Self Project

Fracture and Delamination Analysis of a Double Cantilever Beam Using VCCT

Submitted by:

24M0045 - Jayshree Chauhan

Aerospace Engineering Department

Indian Institute of Technology, Bombay

Contents

List of Figures

1 Introduction

Fracture mechanics is a critical field within solid mechanics that deals with the prediction and analysis of crack initiation and propagation in materials and structures. It enables engineers to understand the conditions under which materials fail due to cracks, and to design components that can withstand such failures.This is especially important in high-performance industries such as aerospace, automotive, and energy, where structural reliability is essential.

The main objective of fracture mechanics is to evaluate the strength of a component containing cracks or flaws.Unlike classical strength of materials approaches, which assume materials are defect-free, fracture mechanics considers the presence of inherent flaws and provides tools to assess their impact under loading.Two primary approaches used are the energy-based methods, such as Griffith's criterion, and stress-based methods, such as Stress Intensity Factors (SIFs).

One of the widely used computational techniques in fracture analysis is the Virtual Crack Closure Technique (VCCT).VCCT is based on the concept that the energy required to close a crack equals the energy released when the crack grows. It enables the evaluation of energy release rates (G) for different crack modes — Mode I (opening), Mode II (sliding), and Mode III (tearing).VCCT is particularly suitable for bonded joints and composite structures where delamination is a critical failure mode.

This project focuses on the simulation of Mode I fracture in a Double Cantilever Beam (DCB) specimen using ANSYS Workbench.The DCB test is a standard configuration for evaluating delamination toughness in materials. A pre-meshed crack is introduced between two bonded layers, and fracture parameters such as energy release rate (G1) and stress intensity factor (K1) are extracted using VCCT. Mesh refinement and proper boundary conditions are applied to ensure accurate results near the crack tip.

The goal of this analysis is to demonstrate the application of fracture mechanics principles in a numerical environment, validate crack tip behavior, and visualize crack propagation potential.The framework developed here can be extended to more complex scenarios such as composite delamination, interface debonding, or fatigue-driven fracture in aerospace-grade materials.

2 Model Geometry, Material Properties, and Setup

In the first part of the project, a Double Cantilever Beam (DCB) geometry was created to demonstrate Mode I fracture analysis using the Virtual Crack Closure Technique (VCCT).The geometry, material, and setup were configured to simulate crack opening at a bonded interface using a pre-meshed crack approach.

2.1 Geometry

A 3D model was created by splitting the structure into two surfaces (top and bottom) along a horizontal interface where the crack is expected to propagate.

Dimensions:

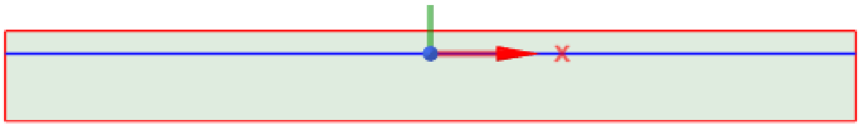

Figure 1: 2D Model for Analysis

- Length: 38mm
- Width: 4mm
- Crack Location: 3.8mm

The crack was introduced by splitting the edge in the geometry and separating the coincident surfaces to define a pre-meshed crack path.

2.2 Material Properties

Materials used in this analysis are Aluminium and Structural steel and the properties given in Ansys Mechanical Library are used.

Properties of Outline Row 3: Aluminum Alloy

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	2770	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
5	Coefficient of Thermal Expansion	2.3E-05	C^-1		
6	Isotropic Elasticity				
7	Derive from	Young's Modulus an...			
8	Young's Modulus	7.1E+10	Pa		
9	Poisson's Ratio	0.33			
10	Bulk Modulus	6.9608E+10	Pa		
11	Shear Modulus	2.6692E+10	Pa		
12	S-N Curve	Tabular			
16	Tensile Yield Strength	2.8E+08	Pa		
17	Compressive Yield Strength	2.8E+08	Pa		
18	Tensile Ultimate Strength	3.1E+08	Pa		
19	Compressive Ultimate Strength	0	Pa		

Figure 2: Aluminium Properties

Properties of Outline Row 5: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
5	Coefficient of Thermal Expansion	1.2E-05	C^-1		
6	Isotropic Elasticity				
7	Derive from	Young's Modulus an...			
8	Young's Modulus	2E+11	Pa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.6667E+11	Pa		
11	Shear Modulus	7.6923E+10	Pa		
12	Strain-Life Parameters				
20	S-N Curve	Tabular			
24	Tensile Yield Strength	2.5E+08	Pa		
25	Compressive Yield Strength	2.5E+08	Pa		
26	Tensile Ultimate Strength	4.6E+08	Pa		
27	Compressive Ultimate Strength	0	Pa		

Figure 3: Structural Steel Properties

2.3 Setup and Boundary Conditions

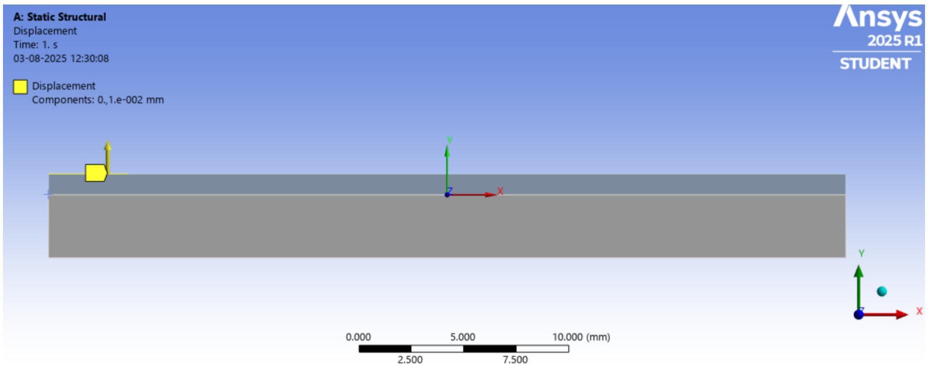

Figure 4: Displacemet

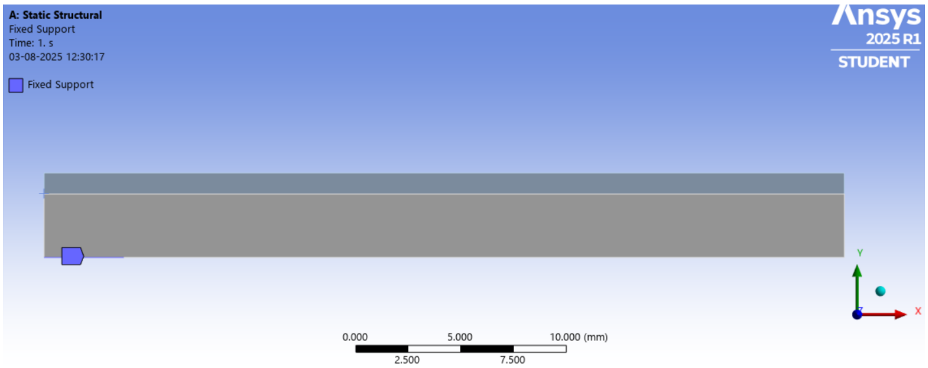

Figure 5: Fixed Support

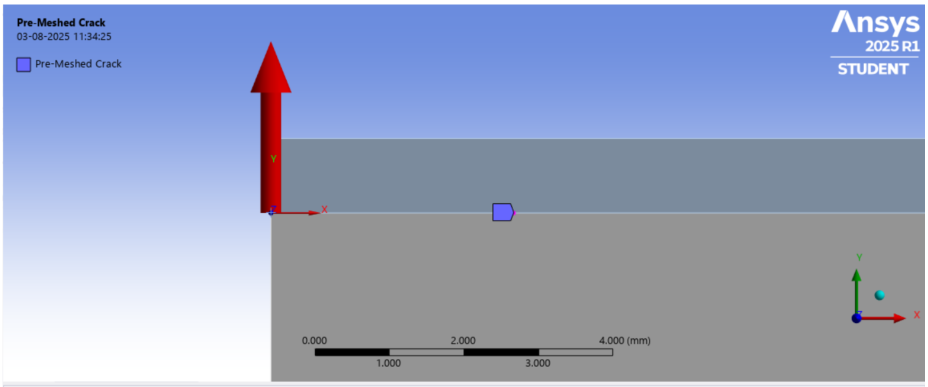

Figure 6: Pre-Meshed Crack

3 Results

The simulation was successfully run using the static structural module in ANSYS Workbench with a pre-meshed crack defined at the edge of the Double Cantilever Beam (DCB). The results obtained provide clear insights into Mode I fracture behavior under displacement-controlled loading.

3.1 Total Deformation

- Upon applying vertical displacement to the top free end, the DCB arms separated along the crack plane.
- The deformation plot confirmed that crack opening (Mode I) was dominant, as expected from the boundary conditions and geometry.

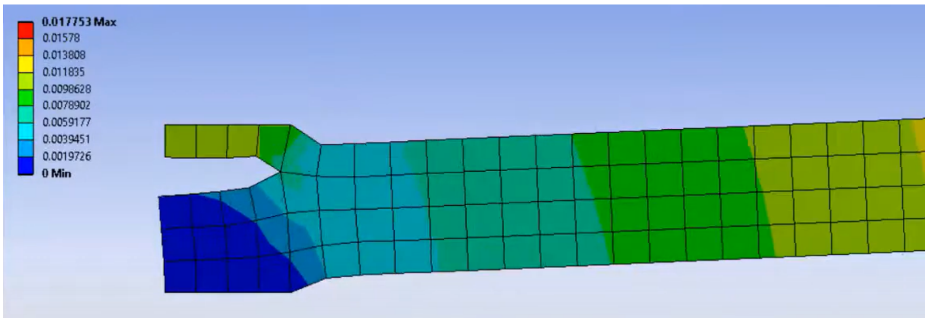

Figure 7: Deformation

3.2 Stress Intensity Factor(SIFS)

The Mode I Stress Intensity Factor (K1) was also evaluated using the fracture tool which is 1.7753.

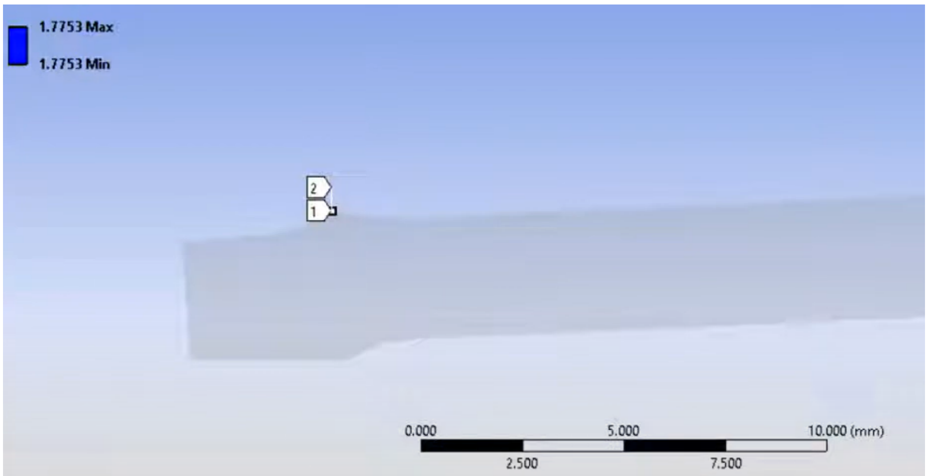

Figure 8: Stress Intensity Factor

4 VCCT Energy Release Rate

The Virtual Crack Closure Technique (VCCT) was used to evaluate the strain energy release rates along the crack front.

The following fracture parameters were extracted:

- G1 (Mode I Energy Release Rate): Non-zero and the value is 2.3518.
- G2 and G3: 0.026873 and 0.This shows the dominant behavior of mode 1 here.
- GT (Total Energy Release Rate): Approximately equal to G1. The value is 2.3787.

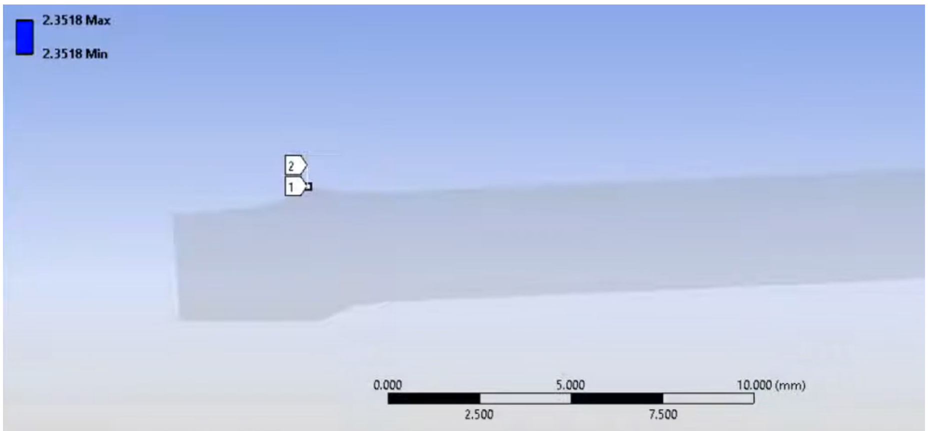

Figure 9: Energy Release Rate for Mode 1

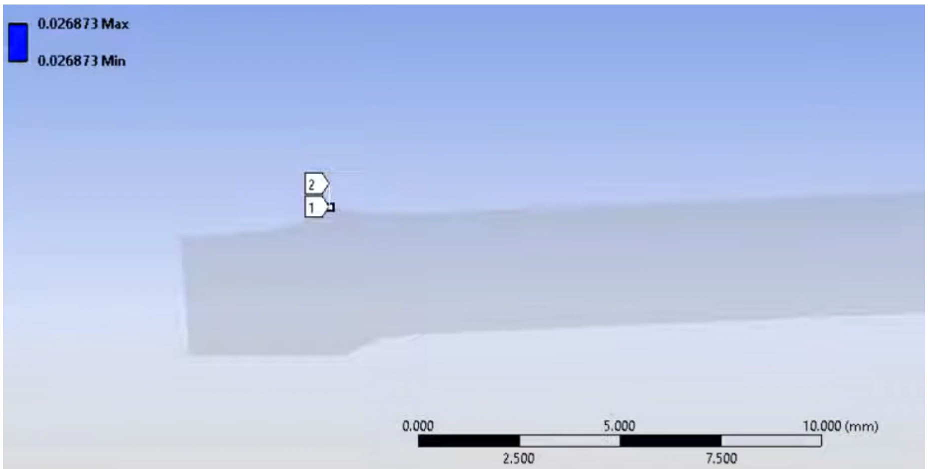

Figure 10: Energy Release Rate for Mode 2

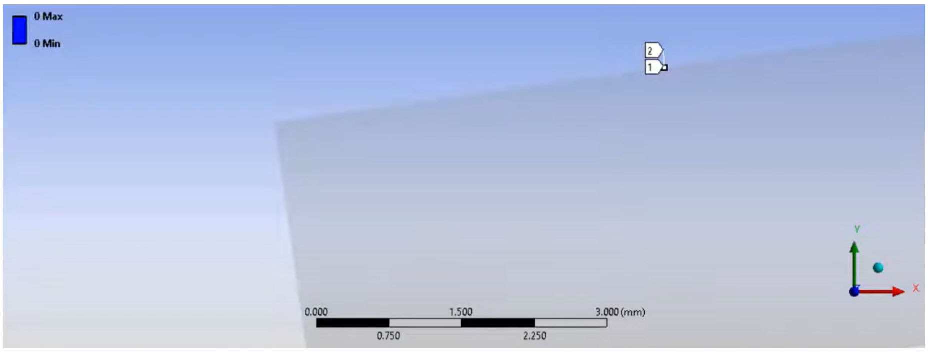

Figure 11: Energy Release Rate for Mode 3

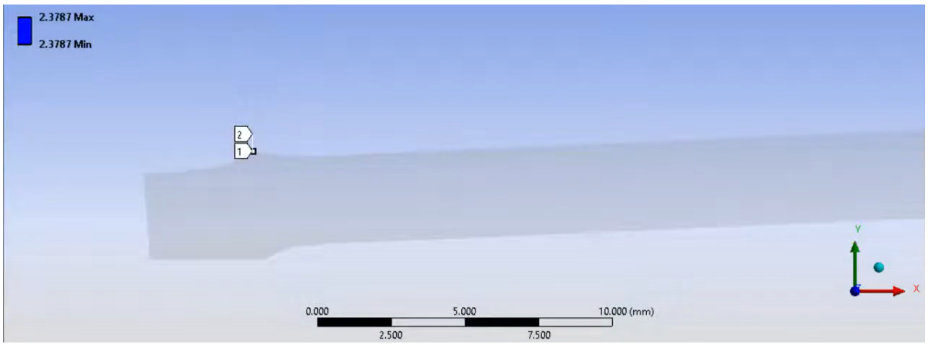

Figure 12: Total Energy Release Rate

4.1 Thermal Loading and Its Effect on Fracture Behavior

To investigate the influence of temperature-induced stress on fracture behavior, a thermal load was applied to the double-cantilever beam (DCB) model without any external mechanical displacement. The entire structure was subjected to a uniform temperature increase from 22 ° C to 100 ° C, simulating conditions in which the bonded structures experience thermal expansion.

Due to the fixed boundary condition at one end of the beam, thermal expansion was restrained, resulting in the development of internal stresses. These stresses generated crack-opening forces at the interface, causing the pre-meshed crack to separate slightly. The fracture tool detected a nonzero total energy release rate,confirming that thermal loading alone can contribute to delamination in constrained systems.

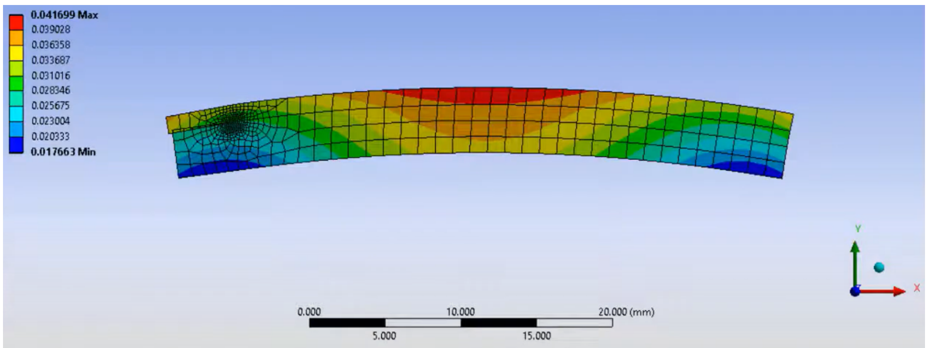

Figure 13: Deformation Due to Thermal Load

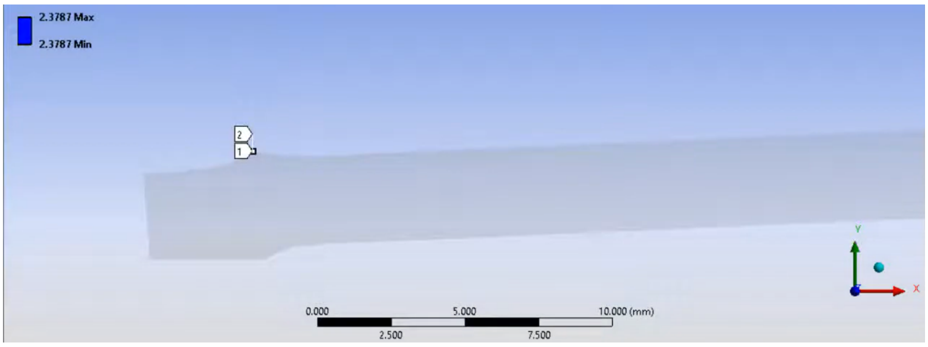

Figure 14: Total Energy Release Rate

This result highlights the importance of considering thermally induced fracture mechanisms in bonded or layered structures, especially in environments subject to temperature fluctuations, such as aerospace and electronics applications.

5 Conclusion

This project successfully demonstrated Mode I fracture behavior in a Double Cantilever Beam (DCB) using the Virtual Crack Closure Technique (VCCT) in ANSYS Workbench. A pre-meshed crack was modeled at the interface, and simulation results showed accurate crack opening with a progressively increasing Mode I energy release rate (G1), confirming correct setup and mesh alignment. The application of thermal loading, even without mechanical displacement, led to crack opening due to thermally induced stresses, producing non-zero G1 values. These findings highlight that both mechanical and thermal loads can contribute to fracture propagation, and that VCCT is an effective tool for evaluating delamination risks in bonded structures. The project establishes a reliable workflow for fracture analysis, which can be extended to composite materials and multi-physics environments.