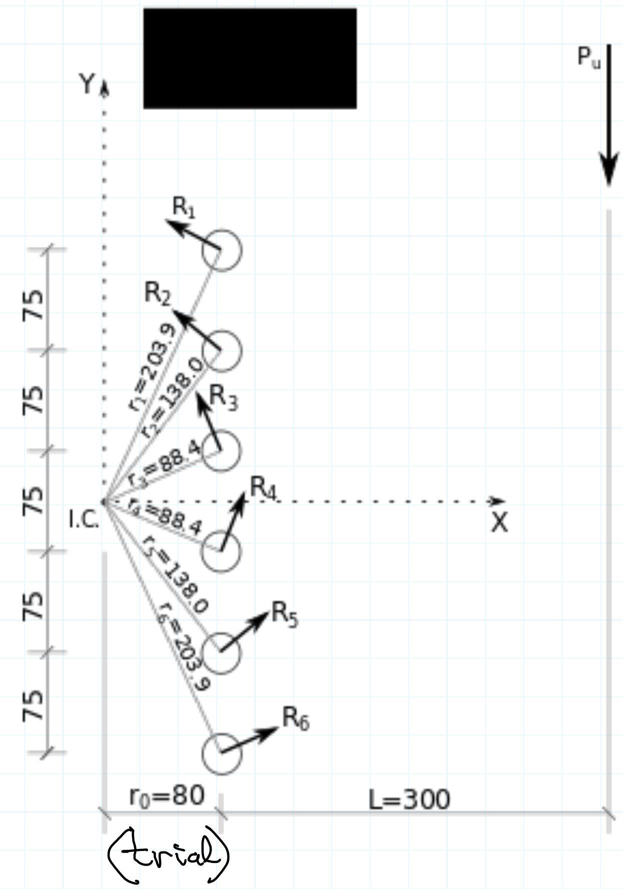
Example ECCENT-1

Determine the ultimate resistance of the following 6-bolt eccentrically load connection. Use the established theory and method, not the design tables in the handbook.



Bolts are $\frac{3}{4}''$ A325 in double shear, threads excluded from the shear plane.

$$A_b = \left(\frac{3}{4} \times 25.4\right)^2 \times \frac{\pi}{4}$$

$$= 285 \text{ mm}^2$$

Ult shear force in 1 bolt:

$$R_v = 0.6 \times 285 \text{ mm}^2 \times 2 \times 825 \text{ MPa}$$

$$R_v = 282 \text{ kN} \quad \text{(per bolt)}$$

The shear force, R, in a bolt as a function of its shear displacement, Δ, is

$$R = R_v \left(1 - e^{-\mu \Delta}\right)^{\lambda}$$

For these bolts, $\mu = 0.4$ (for Δ in mm) and $\lambda = 0.55$ and $\Delta_{max} = 8.64$ mm

The above figure shows a trial value of $r_o = 80$ mm chosen.

Show the complete set of calculations for R_2 (2nd bolt down from top).

Distance from I.C.:

$$x = 80 \text{ mm}$$

$$y = 1.5 \times 75 \text{ mm} = 112.5 \text{ mm}$$

$$r_2 = \sqrt{80^2 + 112.5^2} = 138.0 \text{ mm}$$

Dist. of furthest bolt from I.C.

$$r_1 = \sqrt{80^2 + 187.5^2} = 203.9\text{ mm}$$

Shear displacement, bolt 2

$$\Delta_2 = \frac{138.0}{203.9} \times 8.64\text{mm} = 5.848\text{ mm}$$

Shear force, bolt 2

$$R_2 = 282\left(1 - e^{-0.4 \times 5.848}\right)^{0.55}$$

$$= 266.7\text{ kN}$$

Moment about I.C.

$$= 266.7\text{ kN} \times 0.138\text{ m}$$

$$= 36.81\text{ kN-m}$$

Vertical component

$$(R_2)_y = \frac{80}{138.0} \times 266.7\text{ kN}$$

$$= 154.6\text{ kN}$$

Show all 6 bolts in tabular form:

i	x mm	y mm	r mm	Δ mm	R kN	$R_i r_i$ kN-m	$(R_i)_y$ kN
1	80	187.5	203.9	8.640	277.1	56.50	108.7
2	80	112.5	138.0	5.848	266.7	36.81	154.6
3	80	37.5	88.4	3.745	245.4	21.69	222.1
4	80	-37.5	88.4	3.745	245.4	21.69	222.1
5	80	-112.5	138.0	5.848	266.7	36.81	154.6
6	80	-187.5	203.9	8.640	277.1	56.50	108.7
					Σ	230.00	970.8

Using moment equilibrium $\Sigma M_{IC} = 0$

$$-P_u(L + r_o) + \Sigma R_i r_i = 0$$

$$P_u = \frac{\Sigma R_i r_i}{L + r_o}$$

$$= \frac{230.0 \times 10^3\text{ kN}\cdot\text{mm}}{(300 + 80)\text{ mm}}$$

$$P_u = 605.3\text{ kN}$$

Using vertical equilibrium $\Sigma F_y = 0$ to check

$$(\Sigma R_i)_y - P_u$$

$$970.8 - 605.3 = 365.5 \neq 0 \, !$$

Equilibrium not satisfied

$\therefore$ Posn of I.C. (r_o) is not correct

I.C. must be moved to reduce $\Sigma (R_i)_y$

(i.e. r_o should be decreased)

After many trials, we find

$r_o = 36.4$ mm

$\Sigma R_i r_i = 190.6$ kN-m

$P_u = 567$ kN

$\Sigma (R_i)_y = 567$ kN   O.K. !