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INVESTIGATION OF THE INFLUENCE OF FACE THICKNESS ON FACE/CORE FRACTURE TOUGHNESS OF FOAM AND HONEYCOMB CORE SANDWICH

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1. INTRODUCTION

A critical failure mode of sandwich structures is crack propagation at the interface between face and core. Fracture toughness, G_C, i.e. the critical value of the energy release rate, is used to characterize the resistance to such crack propagation. Several tests method are available to study the interfacial fracture of sandwich. The Single Cantilever Beam (SCB) test, Fig. 1, has emerged during recent years as a potential ASTM test standard [1].

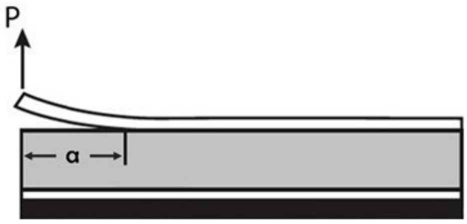

Fig. 1: Schematic of SCB test.

The loading and support conditions lead to mode I dominated crack propagation at or near the face/core interface. When a crack advances between two dissimilar materials, it will experience mixed mode conditions i.e. both tension and shear. Under such loading, unless the crack is trapped at a certain plane, the crack will try to find a new plane where mode I exists [2]. The possibility of oblique crack propagation is known as kinking behavior for sandwich structures, see Fig. 2. Interfacial crack growth occurs when crack propagates under mode I dominance and when the face/core bonding is weak. As discussed by He and Hutchinson [2] a tough core material will also prevent kinking. Crack propagation inside the core may occur when the bonding of face and core is strong enough. Kinking into core may occur due mode II loading if the core material is brittle.

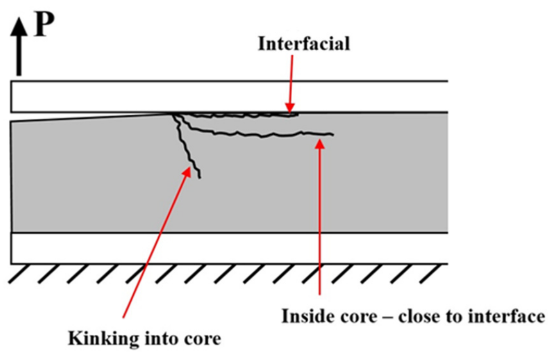

Fig. 2: Different crack propagation scenarios.

In this study, SCB tests will be conducted on PVC H100 foam and honeycomb core SCB specimens with aluminum face sheets with a range of thicknesses. As discussed by e.g. Li et al. [3], increased face thickness will promote shear loading (mode II) which would lead to crack kinking into the core. Furthermore, thicker face sheets are expected to promote linear load-displacement response allowing use of the MBT method with more confidence. These issues are fundamental for the design of the SCB test and wider acceptance of the test method as an ASTM standard.

2. EXPERIMENTAL

PVC H100 foam core panels of 25.4 mm thickness were provided by DIAB. HC core panels of the type ECA- HC $3/16''$ with 12.7 mm thickness were obtained from Eurocomposites. The thickness of top face sheets was varied from 3 to 6.35 mm. The thickness of bottom face was same for all specimens, 3.20 mm. An artificial precrack was defined by placing a 250 μm thick Teflon film of 3.18 cm length between top face and core. The bottom face sheet was bonded to the core with Araldite 2015, while the top face sheet was bonded with Hysol EA 9309.3NA adhesive. To accommodate load application, a hinge was mounted to the top face sheet above the precrack. The test program is presented in Table 1.

Table 1: Material properties of sandwich elements.

Materials	Mechanical Properties	Thickness *(mm)*	Density (kg/m^3)
Top Facesheets (6061-T6 Aluminum)	$E = 68.9GPa$ $\sigma_y = 240MPa$	3, 4.76, 6	2700
PVC-H100 Core	$E_c = 130MPa$	25.4	100
ECA- HC $3/16''$ Core	$E_c = 140MPa$ (Out of plane)	12.7	48

The SCB specimens were 5.1 cm wide, and 30.5 cm long. All HC specimens were tested with the L direction along the specimen. A SCB test fixture was mounted to the base of a Tinis-Olsen test frame of 133 kN load capacity. Sharp edge clamps of the fixture hold the lower face sheet during loading. A 30 cm long loading rod attached to the moving crosshead of the test machine was attached to the edge of the face using a pinned connection. Displacement was measured by a linear voltage differential transducer (LVDT). Load was recorded by a 13.3 kN load cell mounted on the moving crosshead.

During the experiments, the crosshead was moved at a constant speed of 2.5 mm/min. Load-displacement data was recorded throughout the test using a LabVIEW data acquisition system. Crack growth was monitored by visual observation of the crack tip region on both sides of the specimen. The location of the crack front was marked by pencil after each cycle allowing for subsequent evaluation of crack length. The testing was conducted by loading-unloading cycles with propagation of the crack in increments of about $1-2$ cm.

3. FRACTURE TOUGHNESS DETERMINATION

Fracture toughness G_C is estimated for each loading cycle by using the modified beam theory (MBT) [1, 4] and area methods [1, 5]. MBT is based on multiple compliance measurements. Therefore, several crack growth cycles are considered to generate a plot of cube root compliance, $C^{1/3}$, vs. disbond length, a which allows determination of the offset crack length Δ. The fracture toughness from MBT method is determined for each crack increment by

$$G_C = \frac{3P_C\delta_C}{2b(a+\Delta)} \tag{1}$$

where P_C is the load at the onset of debond growth, δ_C is corresponding displacement, b is the width of the specimen and a is the crack length. It is straight-forward to evaluate the critical load P_C for an ideal linear load-displacement curve, where the crack propagates at a well defined point. However, the actual $P-\delta$ curve display nonlinear response prior to the crack growth. The nonlinear response could be attributed to several reasons such as slow stable crack growth etc. When the nonlinear response is softening, P_C is considered as the load at the onset of a distinct nonlinearity in the curve. The toughness value , G_C , is referred to as initiation toughness. Thin face sheets, however, promote a stiffening nonlinearity which obscures determination of P_C and δ_C.

The area method provides a direct measure of G_C from the energy dissipation ΔU required to achieve a disbonded area increment ΔA .

$$G_C = \frac{\Delta U}{b\Delta a} \tag{2}$$

where ΔU is the area enclosed within a loading-unloading cycle and Δa is the increment in crack length. The fracture toughness value G_C represents an average value including both initiation and propagation of the crack.

At the time of writing this abstract, we have tested only a few specimens, and more specimen will be tested before we can assess the importance of face thickness in the SCB test.

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