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University
of Science
and Technology

INVESTIGATION OF THE COLD PROCESS PIPE RUPTURE MECHANISM

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OVERVIEW

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STUDIES MOTIVATION

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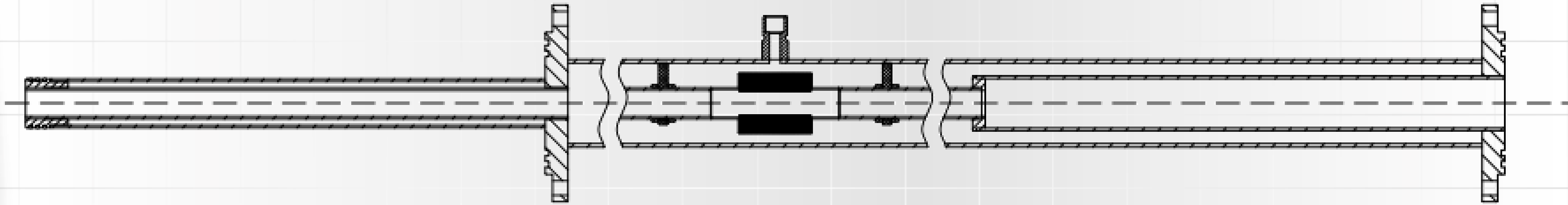

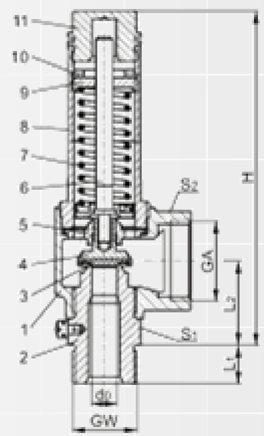

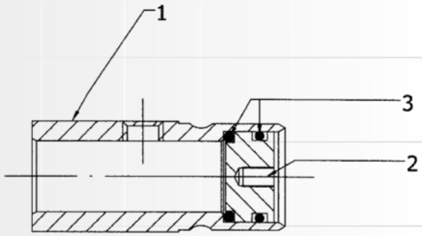

EN ISO 4126-1:2007 Safety devices for protection against excessive pressure - Part 1: Safety valves

$$\dot{m} = 0.2883 \cdot C \cdot K_{dr} \cdot K_b \cdot \sqrt{\frac{p_0}{v}}$$

$$C = 3.984\sqrt{\kappa\left(\frac{2}{\kappa+1}\right)^{\frac{\kappa+1}{\kappa-1}}}$$

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_o}\right)^{2/k} - \left(\frac{p_b}{p_o}\right)^{(k+1)/k}\right]}{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}}$$

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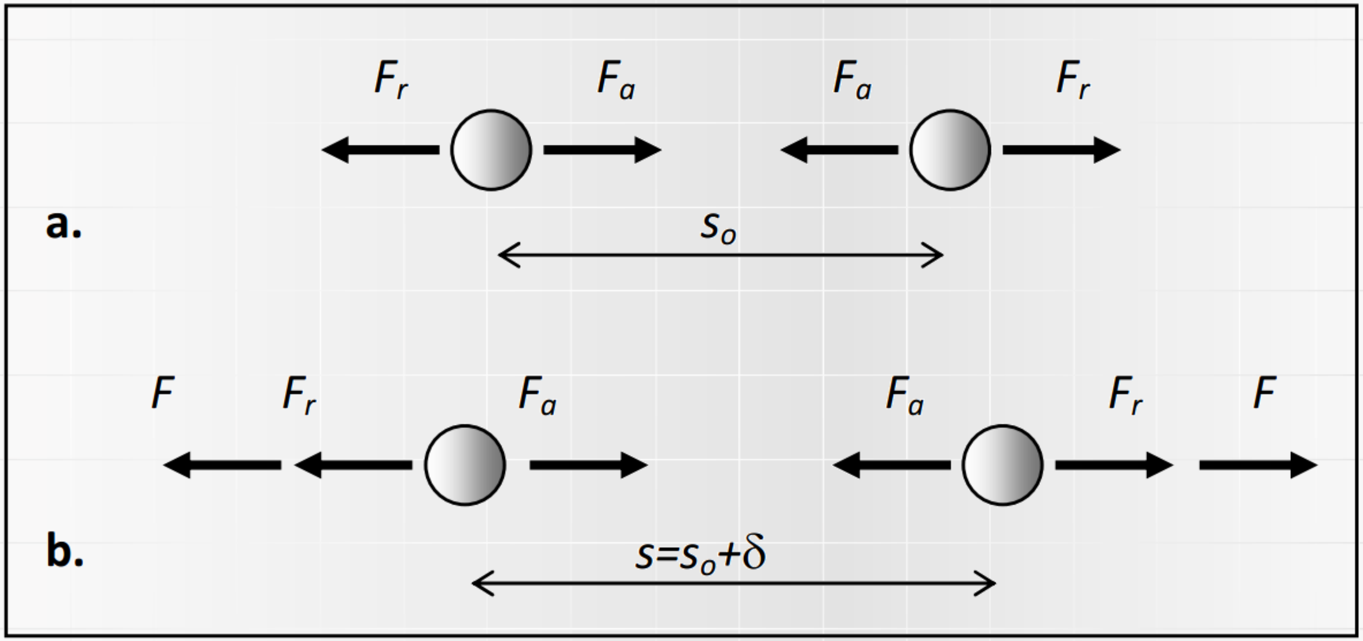
ACTION PLAN

1. Literature study and review paper (February 2017)
2. Development of numerical model for process pipes rupture at cryo temperatures - simulations (June 2017)
3. Construction of test stand (October 2017)
4. Experimental confirmation (and correction) of the simulations (February 2018)
5. Proposal of new method of safety valves selection (or correction factor) for vacuum shells (October 2018)

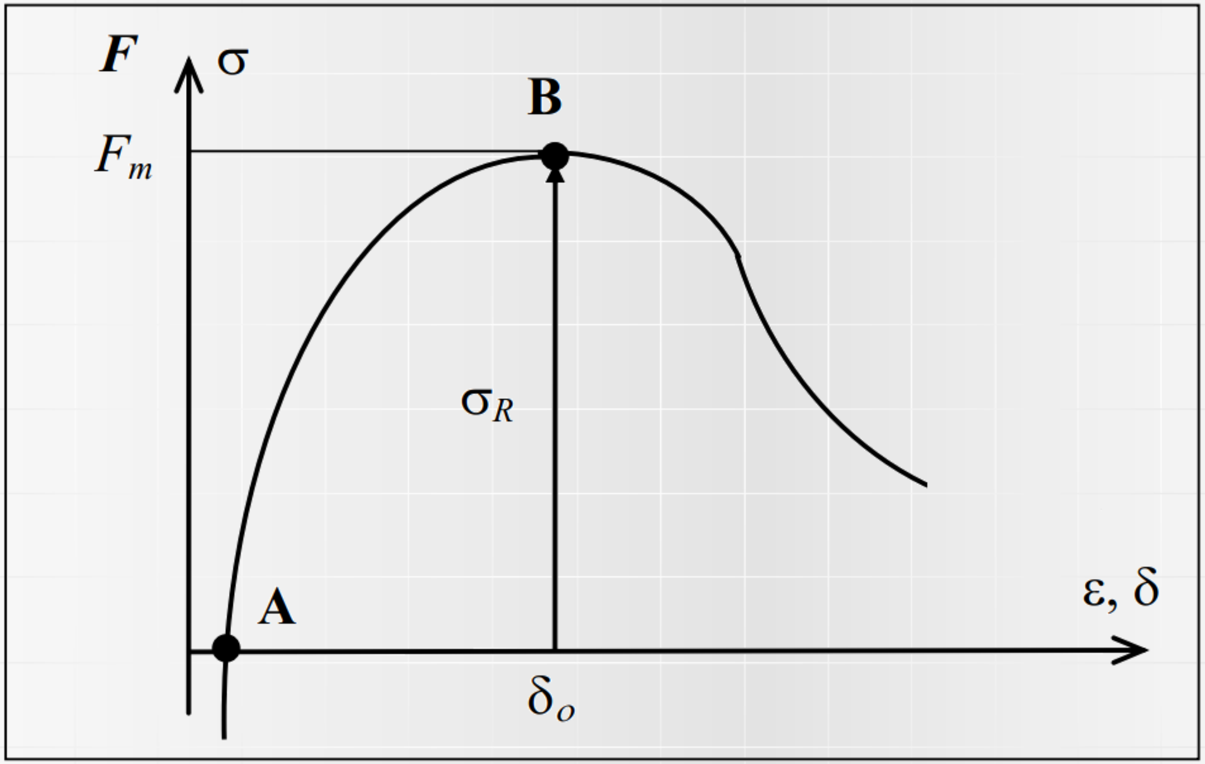
PRINCIPLES OF MATERIAL CRACKING



$$F_a = \frac{C_a}{s^n} \qquad F_r = \frac{C_r}{s^m}$$

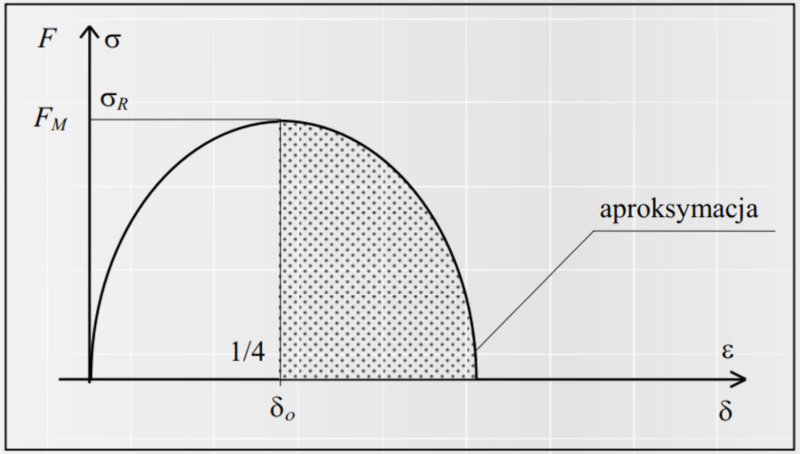
$$F = \frac{C_a}{s_o^n}\left[\left(1+\frac{\delta}{s_o}\right)^{-n} - \left(1+\frac{\delta}{s_o}\right)^{-m}\right]$$

PRINCIPLES OF MATERIAL CRACKING



$$F_{\max} = \frac{C_a}{s_o^n}\left[\left(\frac{m}{n}\right)^{\frac{-n}{m-n}} - \left(\frac{m}{n}\right)^{\frac{-m}{m-n}}\right]$$

PRINCIPLES OF MATERIAL CRACKING



$$E = \left.\frac{d\sigma}{d\varepsilon}\right|_{\varepsilon=0} = 2\pi\sigma_R \cos 2\pi\varepsilon\Big|_{\varepsilon=0} = 2\pi\sigma_R$$

$$\sigma_R = \frac{E}{2\pi}$$

In real materials:

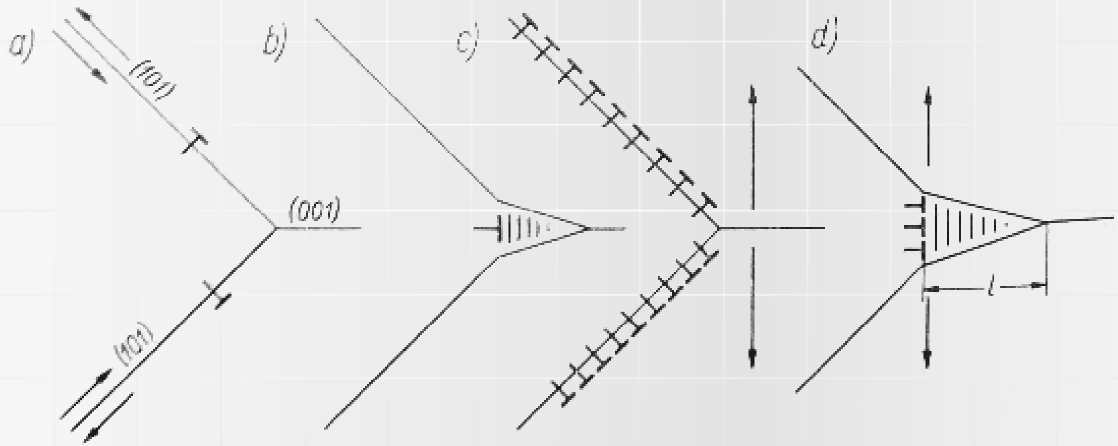
$$\sigma_R \cong 0.001 \div 0.01E$$

PRINCIPLES OF MATERIAL CRACKING

Reducing the strength of the material with respect to the theoretical strength is linked with the presence - in fact unavoidable - two types of defects:

1. Geometrical stress contentrators – sharp gaps and notches
2. Stress concentrators in the form of dislocations

Cotrell mechanizm



TEST STAND

Questions:

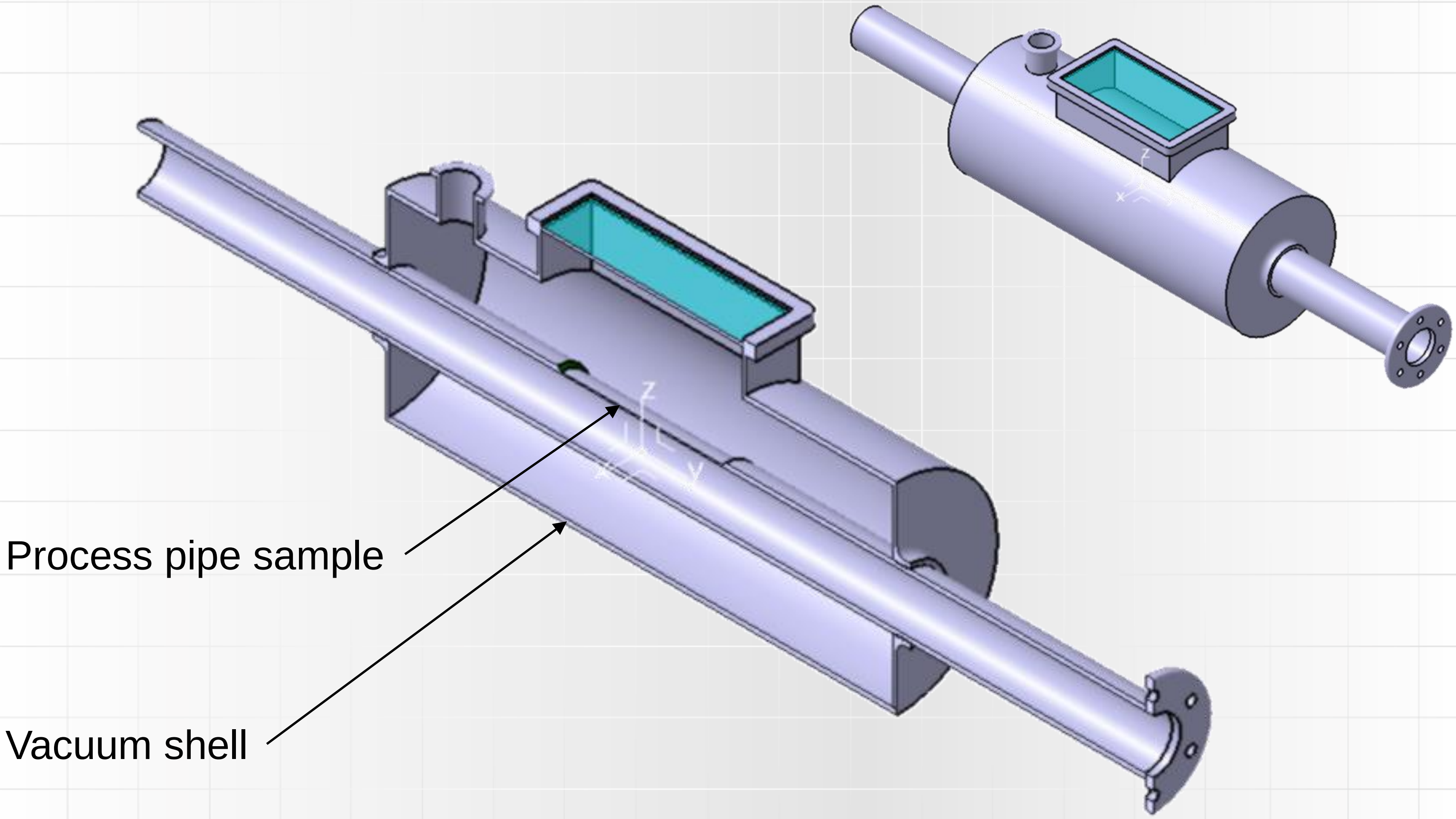
1. How low temperature impacts on the rupture „hydraulic diameter”?
2. How low temperature impacts on the cracking propagation?
3. How low temperature impacts on stress concetrators?
4. How related processes (e.g. degassing of the solids in vacuum) impacts on material strenght.

TEST STAND

To measure:

1. Temperature at gas pipe surfaces.
2. Cryogen pressure.
3. Vacuum level.
4. Rupture propagation in time.

TEST STAND



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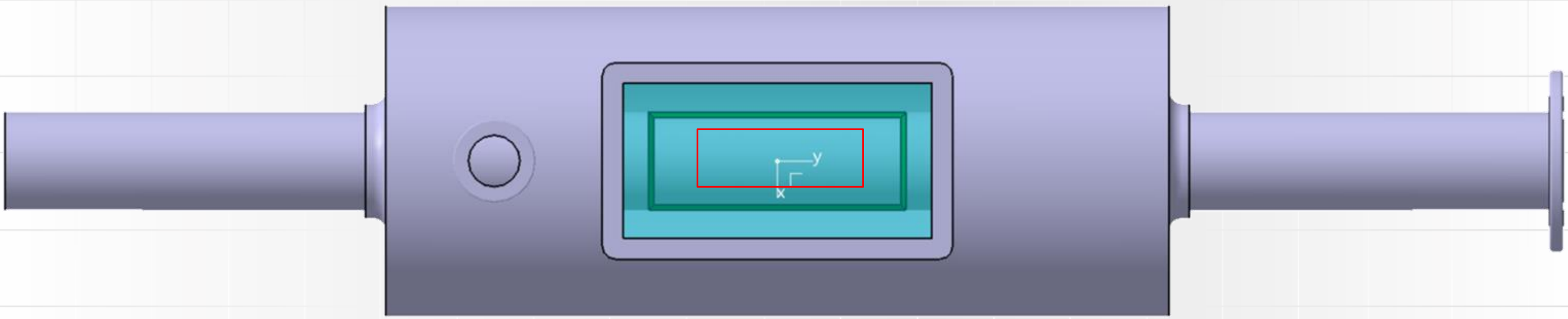
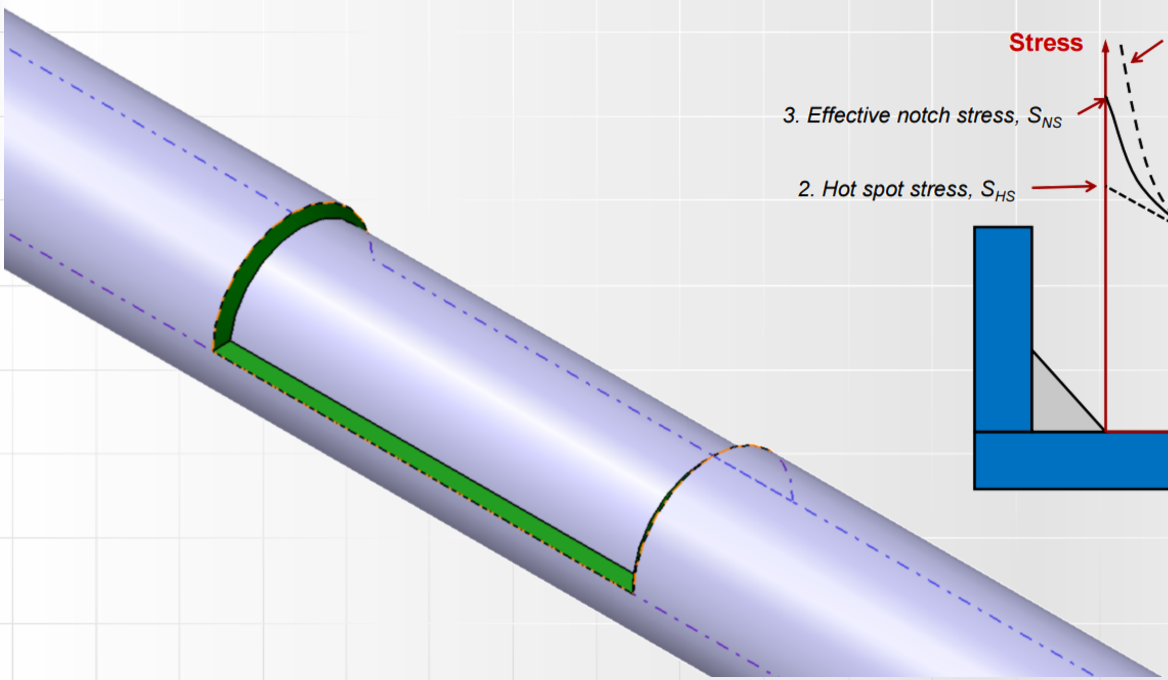
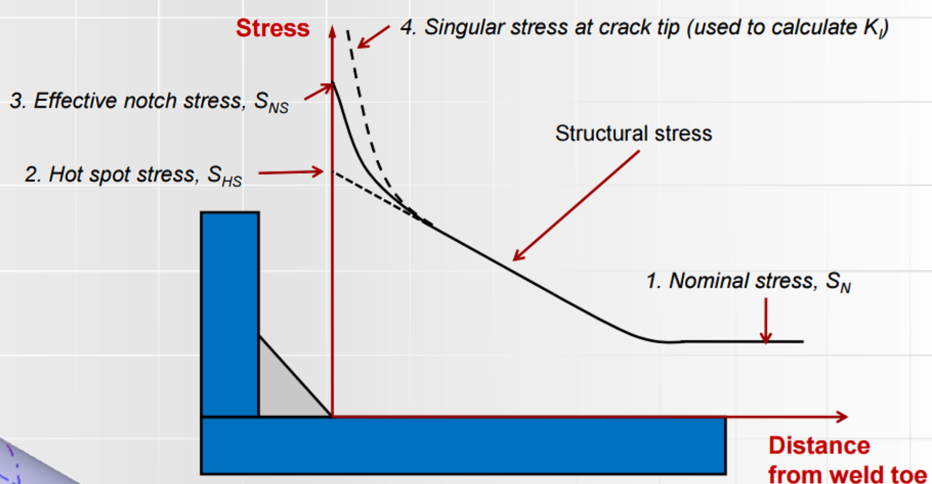
TEST STAND







CONCLUSIONS

1. There is a need for mathematical or numerical model of pipes cracking in cryogenics conditions
2. Model should be confirmed with experimental data
3. There is possibility to optimize vacuum shell safety devices selection procedure with correction factors
4. We have a lot of work to do and we are be grateful for any input or comments!

THANK YOU.

Literature:

1. German J., Podstawy Mechaniki Pękania, Politechnika Krakowska, 2011

2. Gdoutos E., Fracture Mechanics, An introduction, Kluwer Academic Publishers, 1991

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