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# Crack Opening Profile method for stress intensity factor estimation in interacting, interface and mixed mode cracks

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Introduction
The Crack Opening Profile (COP) method estimates the stress intensity factor (K) directly from measurements of crack face displacements along the whole crack front, avoiding detailed stress analysis. Previous work showed that Westergaard based COP expressions can recover K for symmetric centre cracked plates in linear elastic materials [1–2]. However, many real components contain non symmetric configurations, where cracks interact with free edges, material interfaces or neighbouring cracks, producing different loading and stress intensity factor at the two tips [3]. In such cases, conventional stress based approaches require complex modelling and accurate boundary conditions, which are difficult to guarantee in practice [4]. The aim of this work is to extend the COP concept to these interacting and interface cracks by introducing a two parameter formulation capable of capturing independent stress intensity factors at the two crack tips, and to outline a generalized mixed mode framework for more complex loading scenarios.

Materials and Methods
Starting from Westergaard's solution for a centre crack, we derive an analytical COP expression with two independent stress intensity factors, K_A and K_B, associated with each crack tip [2]. The approach is evaluated using two dimensional plane stress finite element simulations on three classes of interacting cracks (crack–edge, crack–interface and crack–crack) and on mixed mode configurations, covering a wide range of non dimensional geometric parameters. For each model, displacement fields along the crack are extracted and fitted with the proposed COP equation to obtain K_A and K_B, which are then compared with J integral results and handbook solutions. Experimental validation is performed on PMMA plates containing selected interacting crack and crack–edge geometries, as well as mixed mode specimens, tested in tension and compression and analysed by Digital Image Correlation (DIC) using Zeiss software to obtain COP measurements.

Results
Across the plane stress simulations, the two parameter COP expression reproduced the crack opening profiles for all interaction classes and mixed mode cases with coefficients of determination above 0.96, accurately capturing both magnitude and asymmetry. COP derived stress intensity factors K_A and K_B generally agreed with J integral and handbook values within a few percent, with larger deviations (up to about 10–20%) only in the most severe interaction geometries. PMMA experiments confirmed these trends: COP based stress intensity factors followed the expected linear scaling with applied stress and reproduced the differences between the two crack tips with acceptable scatter.

Conclusion
The present study demonstrates that the Crack Opening Profile method can be extended from symmetric cracks to interacting and interface cracks, and to mixed mode loading. This displacement based framework allows local mode I and, in mixed mode configurations, mode II stress intensity factors to be extracted directly from measured crack openings, reducing reliance on detailed stress analysis and complex finite element modelling in non symmetric configurations. The approach provides a practical basis for further development of generalized mixed mode COP formulations and for application to more complex geometries relevant to structural and biomedical systems.

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