Title:

On the Size and Shape of Plastic Zones Ahead of Crack Tips

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Abstract:

The estimates of the size and shape of the plastic zones, traditionally used in Linear Elastic Fracture Mechanics (LEFM), are based on the supposition that the stress intensity factor (SIF) K_I (or K_{II} or K_{III}) is the only necessary parameter to describe them. However, it is verified that traditional estimates significantly underestimate the position of the elastic-plastic border [1]. This happens because of the influence of the nominal stress σ_n on the stress field, which should not be ignored. Since most structural designs allow nominal stresses of up to 80% of the yielding strength, there is a need for better estimates for the plastic zones ahead of the crack tips. In addition, these estimates also have a significant impact on the critical damage model predictions [2]. In this work, the Inglis' solutions and a complete Westergaard function are used to more accurately estimate the plastic zone border. The resulting equations considering the nominal stress effects are developed in this work, numerically solved to obtain the plastic zone border. This process is computationally intensive, but it can be easily applied to both plane stress and plane strain cases. Figure 1 compares the plastic zones estimated from Inglis, assuming (i) that the crack is an Inglis' hole with tip radius equal to half the *CTOD* associated with K_I; and (ii) using the complete Westergaard function, without the simplification that Inglis used to obtain K_I. The near overlapping of these two curves, which were generated from totally different equations, certainly is not coincidental. Therefore, unlike what is usually accepted and taught in the traditional LEFM literature, the plastic zones do not depend only on the magnitude of the stress intensity factor K_I. This fact has important consequences, because it can be used to question the similarity principle, one of the pillars of the mechanical design methods against fracture.

[1] Rodriguez, HZ; Castro, JTP; Meggiolaro, MA. On the Plastic Zone Size and Shape Dependence on the Nominal Stress in Fracture Mechanics. 19th International Congress of Mechanical Engineering, 2007.

[2] Castro, JTP, Meggiolaro, MA, Miranda, ACO. Singular and Non-Singular Approaches for Predicting Fatigue Crack Growth Behavior, International Journal of Fatigue 2005;27(10-12):1366-1388.

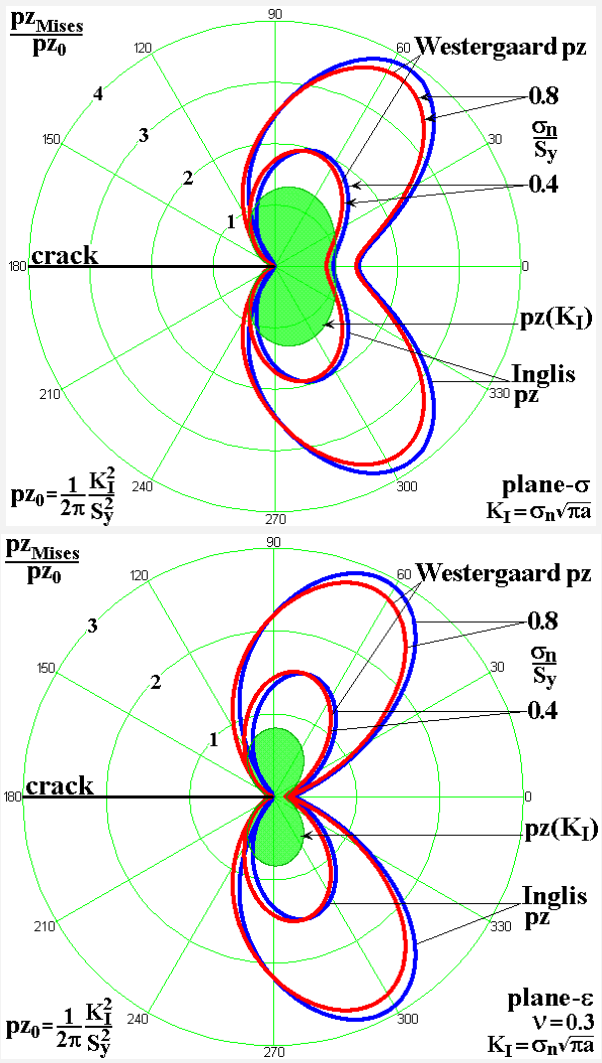

Fig. 1: Comparison between the plastic zones estimated from Inglis and from Westergaard, under plane stress (top) and plane strain (bottom), and the classical estimate (in green), which considers only the K_I influence, neglecting the nominal stress effects.