中广核 CGN

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Beyond Design Code, Introduction of Defect Tolerance Assessment of UK HPR1000

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Natural Energy Powering Nature

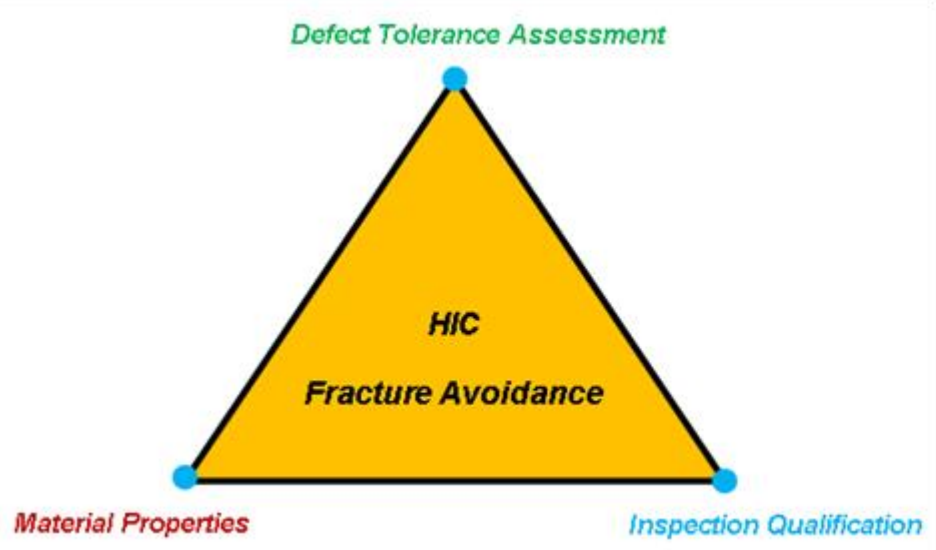
Comprehensive of terminology "structural integrity" in UK:

a) A much more wider range than China practice whereas mainly mechanical analysis is focused in China practice.
b) No design codes & standards specified, and codes & standards are not enough.
c) Demonstrated by "safety case".

Besides design codes & standards, the UK HPR1000 also considers UK context. In terms of stress and assessment, it is mainly called 'Avoidance of Fracture'.

The avoidance of fracture demonstrates that the High Integrity Components are tolerant of defects to through-life degradation

The integration of DTA, high reliability NDT and lower bound material properties support the avoidance of fracture demonstration



- ***Defect tolerance assessment / DTA***

$$DSM = ELLDS / (QEDS + LFCG) \geq 2$$

DSM:	*Defect Size Margin*
ELLDS:	*End of Life Limiting Defect Size*
QEDS:	*Qualified Examination Defect Size*
LFCG:	*Life time Fatigue Crack Growth*

- ***DTA main Procedure is following:***

1. *Material property determination*
2. *Classify loadings and consequences stresses*
3. *Defect characterization*
4. *Analysis type selection (crack initiation or tearing)*
5. *Determine final defect size (crack fatigue crack growth)*
6. *Determine end of life limiting defect size*
7. *DSM target check and refinement*

- ***Characteristic of DTA:***

1. *FAD diagram method, no safety factor inherent (R6 procedure)*
2. *Conservative material properties assumption*
3. *Conservative loads and loads combination*
4. *Residual stresses involved*

Loading

1. Steady load, dead weight, mechanical loads and thermal loads
2. Transients load, pressure, thermal and flow rate transients
3. Residual stresses
4. others

Stress and SIF

The stresses arising from loadings should be divided into primary stresses and secondary stresses according to the contribution to plastic collapse. Due to the interaction between primary and secondary stresses, a coefficient will be applied to Stress Intensity Factor (SIF) caused by secondary stresses, and then combined with SIF resulted by primary stresses.

❑ *Defect Characterisation*

For defect tolerance assessment in GDA, only surface planar flaws are assumed.

The flaw depth, width and shapes cause different stress intensity factor forms.

❑ *Analysis Type Selection*

- ✓ Crack initiation

  Base analysis type for all conditions.

- ✓ Crack tearing

  Alternative analysis type for emergency and fault condition.

❑ ***Determine Final Defect Size***

✓ Fatigue Crack Propagation

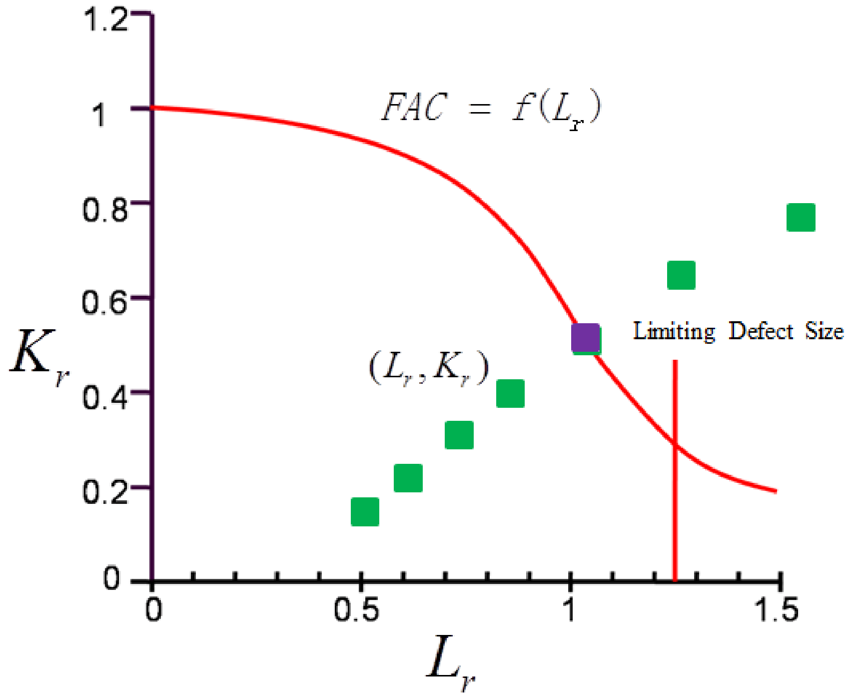
Paris Law is introduced for fatigue crack growth.

$$da / dN = A(\triangle K)^m$$

Final defect size = initial crack size + fatigue crack growth

Determine ELLDS

If the point (Lr, Kr) is on FAC, or a little bit below, the responding defect size can be defined as limiting defect size.



❑ ***FAC Curves Selection***

1. R6 offers three types of failure assessment curves, named option 1, 2 and 3.
2. For conservative purpose, it is prior to select option 1 for DTA. If option 1 is too conservative, option 2 and 3 are the candidate options.
3. Lr(max) could be determined as following approximately:

$$L_r(max) = (\sigma_y + \sigma_u) / 2\sigma_y$$

❑ *Lr and Kr*

Lr is defined as following

$$L_r = \frac{P}{P_L} = \frac{\sigma_{ref}}{\sigma_y}$$

Involved a coefficient V, the combination of primary and secondary SIF are defined as following:

$$K_r = \frac{K_I^P}{K_{mat}} + \frac{VK_S^P}{K_{mat}}$$

DSM Check

1. Amount of crack tearing instead of initiation in Level D
2. More realistic material property in some cases
3. Selection of more realistic FAC curve while in large L_r regime
4. Alternative methods

Thanks