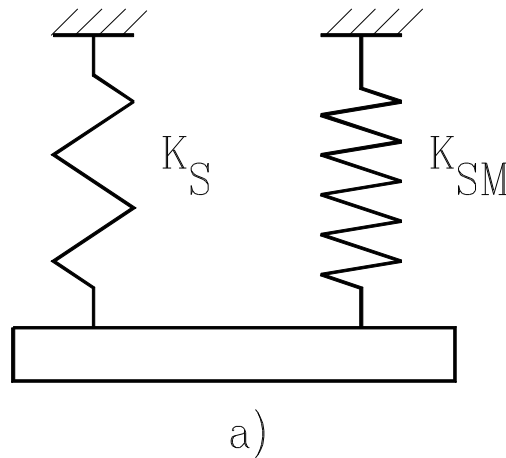
$$M_{T1a}^{Fz} = M_1 - \frac{2a}{L-h} \cdot (M_1 + M_2)$$

$$\varepsilon_{T1a}^{Fz} = \frac{M_{T1a}^{Fz}}{E \cdot W_z}$$

Rigiditatea elementului elastic



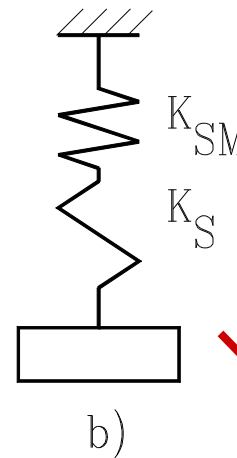
Se impune determinarea condițiilor, astfel încât diferența între rigiditatea K a ansamblului și rigiditatea inițială a sistemului mecanic K_{SM} să fie cât mai mică (de exemplu 0.1 %) , prin montarea elementului elastic din componența senzorului de rigiditate K_S .



$$K = K_{SM} + K_S$$

$$K = 1.001 K_{SM}$$

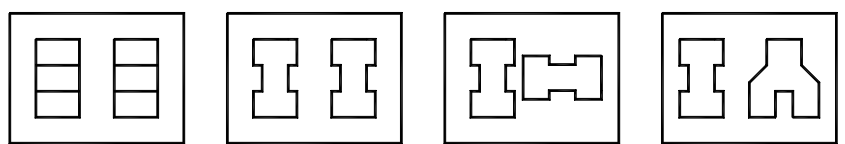
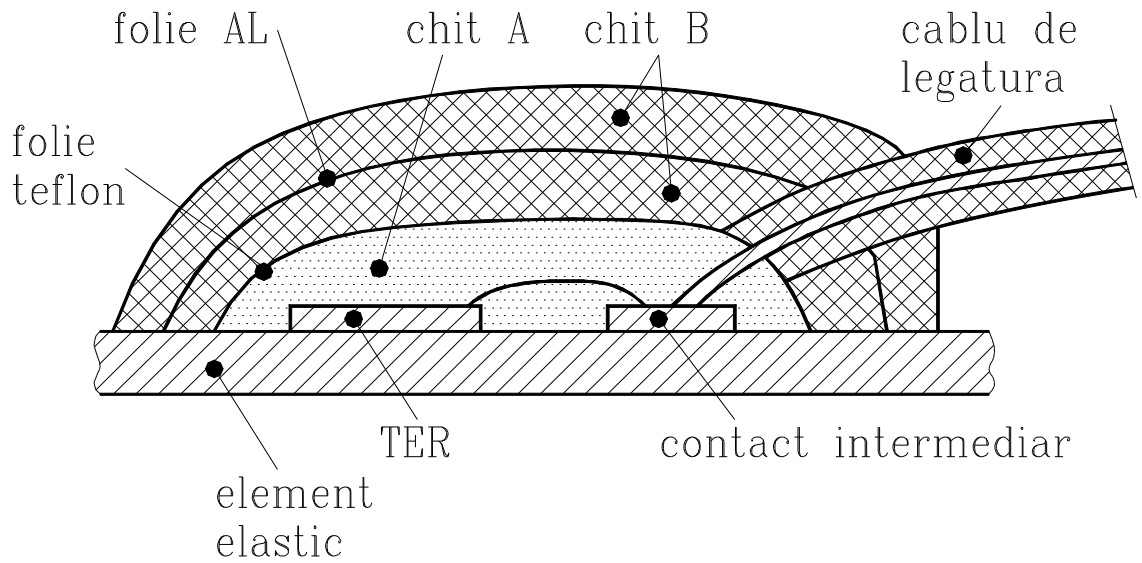
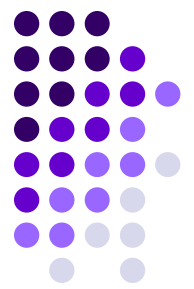
$$K_S = 0.001 K_{SM}$$



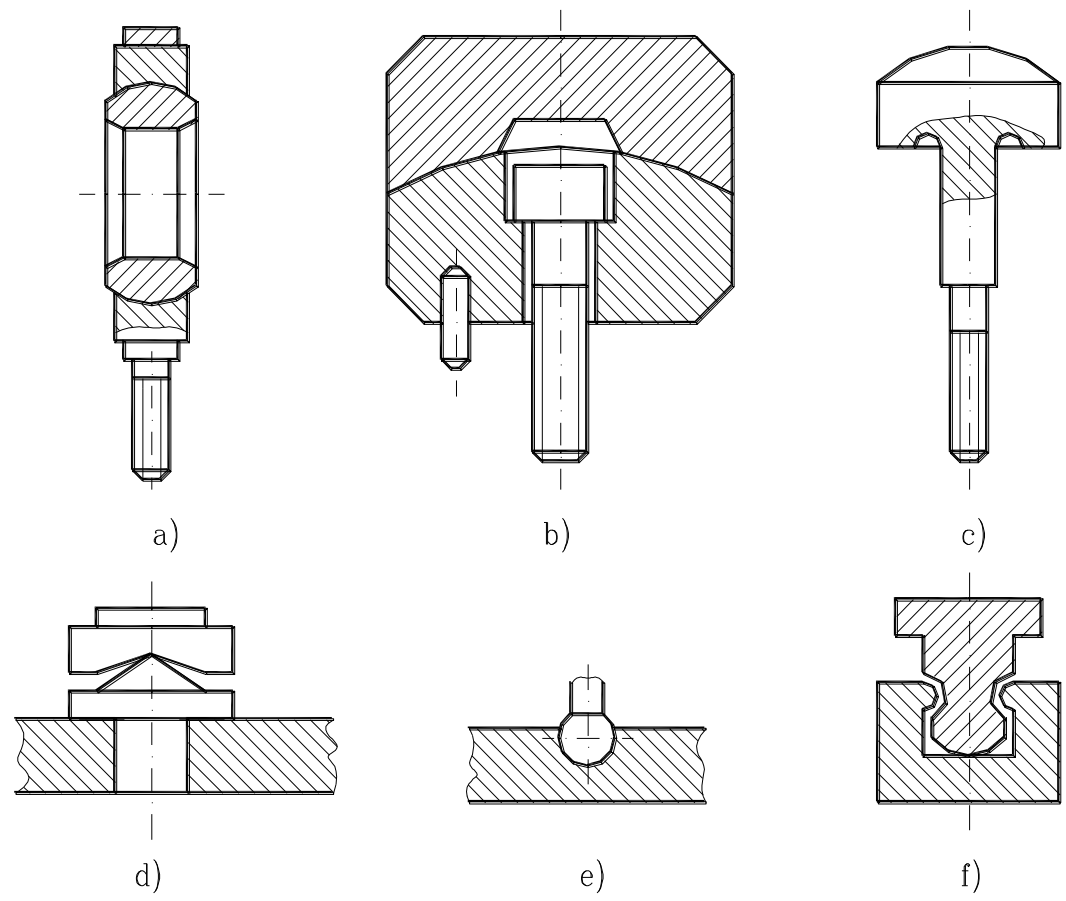
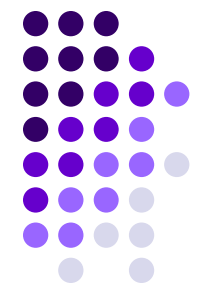
$$K = \frac{K_S \cdot K_{SM}}{K_S + K_{SM}}$$

$$K_S = 1000 K_{SM}$$

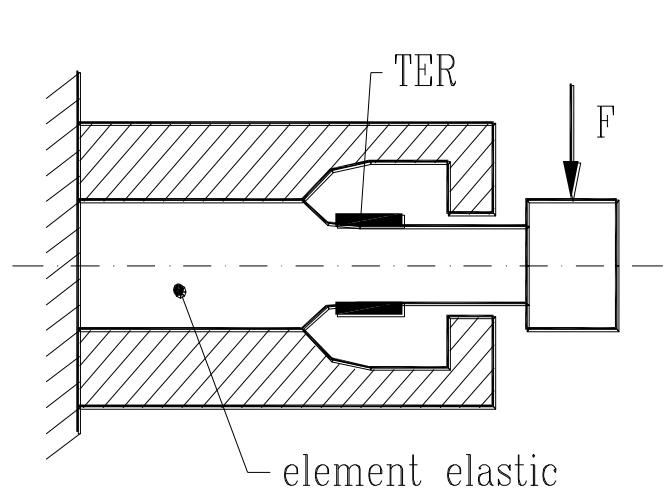
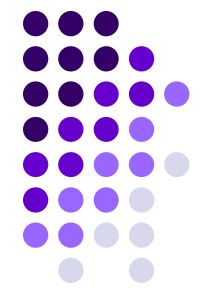
Construcția senzorului



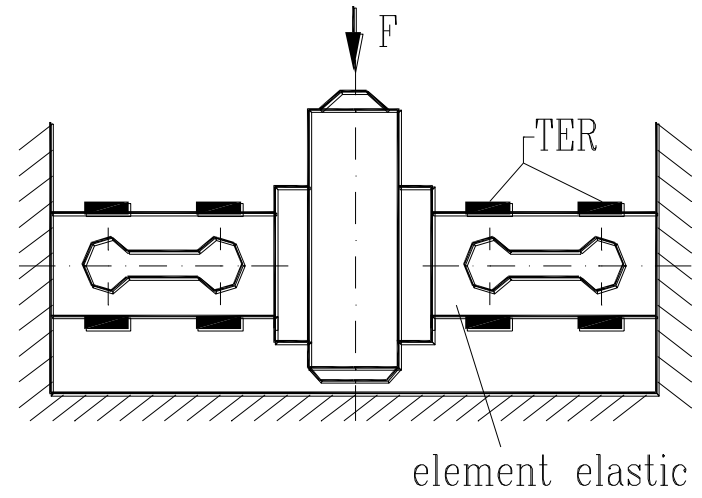
Contacte intermediare



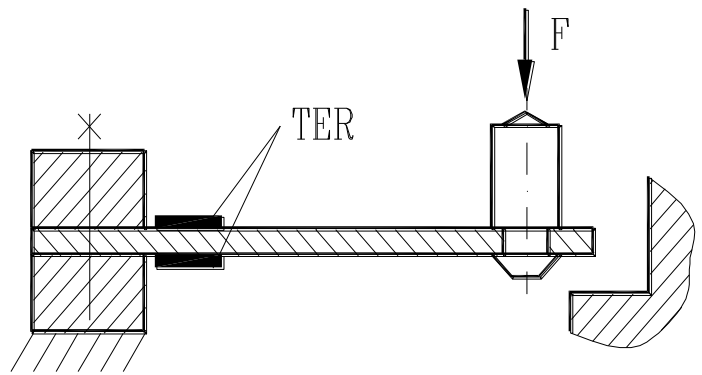
Elemente auxiliare mecanice pentru aplicarea forțelor



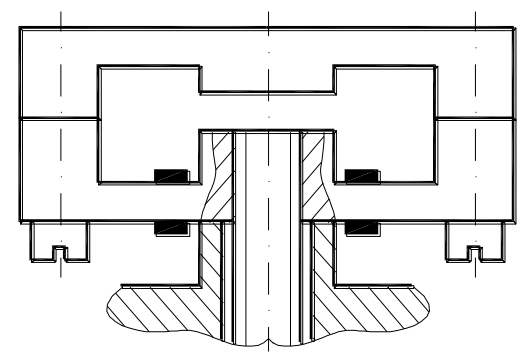
a)



b)



c)



d)

Sisteme de protecție la supraîncărcare