Fracture Mechanics of Brittle and Ductile Specimens

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Group 20 12/8/19

***Abstract*—The purpose of this lab was to determine the mode I fracture toughness of 2024 Aluminum and Acrylic test samples by characterizing the stress intensity factors of material samples with varying sample geometry. An Instron electro-mechanical test frame was used to conduct four-point bending fracture testing on test samples containing cracks that were cut into the samples by lab instructors. The maximum force during each experiment was recorded to determine the nominal stress in each sample before failure. Using knowledge of fracture mechanics and iterative numerical methods, it was then possible to determine a curve fit for each material's stress intensity factor as a function of beam thickness which resulted in a nominal value for each material's fracture toughness. The acrylic and 2024 aluminum samples had fracture toughness's of 2720 ± 191 psi$\sqrt{in}$ and 39800 ± 1140 psi$\sqrt{in}$. In the future, it will be possible to perform these experiments to quantify a material's fracture toughness to validate material selection during design phases of future projects.**

***Index Terms*—Four-Point Bending, Fracture Toughness, Plane Strain, Stress Intensity Factor.**

I. Introduction

THE objective of this lab was to characterize mode I fracture toughness (K_{IC}) and stress intensity factors (K_C) for ductile and brittle materials by preforming four-point bending tests on materials with varying beam and crack geometries. A material's K_C is a measure of how sensitive a material is to cracks and is a function of thickness, while its K_{IC} value dictates how much the material will resist failure due to deformities in plane strain. Plane strain is a condition in which the thickness of the material orthogonal to the applied forces is so large that strain in that direction is considered negligible.

In this lab, an 5967 Instron electro-mechanical test frame fitted with load and support rollers was used to create the four-point bending condition and calculate the bending moment in the crack area which is a function of the total force (P) and the horizontal distance between the load and support rollers (L)(1).

$$M = \frac{PL}{2} \tag{1}$$

The advantage of using a 4-point bending condition is that the bending moment is constant in a well-defined area under the load rollers. The constant bending moment ensures that the member will fail due to the weakest portion of the beam subject to the bending moment, which is the area with the crack. The force is calculated with Instron software which uses internal load cells to determine the applied force [1].

Fracture mechanics states that in four-point bending, the K_c for a member with a crack of zero notch radius depends strictly on the geometry of the beam and the nominal stress in the beam at failure (2-3) (Fig. 1).

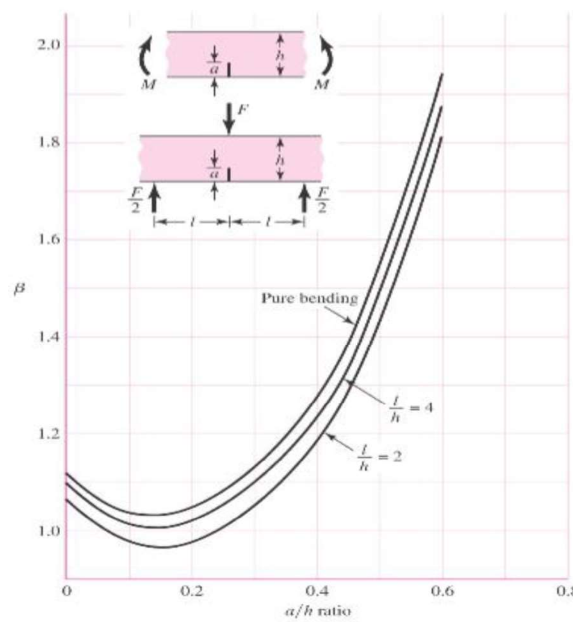

Fig. 1. β values for varying beam geometry in various states of bending [2].

$$K_c = \beta \sigma_b \sqrt{\pi a} \tag{2}$$

$$\sigma_b = \frac{6M}{th^2} \tag{3}$$

As previously stated, K_C is a function of the member's thickness. A thin member will fail in shear which is a plastic mode of failure and can be easily identified by the presence of