T73S02 Session 14 Homework: Elastic SIFs

Mentor Guide K&S Questions:_

1.2 State the base formulae for K in terms of applied stress and crack length for an embedded crack and an edge crack. Define the "compliance factor" or normalised SIF.

4.1 Describe the limit load of a homogenous component and how it may be affected by the presence of a defect.

4.2 Summarise the analytical and numerical methods for determining the limit load.

4.3 State a selection of sources of advice on limit load solutions for common geometries and loadings.

5.9 State a selection of sources of advice on stress intensity factor solutions for common geometries and loadings.

5.14 Describe how the stress intensity factor may be found for a through-thickness crack in a self-equilibrating secondary stress field.

Numerical/Matthematical Questions:-

1) A long plate of width 100mm has a stress of 100 MPa applied at its ends. It contains a 50mm long edge crack at its midsection. The crack is of uniform length through the plate thickness, and oriented perpendicular to the plate edge. The nature of the loading is such that it is intended to restrain any bending of the plate, but it is possible that the loading grips could slip and allow bending to occur. If the toughness of the material is 100 MPa√m, is the plate safe from failure? (Treat the problem as LEFM).

2) A pipe of mean radius 200mm and wall thickness 20mm contains an external surface circumferential crack of semi-elliptic shape. The crack lies in the radial-circumferential plane, so that the axial stress is Mode I. The crack depth is 14mm and its surface length is 280mm. Show that, assuming LEFM behaviour and a fracture toughness of 90 MPa√m, the crack remains stable under an internal pressure of 200 Barg.

To cover the possibility that a sub-critical crack growth mechanism might be operating, the safety case author wishes to make a leak-before-break case for this defect. Is this possible?

3) You are conducting a technical review of an assessment. A crack is being considered in a region of welding residual stress in a long pipe. In this area all other stresses are negligible. The residual stress is of bending distribution, being tensile on the inner half wall and compressive on the outer half wall. The crack is a surface crack starting from the bore, and a growth mechanism exists, driven by the residual stresses. The claim has been made in the report that once the crack depth has grown to half-wall the crack will "run out of driving force" because the stresses at the crack tip are then compressive. The assessment therefore argues that it is not necessary to consider cracks deeper than half-wall. Is this valid?

4) Person A is asked to carry out an accurate assessment of the situation described in (3). He decides to find the SIF by carrying out an FEA and applying the uncracked body stresses to the crack faces as tractions, as per Bueckner's Principle. Person B objects to this claiming that, because the residual stresses are secondary (strain controlled) the stresses will reduce as the crack grows – due to the increased compliance of the structure. Person B claims that Person A's procedure is conservative but not accurate. Who is right?

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5) It is required to make an assessment of a cracked plate under applied displacement loading. Person A argues that this can be done by, (a)finding the stress which corresponds to the applied displacement for the uncracked body, then, (b)using the SIF solution for this stress as an applied stress, rather than an applied displacement. Person A cites Bueckner's Principle to support his claim. Since (a) provides the correct uncracked body stresses, then the resulting SIF must be correct. Person B, however, argues that this is unnecessarily pessimistic. He claims that the correct SIF will be smaller. This is because the stresses will be relaxed by the presence of the cracks, since the crack reduces the stiffness of the body. Who is right?

[Hint: The answer to questions 4 and 5 are opposite!].