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KINEMATIC STUDY OF DCB-UBM SANDWICH FRACTURE SPECIMEN

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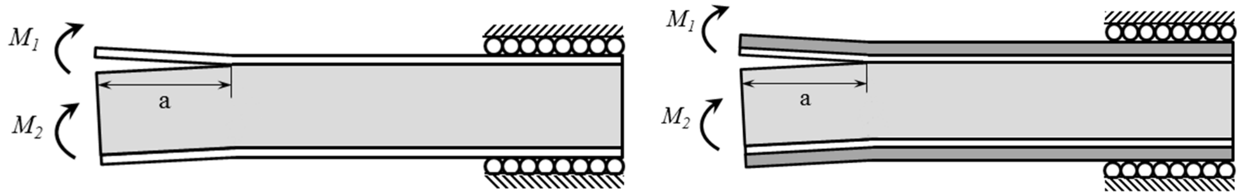
1. INTRODUCTION

The face/core disbond or debond problem in sandwich composites has received wide attention in recent years as many in-service structural failures have been attributed to debonds [1, 2]. There is a need to address the disbond problem under generalized loading conditions for sandwich structural components employed across various sectors. In order to understand the phenomenon of face sheet/core debonding, reliable methodologies to characterize the interface debond must be developed. One such methodology, which have been proven to be robust for mixed-mode fracture characterization of sandwich debonding is the Double Cantilever Beam loaded with Uneven or unequal Bending Moments (DCB-UBM) specimen, which was first introduced by Sorensen et al. [3] for laminate composites and later extended to sandwich composites by Lundsgaard-Larsen et al. [4] (see Fig.1).



(a) (b)

Fig. 1: Schematic illustration of DCB-UBM sandwich specimen: (a) un-reinforced, (b) reinforced with doubler layers.

The DCB-UBM sandwich specimen has been proven to be robust for interface characterization of typical sandwich configurations [5, 6]. It should be noted that the energy-release rate of a moment loaded beam is independent of crack length [7]. There are many ways in which the DCB specimen can be subjected to uneven or unequal bending moments, such as through special jig and fixture design, long wires or through direct independent torsional actuators. A modified DCB-UBM test method in which the specimen is subjected to moments through independent actuators have been shown to achieve a wide range of mixed mode conditions. However, the kinematic solution of the DCB-UBM specimen has not been developed yet. Without any closed-form kinematic expressions, it has become a difficult task to characterize the kinematics of various test rigs. The aim of the current investigation is to derive the kinematic solution of a DCB-UBM sandwich specimen, using the beam on elastic foundation approach.

2. FOUNDATION MODEL APPROACH ON MOMENT-LOADED SCB SPECIMEN

A simplified analysis of DCB-UBM specimen was carried out by assuming the lower face sheet to be fixed. Such a simplification leads to a typical Single Cantilever Beam (SCB) sandwich specimen loaded with an edge couple, M_1. The Winkler mechanical model which was first utilized by Kanninen [8] for homogenous DCB specimens, was employed to obtain the deformation characteristic of a moment-loaded SCB sandwich specimen by Saseendran et al. [7]. A schematic illustration of the beam on elastic foundation approach is shown in Fig. 2. The compliance of a moment loaded SCB specimen can be expressed as the ratio of rotation to the applied moment as [7]:

$$C = \frac{|\theta(-a)|}{M_1} \tag{1}$$

The deflection of the moment loaded SCB specimen (see Fig. 2) is given by [7]:

$$w(x) = M_1 \begin{cases} \dfrac{x^2}{2EI} - \dfrac{4\lambda^3 x}{k} + \dfrac{2\lambda^2}{k}; (-a \le x \le 0) \\ \dfrac{2\lambda^2}{k}\left[f_1(\lambda x) - f_2(\lambda x)\right]; (0 \le x \le \infty) \end{cases} \tag{2}$$

where $f_1(\lambda \mathrm{x}) = e^{-\lambda x}\cos(\lambda \mathrm{x})$ and $f_2(\lambda \mathrm{x}) = e^{-\lambda x}\sin(\lambda \mathrm{x})$, and λ is defined by:

$$\lambda = \sqrt[4]{\frac{k}{4E_f I}} \tag{3}$$

where k is the elastic foundation modulus.

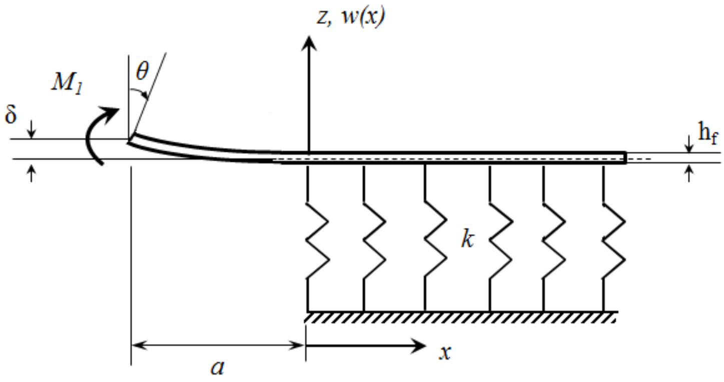


Fig. 2: Beam on elastic foundation approach of a moment-loaded SCB sandwich specimen.

Progressive derivative of Eq. 2 will yield rotation which make it possible to calculate the compliance, C, in Eq. 1. The analysis will be extended to a DCB specimen acted upon by unequal bending moments, representing the case for a DCB-UBM specimen. A full compliance solution of the DCB-UBM specimen will aid in understanding direct comparison of experimental results with the analytic solution. Such a direct comparison will enable in estimating the efficacy of DCB-UBM test rigs. To extend the kinematic analysis to a DCB-UBM specimen case, the crack root rotation should also be take into account. The crack root rotation have been shown to significantly affect the near tip deformation characteristics, especially for specimens with thin cores [9]. The crack tip root rotation angle (φ) can be expressed as [9]:

$$\phi_A = c_M \frac{M}{\bar{E}_f h_f^2} + c_N \frac{N}{\bar{E}_f h_f} + c_V \frac{V}{\bar{E}_f h_f} \tag{4}$$

where c_M, c_P and c_V depend on the face and core stiffnesses. M is the moment, N the axial load and V, the shear force in the upper face (all per unit width) at the crack tip. A comprehensive approach in which the full compliance solution based on the rotations and moments of a DCB-UBM sandwich specimen will be provided followed by a comparison with numerical results for typical sandwich configurations.

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