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MODELS OF CONTINUUM DAMAGE MECHANICS APPLICABLE IN CRYOGENIC CONDITIONS

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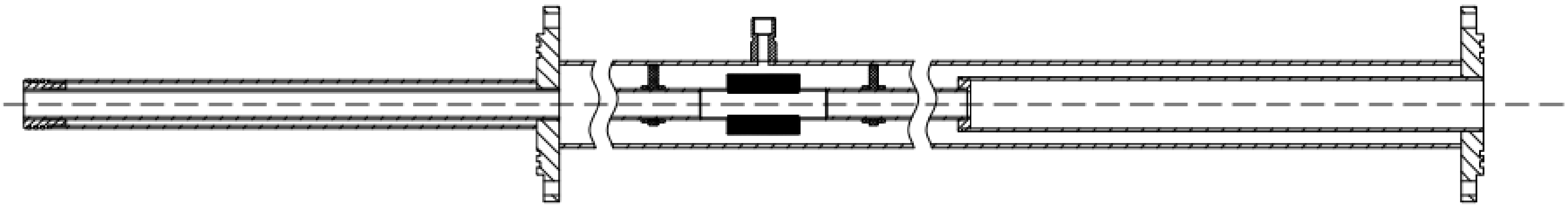
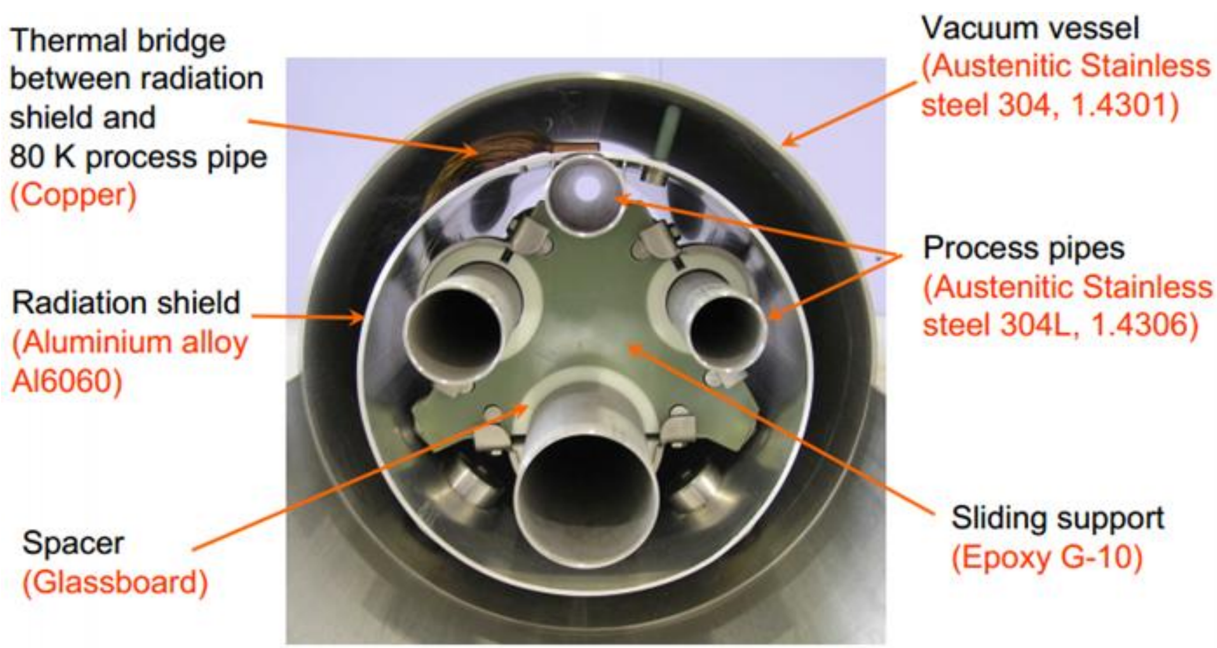
CONTINUUM DAMAGE MECHANICS





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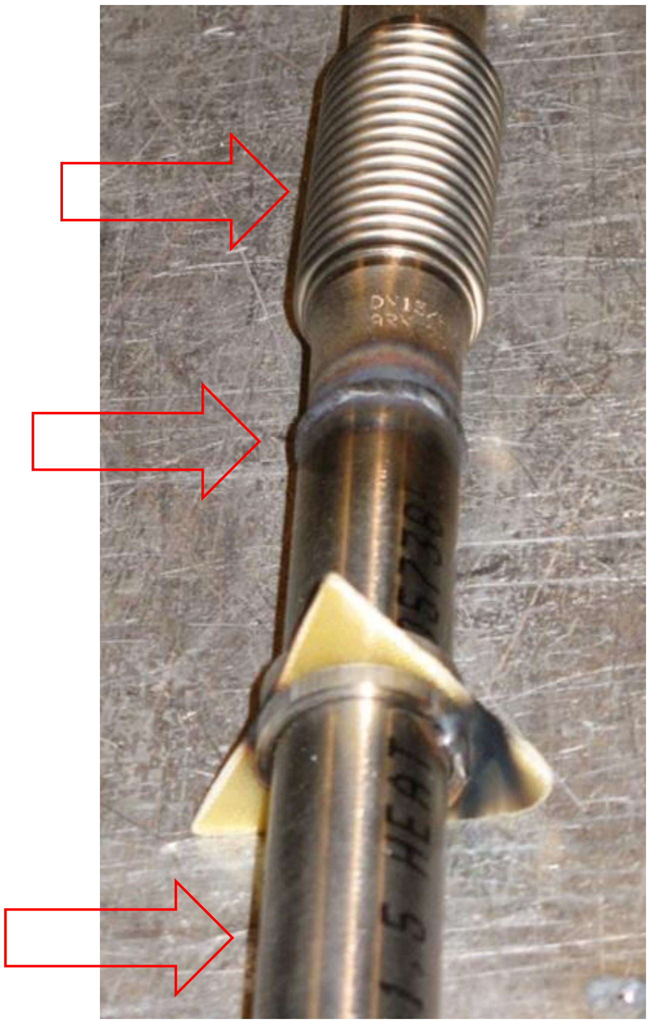
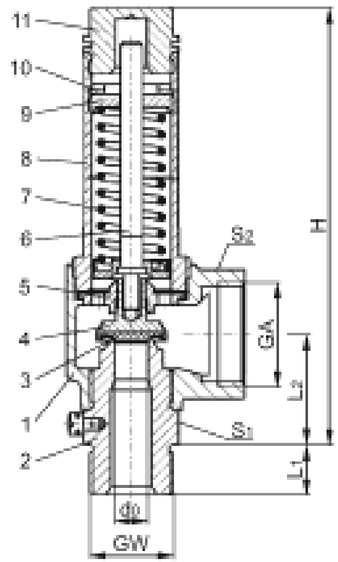


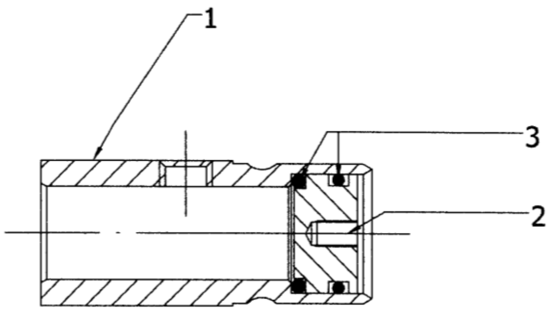
Table 1. Probabilities of defect occurrence (failure rates) of the most common defects

Defect	Failure rate	Source
Cold weld rupture	$2.53 \cdot 10^{-7}$ $m^{-1} \cdot year^{-1}$	1
Cold pipe leakage	$4.61 \cdot 10^{-6}$ $m^{-1} \cdot year^{-1}$	2
Cold pipe rupture	$4.54 \cdot 10^{-7}$ $m^{-1} \cdot year^{-1}$	2
Cold bellows rupture	$8.76 \cdot 10^{-5}$ $year^{-1}$	3
Vacuum jacket rupture	$8.77 \cdot 10^{-3}$ $year^{-1}$	4
Capilary break	$2.0 \cdot 10^{-8}$ $year^{-1}$	5

CONTINUUM DAMAGE MECHANICS

Dobór zaworów bezpieczeństwa





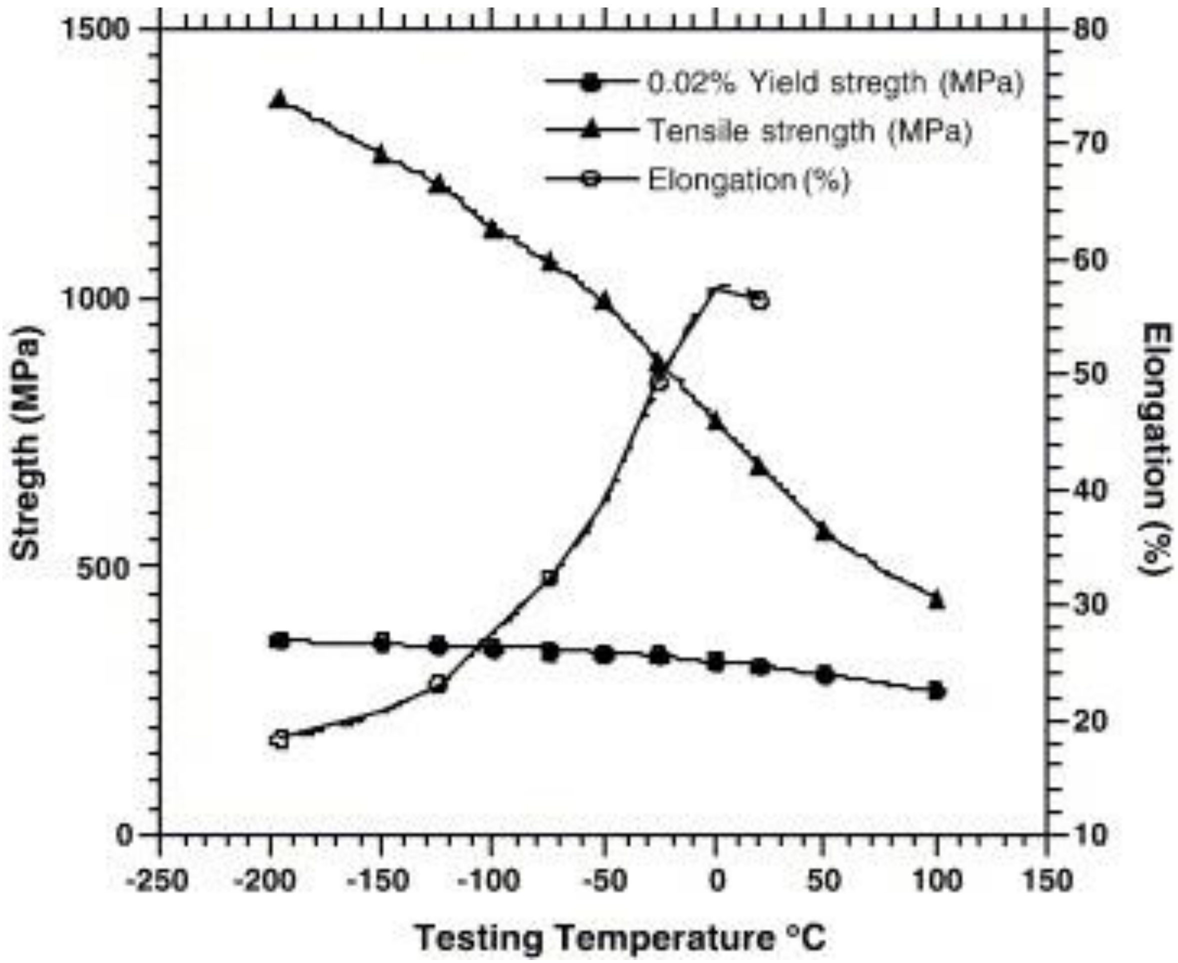
EN ISO 4126-1:2007 Safety devices for protection against excessive pressure - Part 1: Safety valves

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

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

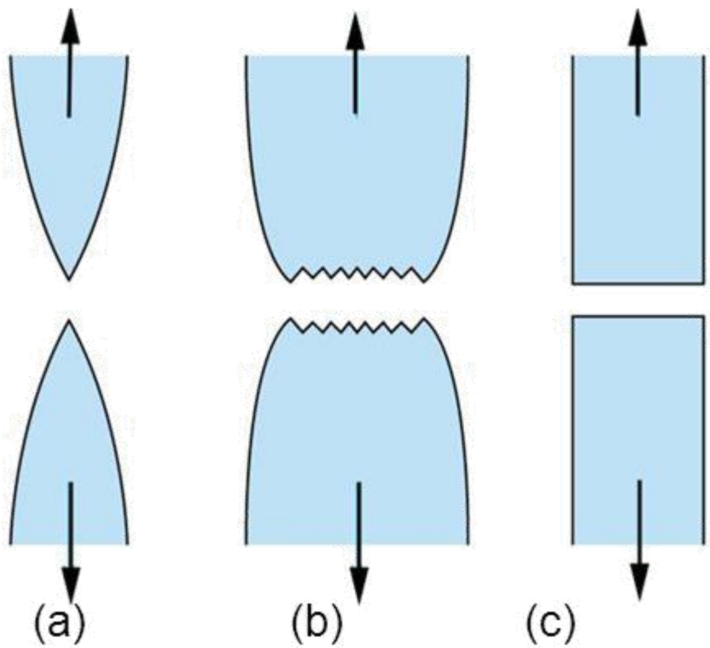
$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_o}\right)^{2/k} - \left(\frac{p_b}{p_o}\right)^{(k+1)/k}\right]}{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}}$$

CONTINUUM DAMAGE MECHANICS



CONTINUUM DAMAGE MECHANICS

Continuum Damage Mechanics (CDM) falls within the group of inelastic materials, and deals with materials that undergo structural weakening as a result of microcrack formation (brittle damage) or of void growth and coalescence (ductile damage)



Ductile: warning before fracture

Brittle: No warning

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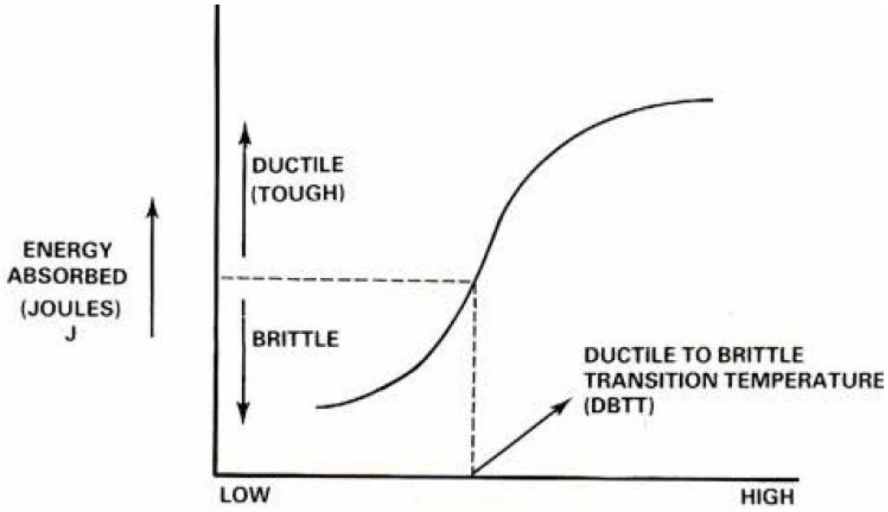
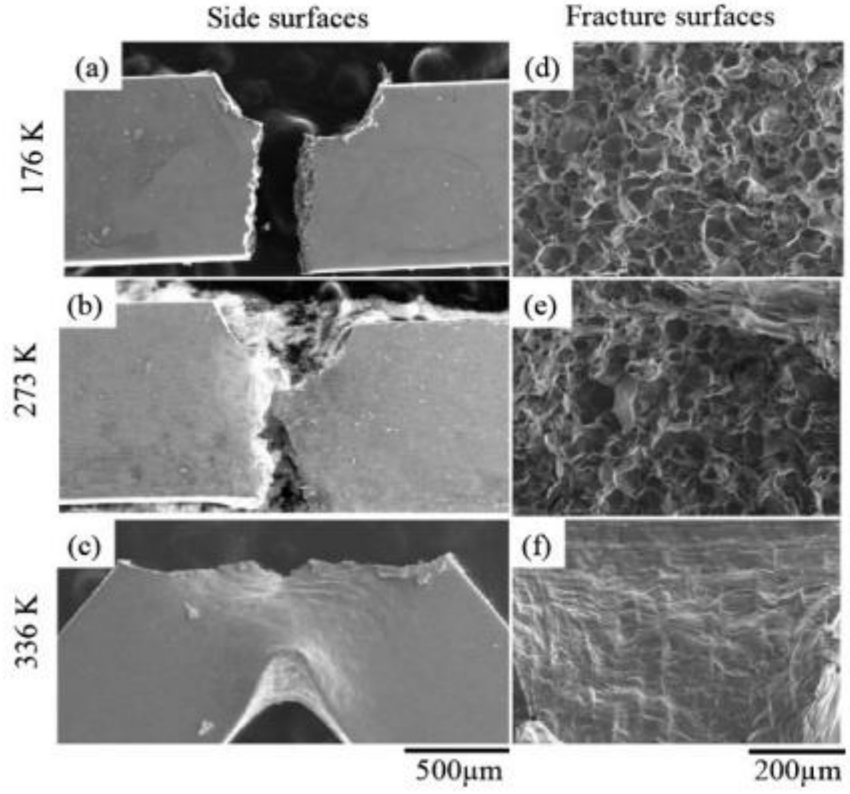
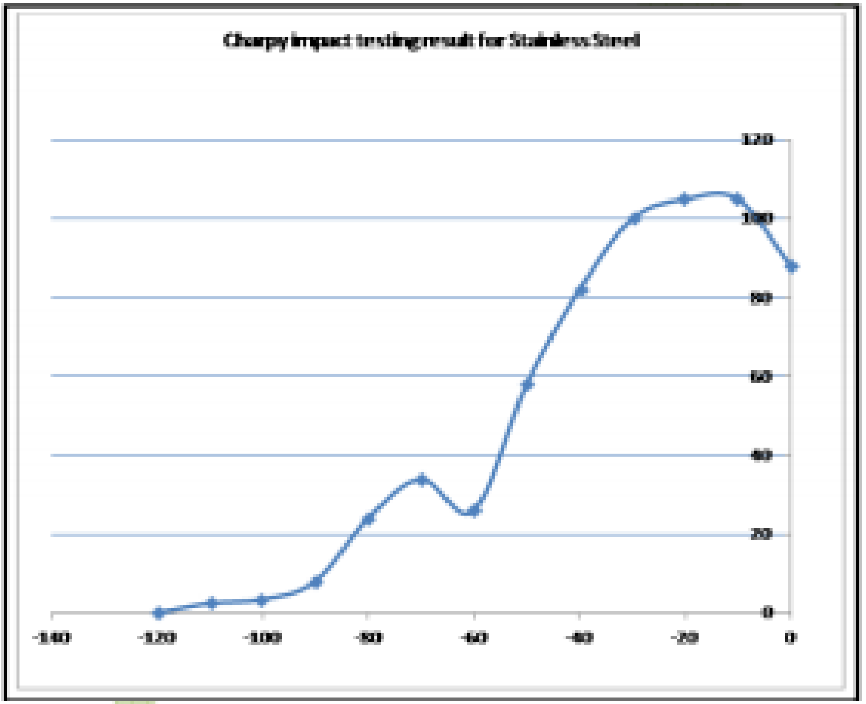
CONTINUUM DAMAGE MECHANICS





CONTINUUM DAMAGE MECHANICS

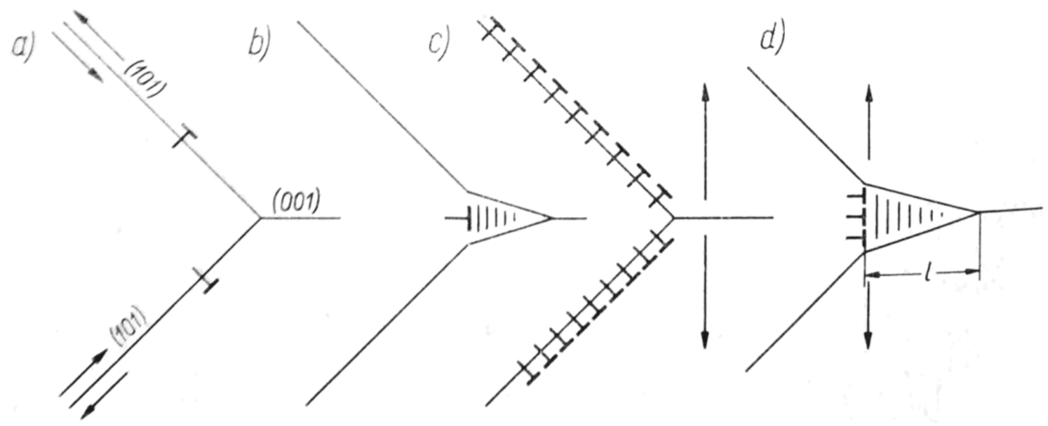
Sr. No	Temperature (In °C)	Energy absorb by specimen (in joule)
1	-120	-
2	-110	2.5
3	-100	3.5
4	-90	8
5	-80	24
6	-70	34
7	-60	26
8	-50	58
9	-40	82
10	-30	100
11	-20	105
12	-10	105
13	0	88

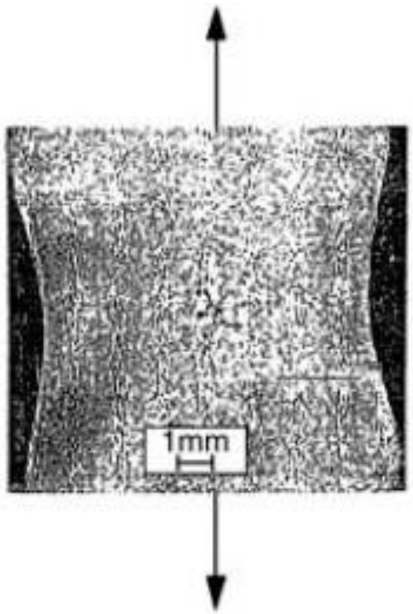


CONTINUUM DAMAGE MECHANICS

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



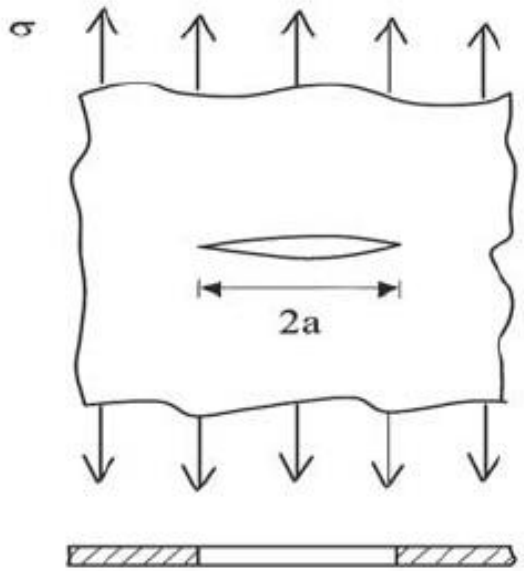


CONTINUUM DAMAGE MECHANICS

Griffith Theory of Brittle Fracture

- **The critical stress required for crack propagation in a brittle material is given by:**

$$\sigma_c = \left(\frac{2E\gamma_s}{\pi a}\right)^{1/2}$$



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  - E = modulus of elasticity
  - gs= specific surface energy
  - a = half the length of an internal crack
- **Applies only in cases where there is no plastic deformation present.**

CONTINUUM DAMAGE MECHANICS

Verification other mathematical models eg:

- Irwin Model
- Dugdale-Barenblatt Model
- Czerepanow Model
- Orowan Model
- …..

Or using a proper numerical analysis (uncoupled/coupled) for cryogenics temperatures (correction factors for material data?)

CONTINUUM DAMAGE MECHANICS

THANK YOU