Stress intensity factor calculation for short cracks initiating from a semi-ellipsoidal pit

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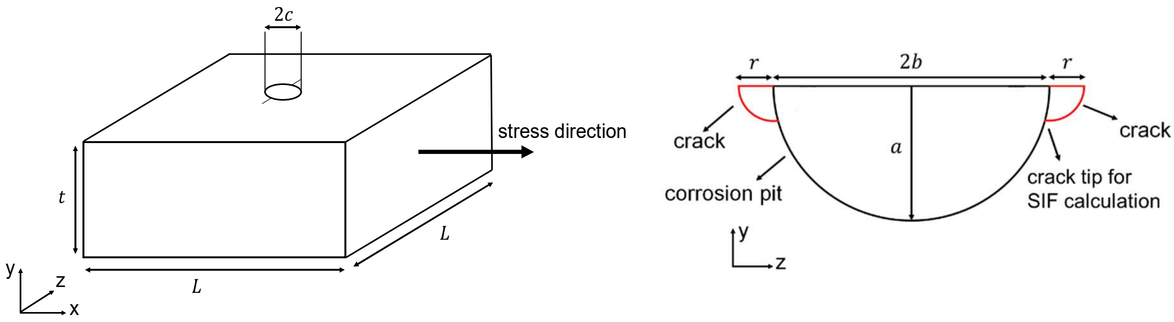
Offshore wind turbine support structures are exposed to maritime conditions, which can lead to corrosion fatigue. This work is part of the FATCOR project funded by the Belgian Energy Transition Fund, aiming to develop a qualitative and quantitative understanding of the mechanisms of corrosion fatigue in seawater. Localized corrosion generates a geometrical defect, raising the local stresses and reducing the fatigue life. The transition from pit growth to short fatigue crack propagation occurs at a critical pit size, which depends upon the microstructure, the applied stress level and the geometry of the pit.

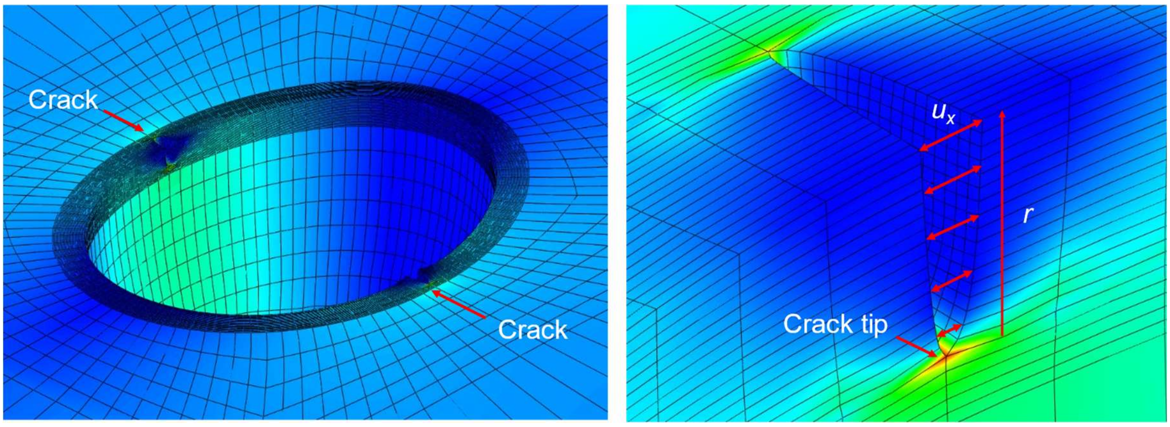
In linear elastic fracture mechanics, the stress intensity factor is used to describe the magnitude of the stress singularity near a crack tip caused by remote stresses and is useful for establishing a failure criterion. Literature lacks stress intensity factor solutions for cracks emanating from a three-dimensional semi-ellipsoidal pit. Fig. 1 (a) shows a schematic representation of a plate subjected to axial tensile stress with a semi-ellipsoidal pit at the center of the top surface. Two cracks in the shape of a circular arc are introduced at the pit mouth perpendicular to the loading direction, see Fig. 1 (b). Finite element analysis is used to calculate the stress intensity factor (K_I) at the crack tip (see Fig. 2).

The displacement extrapolation method is used to quantify the effect of different pit configurations and crack lengths on K_I. This method determines K_I from the displacement field near the crack tip. A parametric study is performed on a range of relative geometrical parameter values ($a/2c, b/c$) and crack lengths (r/a). It is observed that changes in the pit geometry can drastically affect the stress gradient in the vicinity of the pit, which directly influences the magnitude of K_I. For example, ($a/2c$) equal to 1, 0.5 and 0.25, results in K_I values 74.4, 71.1 and 56.6 $MPa/\sqrt{mm}$ respectively, for a remote stress of 100 MPa and (r/a) equal to 0.067. In future work regression analysis will be performed to develop an equation K_I for a wide range of pit configurations and crack lengths.



(a) (b)

Fig. 1 (a) Schematic representation of 3D plate with a semi-ellipsoidal corrosion pit at the centre of the top surface. (b) 2D representation of a corrosion pit and a crack highlighted in red.



(a) (b)

Fig. 2 Stress state of the plate with a crack emanating from a 3D semi-ellipsoidal pit subjected to axial tensile stress: (a) global view (b) detailed view of the crack tip region.