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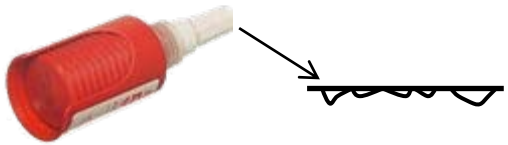
METAL TO METAL FLANGES LEAKAGE ANALYSIS

L. Bertini, M. Beghini, C. Santus
University of Pisa (Mechanical Department) – Italy

G. Mariotti
General Electrics, Oil & Gas, Firenze – Italy

Metal-to-metal flanges

Centrifugal compressor



Silicone sealant

Gasketless flange

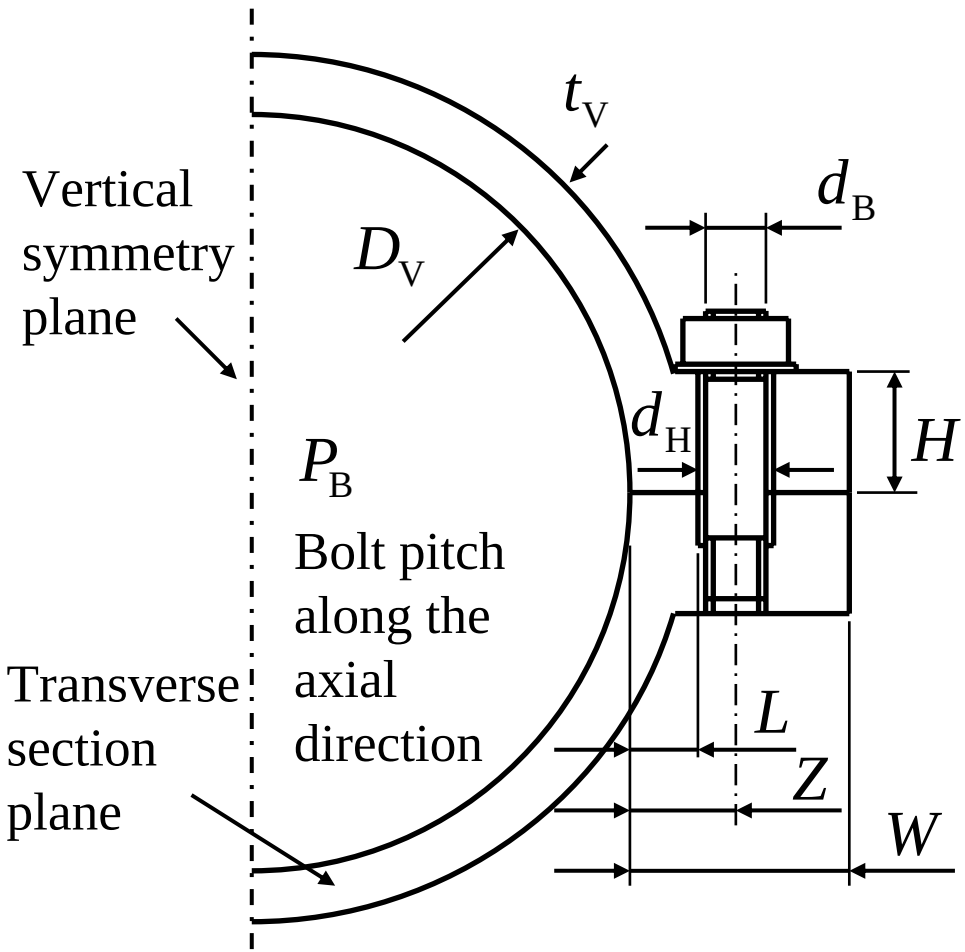
Aim of the paper:

- **Analytical model for the Leakage pressure (fracture mechanics)**

Validations:

- **FE validation**
- **Experimental full scale**
- **Experimental small scale**

Flange geometry



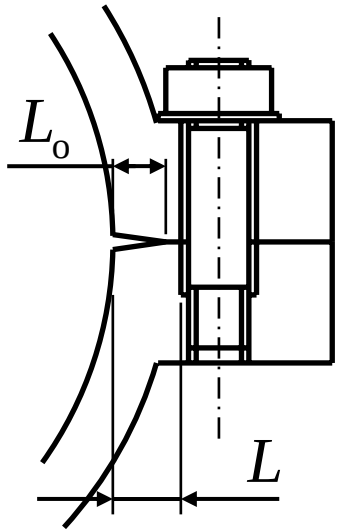
Leakage

No leak.:

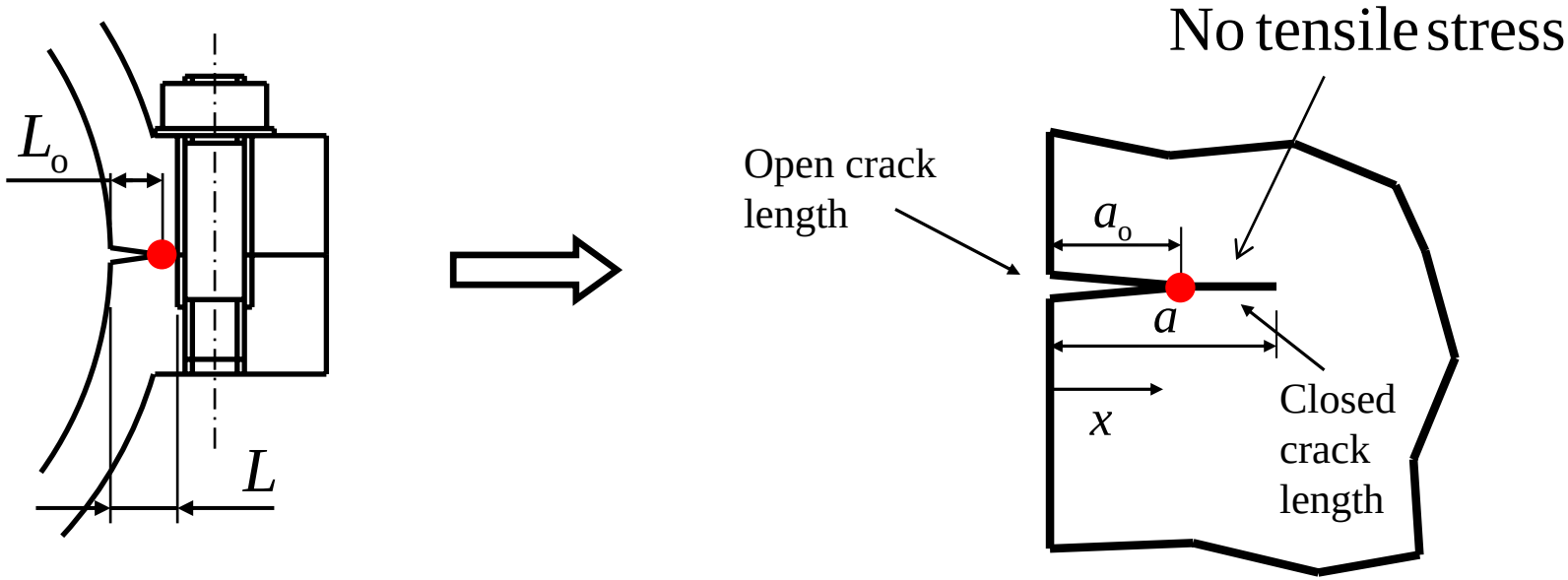
$L_o < L,$

Leakage:

$L_o = L$



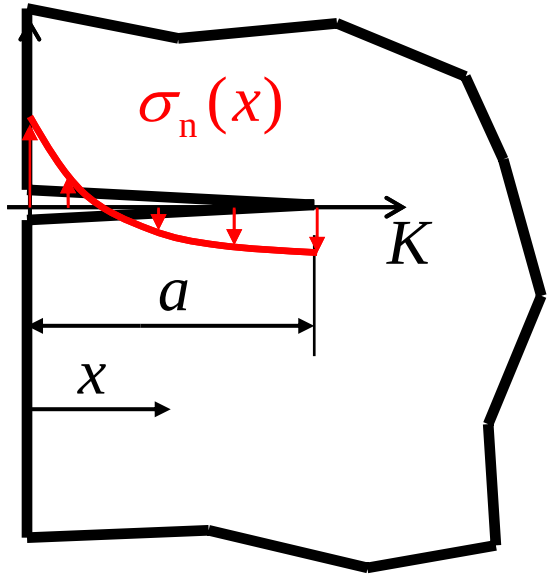
Flange open front as a partially open crack



Partially open crack : NO Stress Intensity Factor

$K = 0$

Weight functions



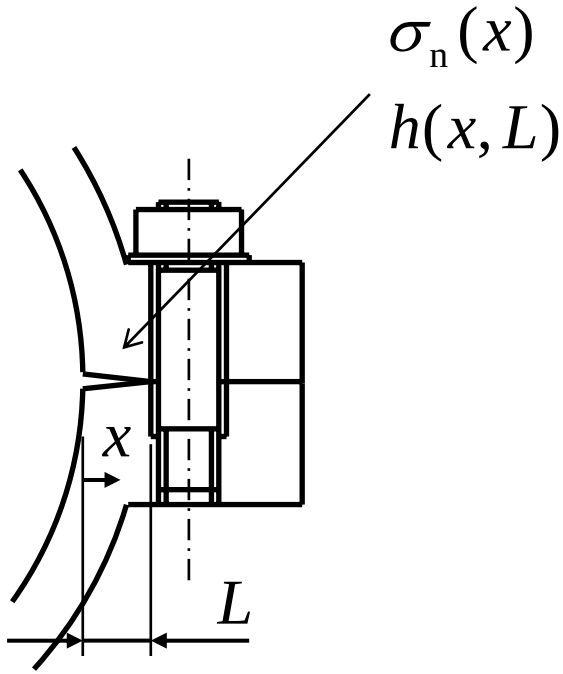
"Nominal"

stress distribution

Weight function

$$K = \int_0^{a_0} \sigma_n(x)\, h(x, a_0)\, \mathrm{d}x$$

Application to the flange geometry



$\sigma_n(x) = ?$

$h(x,L) = ?$

Leakage condition:

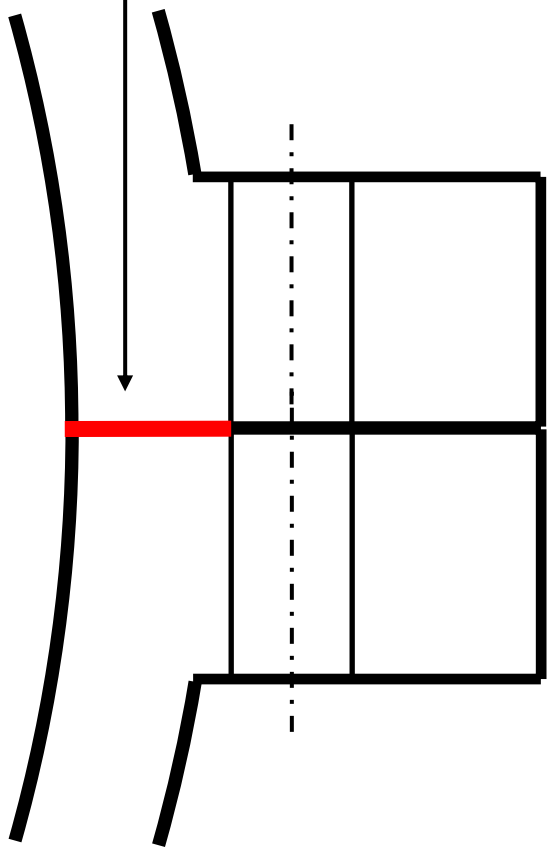
$K = 0, \quad L_0 = L$

$$\int_0^L \sigma_n(x)\, h(x,L)\, \mathrm{d}x = 0$$

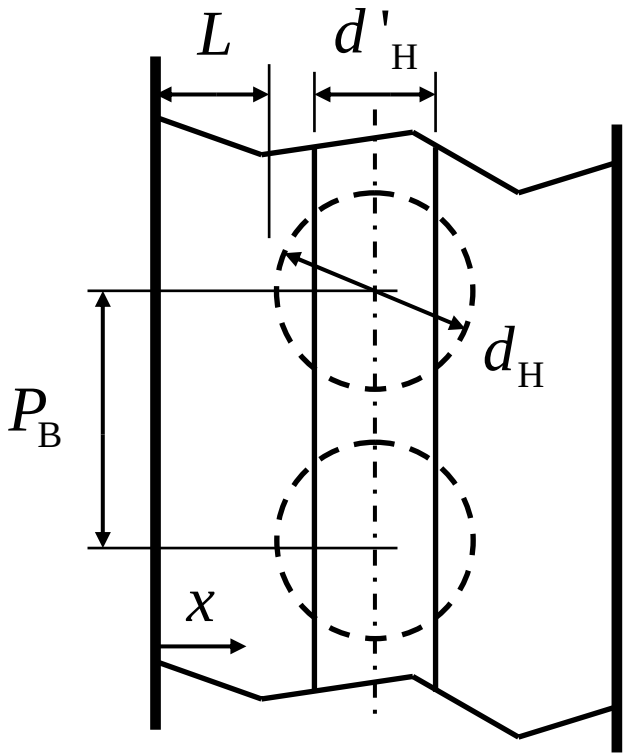
Nominal stress components

$$\sigma_{\mathrm{n}}(x) = \sigma_{\mathrm{n},p}(x) + \text{(Internal pressure)}$$

$$\sigma_{\mathrm{n,B}}(x) \quad \text{(Bolt preload)}$$

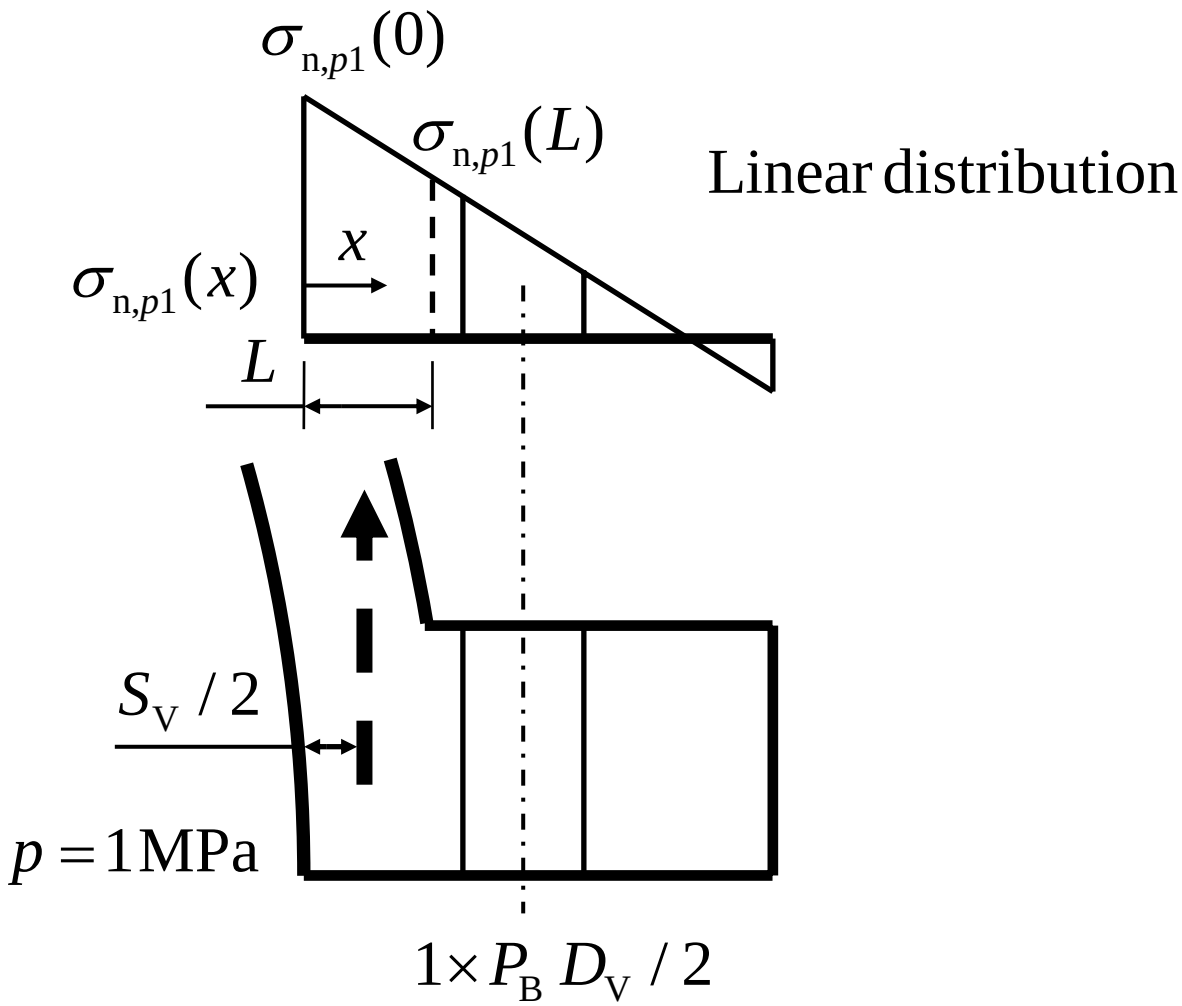


Approximations

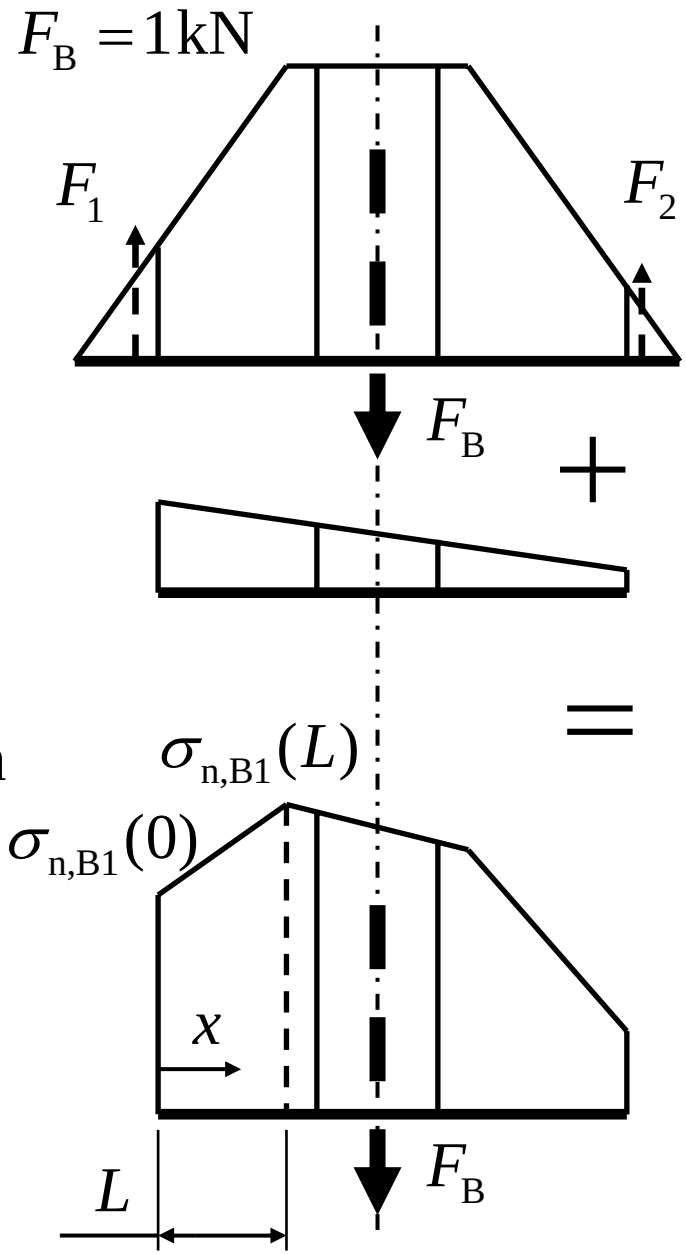


Plane scheme

Internal pressure nominal stress (tensile)



Bolt preload nominal stress (compressive)



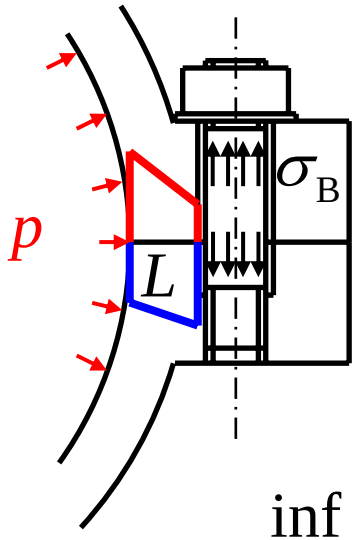
Bolt pressure distribution, larger than the flange surface

Press. distr. equivalent to: F_1, F_2

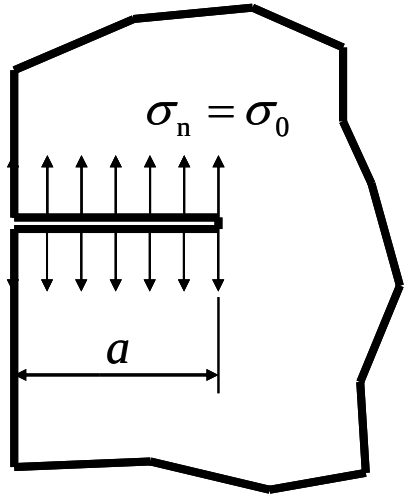
Linear distribution

Bolt pressure actual distribution

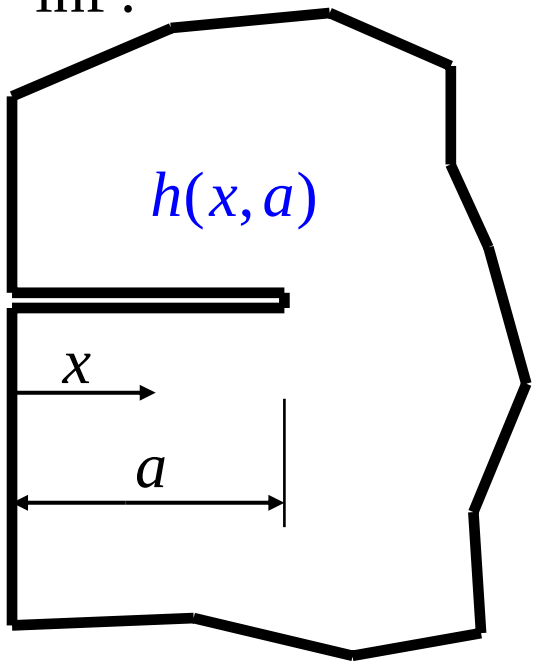
Half space crack weight function



$$K_0 = 1.1215\,\sigma_0\sqrt{\pi a}$$



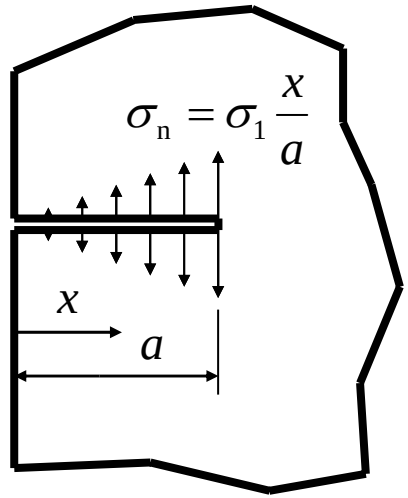
inf .



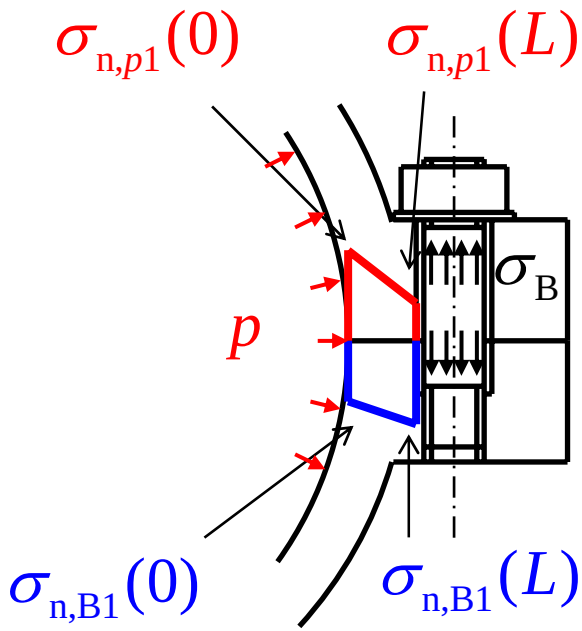
inf .

inf .

$$K_1 = 0.6820\,\sigma_1\sqrt{\pi a}$$

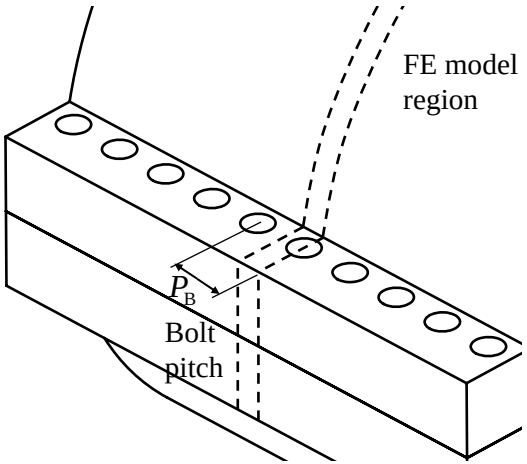


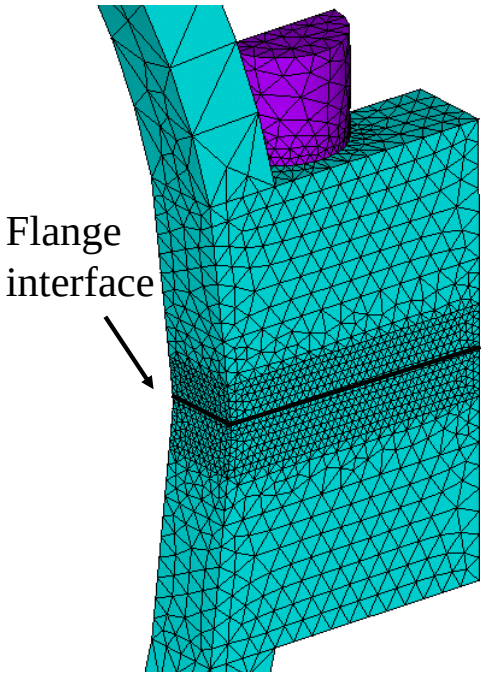
Leakage pressure model

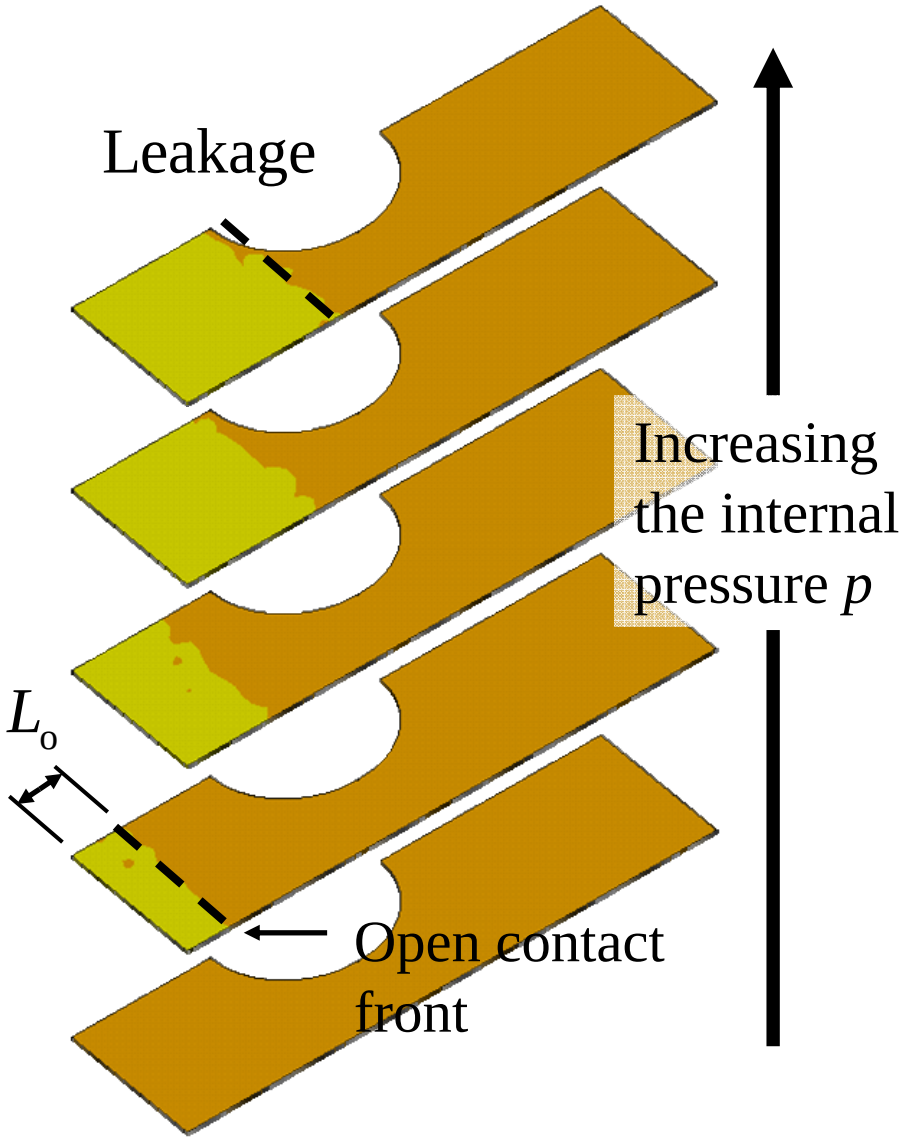


$$p_{\mathrm{L}} = -\sigma_{\mathrm{B}} \frac{\sigma_{\mathrm{n,B1}}(0) + 1.55\,\sigma_{\mathrm{n,B1}}(L)}{\sigma_{\mathrm{n},p1}(0) + 1.55\,\sigma_{\mathrm{n},p1}(L)}$$

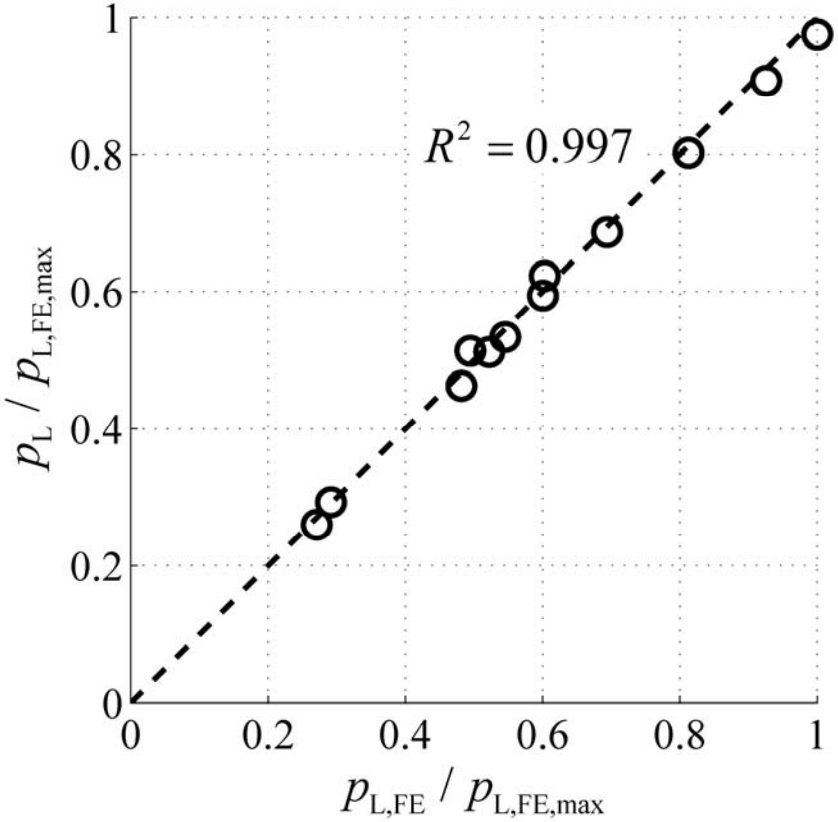
FE validation



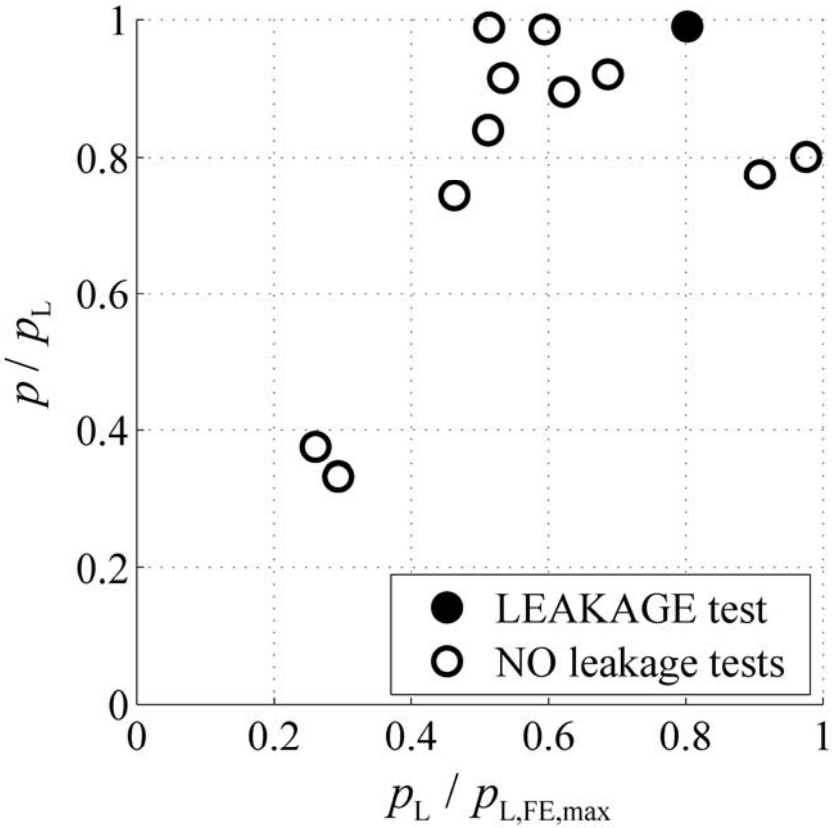




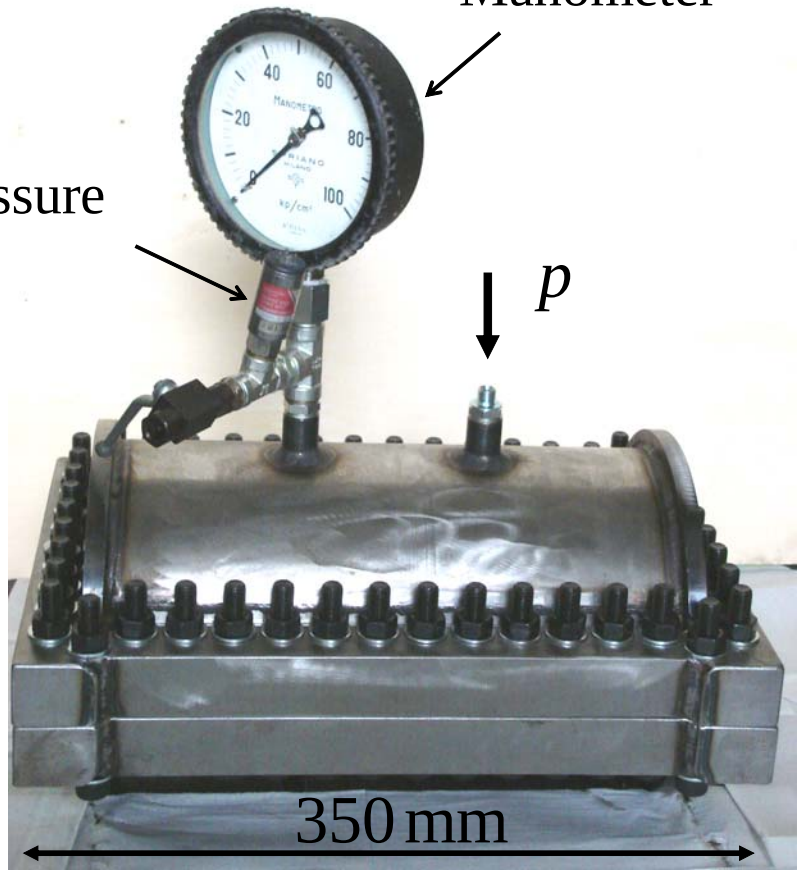
FE validation

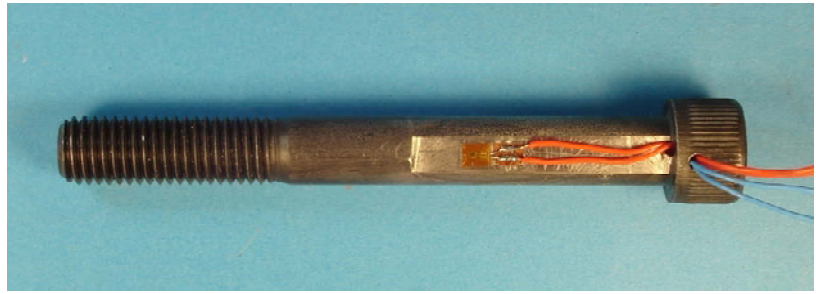


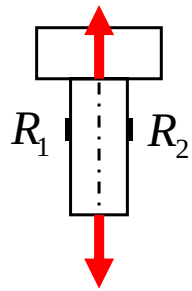
Experimental *full* scale validation

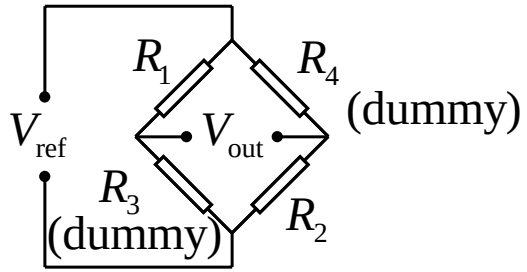


Experimental *small* scale validation









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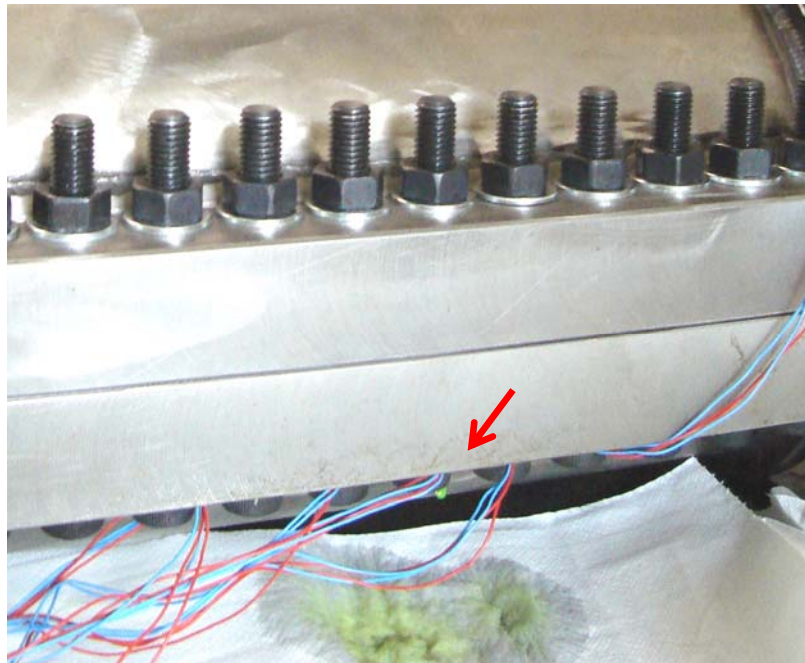


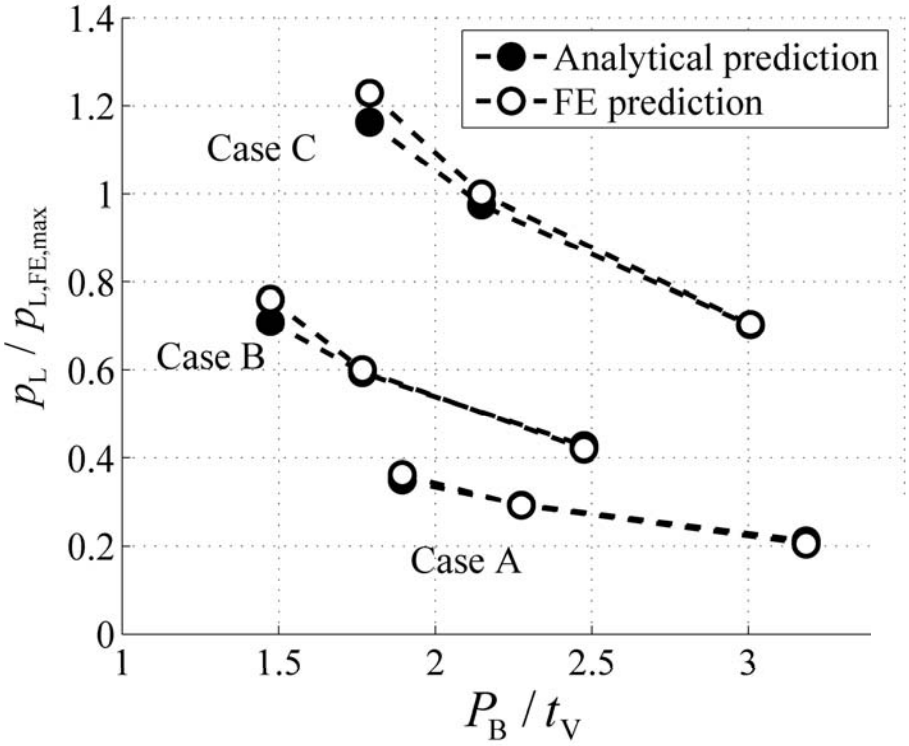
Small scale validation

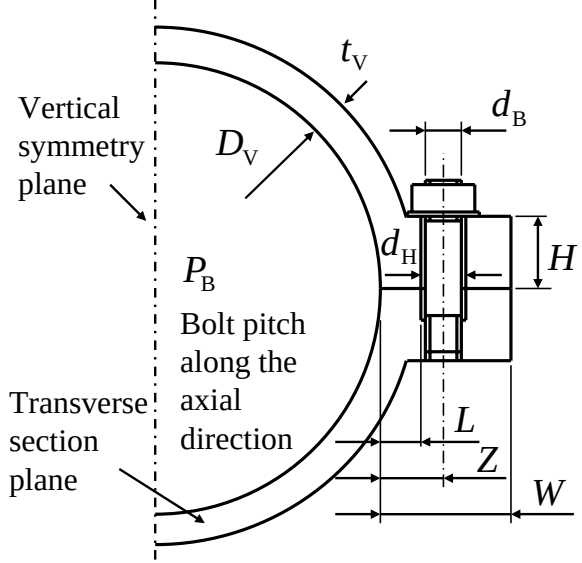
Preliminary results

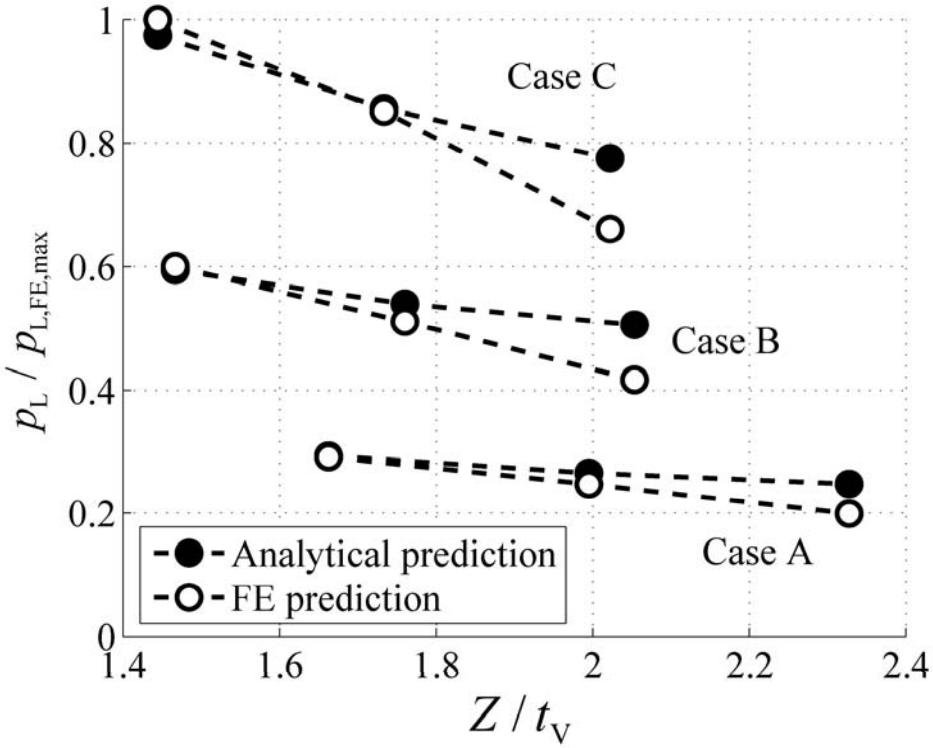
Test	**Bolt preload** [kN]	**Leakage* pressure *experimental*** [bar]	**Leakage pressure *model*** [bar]	**Percentage difference**
1	30.7	63	59	6 %
2	20.2	41	41	< 1 %
3	20.1	43	41	6 %
4	20.4	41	41	< 1 %
5	30.5	57	61	7 %

*** Leakage rate > 15×10^{-3} g/sec**

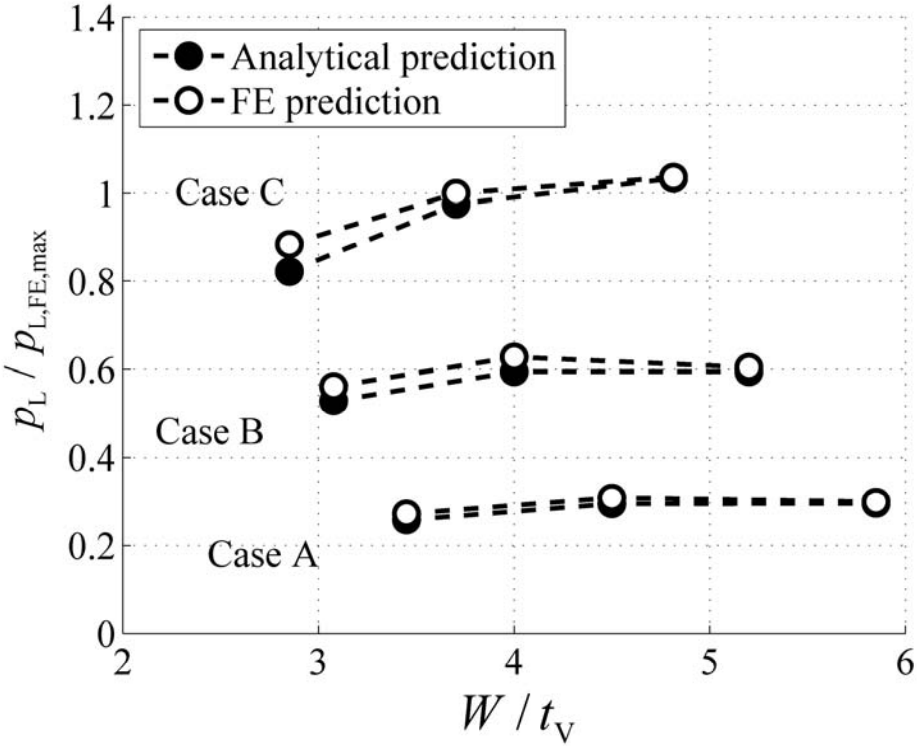
Design guidelines

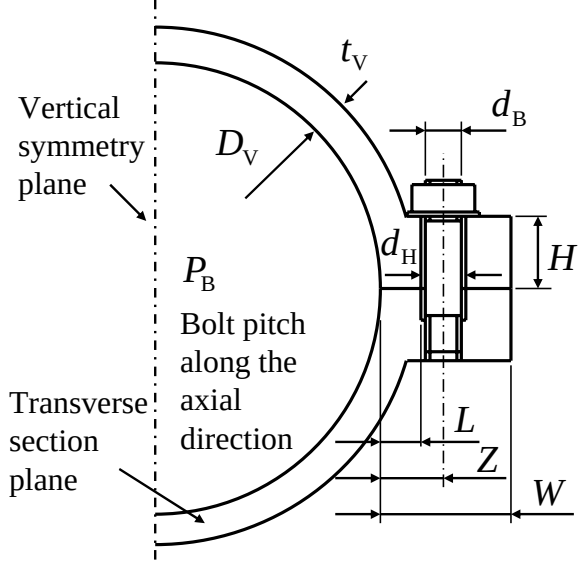


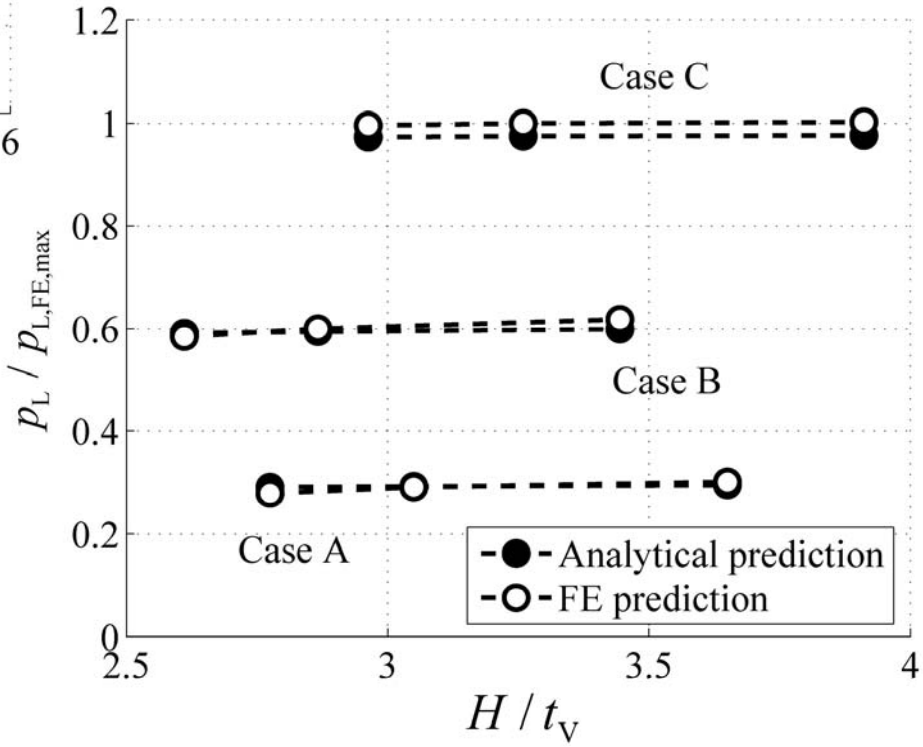




Design guidelines







Conclusions

- Leakage pressure analytical model
- Partially open crack, zero stress intensity factor
- Open front position validation with FE model
- Complete validation of the predicted leakage pressure through Full and Small scale tests
- Design tool to optimize the flange geometry and maximize the Leakage pressure