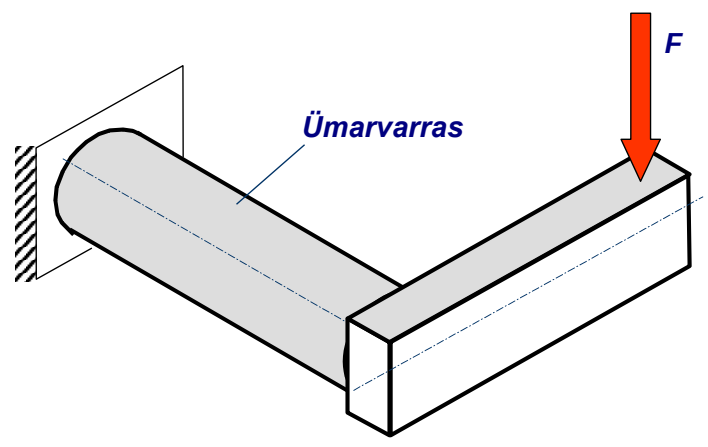
TUGEVUSÕPETUS

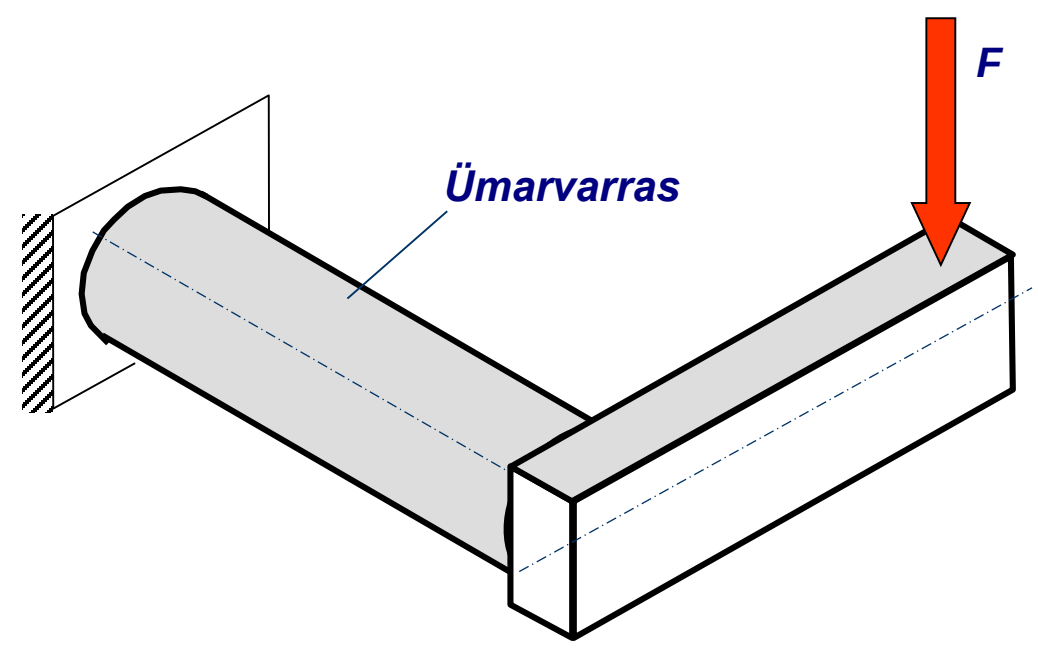
VÄÄNE + PAINE: Varda tugevuskontroll



1. Ülesande püstitus ja algandmed

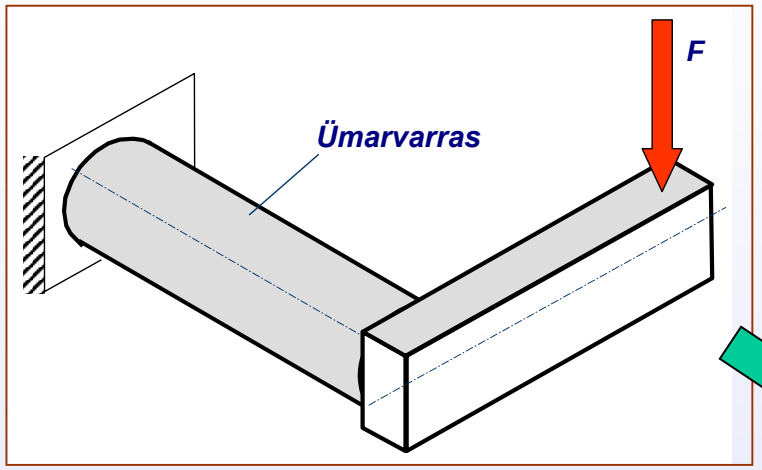
Kahe vardaga tarind

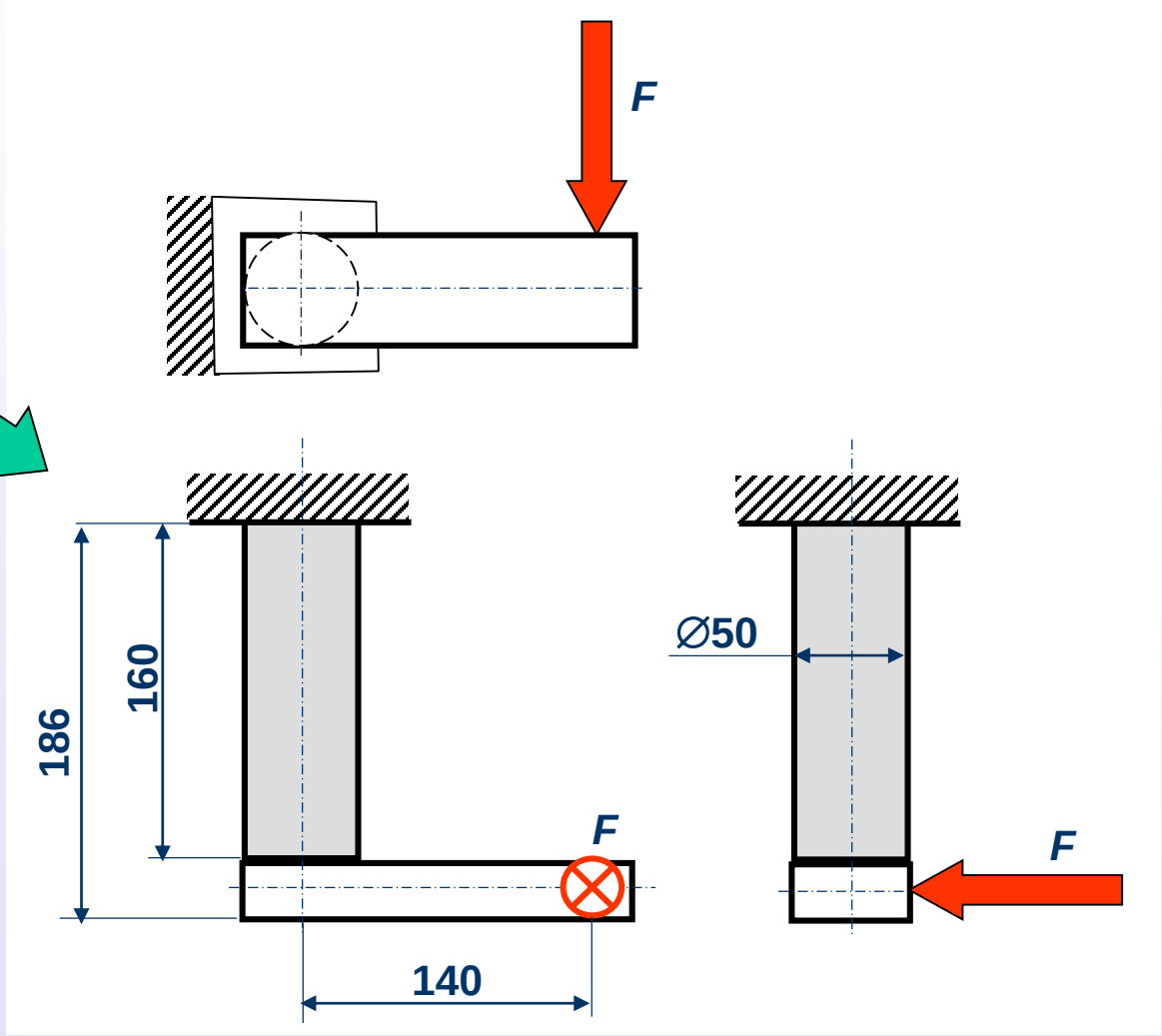
Kontrollida ümarvarda tugevust!



Tarindi koormus: *F* = 10 kN
Ümarvarda läbimõõt: ∅50
Ümarvarda materjal: teras S355
Ümarvarda nõutav varutegur: [S] = 3

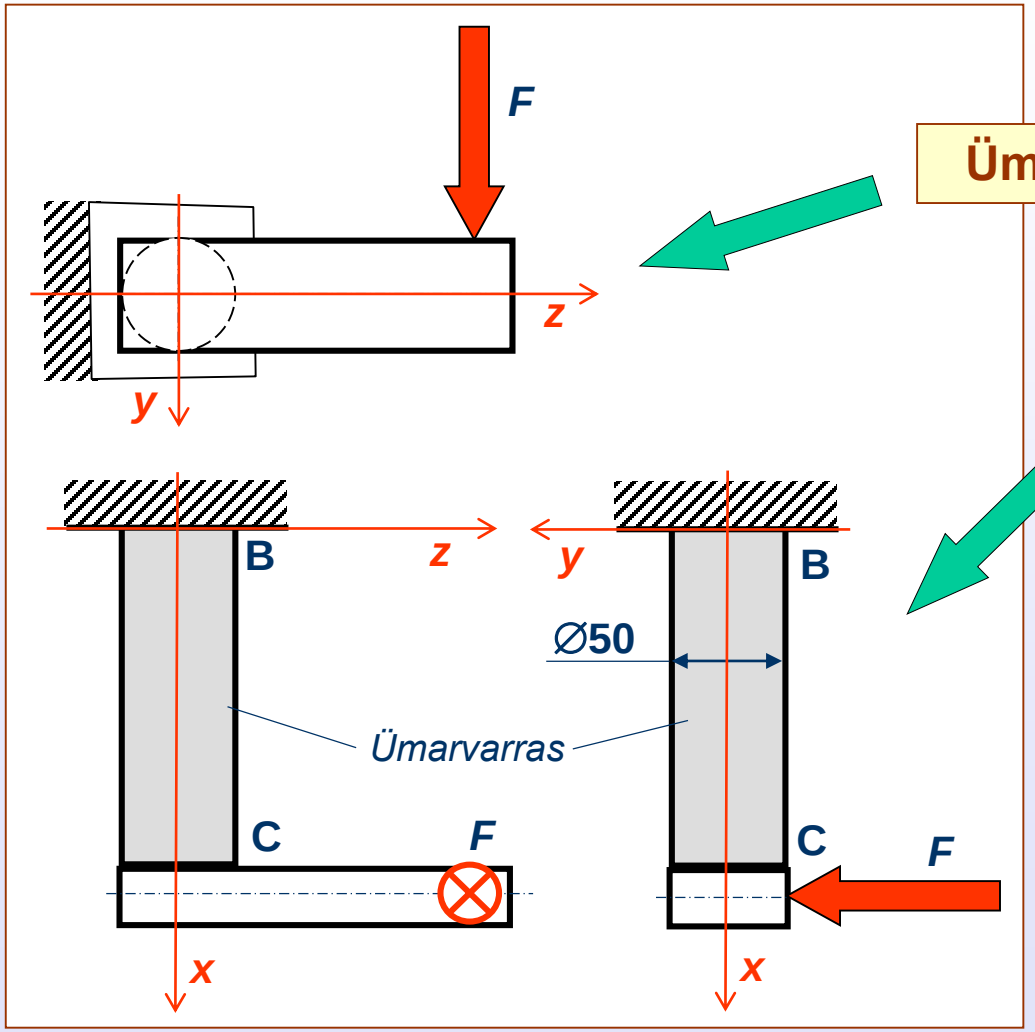
Tarindi kolmvaade





2. Ümarvarda sisejõudude analüüs

2.1. Ümarvarda tööseisund



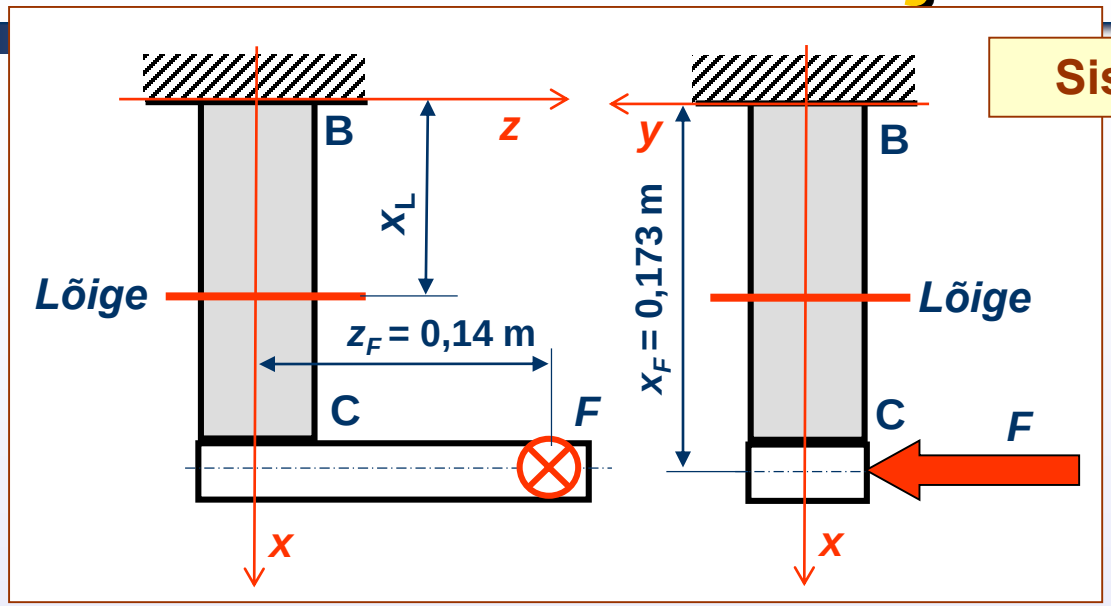
Ümarvarras on väänatud ümber telje *x*

Ümarvarras on painutatud tasandis *xy* ehk ümber telje *z*

Ümarvarras on koormuse *F* toimel tasandiliselt painutatud

Ümarvarda tööseisund on painde ja väände koosmõju

2.2. Ümarvarda sisejõud



Sisejõud arvutatakse lõikemeetodiga

Pöördemomentide tasakaalutingimus telje *x* suhtes

$$\sum \mathcal{M}_x = 0 \Rightarrow T - Fz_F = 0$$

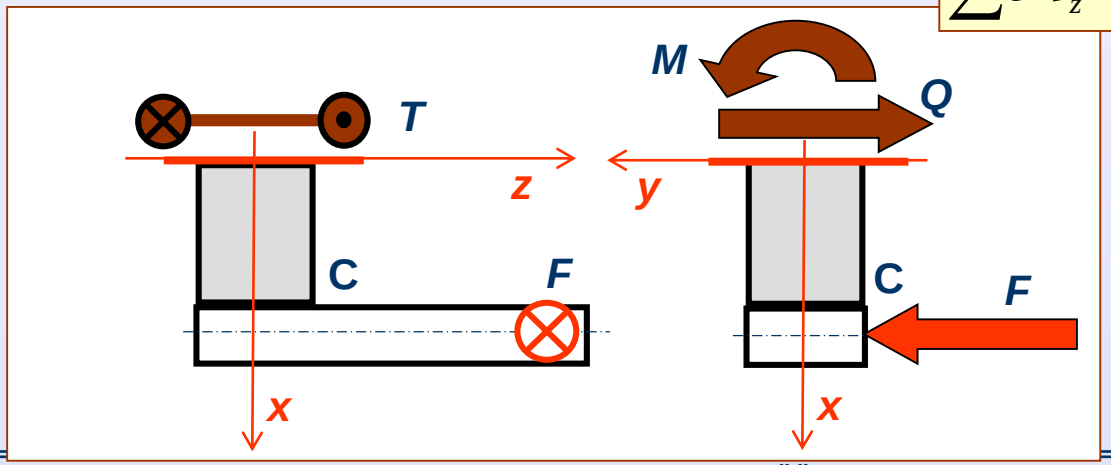
$$T = T_B = T_C = Fz_F = 10^4 \cdot 0{,}14 = 1400 \text{ Nm}$$

Pöördemomentide tasakaalutingimus telje *z* suhtes

$$\sum \mathcal{M}_z = 0 \Rightarrow M - F\left(x_F - x_L\right) = 0$$

$$M = F\left(x_F - x_L\right)$$

Lõige



Kui x_L = 0, siis:

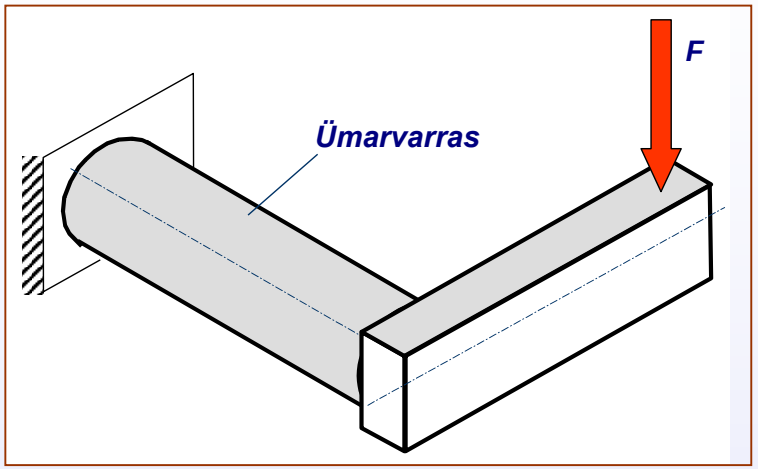
$$M = M_B = 10^4 \cdot \left(0{,}173 - 0\right) = 1730 \text{ Nm}$$

Kui x_L = BC = 0,16 m, siis:

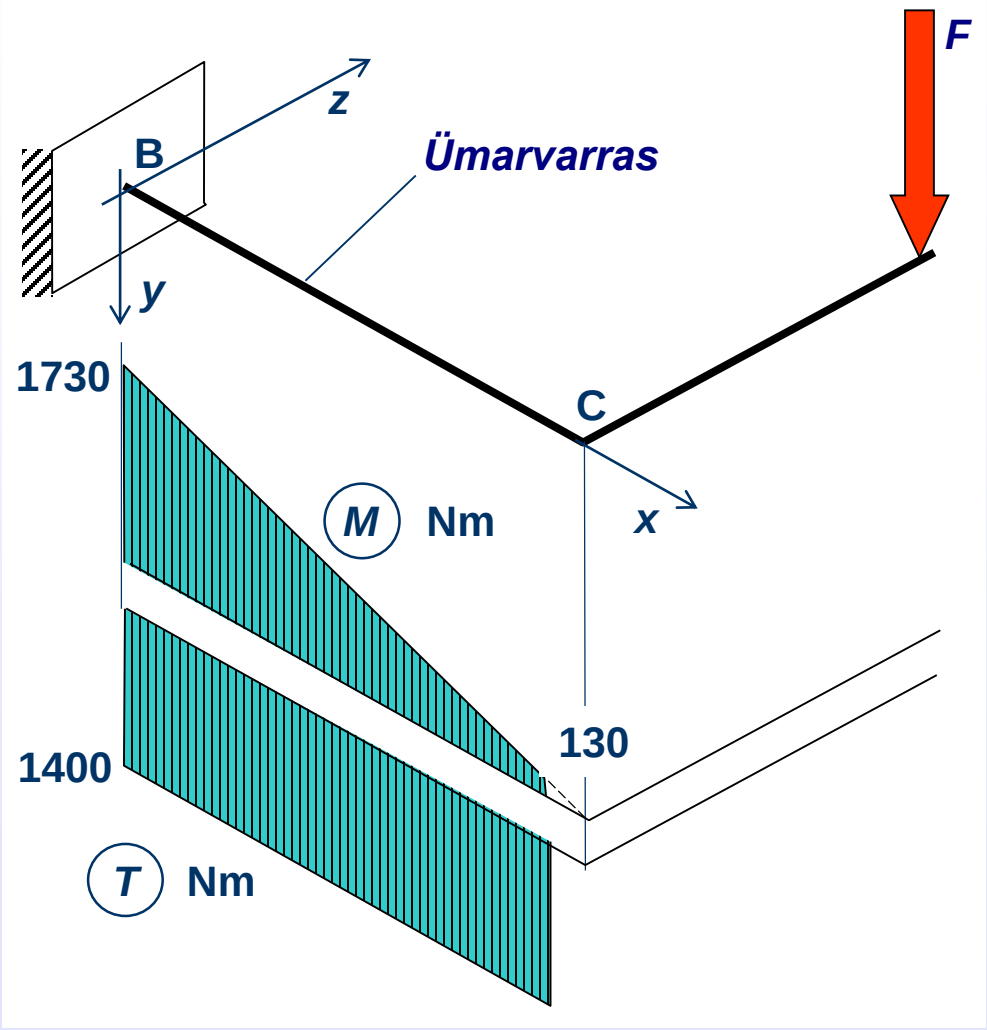
$$M = M_C = 10^4 \cdot \left(0{,}173 - 0{,}16\right) = 130 \text{ Nm}$$

Põikjõu Q arvestamisest loobutakse

2.3. Ümarvarda sisejõudude epüürid



Ühtlase ÜMARvõlli ohtlik ristlõige on B



2.4. Ümarvarda ekvivalentne paindemoment

Ekvivalentne paindemoment

$$M_{\text{Ekv}}^{\text{III}} = \sqrt{M_y^2 + M_z^2 + T^2} = \sqrt{M^2 + T^2}$$

Varda ekvivalentsed paindemomendid

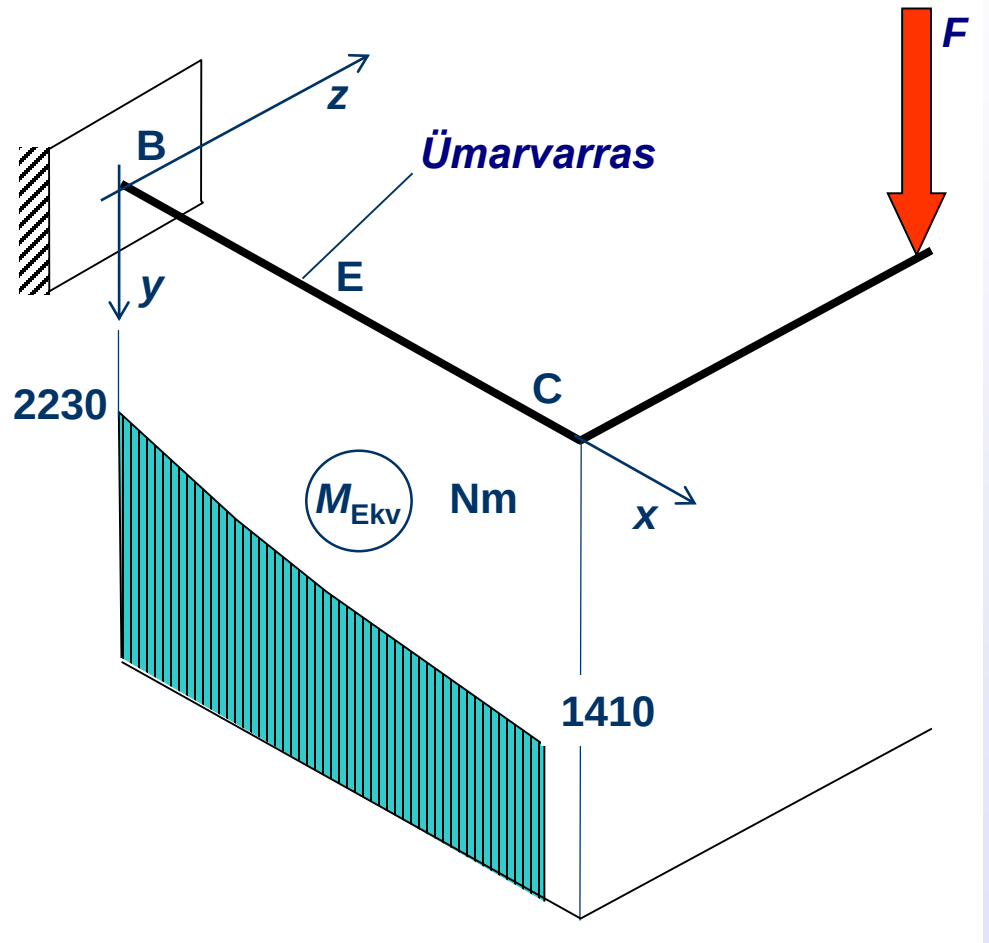
$$M_{\text{Ekv, B}}^{\text{III}} = \sqrt{M_{\text{B}}^2 + T_{\text{B}}^2} = \sqrt{1730^2 + 1400^2} = 2225{,}8 \approx \underline{2230\ \text{Nm}}$$

$$M_{\text{Ekv, C}}^{\text{III}} = \sqrt{M_{\text{C}}^2 + T_{\text{C}}^2} = \sqrt{130^2 + 1400^2} = 1406 \approx \underline{1410\ \text{Nm}}$$

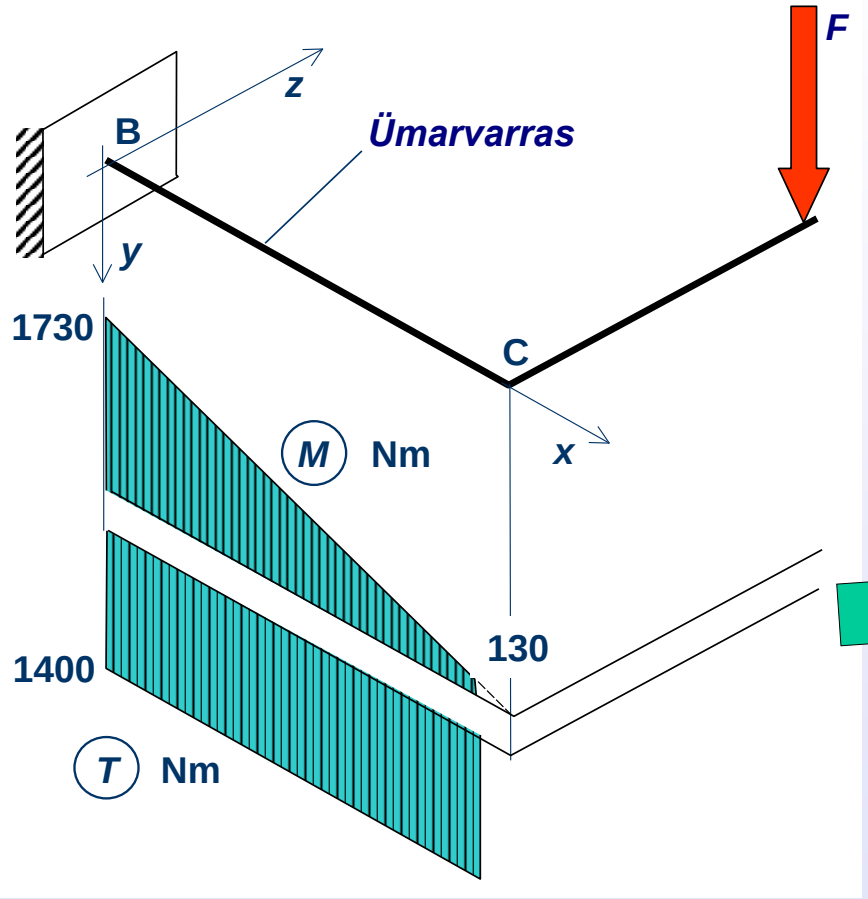
$$M_{\text{Ekv, E}}^{\text{III}} = \sqrt{M_{\text{E}}^2 + T_{\text{E}}^2} = \sqrt{930^2 + 1400^2} = 1680\ \text{Nm}$$

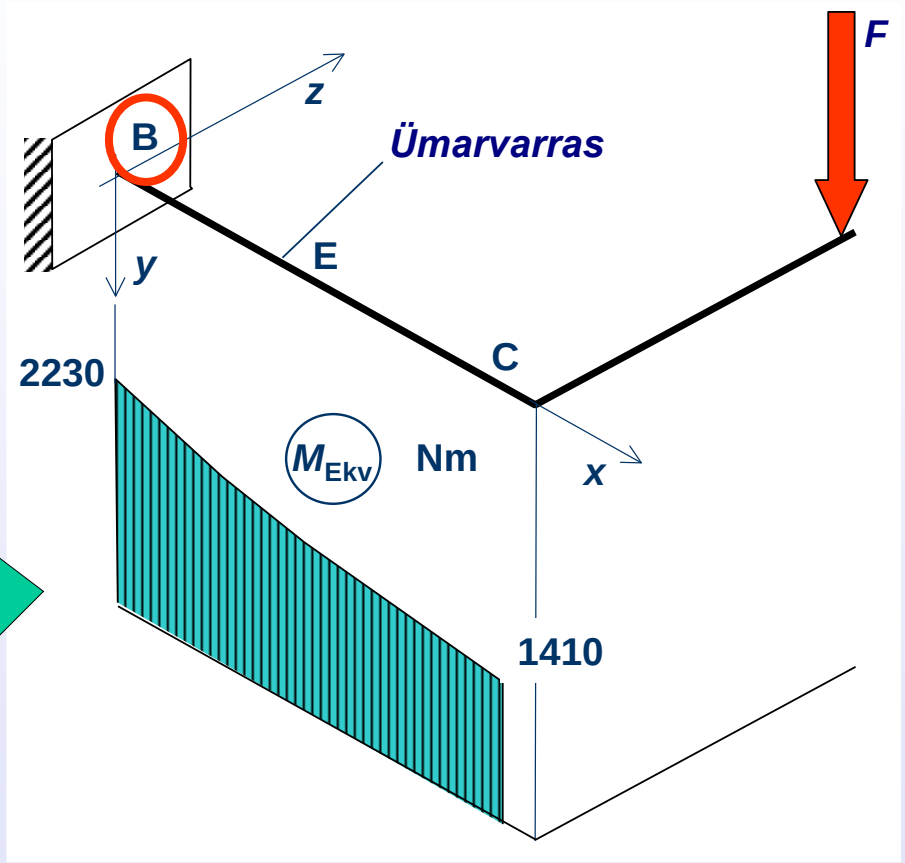
BE = EC ⇨ M_E = 930 Nm

Abipunkt epüüri joonestamiseks



2.5. Ümarvardasisejüudude analüüs





Ühtlase ÜMARvõlli ohtlik ristlõige on B

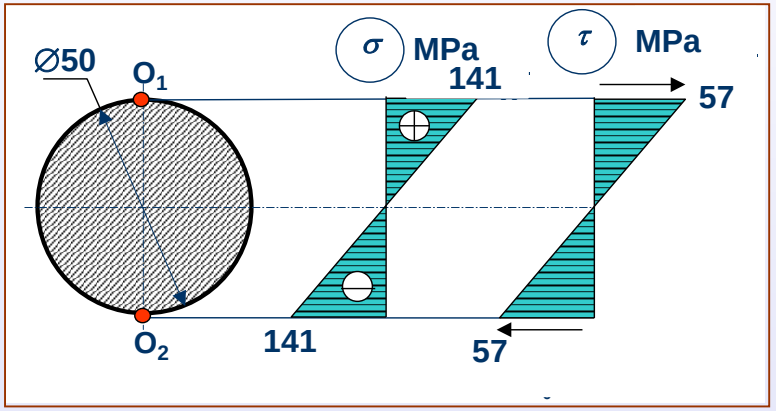
$$M^{III}_{Ekv,\,B} = 2230\ \text{Nm}$$

3. Ümarvarda tugevusarvutus

3.1. Ümarvarda suurimad pinged

Suurim paindepinge ümarvarda ohtlikus lõikes B

$$\sigma_{max} = \frac{M}{W} = \frac{32M}{\pi D^3} = \\ = \frac{32 \cdot 1730}{\pi \cdot 0{,}05^3} = 140{,}9 \cdot 10^6 \text{ Pa} \approx 141 \text{ MPa}$$



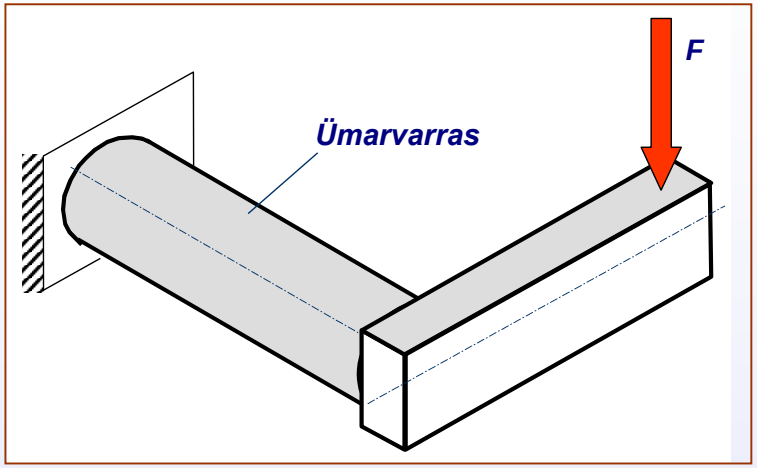
Suurim väändepinge ümarvarda ohtlikus lõikes B

$$\sigma_{max} = \frac{T}{W_0} = \frac{16T}{\pi D^3} = \\ = \frac{16 \cdot 1400}{\pi \cdot 0{,}05^3} = 57{,}04 \cdot 10^6 \text{ Pa} \approx 57{,}0 \text{ MPa}$$

3.2. Ümarvarda tugevusvarutegur

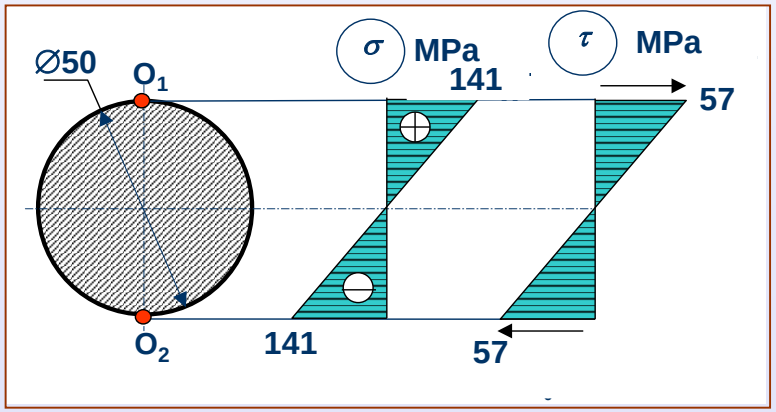
Võrdpinge ümarvarda ohtliku lõike B ohtlikes punktides

$$\sigma_{Ekv} = \frac{M_{Ekv}}{W} = \frac{32M_{Ekv}}{\pi D^3} =$$
$$= \frac{32 \cdot 2230}{\pi \cdot 0{,}05^3} = 181{,}7 \cdot 10^6 \text{ Pa} \approx 182 \text{ MPa}$$



Ümarvarda vähim tugevusvarutegur

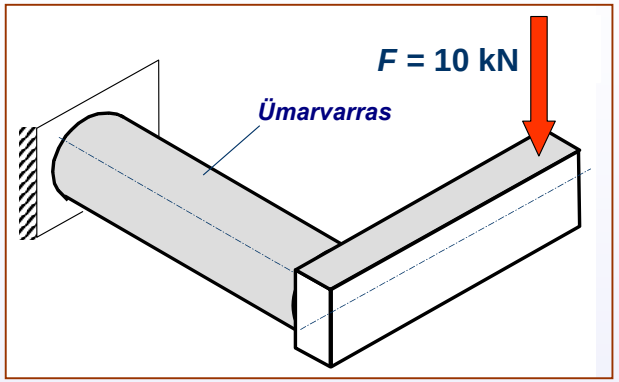
$$S = \frac{\sigma_y}{\sigma_{Max}} = \frac{355}{182} = 1{,}95 \approx 1{,}9 < [S] = 3$$

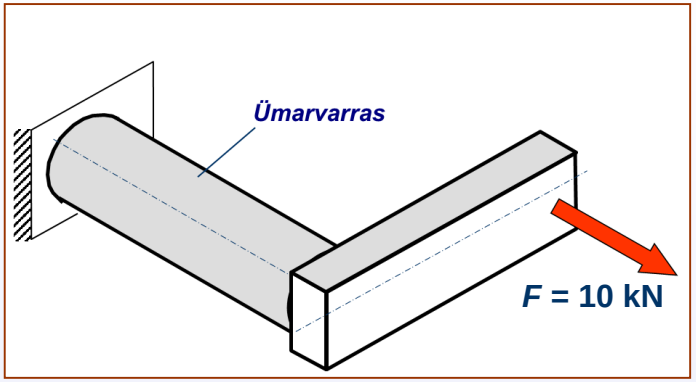


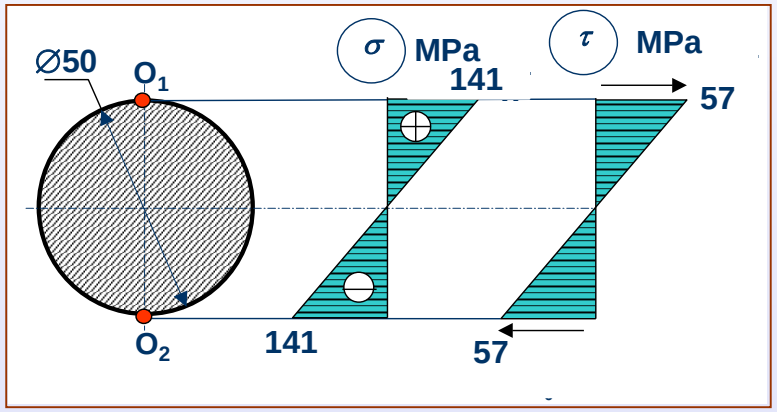
Ümarvarda ∅50 tugevus EI OLE piisav

Konstruktsiooni või koormusseisundit tuleb muuta või valida tugevam materjal

3.3. Tulemuste võrdlus

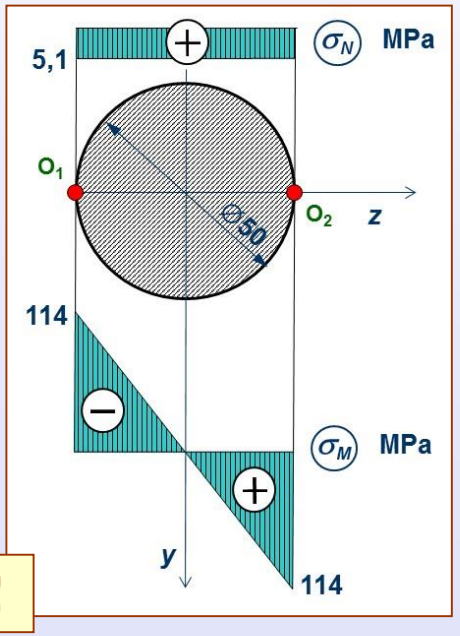






$S = 1{,}9$

$S = 2{,}9$



Tarindi tugevusvaru sõltub koormusskeemist!!!