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ANALYSIS OF CRACKS IN BI-MATERIALS/COMPOSITES WITH VARIABLE ORDER SINGULARITY USING MESHLESS METHOD

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ABSTRACT
In case of crack propagation through bi-materials and composites, depending on the location of the crack tip with respect to the interface, the order of singularity varies. If the crack tip is located in a homogenous material, the order of singularity is $r^{-0.5}$. If it is located at the interface, depending on the material combination and angle made by the crack with the interface, the order of singularity, λ, is variable, i.e. $\sigma_{ij} \propto r^{\lambda-1}$.

Although finite element method (FEM) can be employed to extract the SIFs in the variable order singularity problems, the possibility of exploiting the meshless methods (MMs) remains almost unexploited. This is partly due to the non-availability of special functions to model the variable order singularity, which can be utilized in, for example, element-free Galerkin (EFG) method. This paper deals with the development of such functions. The details of the formulation as well as case studies will be presented in the paper.

Dimensions and Loading: a/W= 1/9 *L/W*=1 *W*=0.2286 m *P*=6.895 kPa
Materials: Aluminium-E=68.95GPa ν=0.3, Epoxy-E=3.102GPa ν=0.35

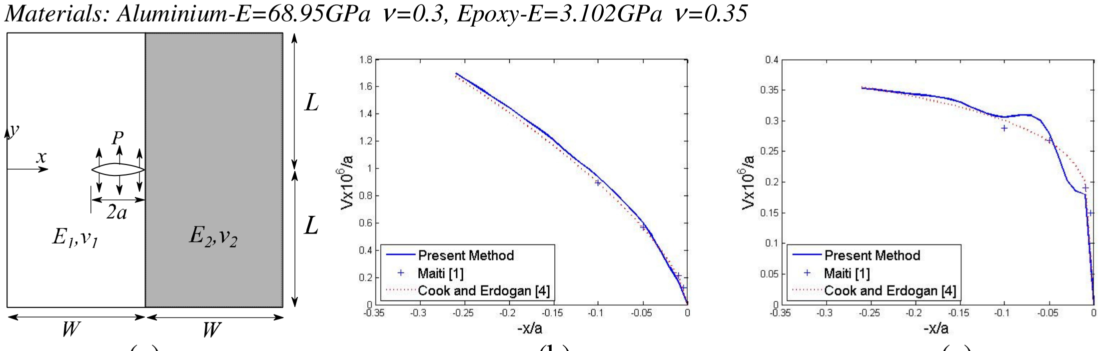

Fig. 1. (a) Crack normal to the bi-material interface. Crack edge profiles for (b) $\mu_2 / \mu_1 = 23.07$. (c) $\mu_2 / \mu_1 = 0.043$.

CASE STUDIES
A pressurized crack whose one tip is embedded in a homogenous material (Fig. 1a) and the other tip is lying at an interface is studied using the proposed scheme. The stress intensity

factor (SIF) is extracted from the crack opening displacement (COD) at 12% of the crack length(a). The SIFs are compared in Table 1 and crack edge profiles are compared in Fig. 1b and c for two ratios of shear modulus ($\mu_2 / \mu_1 = 23.07$ and $\mu_2 / \mu_1 = 0.043$).

Dimensions and Loading: L=2 $2r/L$=0.15 σ=1MPa

Materials: Silicon Carbide-E=6.43×68.95GPa ν=0.17, Aluminium-E=68.95GPa ν=0.3

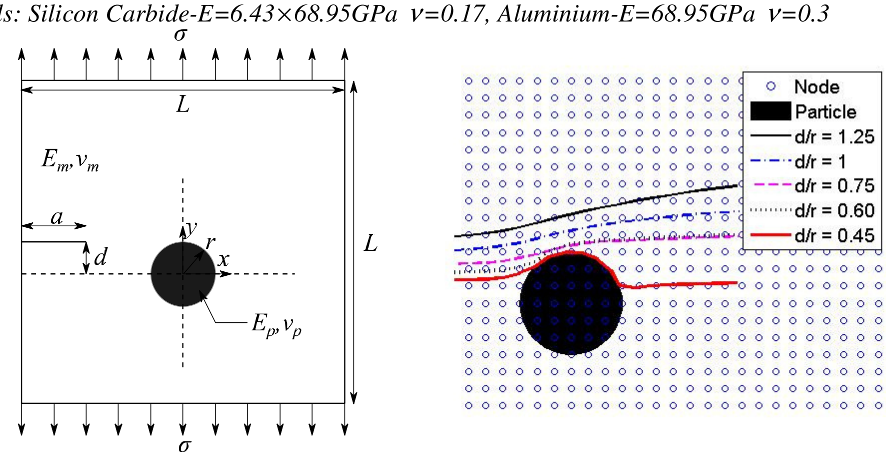

Fig. 2. (a) Crack geometry with a single particle embedded in it. (b) Crack path as per MTPS criteria for various d/r ratios.

The second application involves study of the crack path through a particulate composite (Fig. 2a) for different ratios of d/r. The direction of crack path has been determined using the well known maximum tangential principal stress (MTPS) criteria [2]. For $d/r=0.45$, the crack meets the interface, propagates along it over a span and then moves out of it. Some of these observations (Fig. 2b) are close to the results in [3].

Table 1. Comparison of normalized SIFs $K_I/p(\pi a)^{1-\lambda}$

Shear modulus ratio	$\mu_2 / \mu_1 = 23.07$		$\mu_2 / \mu_1 = 0.043$	
Singularity constant	$\lambda = 0.5$	$\lambda = 0.6619$	$\lambda = 0.5$	$\lambda = 0.1752$
Present EFG method	0.856 (2.73%)	4.283 (3.23%)	1.487 (0.75%)	0.048 (-12.5%)
Maiti [1]	0.880	4.149	1.476	0.042
Cook and Erdogan [4]	0.882	-	1.355	0.048

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